



CLIMATE AND
POLLUTION
AGENCY

Greenhouse Gas Emissions 1990-2011
April 12, 2013

National Inventory Report

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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 2013 National Inventory Report (NIR). 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* prepared by the Intergovernmental Panel on Climate Change (IPCC).

This National Inventory Report 2013 also includes supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol. This supplementary information comprises chapter 11 with emissions and removals from Land Use, Land-Use Change and Forestry. Note that 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. Chapter 12 includes information on Kyoto units, chapter 13 includes information on changes in national systems, chapter 14 includes information on changes in national registries and chapter 15 includes information on minimization of adverse impacts.

The Climate and Pollution Agency, a directorate under the Norwegian Ministry of Environment, is responsible for the reporting. Statistics Norway has been the principle contributor while the Norwegian Forest and Landscape Institute has contributed to the chapter regarding Land Use, Land Use Change and Forestry.

Oslo, 12 April 2013

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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) 2013 for the period 1990-2011.

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 (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF₆). In addition, the inventory includes calculations of emissions of the precursors NO_x, NMVOC, and CO, as well as for SO₂. Indirect CO₂ emissions originating from the fossil part of CH₄ and NMVOC are calculated according to the UNFCCC reporting guidelines and are accounted for in the inventory.

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

In 2011, the total emissions of greenhouse gases in Norway amounted to 53.4 million tonnes CO₂ equivalents, without emissions and removals from Land-Use, Land-Use Change and Forestry (LULUCF). From 1990 to 2011 the total emissions increased by 6 per cent.

Norway has experienced economic growth since 1990, with only minor setbacks in the early nineties, which explains the general increase in emissions. The emissions decreased, however by almost 2 per cent between 2010 and 2011. The decrease was mainly due to lower economic growth causing lower emissions in almost all sectors. In 2011, CO₂ contributed with 84 per cent of the total emission figures, while methane and nitrous oxide contributed with respectively 8 and 6 per cent. PFCs, HFCs and SF₆ together accounted for approximately 2 per cent of the total GHG emissions.

In 2011 the land-use category forest land remaining forest land was the major contributor to the total amount of sequestration with 31.7 million tonnes CO₂. Land converted to forest land contributed with 0.7 million tonnes CO₂. The total net CO₂ removal from the LULUCF sector was 27.6 million tonnes in 2011. The net greenhouse gas emissions, including all sources and sinks were 25.8 million tonnes CO₂ equivalents in 2011, a decrease of almost 26 per cent from the net figure in 1990.

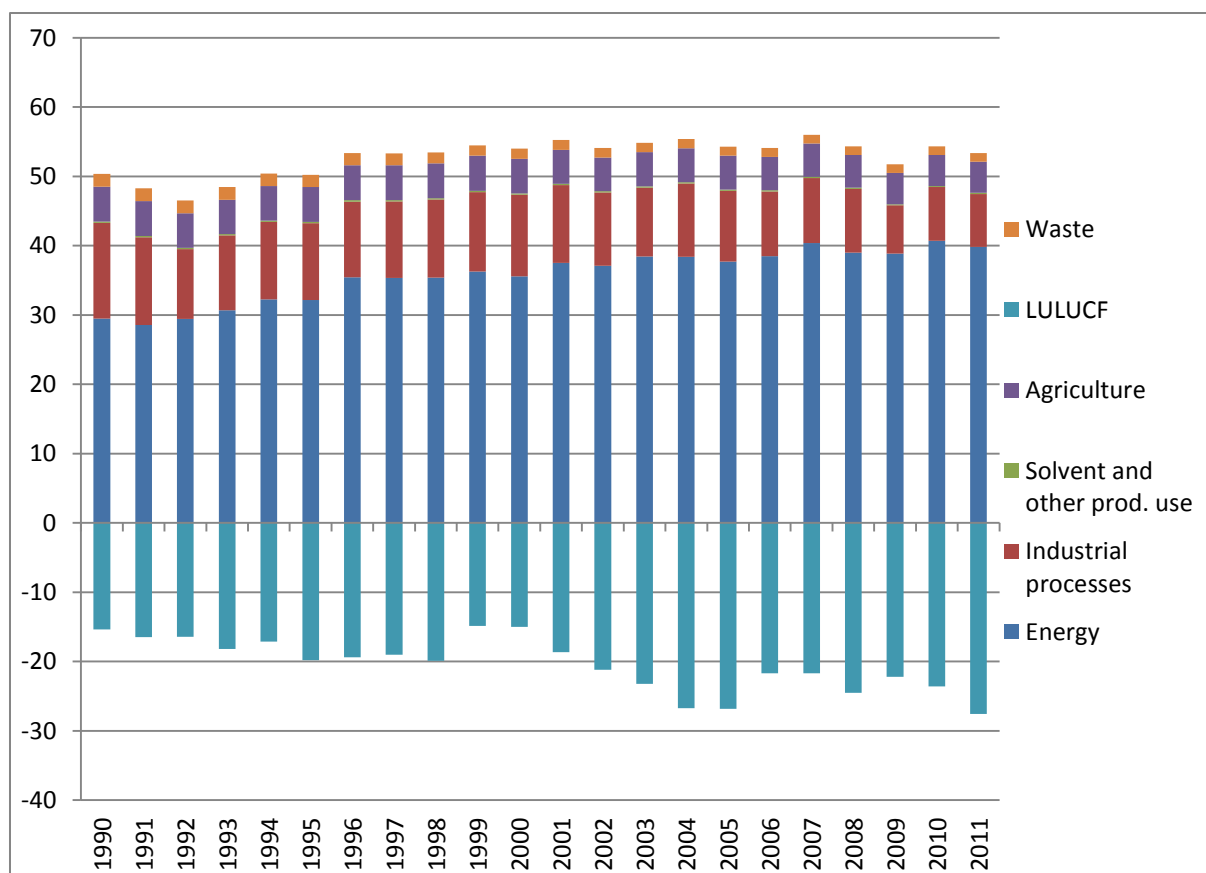


Figure E.S.1. Total emissions of all GHG from the different source categories. 1990-2011. Mtonnes CO₂ equivalents.

Source: Statistics Norway/Climate and Pollution Agency/Forest and Landscape Institute

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

Table E.S.1 shows the overall trend in the total emissions by gas during the period 1990-2011. The proportion of CO₂ emissions of the national total greenhouse gas emissions has increased from about 70 per cent in 1990 to more than 84 per cent in 2011. The increased proportion of CO₂ relative to other gases is due to growth in the CO₂ emissions during this period, as well as a reduction in emissions of N₂O, PFCs and SF₆ gases because of implemented environmental measures and/or technological improvements. This trend is illustrated in Table E.S.2.

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Table E.S.1. Emissions and removals of greenhouse gases 1990-2011.

Gas	CO ₂	CH ₄	N ₂ O	PFK			SF ₆	HFK									Total without LULUCF
				CF ₄	C ₂ F ₆	218		23	32	125	134	134a	143	143a	152a	227ea	Mt CO ₂ -eq.
Year	Mtonnes	ktonnes	ktonnes	tonnes			tonnes	tonnes									
1990	34.8	239.5	15.9	467.4	36.2	0.0	92.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	50.4
1991	33.4	240.4	15.4	416.5	31.0	0.0	87.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.6	0.0	48.3
1992	34.2	244.2	13.6	321.6	21.4	0.0	29.5	0.0	0.1	0.1	0.0	13.6	0.0	0.0	0.8	0.0	46.5
1993	35.8	246.7	14.2	324.3	20.6	0.0	30.9	0.0	0.2	0.2	0.0	21.3	0.0	0.0	0.8	0.0	48.4
1994	37.7	250.2	14.5	286.9	18.3	0.0	36.7	0.0	0.3	1.4	0.0	28.9	0.0	0.6	0.9	0.0	50.4
1995	37.8	247.6	14.6	283.3	18.1	0.0	25.4	0.0	0.4	5.2	0.0	38.4	0.0	4.1	1.3	0.0	50.2
1996	41.0	249.0	14.7	258.5	16.2	0.0	24.0	0.0	0.6	9.0	0.0	46.2	0.0	6.8	1.4	0.1	53.4
1997	41.1	249.2	14.7	229.9	15.1	0.0	24.3	0.1	0.8	15.5	0.1	57.4	0.0	11.7	3.5	0.2	53.3
1998	41.4	242.2	14.8	209.8	13.3	0.0	30.4	0.1	1.1	20.6	0.1	70.1	0.0	15.4	6.1	0.2	53.5
1999	42.1	238.4	15.6	196.2	12.3	0.0	36.6	0.1	1.5	27.2	0.1	82.1	0.0	22.3	6.6	0.2	54.5
2000	41.8	240.8	14.8	186.4	11.6	0.0	39.1	0.1	2.0	34.8	0.1	90.3	0.0	28.7	8.3	0.2	54.0
2001	43.2	241.4	14.5	187.5	11.9	0.0	33.1	0.1	2.6	44.0	0.1	99.7	0.0	38.2	10.6	0.4	55.3
2002	42.3	235.1	15.2	201.3	14.0	0.0	10.0	0.1	3.3	54.8	0.1	115.9	0.0	47.2	10.6	1.4	54.1
2003	43.6	238.8	14.7	125.6	10.1	0.0	9.5	0.1	4.2	51.6	0.1	122.2	0.0	43.2	10.8	1.0	54.8
2004	44.1	237.0	15.2	122.1	9.4	0.0	11.6	0.1	5.1	55.0	0.1	128.7	1.1	46.0	23.1	1.1	55.4
2005	43.1	226.8	15.4	116.7	7.6	0.0	13.1	0.1	6.0	57.0	0.1	139.3	0.8	44.6	30.7	1.0	54.3
2006	43.5	221.5	14.4	102.1	8.6	0.0	8.9	0.1	7.9	63.0	0.1	158.5	0.8	47.9	34.3	0.9	54.1
2007	45.5	225.7	13.8	111.7	10.3	0.0	3.2	0.1	10.0	64.0	0.1	184.8	0.7	46.2	36.2	1.1	56.0
2008	44.4	219.1	12.3	104.7	10.0	0.0	2.7	0.1	12.4	68.6	0.1	218.4	2.8	51.7	35.3	0.8	54.3
2009	42.9	214.6	10.3	49.8	5.8	0.0	2.6	0.1	15.9	73.6	0.1	245.0	2.2	50.1	35.6	0.9	51.8
2010	45.5	215.3	9.8	27.3	3.0	0.0	3.2	0.1	19.6	94.1	0.1	280.1	1.9	69.2	40.0	0.7	54.3
2011	44.7	209.4	9.9	29.9	3.4	0.0	2.5	0.2	22.4	98.8	0.2	305.8	1.8	64.7	40.5	2.1	53.4

Source: Statistics Norway/Climate and Pollution Agency

Table E.S.2 Emissions in million tonnes CO₂ equivalents in 1990, 2010, 2011 and changes (per cent) between 1990-2011 and 2010-2011 (without LULUCF)

Year	CO ₂	CH ₄	N ₂ O	PFCs	SF ₆	HFCs	Total
1990	34.8	5.0	4.9	3.4	2.2	0.0	50.4
2010	45.5	4.5	3.1	0.2	0.1	0.9	54.3
2011	44.7	4.4	3.1	0.2	0.1	1.0	53.4
Changes 1990-2011	28.2 %	-12.6 %	-37.5 %	-93.3 %	-97.2 %		6.0 %
Change 2010-2011	-2.0 %	-2.8 %	0.9 %	10.1 %	-19.5 %	3.9 %	-1.8 %

Source: Statistics Norway/Climate and Pollution Agency

About 46 per cent of the methane emissions in 2011 originated from agriculture, and 24 per cent originated from landfills. The total methane emissions decreased by about 2.8 per cent from 2010 to 2011.

In 2011, agriculture and nitric acid production contributed to 70 per cent and 9 per cent of the total N₂O-emission respectively. Due to technical improvements in production of nitric acid, and despite increased production, the total emissions of N₂O have decreased by 38 per cent since 1990.

The decrease in PFC emissions was 10 per cent from 2010 to 2011, resulting in a total reduction of 93 per cent since 1990. PFC emissions originate primarily from the production of aluminium, where technical measures have been undertaken to reduce them. CO₂ emissions from aluminium production have increased since 1990 due to increased production.

SF₆ emissions have been reduced by 97 per cent from 1990 to 2011, mainly because of technological improvements and the closure of a magnesium production plant and a magnesium recycling foundry.

HFC emissions increased by 4 per cent in 2011 compared to 2010. The emissions in 1990 were insignificant. But the emissions increased significantly from mid-1990 until 2002, when a tax on HFC was introduced in 2003. After that the increase has been somewhat smaller.

The net CO₂ sequestration from the LULUCF category was 27.6 million tonnes in 2011. Since 1990 there has been an increase in carbon stored in living biomass, dead organic matter and in soils in Norway, increasing net sequestration of CO₂ by 26 per cent 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 E.S.2 shows the various sectors' share of the total greenhouse gas emissions in Norway in 2011.

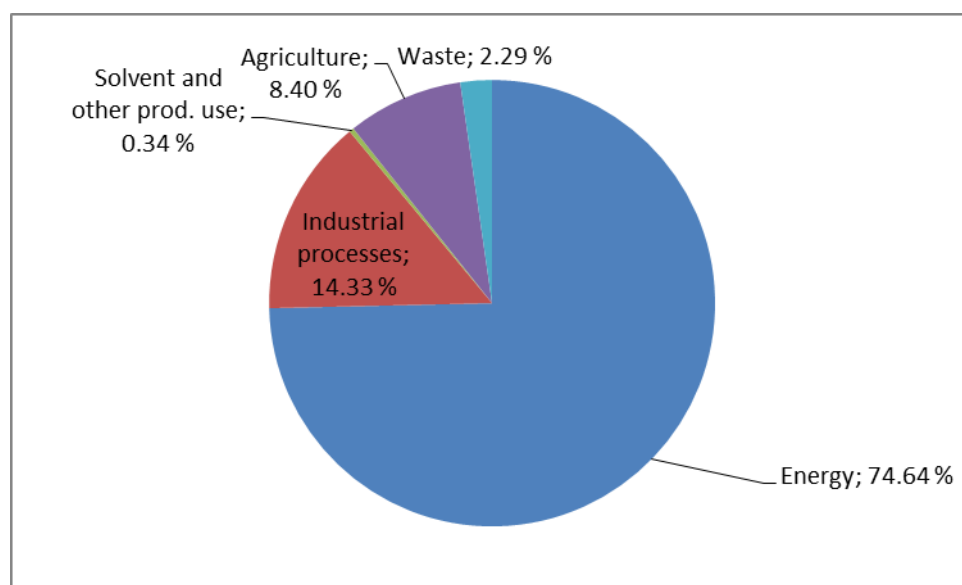


Figure E.S.2. Emissions by IPCC sector in 2011.

Source: Statistics Norway/Climate and Pollution Agency

The most important sector in Norway, with regards to the emissions of greenhouse gases (GHG), is the energy sector, accounting for almost 75 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 E.S.3 shows the percentage change in emissions of greenhouse gases from 1990 to 2011 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.

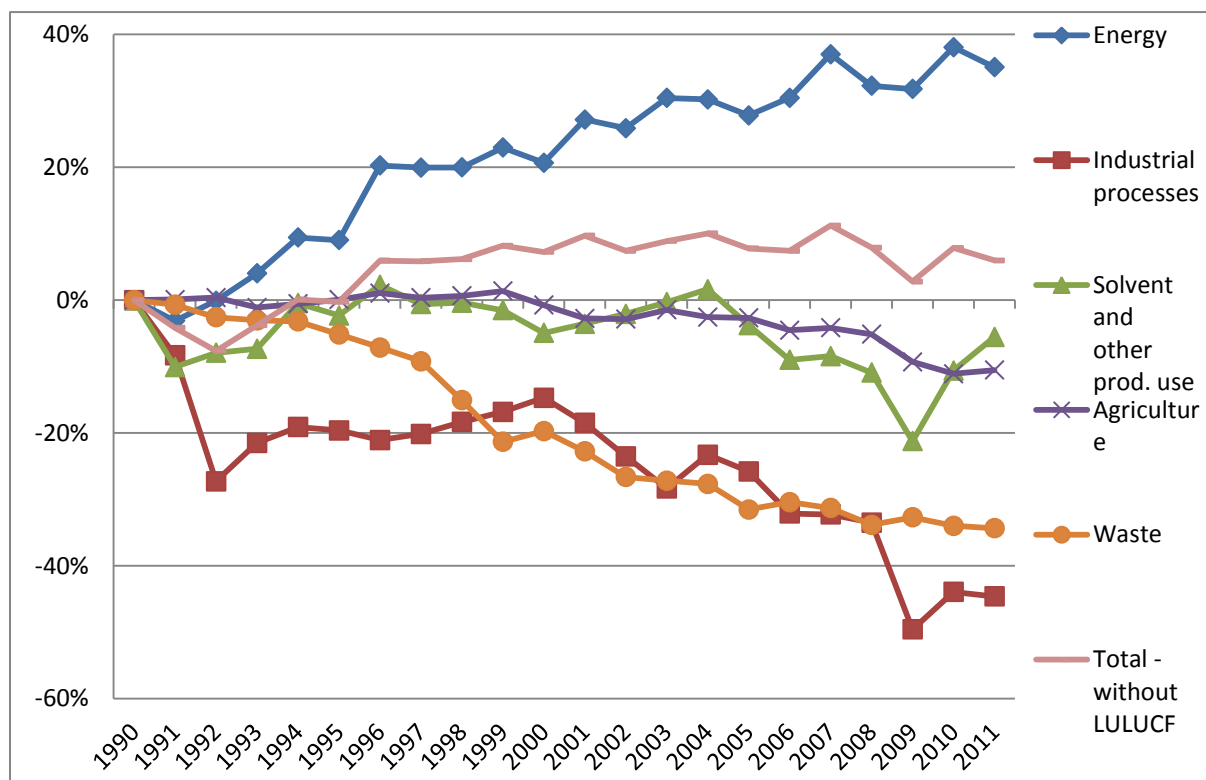


Figure E.S.3. Changes in GHG emissions by IPCC sector 1990-2011 compared to 1990.

Source: Statistics Norway/Climate and Pollution Agency

From 1990 to 2011 the increase in the emissions from the energy sector was almost 35 per cent, or more than 10 million tonnes, mainly due to higher activity in the offshore and transport sectors. The energy sector's emissions decreased by almost 1 per cent from 2010 to 2011. Between 1990 and 2011 there have been temporary emission reductions in e.g. 1991 and 2005 and again in 2008 and 2009, when the energy sector emissions decreased due to economic recession.

Emissions from transport showed an overall increase of about 33 per cent from 1990 to 2011, while the emissions increased by almost 1 per cent from 2010 to 2011. The share of transport in the total GHG emissions has increased from 22 per cent in 1990 to almost 29 per cent in 2011. Road transportation accounts for more than 66 per cent of the total mobile emissions, while emissions from navigation and civil aviation accounts for 14 and 8 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.

Industrial processes contributed to more than 14 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 CO₂ and other greenhouse gases such as N₂O (fertilizer

production) and PFCs (aluminium production). Between 1990 and 2011 emissions from industrial processes experienced an overall decrease by over 45 per cent. This is mainly due to reduced PFC emissions from the production of aluminium and SF₆ from the production of magnesium.

Solvent and other product use accounted for only 0.3 per cent of the total emissions of greenhouse gases in Norway. This contribution has been stable since 1990.

The agricultural sector contributed in 2011 to about 8 per cent to the total emissions of greenhouse gases. This corresponds to 4.5 million tonnes CO₂ equivalents, which is 0.6 per cent lower than in 2010. This sector has experienced an emission reduction of about 11 per cent over the period 1990-2011. The dominant sources of GHGs are agricultural soils (N₂O) and enteric fermentation (CH₄) from domestic animals. These sources contributed to about 45 per cent each to the sector's emissions.

The waste sector contributed with 2 per cent of total Norwegian greenhouse gas emissions in 2011. The emissions of greenhouse gases from the waste sector were relatively stable during the 1990s. From 1998 the emissions declined, and in 2011 they were about 34 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.

E.S.4 Precursors and SO₂

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 (SO₂) 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 8 per cent from 1990 to 2011, primarily because of stricter emission regulations directed towards road traffic, which counteracted increased emissions from oil and gas production and from navigation. From 2010 to 2011 the total NO_x emissions decreased by almost 6 per cent.

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 64 per cent from 2001 to 2011, and are now 53 per cent lower than in 1990. From 2010 to 2011 the emissions of NMVOC decreased by 3.5 per cent.

Over the period 1990-2011 emissions of CO decreased by approximately 58 per cent. This is explained primarily by the implementation of new emissions standards for motor vehicles.

Emissions of SO₂ were reduced by 64 per cent from 1990 to 2011. 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.

Part I: Annual Inventory Submission

1 Introduction

1.1 Background information on greenhouse gas inventories

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 CO₂, CH₄, N₂O as well as fluorinated greenhouse gases not controlled by the Montreal Protocol (HFCs, PFCs and SF₆), using methodologies agreed upon by the Conference of the Parties to the Convention (COP).

In compliance with its reporting requirements, Norway has submitted to the UNFCCC national emission inventory reports on an annual basis since 1993. 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.

The National Inventory Report 2013 together with the associated Common Reporting Format (CRF) tables are Norway's contribution to the 2013 round of reporting under the Convention, and it covers emissions and removals for the period 1990-2011.

This report also includes supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol, in accordance with paragraph 3(a) of decision 15/CMP.1.1. This supplementary information comprises:

- Information on anthropogenic greenhouse gas emissions by sources and removals by sinks from land use, land-use change and forestry (LULUCF) activities under Article 3, paragraph 3, and elected activities under Article 3, paragraph 4, of the Kyoto Protocol.
- Information on Kyoto units (emission reduction units, certified emission reductions, temporary certified emission reductions, long-term certified emission reductions, assigned amount units and removal units).
- Changes in national systems in accordance with Article 5, paragraph 1.
- Changes in national registries.
- Minimization of adverse impacts in accordance with Article 3, paragraph 14.

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 National Inventory Report has been prepared according to the system described in the report "National Greenhouse Gas Inventory System in Norway" (Annex V).

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 2003), 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 (CO₂);
- Methane (CH₄);
- Nitrous oxide (N₂O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs);
- Sulphur hexafluoride (SF₆).

Aggregated emissions and removals of greenhouse gases expressed in CO₂-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.

Indirect CO₂ emissions originating from the fossil part of CH₄ 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 SO₂, 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 (2012a).

Since the introduction of annual technical reviews of the national inventories by independent experts in 2000, Norway has undergone desk/centralized/in-country reviews in the years 2000-2012. Recommendations from these reviews have resulted in many improvements to the inventory. For the latest implemented improvements and planned improvements, see chapter 9.4.

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 and the Climate and Pollution Agency. 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. The Climate and Pollution Agency, Statistics Norway and the Norwegian Forest and Landscape Institute are the core institutions in the national greenhouse gas inventory system in Norway. 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.

The Climate and Pollution Agency 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 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 V. An overview of institutional responsibilities and cooperation is shown in Figure 1.1.

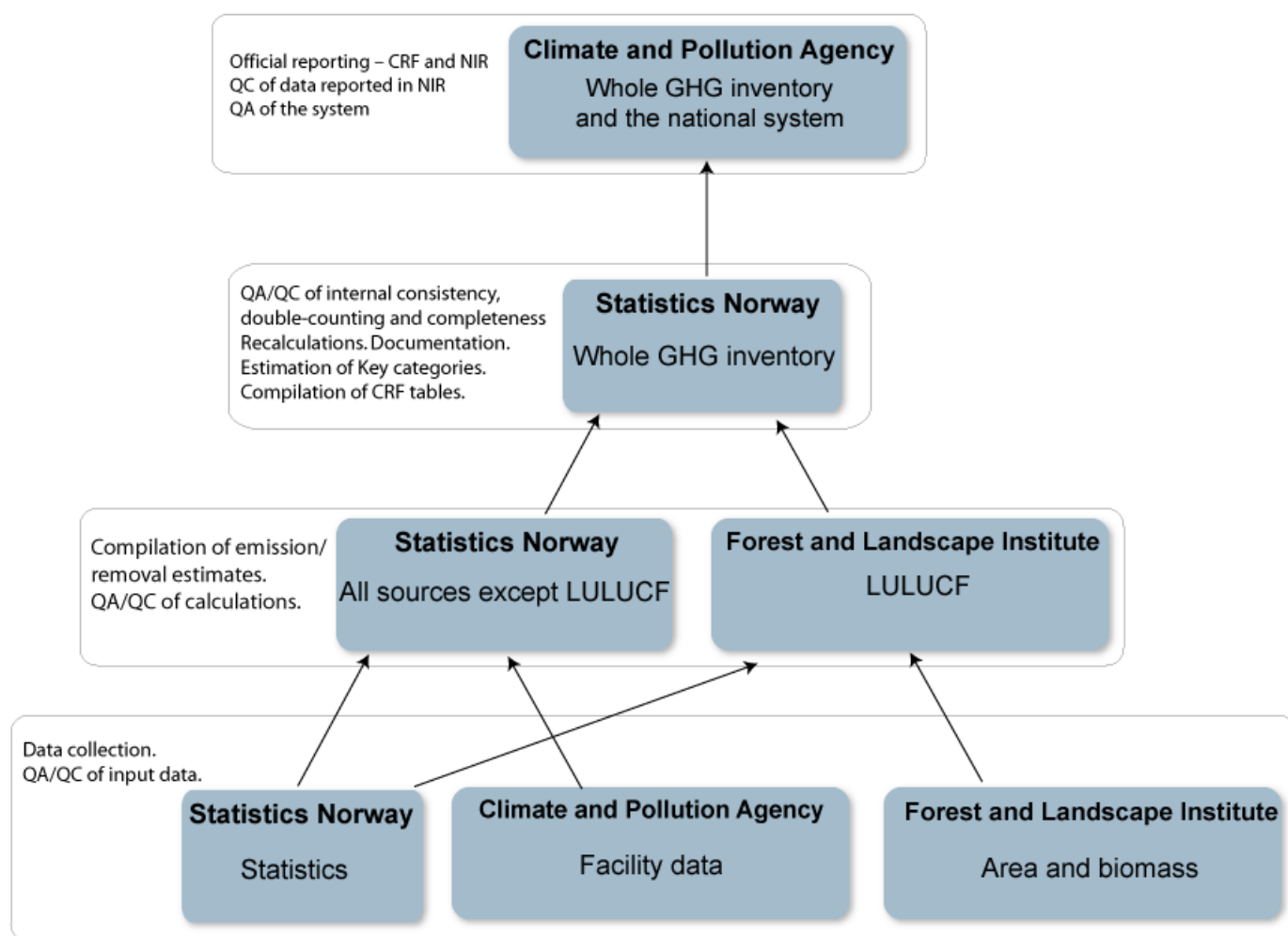


Figure 1.1. Overview of institutional responsibilities and cooperation

To ensure that the institutions comply with their responsibilities, Statistics Norway and The Norwegian Forest and Landscape Institute have signed agreements with Climate and Pollution Agency 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; Climate and Pollution Agency, Statistics Norway and the Norwegian Forest and Landscape Institute have agreed on a “milestone” production plan. This plan has been changed in the revised report of the National Greenhouse Gas Inventory System in Norway, to better reflect existing national publishing obligations etc. This plan is further described in Annex V. 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 V.

Statistics Norway is responsible for the collection and development of activity data, and emission figures are derived from models operated by Statistics Norway. The Climate and Pollution Agency is responsible for the emission factors, for providing data from specific industries and sources and for considering the quality, and assuring necessary updating, of emissions models like e.g. the road traffic model and calculation of methane emissions from landfills. Emission data are used for a range of national applications and for international reporting. The Norwegian Forest and Landscape Institute collects almost all data regarding the LULUCF sector. The collected data are subjected to the Quality Assessment and Quality Control (QA/QC) routines described in section 1.6 as well as source specific routines as described under each source chapter. They are all (except data regarding LULUCF) subsequently processed by Statistics Norway into a format appropriate to enter the emission models. The models are designed in a manner that accommodates both the estimation methodologies reflecting Norwegian conditions and those recommended internationally.

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, the Climate and Pollution Agency is establishing a library with the most important methodology reports.

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 report “The Norwegian Emission Inventory 2012. Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants” (Statistics Norway 2012). This report is updated annually in conjunction with important methodological changes and used as a basis for the NIR. A revised, draft version of (Statistics Norway 2013, not published) which is due to be published in 2013 has also been used in the preparation for this inventory. Information on the methods and framework for the production of data for the LULUCF sector are mainly given in the Report “Emissions and removals of greenhouse gases from land use, land-use change and forestry in Norway” (NIJOS 2005).

Norway has an integrated inventory system for producing inventories of the greenhouse gases included in the Kyoto Protocol and the air pollutants SO₂, 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 the Climate and Pollution Agency have carried out several studies on specific emission sources. Often, 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 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).

$$(1) \quad \text{Emissions (E)} = \text{Activity level (A)} \cdot \text{Emission Factor (EF)}$$

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 the Climate and Pollution Agency). When such measured data are available, the estimated values are replaced by the measured ones:

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

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 the Climate and Pollution Agency, 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.

1.4.3 The LULUCF model

The Norwegian Forest and Landscape Institute is in charge of estimating emissions and removals from Land use, Land-Use Change and Forestry (LULUCF) for all categories where area statistics are used for activity data. They have developed a calculation system in the form of computer programs that uses primarily R and excel for the implementation of the IPCC good practice guidance for the LULUCF sector. The systems use input data from different sources and create final output datasets. These final datasets include all data needed for the tables in the common reporting format (CRF), both for the Climate Convention and the Kyoto-protocol.

The National Forest Inventory (NFI) database contains data on areas for all land uses and land-use conversions as well as carbon stocks in living biomass. The NFI is used to establish total area of forest, cropland, wetlands, settlements and other land and land-use transitions between these. The data from the NFI is complemented with other data (e.g. horticulture, tillage practice, amount of fertilizer used, liming and drainage of forest soil, liming of lakes and forest fires) collected by Statistics Norway, Norwegian Agricultural Authority, Food Safety Authority, The Norwegian Directorate for Nature Management and The Directorate for Civil Protection and Emergency Planning.

The sampling design of the NFI is based on a systematic grid of geo-referenced sample plots covering the entire country. The NFI utilizes a 5-year cycle based on a re-sampling method of the permanent plots. Up to 2010 the estimates were based on detailed information from sample plots below the coniferous limit. To confirm the land use, the extent of the area of forest and other wooded land at higher altitudes and in Finnmark County, the NFI conducted a complete forest inventory during 2005–2010 for these areas. All areas were for the first time included in the estimates for the LULUCF sector in the 2012 submission. The land-use change areas above the coniferous limit and in Finnmark County, have been recalculated in the 2013 submission, due to the inclusion of information from NFI, maps, old and new aerial photos that have been used to improve the estimates back to 1990.

The 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 Ståhl 2006). These equations provide biomass estimates for various tree biomass components: stem, bark, living branches, dead branches and needles, stumps and

roots. These components are used to calculate above- and belowground biomass. The biomass of trees below and above coniferous limit and with diameter less than 50 mm (small trees) at 1.3 meter height (DBH), trees from higher altitudes and trees in Finnmark County are included in the estimates for the whole time-series. The standing volume of these biomass pools constitute 7 percent of the stem volume of standing trees with DBH equal to or larger than 50 mm from the area below the coniferous limit. Hence, 7 percent of the net change of CO₂ removals of living trees below the coniferous limit is included in the estimates. It is assumed that these proportions have remained constant over the last twenty years.

The dynamic soil model Yasso07 was used to calculate changes in carbon stock in dead organic matter and in soil for forest land remaining forest land (Tuomi et al., 2011; Tuomi et al., 2009). Simulations were made for individual NFI plots for the entire time-series. The Yasso07 model provides an aggregated estimate of carbon stock change for the total of litter, dead wood and soil organic matter. The system is still under development. All data used as input to the models is provided by the Norwegian Forest and Landscape Institute. Data used for estimation of C emissions from cropland, grassland, wetlands, and settlements are derived from Statistics Norway, Norwegian Meteorological Institute and Bioforsk research institute.

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. N₂O from agriculture, CH₄ and N₂O from stationary combustion, CH₄ and N₂O road transport) 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 Climate and Pollution Agency 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 method. A description of the methodology as well as background tables and the results from the analyses is presented in Annex I. In this chapter a summary of the analysis 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 Tier 1 and Tier 2.

The Tier 2 and Tier 1 analyses were 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.

The results from the key category analyses are summarized in Table 1.1. The Tier 2 analysis identified 30 key categories which are arranged primarily according to contribution to the uncertainty in level in 2011. 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 there are 39 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 I together with background data and the complete analysis including LULUCF. Fugitive emissions from coal mining and handling are 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 CO₂ capture and storage. This removal category is considered key since there until recently has been no methodology as such defined in the IPCC guidelines and because these operations are unique internationally.

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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 2011	Trend assessment Tier 2 1990-2011	Method (Tier) 2011
<i>Tier 2 key categories (large contribution to the total inventory uncertainty)</i>						
4D1	Direct soil emissions	N ₂ O	27.16	22.70	11.15	Tier 1a
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Gaseous Fuels	CO ₂	4.32	9.50	12.57	Tier 2
4D3	Indirect emissions	N ₂ O	6.74	6.13	1.56	Tier 2
1A3b	Road Transportation	CO ₂	4.59	5.70	2.63	Tier 1a
4A	Enteric Fermentation	CH ₄	6.10	5.05	2.62	Tier 1/2*
2F	Consumption of Halocarbons and Sulphur Hexafluoride	HFCs	0.00	4.65	11.33	Tier 2
1B2a	Oil (incl. oil refineries, gasoline distribution)	CO ₂	4.75	4.18	1.44	Tier 2
1A3d	Navigation	CO ₂	3.54	3.98	1.03	Tier 2
6A	Solid Waste Disposal on Land	CH ₄	6.42	3.78	6.48	Tier 2
1A3e	Other (snow scooters, boats, motorized equipment)	CO ₂	1.59	3.25	4.04	Tier 2
1A3a	Civil Aviation	CO ₂	1.42	2.38	2.32	Tier 2
1B2c	Venting and Flaring	CH ₄	1.14	2.35	2.94	Tier 2
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Liquid Fuels	CO ₂	2.81	2.18	1.57	Tier 2
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Other Fuels	CO ₂	0.31	1.88	3.82	Tier 2
1A4	Other sectors - Mobile Fuel Combustion	CO ₂	1.98	1.88	0.26	Tier 2
1A3e	Other (snow scooters, boats, motorized equipment)	N ₂ O	0.73	1.79	2.59	Tier 1a
2C3	Aluminium Production	CO ₂	1.53	1.72	0.44	Tier 2
1B2c	Venting and Flaring	CO ₂	1.67	1.63	0.11	Tier 2
4D2	Animal production	N ₂ O	1.89	1.59	0.76	Tier 2
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Biomass	CH ₄	0.96	1.16	0.49	Tier 1
4B	Manure Management	N ₂ O	1.20	1.11	0.23	Tier 2
6B	Wastewater Handling	N ₂ O	0.90	1.01	0.27	Tier 1

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1B2a	Oil (incl. oil refineries, gasoline distribution)	CH ₄	0.68	0.81	0.30	Tier 2
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Solid Fuels	CO ₂	0.90	0.77	0.33	Tier 2
2C2	Ferroalloys Production	CO ₂	0.79	0.66	0.32	Tier 2
1A3d	Navigation	CH ₄	0.03	0.46	1.05	Tier 2
2C3	Aluminium Production	PFCs	7.04	0.45	16.13	Tier 2
1B2b	Natural Gas	CH ₄	0.02	0.34	0.77	Tier 2
2B2	Nitric Acid Production	N ₂ O	1.28	0.17	2.72	Tier 2
2B4	Carbide Production	CO ₂	0.43	0.07	0.88	Tier 2
<i>Tier 1 key categories (large contribution to the total emissions)</i>						
4B	Manure Management	CH ₄	0.79	0.78	0.03	Tier 2
2B5	Other Chemical Industry	CO ₂	0.27	0.38	0.26	Tier 2
2B1	Ammonia Production	CO ₂	0.39	0.24	0.38	Tier 2
1A5b	Military - Mobile	CO ₂	0.29	0.15	0.35	Tier 2
2A1	Cement Production	CO ₂	0.05	0.05	0.01	Tier 2
2A2	Lime Production	CO ₂	0.00	0.01	0.02	Tier 2
2C4	SF ₆ Used in Aluminium and Magnesium Foundries	SF ₆	0.06	.	.	Tier 2
<i>Qualitative key categories</i>						
1B1a	Coal Mining and Handling	CH ₄	0.43	0.22	0.53	Tier 2
	Capture and storage	CO ₂				CS (Tier 2)

Bold figures indicate whether the source category is a key in level and trend according to Tier 2 analyses.

One new category has been identified as key at tier 1. CO₂ emissions from the source 2B5 – Other chemical industry is now included as key, primarily due to a reallocation of titanium oxide from 2C1 – Iron and steel production. This sector is no longer key at tier 1. 2D2 – Food and drink is also no longer key at tier 1, while the source 2C2 - Ferroalloys Production was now identified as key at tier 2 in 1990.

Table 1.2 lists the LULUCF categories identified as key categories. The methodological changes in the estimates of the LULUCF sector resulted in changes in the key categories. Two key categories from last year were not identified as key categories this year, namely forest remaining forest - mineral soils and grassland remaining grassland – histosols (organic soil). The Yasso07 application for simulation of mineral soils on forest land remaining forest land resulted in a lower C stock change in the soil estimate compared to the methods used in the previous years because a larger share of the total organic carbon pool simulated by the model

was assigned to dead organic matter. The cultivated histosols were previously reported under grassland (5C1) but are now reported under cropland (5B1) due to a redefinition of grassland. New key categories were identified due to the implementation of a Tier 1 method for the estimation of soil organic carbon changes for land in conversion, a Tier 2 for emission estimates arising from C stock changes in dead organic matter, and also the implementation of a Tier 3 method for C stock changes in living biomass on grassland remaining grassland and forest land converted to grassland.

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

	Source category	Gas	Level assessment Tier 2 1990	Level assessment Tier 2 2011	Trend assessment Tier 2 1990-2011	Method (Tier) 2011
<i>Tier 2 key categories (large contribution to the total inventory uncertainty)</i>						
5A1	Forest Land remaining Forest Land, Forest inventory area, Living Biomass	CO ₂	12.13	20.38	28.56	Tier 3
5A1	Forest Land remaining Forest Land, Forest inventory area, Soils, Organic	CO ₂	19.90	16.66	10.78	Tier 2
5A1	Forest Land remaining Forest Land, Forest inventory area, Dead organic matter	CO ₂	13.05	7.57	0.15	Tier 2
5E2	Land converted to Settlements, Soils	CO ₂	0.29	6.58	13.79	Tier 1
5B1	Cropland remaining Cropland, Arable, Soils (organic)	CO ₂	9.13	6.02	1.45	Tier 2
5A2	Land converted to Forest Land, Soils, Mineral	CO ₂	0.05	1.44	3.05	Tier 1
5A2	Land converted to Forest Land, Living biomass	CO ₂	0.35	0.86	1.41	Tier 3
5E2	Land converted to Settlements, Living biomass	CO ₂	0.94	0.78	0.48	Tier 3
5E2	Land converted to Settlements, Dead organic matter	CO ₂	0.03	0.58	1.23	Tier 2
5C1	Grassland remaining Grassland, Managed Grassland, Living biomass	CO ₂	0.37	0.58	0.79	Tier 1
5C2	Forest converted to Grassland, Living biomass	CO ₂	0.16	0.50	0.88	Tier 3
5F2	Land converted to Other land, Soils	CO ₂	0.02	0.36	0.76	Tier 1
5B2	Land converted to Cropland, Soils, Mineral	CO ₂	0.01	0.36	0.75	Tier 1

5A2	Land converted to Forest Land, Dead organic matter	CO ₂	0.01	0.28	0.60	Tier 3
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Tier 1 key categories (large contribution to the total emissions)

No additional categories – all tier 1 key categories were also key at tier 2.

Bold figures indicate whether the source category is a key in level and trend according to Tier 2 analyses

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 V. 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.

This chapter describes general QA/QC procedures. For source specific QA/QC, see each source sector for detailed descriptions. The QA/QC work has several dimensions. In addition to accuracy, also timeliness is essential. As these two aspects may be in conflict, the QA/QC improvements in recent years have been focused on how to implement an effective QA/QC procedure and how to obtain a more efficient dataflow in the inventory system.

The established QA/QC procedures include the following:

- The Climate and Pollution Agency is the national entity designated to be responsible for the reporting of the national inventory of greenhouse gases to the UNFCCC. This includes coordination of the QA/QC procedures;
- Statistics Norway is responsible for the quality control system with regard to technical activities of the inventory preparation;
- A Tier 1 general inventory level QC procedures, as listed in table 8.1 of the IPCC Good Practice Guidance is performed every year;
- Source category-specific QC procedures are performed for all key categories and some non-key categories; with regard to emission factors, activity data and uncertainty estimates (Tier 2).

1.6.2 QA Procedures

According to the IPCC Good practice guidance, good practice for QA procedures requires an objective review to assess the quality of the inventory and to identify areas where improvements could be made. Furthermore, it is good practice to use QA reviewers that have

not been involved in preparing the inventory. In Norway, the Climate and Pollution Agency is responsible for reviewing the inventory with regard to quality and areas for improvement. For most sources it is a person within the Climate and Pollution Agency who has not been involved in the calculations and the quality controls who performs the QA for the particular source.

Norway has performed several studies comparing inventories from different countries (SFT/Statistics Norway 2000). Verification of emission data is another element to be assessed during the elaboration of a QA/QC and verification plan.

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.

1.6.3 General QC procedures

The Norwegian emission inventory is produced in several steps. Preliminary estimates are first produced three months after the end of the inventory year. These data are based on preliminary statistics and indicators and data that have been subjected to a less thorough quality control. The "final" update takes place about one year after the inventory year. At this stage, final statistics are available for all sources. Until 2011, also regional emission data were calculated. Due to quality problems, the production of these statistics has been stopped, and per April 2013 it is uncertain whether it will be resumed. Recalculations of the inventory are performed annually, as methodological changes and refinements are implemented. In itself, this stepwise procedure is a part of the QA/QC-procedure since all differences in data are recorded and verified by the Climate and Pollution Agency before publication of the emission figures (see section 1.2).

For each of the steps described above, general quality control procedures are performed, but with different levels of detail and thoroughness as mentioned. The national emission model was revised in 2002 in order to facilitate the QC of the input data rather than the emission data only. Input data include emissions reported from large plants, activity data, emission factors and other estimation parameters.

In the following, the procedures listed in table 8.1 of the Good Practice Guidance (IPCC 2000), the Tier 1 General Inventory Level QC Procedures, are gone through, and it is described how these checks are performed for the Norwegian greenhouse gas emission inventory.

Check that assumptions and criteria for the selection of activity data and emissions factors are documented

Thorough checks of emission factors and activity data and their documentation have been performed for existing emission sources. When new sources appear (for example a new industrial plant) or existing sources for the first time are recognised as a source, the Climate and Pollution Agency delivers all relevant information to Statistics Norway. This information is then thoroughly checked by two members of the inventory team at Statistics Norway. All changes in methodologies or data are documented and kept up to date.

Check for transcription errors in data input and references

Activity data are often statistical data. Official statistical data undergo a systematic revision process, which may be manual or, increasingly frequently, computerised. The revision

significantly reduces the number of errors in the statistics used as input to the inventory. Furthermore, all input data (reported emissions, emission factors and activity data) for the latest inventory year are routinely compared to those of the previous inventory year, using automated procedures. Large changes are automatically flagged for further, manual QC. In addition, implied emission factors are calculated for emissions from stationary combustion at point sources. The IEFs are subjected to the same comparison between the years t and $t-1$. The most thorough checks are made for the gases and categories with the largest contribution to total emissions.

Check that emissions are calculated correctly

When possible, estimates based on different methodologies are compared. An important example is the metal production sector where CO₂ estimates reported by the plants are compared with estimates based on the Good Practice methodology corrected for national circumstances. In this case, both production based and reducing agent based calculations are performed to verify the reported value. The Climate and Pollution Agency and Statistics Norway control and verify emission data reported to the Climate and Pollution Agency by industrial enterprises, registered in the database Forurensning. First, the Climate and Pollution Agency checks the data received from these plants, and if errors are discovered, they may then ask the plants' responsible to submit new data. Subsequently, Statistics Norway makes, where possible, comparable emission calculations based on activity data sampled in official statistics, and deviations are explained through contact with the plants. Regarding more detailed information about the QC of data reported by industrial plants, see section 1.6.4.

Check that parameter and emission units are correctly recorded and that appropriate conversion factors are used

All parameter values are compared with values used in previous years and with any preliminary figures available. Whenever large deviations are detected, the value of the parameter in question is first checked for typing errors or unit errors. Changes in emissions from large plants are compared with changes in activity level. If necessary, the primary data suppliers (e.g. the Norwegian Forest and Landscape Institute, The Norwegian Petroleum Directorate, Norwegian Public Roads Administration, various plants etc.) are contacted for explanations and possible corrections.

Check the integrity of database files

Control checks of whether appropriate data processing steps and data relationships are correctly represented are made for each step of the process. Furthermore, it is verified that data fields are properly labelled and have correct design specifications and that adequate documentation of database and model structure and operation are archived.

Check for consistency in data between source categories

Emission data for the last year are compared with data for the previous year, in order to check the consistency and explain any changes in the data behaviour. For example, in 2012 Statistics Norway and the Climate and Pollution Agency calculated emission data for 2011 for the first time. These data were compared with the 2010 figures for detection of any considerable deviations. There may be large deviations that are correct, caused for instance by the shutdown of large industrial plants or the launch of new ones.

Check that the movement for inventory data among processing steps is correct

Statistics Norway has established automated procedures to check that inventory data fed into the model does not deviate too much from the figures for earlier years, and that the calculations within the model are correctly made. Checks are also made that emissions data are correctly transcribed between different intermediate products. The model is constructed so

that it gives error messages if factors are lacking, which makes it quite robust to miscalculations.

Check that uncertainties in emissions and removals are estimated correctly

A tier 2 uncertainty analysis for greenhouse gases was undertaken in 2011; see further information in section 1.7.2 and Annex II.

Undertake review of internal documentation

For some sources expert judgements dating some years back are employed with regard to activity data/emission factors. In most of the cases these judgements have not been reviewed since then, and may not be properly documented, which may be a weakness of the inventory. The procedures have improved the last few years, and the requirements for internal documentation to support estimates are now quite strict; all expert judgements and assumptions made by the Statistics Norway staff must be documented. This should enable duplication of emissions and uncertainty estimates. In 2011, work was begun to go through all emission factors, register digitally those that have sufficiently documentation and flag those that do not, for future revision. The new model at Statistics Norway has improved the process of archiving inventory data, supporting data and inventory records, which does facilitate review. The model runs are stored and may be reconstructed, and all input data from the Climate and Pollution Agency as well as notes with explanations on changes in emissions are stored. This is a continuous process of improvement at Statistics Norway.

Check methodological data changes resulting in recalculations

Emission time series are recalculated every year in order to account for methodological changes. The recalculated emission data for a year is compared with the corresponding figures estimated the year before. For example, CO₂ data calculated for 1990 in 2010 are compared with the 1990 CO₂ data calculated in 2009. It is our intention to explain all major differences as far as possible. Changes may be due to revisions in energy data, new plants, correcting for former errors, new emission methodologies or there may be caused by new errors. These checks lead to corrections and re-runs of the emission model.

Undertake completeness checks

Estimates are reported for all source categories and for all years as far as we know, apart from a few known data gaps, which are listed in section 1.8 Completeness. There may, of course, exist sources of greenhouse gases which are not covered. However, we are quite certain that emissions from potentially additional sources are very small or negligible.

Compare estimates to previous estimates

Internal checks of time series for all emission sources are performed every year when an emission calculation for a new year is done. It is then examined whether any detected inconsistencies are due to data or/and methodology changes. For example, in 2012 Statistics Norway/the Climate and Pollution Agency calculated emission data for 2011 for the first time. These data were compared with the 2010 figures for detection of any considerable deviations. There may be large deviations that are correct, caused for instance by the shutdown of large industrial plants or the launch of new ones.

1.6.4 Source category-specific QC procedures

Statistics Norway and the Climate and Pollution Agency have carried out several studies on specific emission sources, e.g. emissions from road, sea, and air transport, emissions from landfills as well as emissions of HFCs and SF₆. These projects are repeated in regular intervals when new information is available. During the studies, emission factors have been assessed and amended in order to represent the best estimates for national circumstances, and

a rational for the choice of emission factor is provided. The emission factors are often compared with factors from literature. Furthermore, activity data have been closely examined and quality controlled and so has the uncertainty estimates.

The QC procedures with regard to emissions data, activity data and uncertainty estimates for the different emission sources are described in the QA/QC-chapters of the relevant source-categories. The source category-specific analyses have primarily been performed for key categories on a case-by-case basis, which is described as being good practice. The QA/QC process for many of the sources could be improved. The QC procedures are described in the report on the National System which was submitted by 1. January 2007 (see Annex V for more information).

The ERT requested in 2005 further information regarding the verification of quality of data reported by companies. The general checks performed are described under section 1.6.3. In the following is a more detailed description of QC of emission data reported from plants:

Plant emission data that are used in the emission trading system will undergo annual QC checks. The source-specific QC checks for other plants are performed less frequently (every 3 years) for emission estimates used in key categories, which account for 25-30 per cent of the total of that category. The frequency of checking of non-key plants which are not included in the emission trading scheme is every 5 years. Statistics Norway is responsible for reporting the results of the key category analysis to the Climate and Pollution Agency, while the Climate and Pollution Agency will perform the assessment of the “key plants” within a category.

The QC checks include:

- An assessment of the internal QA/QC of the plants reporting data to the Climate and Pollution Agency
 - o Their QA/QC system including archiving
 - o Any changes to the QA/QC system
- An assessment and documentation of measurements and sampling
 - o Measurement frequency
 - o Sampling
 - o Use of standards (e.g. ISO)
 - o Documentation for archiving
- An assessment and explanation of changes in emissions over time (e.g. changes in technology, production level or fuels) (annual check)
- An assessment of time-series consistency back to 1990 in cooperation with the Climate and Pollution Agency (if plant emission data are missing for some years and estimates are made using aggregate activity data and emission factors)
- A comparison of plant emissions to production ratios with those of other plants, including explanations of differences
- A comparison of the production level and/or fuel consumption with independent statistics
- An assessment of reported uncertainties (including statistical and non-statistical errors) to the extent this has been included in the reporting

The QC checks are made in close cooperation with the emission reporting plants.

For more details of QA/QC of specific source categories, see “source specific QA/QC” in relevant chapters.

1.6.5 Verification studies

In general, the final inventory data provided by Statistics Norway are checked and verified by Climate and Pollution Agency. 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 realize 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.

In 2006, as part of the improvements for the Initial report, Klif performed a major QA/QC exercise on the time series from 1990 to 2004 of greenhouse gas (GHG) emissions from the largest industrial plants in Norway. For each plant a first time series of emission data as well as activity data were established with basis on existing sources of data. It was then possible to identify lack of emission data and activity data for any year or time series and possible errors in the reported data. Possible errors were typically identified if there were discrepancies between reported activity data (consumption of raw materials, production volumes etc.) and emissions, or if there were large variations in the existing time series of emissions. The emission data were supplemented and/or corrected if possible by supply of new data from the company, supplementary data from Klif paper archives, verification of reported emission data by new calculations based on reported activity data and calculation of missing emissions (if sufficient activity data were present). A final time series of greenhouse gas emissions from 1990 to 2004 were established and the main documentation from this work is contained in Excel spread sheets and in a documentation report (SFT 2006). This approach is described in Annex IX.

From 2005 and especially from 2008, Norway's use of plant specific data has been strengthened by the availability of data from the EU ETS. The Climate and Pollution Agency conducts the verification of the annual reports. The new data source provides data of better quality and these are checked against the emissions reported under the regular permits and the reports submitted as part of the voluntary agreement. More details are found in Annex IX.

In 2009, a new model for calculating the emissions of NMVOC from the use of solvents and other product uses was developed. The emission factors were evaluated and revised through a cooperation project between the Nordic countries. The results from the new model were

compared against the similar results in Sweden and the United Kingdom; see Holmengen and Kittilsen (2009) for more details.

In 2011, the Norwegian University of Life Sciences (UMB) published a comparison of the methodologies used for calculating CH₄ emissions from manure management in Sweden, Finland, Denmark and Norway (Morken 2011).

In a project in 2012 at the Norwegian University of Life Sciences (UMB) that updated the Norwegian nitrogen excretion factors and the values for manure excreted for the different animal species, comparisons was made with the corresponding factors used in Sweden, Denmark and Finland and with IPCC default factors as a verification of the Norwegian factors (Karlengen et al. 2012). Comparisons were also made of the emission factors used for calculating enteric methane.

1.6.6 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 Climate and Pollution Agency. All emission data and activity data necessary for the CRF are publicly available.

1.7 Uncertainty evaluation

1.7.1 Tier 1 uncertainty analysis

The uncertainties in the emission levels for 2011 have been investigated by a tier 1 analysis. The results are given in Table 1.3 and Table 1.4

Table 1.3. Tier 1 uncertainties in emission levels. Each gas and total GWP weighted emissions. Excluding the LULUCF sector. 2011.

2011	μ (mean)	Uncertainty 2 σ (per cent of mean)
Total	53.4 mill. tonnes	3.8
CO ₂	44.7 mill. tonnes	2.4
CH ₄	4.4 mill. tonnes	14.7
N ₂ O	3.1 mill. tonnes	49.2
HFC	950 ktonnes	52.9
PFC	226 ktonnes	21.4
SF ₆	61 ktonnes	63.4

Table 1.4. Tier 1 uncertainties in emission levels. Each gas and total GWP weighted emissions. Including the LULUCF sector. 2011.

2011	μ (mean)	Uncertainty 2 σ (per cent of mean)
Total	25.8. mill. tonnes	34.7
CO ₂	17.1 mill. tonnes	51.5
CH ₄	4.4 mill. tonnes	14.7
N ₂ O	3.1 mill. tonnes	49.0
HFC	950 ktonnes	52.9
PFC	226 ktonnes	21.4
SF ₆	61 ktonnes	63.4

1.7.2 Tier 2 uncertainty analysis

The uncertainty in the Norwegian greenhouse gas emission inventory has been investigated by a tier 2 analysis in 2011 and the results are given in Table 1.5 to Table 1.8. The tier 2 uncertainty analysis is also further described in Annex II.. A tier 2 analysis for the greenhouse gases was also performed in 2006, and the results from that analysis is given in (Statistics Norway 2010c). The uncertainty in the Norwegian emission inventory has also earlier been investigated systematically in three reports SFT/Statistics Norway 1999, Statistics Norway 2000, Statistics Norway 2001c). The first two reports focused on the uncertainty in the greenhouse gas emissions, and the last report investigated the uncertainty in the emission estimates of long-range air pollutants.

The uncertainty analysis performed in 2011 (Statistics Norway 2011b) was an update of the uncertainty analyses performed for the greenhouse gas inventory in 2006 and 2000. The report *Uncertainties in the Norwegian Greenhouse Gas Emission Inventory* (Statistics Norway 2000) includes more detailed documentation of the analysis method used in all analyses.

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).

Table 6.2 from the IPCC good practice guidance is included in Annex II as Table AII-4. This is as a response to recommendations in previous ERT review reports. Column G in Table 6.2 is estimated as uncertainty for source category divided by total GHG emissions.

1.7.3 Uncertainty in emission levels

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

Table 1.5. Uncertainties in emission levels. 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	5
CO ₂	35 mill. Tonnes	0.70	3
CH ₄	4.7 mill. Tonnes	0.09	17
N ₂ O	4.7 mill. Tonnes	0.10	40
HFC	18 tonnes	0.00	50
PFC	3.4 mill. Tonnes	0.07	21
SF ₆	2.2 mill. Tonnes	0.04	2
2009	μ (mean)	Fraction of total emissions	Uncertainty 2σ (per cent of mean)
Total	51 mill. Tonnes	1	4
CO ₂	43 mill. Tonnes	0.84	2
CH ₄	4.3 mill. Tonnes	0.08	14
N ₂ O	3.0 mill. Tonnes	0.06	58
HFC	708 ktonnes	0.01	48
PFC	379 ktonnes	0.01	20
SF ₆	64 ktonnes	0.00	56

Table 1.6. Uncertainties in emission levels. 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	41 mill. tonnes	1	7
CO ₂	26 mill. tonnes	0.64	9
CH ₄	4.7 mill. tonnes	0.11	16
N ₂ O	4.7 mill. tonnes	0.12	38
HFC	18 tonnes	0.00	50
PFC	3.4 mill. tonnes	0.08	21
SF ₆	2.2 mill. tonnes	0.05	1
2009	μ (mean)	Fraction of total emissions	Uncertainty 2σ (per cent of mean)
Total	26 mill. tonnes	1	17
CO ₂	17 mill. tonnes	0.67	23
CH ₄	4.3 mill. tonnes	0.16	14
N ₂ O	3.1 mill. tonnes	0.12	55
HFC	708 ktonnes	0.03	48
PFC	379 ktonnes	0.01	20
SF ₆	64 ktonnes	0.00	63

The total national emissions of GHG (LULUCF sector excluded) in 1990 are estimated with an uncertainty of 5 per cent of the mean. The main emission component CO₂ is known with an uncertainty of 3 per cent of the mean. The total uncertainty level was 4 per cent of the mean in 2009. There have been major changes in uncertainty level for the different emission components between the two years. The highest uncertainty change between 1990 and 2009 is in the uncertainty estimates for the SF₆ emissions, which has increased from 2 to 56 per cent of the mean. However, the SF₆ emissions are strongly reduced because magnesium production was closed down. The figures for the emission of SF₆ from magnesium production was quite well known, but now a larger part of the SF₆ emissions comes from sources with higher uncertainty. For N₂O there is also a considerable increase in the uncertainty between the years. One reason for the change can be found in that N₂O from the production of synthetic fertilizer with a quite low uncertainty contributes to a smaller part of the total N₂O emissions in 2009 than in 1990. For the other gases there are only smaller changes in the uncertainty from 1990 to 2009.

By including the LULUCF sector the results from the analysis show a total uncertainty of 7 per cent of the mean in 1990 and 17 per cent in 2009. This is due to the fact that the uncertainty in the LULUCF sector in general is higher than in most other sectors.

In the tier 2 uncertainty analysis carried out in the year 2006 (Statistics Norway 2010c), the uncertainty for the total national emissions of GHG (LULUCF sector excluded) in 1990 was estimated to be 7 per cent of the mean. In the new analysis the uncertainty estimate is reduced with two percentage points. There are several reasons for the new lower estimate. One reason is that Statistics Norway and the Climate and Pollution Agency have increased the inventory

quality by using improved methodologies for important sources, as for example emissions from road traffic and from plants that participate in EU's emission trading system. 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 much of the reduction in the total uncertainty of the inventory is not due to improved inventory methods, since the lower uncertainty partly is an effect of improved uncertainty estimates for some source categories which earlier were overestimated. A source category with important reductions in uncertainty since the analysis in 2006 is the uncertainty in emissions of direct N₂O from other agricultural soil sources. This category includes emissions from crop residues, and the uncertainty reduction is mainly a result of lower crop production. Since the uncertainty estimates for agricultural soils are very dominating, changes in these source categories have large impact on the total uncertainty for the inventory.

In the 2006 analysis, the uncertainty in the N₂O estimate was estimated to 57 per cent of the mean. In this years' analysis the uncertainty estimate is reduced to 40 per cent of the mean. The other emission components show just minor changes in the uncertainty estimates for 1990 in the new analysis compared to the analysis from 2006.

For the last year in the two analyses (2004 in the 2006 analysis, 2009 in the present work), the reduction in total uncertainty from 6 to 4 per cent may simply reflect changes in the relative importance of the gases. The share of CO₂ is increased, while the share of N₂O is reduced.

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. New emission sources have also been included to make the greenhouse gas inventory for Norway more complete.

1.7.4 Uncertainty in emission trend

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

Table 1.7. Uncertainty of emission trends. 1990-2009. Excluding the LULUCF sector.

	Per cent change ((μ2004-μ1990)*100/μ1990)	Uncertainty (2*σ*100/μ1990)
Total	3	3
CO ₂	23	3
CH ₄	-9	10
N ₂ O	-36	11
HFC	-	-
PFC	-89	17
SF ₆	-97	0

Table 1.8. Uncertainty of emission trends, 1990-2009. Including the LULUCF sector.

	Per cent change ((μ 2004- μ 1990)*100/ μ 1990)	Uncertainty (2* σ *100/ μ 1990)
Total	-37	7
CO ₂	-33	10
CH ₄	-9	10
N ₂ O	-36	12
HFC	-	-
PFC	-89	19
SF ₆	-97	0

The result shows that the increase in the total GHG emissions from 1990 to 2009 is 3 per cent, with an uncertainty in the trend on ± 3 percentage points, when the LULUCF sector is not included. This means that the 2009 emissions are likely between 0 and 6 per cent above the 1990 emissions (a 95 percent confidence interval). Norway is 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 CO₂ quotas and the other Kyoto mechanisms is taken into account. It is important to keep in mind that the emission figures reported to the Kyoto Protocol has an uncertainty connected to the reported values.

With the sector LULUCF included in the calculations there has been a decrease in the total emissions figures on -37 per cent, with a trend uncertainty on ± 7 percentage points.

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 desk/centralized/in-country reviews, in the years 2000-2012. The in-country reviews took place in 2002, 2007 (covering Norway's Initial Report and Norway's 2006 greenhouse gas inventory submission) and 2012. Norway has not yet received the final review report from the review held in 2012.

The ERT's main conclusions from the review of the 2011 submission with regards to the completeness of the inventory are **(text below in bold is Norway's remark (if any) to the status of the different issues raised in the review report)**:

The inventory covers all source and sink categories with the exception of CO₂ from soda ash use in industrial processes and CO₂ from organic soils in the LULUCF sector. The ERT recommends that Norway obtain data on soda ash use as well as on organic soils and include corresponding estimates in its 2012 annual submission.

Some emissions from the use of soda ash has for many years been reported under 2C5, this is now clearer in the NIR, see chapter 4.4.6. In addition, we have reported emissions in 2A7 (glassworks), see chapter 4.2.5. The remaining uses of soda ash are now reported under 2A4, see chapter 4.2.4.

As for the organic soils in the LULUCF sector, areas of organic soils are estimated for land-use conversion to and from forest land. Drained organic soils are estimated.

The inventory is generally in line with the Intergovernmental Panel on Climate Change (IPCC) Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the Revised 1996 IPCC Guidelines), the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (hereinafter referred to as the IPCC good practice guidance) and the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (hereinafter referred to as the IPCC good practice guidance for LULUCF) and is complete in terms of gases, years (1990–2009) and geographical coverage. Norway has reported inventory data in a complete set of CRF tables and used appropriately notation keys.

The ERT's main conclusions from the review of the 2012 submission (in the draft ARR2012) with regards to the completeness of the inventory are **(text below in bold is Norway's remark (if any) to the status of the different issues raised in the review report):**

The inventory covers all mandatory source and sink categories for the period 1990–2010 and is complete in terms of years and geographical coverage. However, some categories under the LULUCF sector (see para. 118) and under the KP-LULUCF activities (see para. 160 below) have not been reported. In addition, CO₂ emissions from soda ash use under the industrial processes sector have not been reported for all years of the time series (see para. 87 below). The ERT recommends that Norway provide estimates for these categories/activities in its next annual submission.

With regards to §118, several other categories, previously noted NE, now have estimates. With regards to §160, we now have reported emissions from liming and N₂O from cultivation of new cropland under deforestation. Under afforestation, we have reported biomass burning and fertilization. Drainage is reported for forest management and this is not mandatory for ARD.

Some emissions from the use of soda ash has for many years been reported under 2C5, this is now clearer in the NIR, see chapter 4.4.6. In addition, we have reported emissions in 2A7 (glassworks), see chapter 4.2.5. The remaining uses of soda ash are now reported under 2A4, see chapter 4.2.4.

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. They are:

- Emissions of CH₄ from agricultural waste, after it is applied to soils. In the IPCC Guidelines it is written that "Agricultural soils may also emit CH₄", but no calculation methodology is proposed. **(Comment: As far as we know there is no calculation method for this in (IPCC 1997b) or GPG (IPCC 2000). From our knowledge there is no other party reporting CH₄ in this sector.)**
- 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 VII to this report.

2 Trends in Greenhouse Gas Emissions

2.1 Emission trends for aggregated greenhouse gas emissions

Total greenhouse gas (GHG) emissions in Norway, expressed in carbon dioxide equivalents, were 53.4 million tonnes in 2011, which is a decrease of approximately 1 million tonnes compared to 2010. From 2000 the emissions increased and reached its peak point at 56 million tonnes in 2007. Between 1990 and 2011 the total greenhouse gas emissions have increased by almost 3 million tonnes, or by more than 6 per cent.

Norway's emission target under the Kyoto Protocol for the period 2008-2012 is 1 per cent higher than the emissions were in 1990. Current emissions are about 5 per cent higher than this, but the emission target will be met through participation in the EU emission trading system and governmental purchase of allowances. In 2011 the land-use category forest land remaining forest land was the major contributor to the total amount of sequestration with 31.7 million tonnes CO₂. Land converted to forest land contributed with 0.7 million tonnes CO₂. The total net CO₂ removal from the LULUCF sector was 27.6 million tonnes in 2011.

The net greenhouse gas emissions including all sources and sinks are approximately 25.8 million tonnes in 2011. The total contribution from different sources from 1990 to 2011 is illustrated in Figure 2.1 and in Table 2.1.

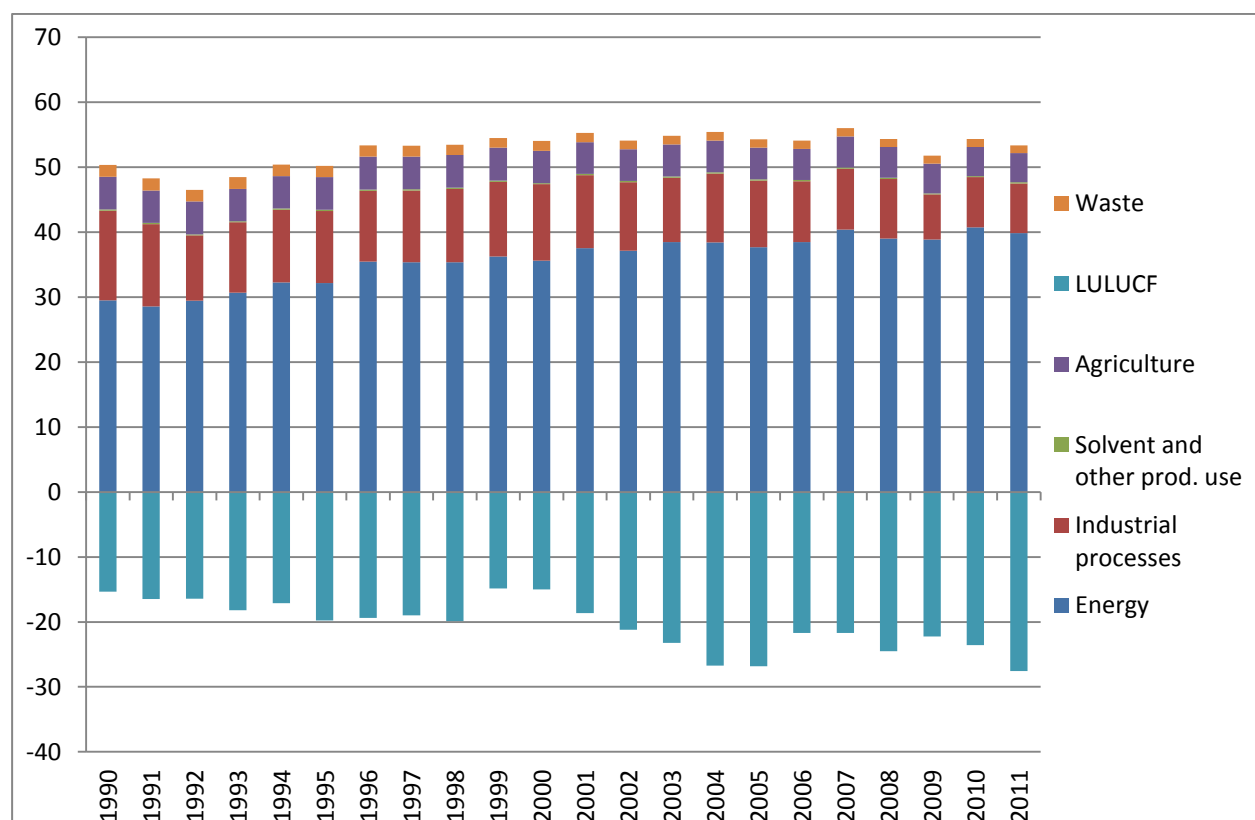


Figure 2.1. Total emissions of all GHG emissions calculated in Mtonnes CO₂ equivalents from the different sectors from 1990 to 2011. Source: Statistics Norway/Climate and Pollution Agency/Forest and Landscape Institute.

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Table 2.1 Total emissions of greenhouse gases by sources and removals from LULUCF in Norway 1990-2011. The emissions are given in million tonnes CO₂ equivalents.

Year	Energy	Industrial processes	Solvent and other prod. use	Agriculture	LULUCF	Waste	Total - without LULUCF
1990	29.5	13.8	0.2	5.0	-15.3	1.9	50.4
1991	28.6	12.7	0.2	5.0	-16.5	1.8	48.3
1992	29.5	10.8	0.2	5.0	-16.4	1.8	46.5
1993	30.7	10.8	0.2	5.0	-18.2	1.8	48.4
1994	32.3	11.2	0.2	5.0	-17.1	1.8	50.4
1995	32.2	11.1	0.2	5.0	-19.8	1.8	50.2
1996	35.5	10.9	0.2	5.1	-19.4	1.7	53.4
1997	35.4	11.0	0.2	5.0	-19.0	1.7	53.3
1998	35.4	11.3	0.2	5.0	-19.9	1.6	53.5
1999	36.3	11.5	0.2	5.1	-14.9	1.5	54.5
2000	35.6	11.8	0.2	5.0	-15.0	1.5	54.0
2001	37.5	11.3	0.2	4.9	-18.6	1.4	55.3
2002	37.1	10.6	0.2	4.9	-21.2	1.4	54.1
2003	38.5	9.9	0.2	4.9	-23.2	1.4	54.8
2004	38.4	10.6	0.2	4.9	-26.7	1.3	55.4
2005	37.7	10.2	0.2	4.9	-26.8	1.3	54.3
2006	38.5	9.4	0.2	4.8	-21.7	1.3	54.1
2007	40.4	9.3	0.2	4.8	-21.7	1.3	56.0
2008	39.0	9.2	0.2	4.8	-24.5	1.2	54.3
2009	38.9	7.0	0.2	4.5	-22.2	1.3	51.8
2010	40.7	7.7	0.2	4.5	-23.6	1.2	54.3
2011	39.8	7.6	0.2	4.5	-27.6	1.2	53.4

Source: Statistics Norway/Climate and Pollution Agency/Forest and Landscape Institute.

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

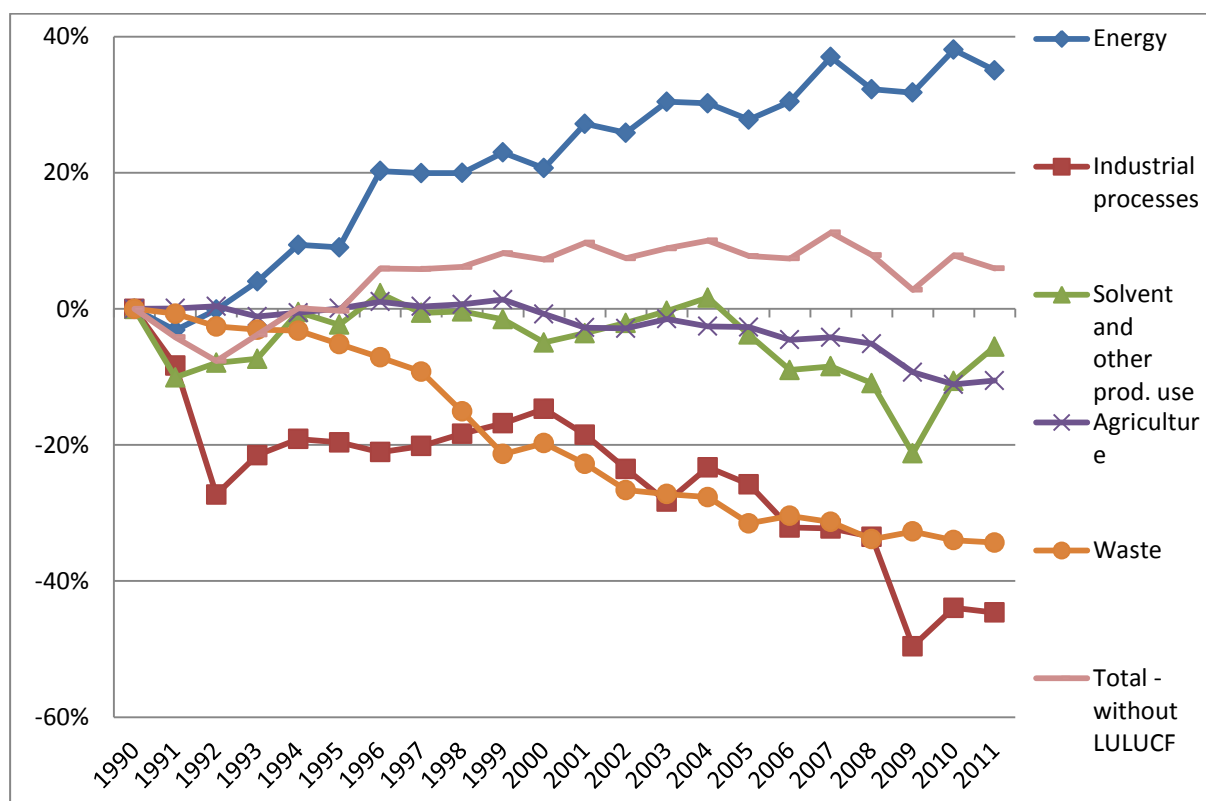


Figure 2.2 Changes in total greenhouse gas emissions by UNFCCC source categories during the period 1990-2011 compared to 1990.

Source: Statistics Norway/Climate and Pollution Agency.

Norway has experienced economic growth since 1990, which explains the general growth in emissions. This has resulted in higher CO₂ 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. Between 2007 and 2009 emissions are reduced by 7.6 per cent, while increasing by 3 per cent again in the period from 2009 to 2011. Looking at the overall trend from 1990 to 2011, the emissions increased by about 6 per cent.

The downward trend in the early 1990's has been primarily due to policies and measures in the magnesium, and aluminium industry resulting in less emission intensive production methods. Low economic activity during that time and the CO₂-tax, which was implemented with effect from 1991, also effected the downward trend.

The total emissions decreased by more than 2 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. In the same period emissions increased 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 1.4 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 about 1 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 some 2 per cent from 2004 to 2005. The reduction were 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 decreased by 0.3 per cent. The emissions from industrial processes (chemical industries and metal production) decreased, while emissions from energy use in transportation increased in the same periode. From 2006 to 2007 the emissions increased by about 3,5 per cent, mainly because emissions from energy use increased. In 2008 economic recession causes total emissions to decrease with 1.6 mtonnes CO₂- equivalents, mostly because of reduced emissions from road traffic and coastal navigation. From 2008 to 2009 the emissions decreased by more than 2.5 mtonnes or 4.3 per cent. The reduction was mainly due to decreased production of ferro alloys and aluminium (e.g. one Sørderberg production line was closed down), reduced production of nitric acid connected with improved technology and decreased emission from road traffic. In 2010 emissions increased by almost 5 per cent, mainly due to economic growth causing higher emissions in almost all sectors. In 2011 emissions went down again by almost 2 per cent, mainly because of the same, but reversed trends.

2.2 Emission trends by gas

As shown in Figure 2.3, CO₂ is by far the largest contributor to the total GHG emissions, followed by CH₄, N₂O, and then the fluorinated gases PFCs, SF₆ and HFCs. In 2011 the relative contributions to the national totals from the different gases were: CO₂ 84 per cent, CH₄ 8 per cent, N₂O 6 per cent and fluorocarbons (PFCs, SF₆ and HFCs) 2 per cent. While the relative share of the gases is the same in 2011 as for 2010, the relative share of CO₂ has increased by approximately 1 per cent each year during the period 2005-2011, from about 80 per cent in 2005 up to 84 per cent in 2011.

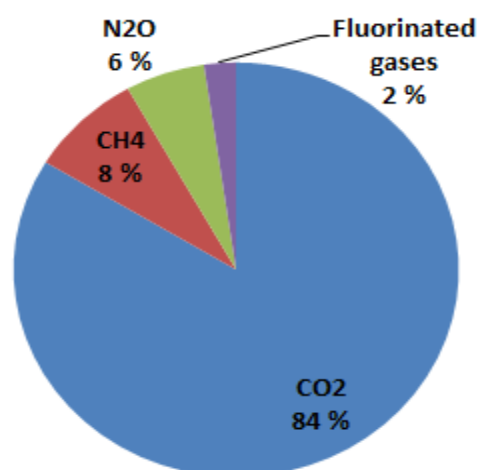


Figure 2.3. Distribution of emissions of greenhouse gases in Norway by gas, 2011.

Source: Statistics Norway/Climate and Pollution Agency

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Table 2.2 presents emission figures for all direct greenhouse gases, expressed in absolute emission figures and total CO₂ equivalents.

Table 2.2 Emissions of greenhouse gases in Norway during the period 1990-2011. Units: CO₂ and CO₂ eq. in Mtonnes (Mt), CH₄ and N₂O in ktonnes (kt) and other gases in tonnes (t).

Gas	CO ₂	CH ₄	N ₂ O	PFC			SF ₆	HFC									Total without LULUCF
				CF ₄	C ₂ F ₆	218		23	32	125	134	134a	143	143a	152a	227ea	Mt CO ₂ -eq.
Year	Mtonnes	ktonnes	ktonnes	tonnes			tonnes	tonnes									
1990	34.8	239.5	15.9	467.4	36.2	0.0	92.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	50.4
1991	33.4	240.4	15.4	416.5	31.0	0.0	87.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.6	0.0	48.3
1992	34.2	244.2	13.6	321.6	21.4	0.0	29.5	0.0	0.1	0.1	0.0	13.6	0.0	0.0	0.8	0.0	46.5
1993	35.8	246.7	14.2	324.3	20.6	0.0	30.9	0.0	0.2	0.2	0.0	21.3	0.0	0.0	0.8	0.0	48.4
1994	37.7	250.2	14.5	286.9	18.3	0.0	36.7	0.0	0.3	1.4	0.0	28.9	0.0	0.6	0.9	0.0	50.4
1995	37.8	247.6	14.6	283.3	18.1	0.0	25.4	0.0	0.4	5.2	0.0	38.4	0.0	4.1	1.3	0.0	50.2
1996	41.0	249.0	14.7	258.5	16.2	0.0	24.0	0.0	0.6	9.0	0.0	46.2	0.0	6.8	1.4	0.1	53.4
1997	41.1	249.2	14.7	229.9	15.1	0.0	24.3	0.1	0.8	15.5	0.1	57.4	0.0	11.7	3.5	0.2	53.3
1998	41.4	242.2	14.8	209.8	13.3	0.0	30.4	0.1	1.1	20.6	0.1	70.1	0.0	15.4	6.1	0.2	53.5
1999	42.1	238.4	15.6	196.2	12.3	0.0	36.6	0.1	1.5	27.2	0.1	82.1	0.0	22.3	6.6	0.2	54.5
2000	41.8	240.8	14.8	186.4	11.6	0.0	39.1	0.1	2.0	34.8	0.1	90.3	0.0	28.7	8.3	0.2	54.0
2001	43.2	241.4	14.5	187.5	11.9	0.0	33.1	0.1	2.6	44.0	0.1	99.7	0.0	38.2	10.6	0.4	55.3
2002	42.3	235.1	15.2	201.3	14.0	0.0	10.0	0.1	3.3	54.8	0.1	115.9	0.0	47.2	10.6	1.4	54.1
2003	43.6	238.8	14.7	125.6	10.1	0.0	9.5	0.1	4.2	51.6	0.1	122.2	0.0	43.2	10.8	1.0	54.8
2004	44.1	237.0	15.2	122.1	9.4	0.0	11.6	0.1	5.1	55.0	0.1	128.7	1.1	46.0	23.1	1.1	55.4
2005	43.1	226.8	15.4	116.7	7.6	0.0	13.1	0.1	6.0	57.0	0.1	139.3	0.8	44.6	30.7	1.0	54.3
2006	43.5	221.5	14.4	102.1	8.6	0.0	8.9	0.1	7.9	63.0	0.1	158.5	0.8	47.9	34.3	0.9	54.1
2007	45.5	225.7	13.8	111.7	10.3	0.0	3.2	0.1	10.0	64.0	0.1	184.8	0.7	46.2	36.2	1.1	56.0
2008	44.4	219.1	12.3	104.7	10.0	0.0	2.7	0.1	12.4	68.6	0.1	218.4	2.8	51.7	35.3	0.8	54.3
2009	42.9	214.6	10.3	49.8	5.8	0.0	2.6	0.1	15.9	73.6	0.1	245.0	2.2	50.1	35.6	0.9	51.8
2010	45.5	215.3	9.8	27.3	3.0	0.0	3.2	0.1	19.6	94.1	0.1	280.1	1.9	69.2	40.0	0.7	54.3
2011	44.7	209.4	9.9	29.9	3.4	0.0	2.5	0.2	22.4	98.8	0.2	305.8	1.8	64.7	40.5	2.1	53.4

Source: Statistics Norway/Climate and Pollution Agency

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 1990–2011, and for 2010-2011.

Table 2.3. Emissions in Mtonnes CO₂ equivalents and changes in per cent for each greenhouse gas.

Year	CO ₂	CH ₄	N ₂ O	PFCs	SF ₆	HFCs	Total
1990	34.8	5.0	4.9	3.4	2.2	0.0	50.4
2010	45.5	4.5	3.1	0.2	0.1	0.9	54.3
2011	44.7	4.4	3.1	0.2	0.1	1.0	53.4
Changes 1990-2011	28.2 %	-12.6 %	-37.5 %	-93.3 %	-97.2 %		6.0 %
Change 2010-2011	-2.0 %	-2.8 %	0.9 %	10.1 %	-19.5 %	3.9 %	-1.8 %

Source: Statistics Norway/Climate and Pollution Agency

As seen in table 2.2 and 2.3, there has been a significant increase in CO₂ emissions and a significant decrease in emissions of fluorocarbons in the period from 1990 to 2011, except for HFCs which has increased from almost 0 to 0.95 Mtonnes CO₂ equivalent during the period.

The fluorocarbons constituted a larger fraction of the greenhouse gas emission total in the early 1990s than that in 2011, while CO₂ represented a smaller share in 1990 than in 2011.

The emissions of CH₄ and N₂O 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 2011.

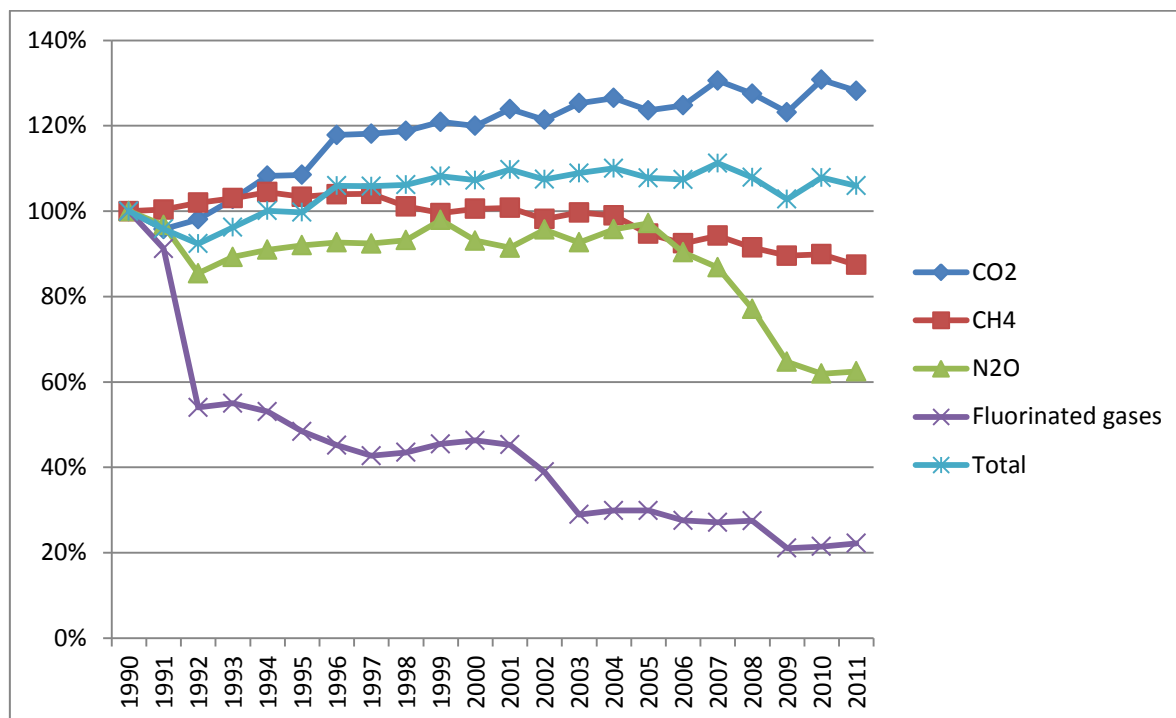


Figure 2.4. Changes in emissions of greenhouse gases by gas in Norway 1990-2011, compared to 1990.

Source: Statistics Norway/Climate and Pollution Agency

Figure 2.4 shows that the overall increasing trend has been weakened by decreased emissions of fluorinated gases. The CO₂ emissions went down 2 per cent from 2010 to 2011.

Note the fact that the source categories in this chapter are not completely consistent with the IPCC source categories.

2.2.1 Carbon dioxide (CO₂)

The Norwegian CO₂ 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 CO₂ emissions on various categories is shown in Figure 2.5.

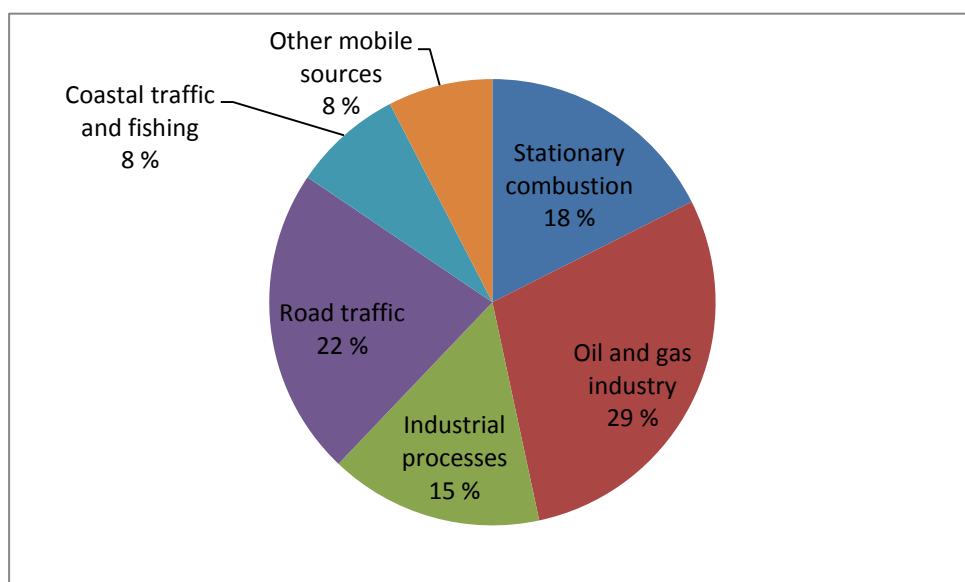


Figure 2.5. Distribution of CO₂ emissions in Norway by source in 2011.

Source: Statistics Norway/Climate and Pollution Agency

Table 2.4 lists CO₂ emissions from each source category for the whole period 1990-2011. The change in emissions from 1990 to 2011 compared to 2011 is displayed in Figure 2.6.

Table 2.4. CO₂ emissions (million tonnes) from different source categories for the period 1990-2011.

Year	Stationary combustion	Oil and gas industry	Industrial processes	Road traffic	Coastal traffic and fishing	Other mobile sources	Total
1990	7.5	7.4	6.8	7.6	3.2	2.3	34.8
1991	7.0	7.3	6.2	7.6	3.0	2.2	33.4
1992	6.9	7.8	6.4	7.7	3.1	2.2	34.2
1993	7.1	8.2	6.9	8.2	3.2	2.1	35.8
1994	7.9	8.9	7.3	7.9	3.1	2.5	37.7
1995	7.4	9.1	7.4	8.1	3.2	2.6	37.8
1996	9.0	10.0	7.5	8.3	3.4	2.8	41.0
1997	8.3	10.4	7.6	8.3	3.7	2.8	41.1
1998	8.5	10.0	7.8	8.6	3.9	2.5	41.4
1999	8.1	10.6	7.8	8.5	4.1	3.0	42.1
2000	7.2	11.9	8.2	8.4	3.7	2.5	41.8
2001	7.5	12.8	7.8	8.9	3.5	2.7	43.2
2002	7.4	12.6	7.2	8.9	3.4	2.7	42.3
2003	8.2	12.9	7.4	9.1	3.4	2.5	43.6
2004	7.4	13.1	7.8	9.4	3.5	2.8	44.1
2005	6.9	13.2	7.4	9.6	3.4	2.6	43.1
2006	7.5	12.9	7.1	9.9	3.4	2.8	43.5
2007	7.3	14.2	7.2	10.1	3.5	3.1	45.5
2008	7.0	14.0	7.3	10.0	3.2	3.0	44.4
2009	7.7	13.0	6.0	9.8	3.5	2.9	42.9
2010	8.7	13.2	6.9	10.0	3.6	3.2	45.5
2011	7.8	13.0	6.9	10.0	3.5	3.4	44.7

Source: Statistics Norway/Climate and Pollution Agency

In the period from 1990 to 2011 the total emissions of CO₂ increased by 28 per cent, or by 9.8 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 CO₂ increase.

In 2011 the total Norwegian emissions of CO₂ were 44.7 million tonnes, which is a decrease of 1 million tonnes, or 2 per cent less than in 2010. The sector which is contributing to the majority of the decreased emissions, is energy use in the industry, with a decrease of 0.3 million tonnes, or 3 per cent decrease from 2010 to 2011.

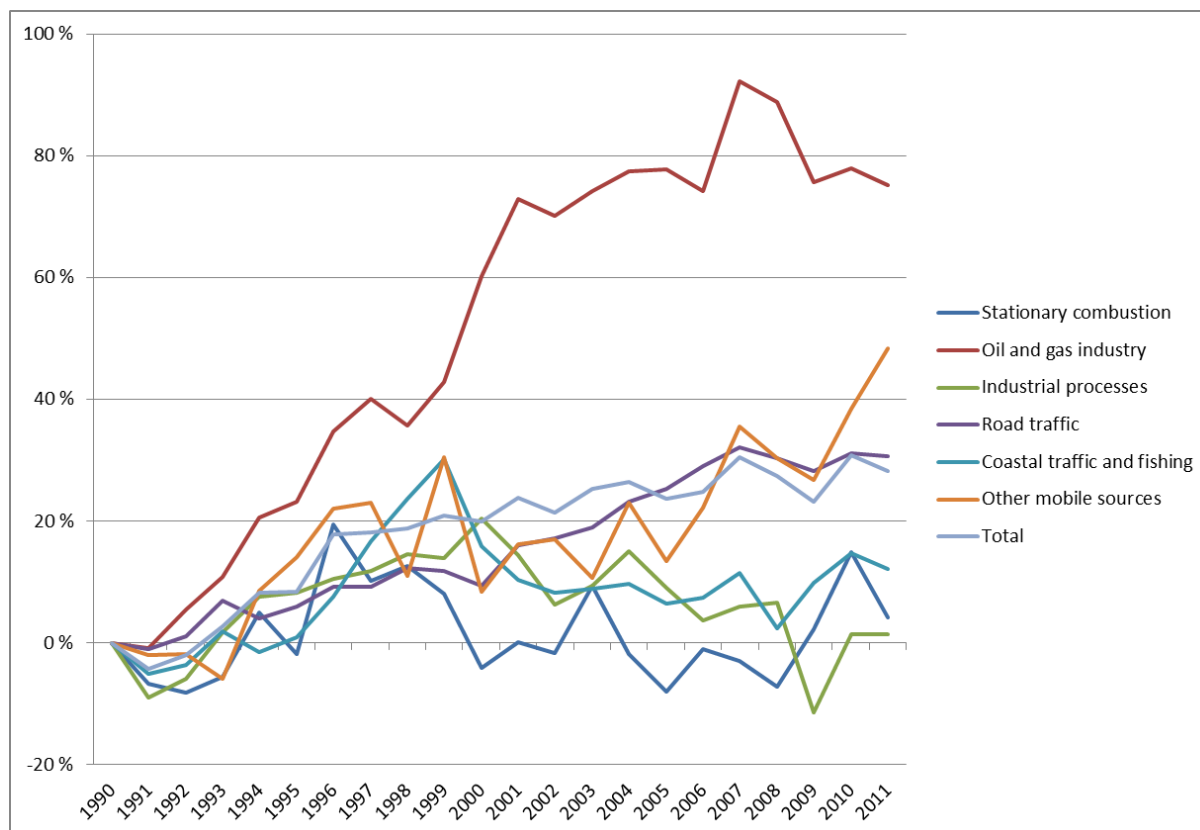


Figure 2.6. Changes in Norwegian CO₂ emissions 1990-2011 for major sources compared to 1990.

Source: Statistics Norway/Climate and Pollution Agency.

CO₂ emissions from the oil- and gas industry have increased by about 75 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. In the 90s, emissions per unit produced oil/gas decreased, because of technical and administrative improvements partly induced by a CO₂ taxation regime established in 1991. Nevertheless, this trend has been reversed from 2000, 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 CO₂-emissions from oil and gas increased by 1.3 million tonnes from 2006 to 2007, but from 2007 to 2011 the total CO₂-emissions from this sector decreased by almost the same amount, 1.3 million tonnes.

Road transportation has had an increase of 31 per cent CO₂ emission from 1990 to 2011. Although emissions from personal cars powered by gasoline decreased by 40 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 CO₂ from coastal traffic and fishing are 12 per cent higher in 2011 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.

CO₂ emissions from industrial processes increased by 2 per cent from 1990 to 2011, and the sector contributed with 15 per cent of total CO₂ emissions. Approximately 67 per cent of the CO₂ emissions from this sector are from metal production.

The CO₂ emissions from stationary combustion are approximately 12 per cent of the total CO₂ emissions. They have increased by 4 per cent compared to 1990, and decreased by 9 per cent from 2010 to 2011. The latter is due to decreased emissions from gas fired-, combined heat and power plant and decreased

2.2.2 Methane (CH₄)

About 46 per cent of the methane emissions in 2011 originated from agriculture, and 24 per cent originated from landfills. Methane emissions from agriculture are dominated by releases from enteric fermentation. Combustion and evaporation/leakage in the oil and gas industry accounted for 13 per cent of the total methane emissions in 2011, 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 CH₄-emissions in 2011.

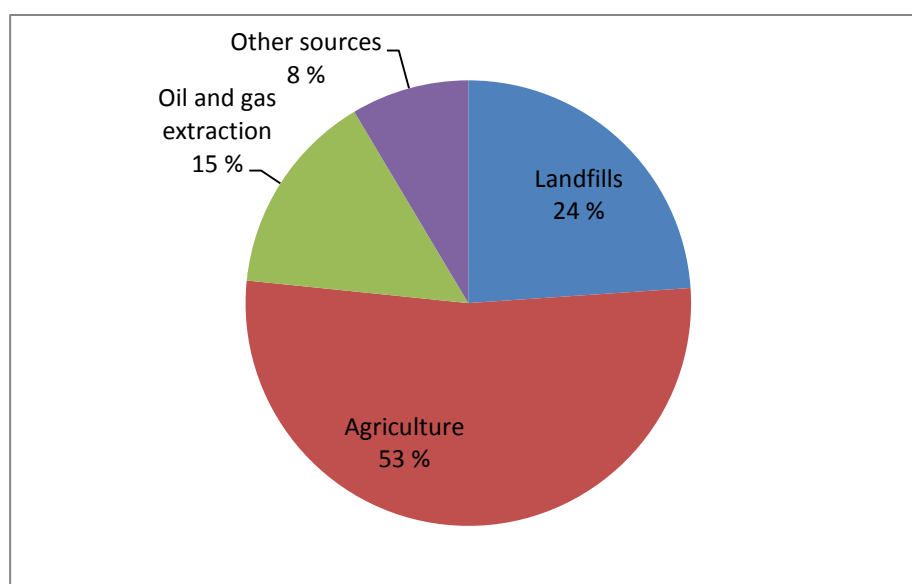


Figure 2.7. Distribution of Norwegian CH₄ emissions in 2011.

Source: Statistics Norway/Climate and Pollution Agency

The methane figures from 1990 to 2011, distributed on the different categories are displayed in table 2.5.

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Table 2.5. Emissions of CH₄ in Norway 1990-2011. The emissions are given in ktonnes CH₄.

Year	Sectors				
	Landfills	Agriculture	Oil and gas industry	Other sources	Total
1990	82.1	124.5	15.4	17.6	239.5
1991	81.5	125.0	17.5	16.4	240.4
1992	79.9	126.3	22.5	15.5	244.2
1993	79.4	124.5	26.1	16.7	246.7
1994	79.0	126.6	27.8	16.8	250.2
1995	77.2	126.5	27.6	16.3	247.6
1996	75.5	128.0	28.6	16.9	249.0
1997	73.7	126.9	32.0	16.6	249.2
1998	68.5	127.5	30.0	16.2	242.2
1999	63.0	130.7	28.1	16.7	238.4
2000	65.0	125.7	33.1	17.0	240.8
2001	62.3	124.0	38.3	16.8	241.4
2002	59.3	123.8	34.9	17.0	235.1
2003	58.5	125.8	35.8	18.7	238.8
2004	58.1	123.1	39.1	16.8	237.0
2005	54.5	122.6	33.7	16.0	226.8
2006	55.3	119.9	30.4	15.8	221.5
2007	54.1	119.1	34.4	18.0	225.7
2008	51.8	118.1	32.1	17.2	219.1
2009	52.6	114.0	30.8	17.3	214.6
2010	51.5	113.5	31.9	18.4	215.3
2011	51.0	111.2	29.3	17.9	209.4

Source: Statistics Norway/Climate and Pollution Agency

The total methane emissions decreased by about 2.8 per cent from 2010 to 2011. During the period 1990-2011 the total CH₄ emissions decreased by almost 12.6 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.

The waste volumes have grown during the period from 1990 to 2011, but this effect has been more than offset by increased recycling and incineration of waste and increased burning of methane from landfills.

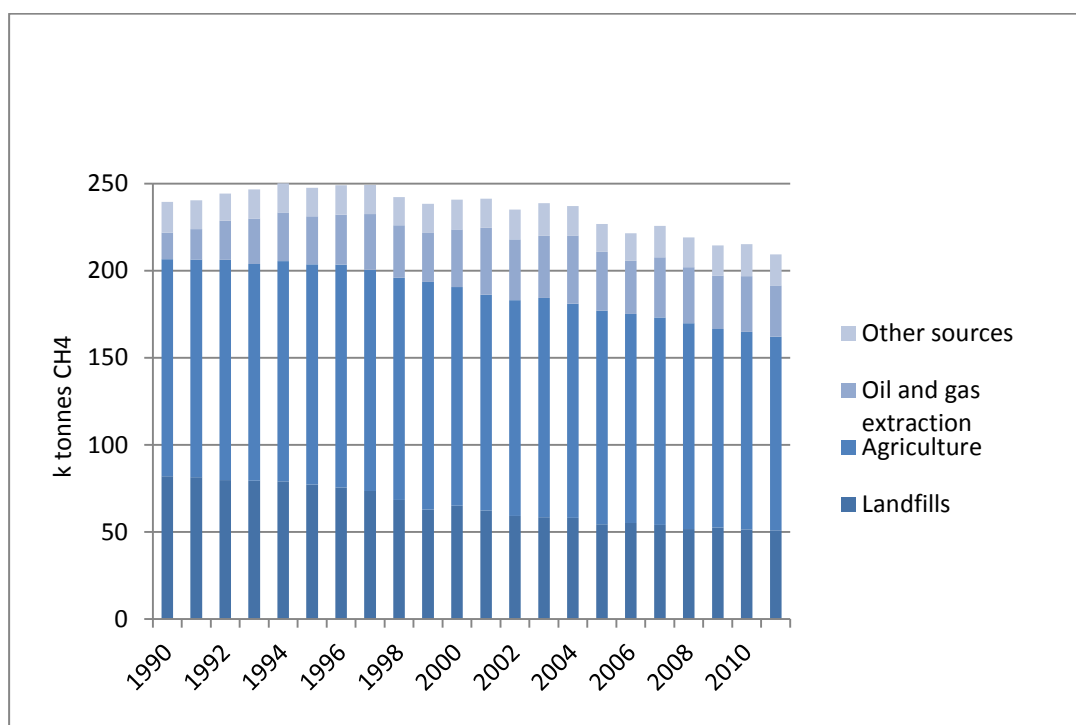


Figure 2.8. CH₄ emissions (ktonnes) for major Norwegian sources between 1990 and 2011.

Source: Statistics Norway/Climate and Pollution Agency

2.2.3 Nitrous oxide (N₂O)

Figure 2.9 shows that 70 per cent of the Norwegian emissions of N₂O 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 9 per cent of the total. The contribution from road traffic amounted to 9 per cent in 2011. Included under “other” are emissions from e.g. fuel combustion, manure management and waste-water handling.

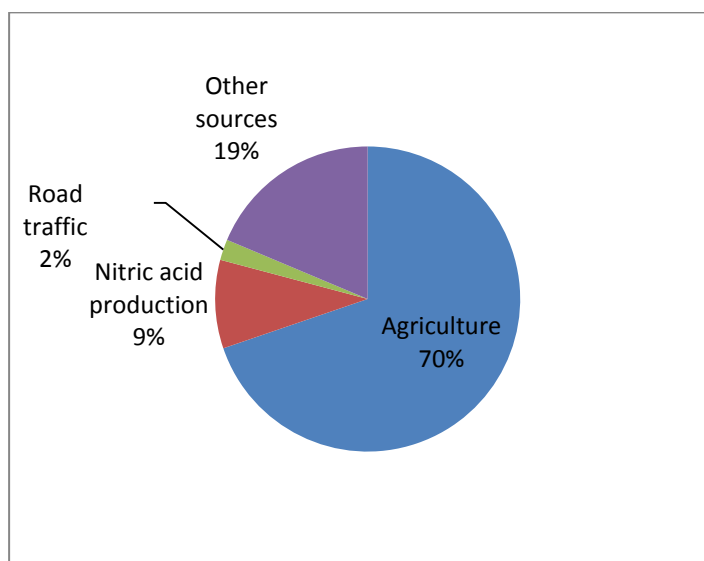


Figure 2.9. Distribution of Norwegian N₂O emissions by major sources in 2011.

Source: Statistics Norway/Climate and Pollution Agency

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The emissions of N₂O have been relatively stable over the years, the exception being nitric acid production. During the period 1990–2011 the total N₂O emissions decreased by 38 per cent. From 2010 to 2011 there was an increase in the emission by approximately 1 per cent, which is notably due to higher emissions from road transport and agriculture soils. Details are shown in Table 2.6 and Figure 2.10.

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 from 2008 to 2010. Emissions of N₂O from production of nitric acid decreased by 19 per cent from 2010 to 2011.

Table 2.6. Emissions of N₂O (ktonnes) in Norway by major sources 1990-2011.

Year	Agriculture	Nitric acid production	Road traffic	Other sources	Total
1990	7.7	6.7	0.2	1.4	15.9
1991	7.7	6.2	0.2	1.4	15.4
1992	7.6	4.4	0.2	1.3	13.6
1993	7.5	5.1	0.2	1.4	14.2
1994	7.5	5.3	0.2	1.5	14.5
1995	7.6	5.3	0.2	1.5	14.6
1996	7.6	5.2	0.3	1.6	14.7
1997	7.6	5.2	0.3	1.6	14.7
1998	7.6	5.4	0.3	1.5	14.8
1999	7.5	6.2	0.3	1.6	15.6
2000	7.5	5.6	0.3	1.4	14.8
2001	7.3	5.4	0.3	1.5	14.5
2002	7.3	6.2	0.3	1.5	15.2
2003	7.4	5.5	0.3	1.5	14.7
2004	7.4	6.0	0.3	1.6	15.2
2005	7.4	6.3	0.2	1.5	15.4
2006	7.3	5.2	0.2	1.6	14.4
2007	7.4	4.4	0.2	1.7	13.8
2008	7.3	3.0	0.2	1.7	12.3
2009	6.9	1.5	0.2	1.7	10.3
2010	6.7	1.1	0.2	1.8	9.8
2011	6.9	0.9	0.2	1.9	9.9

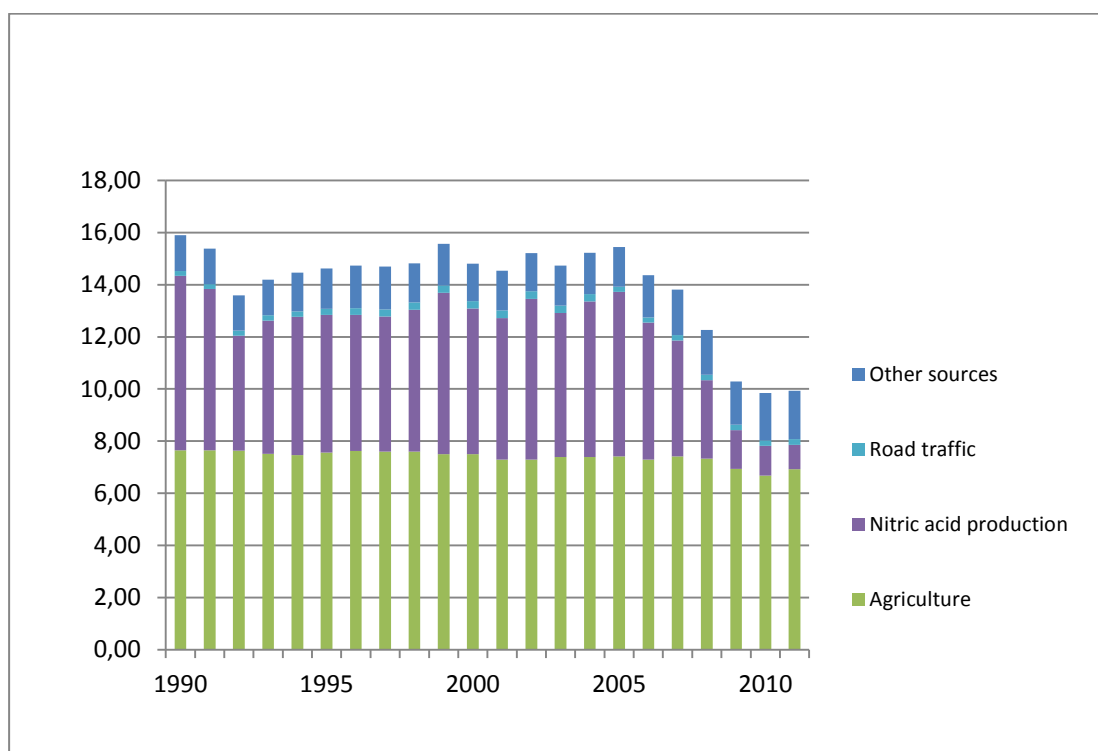


Figure 2.10. Changes in N_2O emissions for major Norwegian sources between 1990 and 2011. Source: Statistics Norway/Climate and Pollution Agency

2.2.4 Perfluorocarbons (PFCs)

The emissions of the perfluorocarbons tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) from Norwegian aluminium plants in 2011 were reported at 30 and 3 tonnes respectively, corresponding to a total of 0.3 million tonnes CO_2 equivalents. The total emissions of PFCs decreased by 93 per cent in the period 1990-2011 following a steady downward trend as illustrated in Figure 2.11. The emission of CF_4 decreased by 94 per cent, while the emission of C_2F_6 decreased by 91 per cent in the same period. PFCs reduction is caused by improved technology and process control which has led to a significant decrease in the amount of PFCs emitted per tonne aluminium produced during the period 1990-2011. The PFC emissions were 10 per cent lower in 2011 compared to 2010. In 1990, the emissions of PFCs were 3.88 kg CO_2 equivalents per tonne aluminium produced. In 2011, this is reduced 0.20 kg per tonne aluminium. This is a reduction of 94.8 per cent from 1990 to 2011.

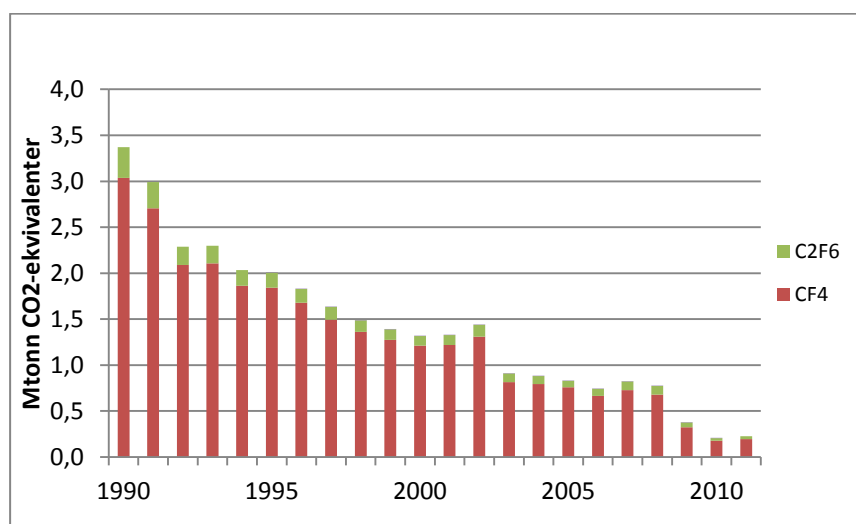


Figure 2.11. Emissions (million tonnes CO₂-eq) of PFCs in Norway 1990-2011.

Source: Statistics Norway/Climate and Pollution Agency

Table 2.7. Emissions of PFCs in Norway 1990-2011 in tonnes. Total CO₂ eq. are in million tonnes.

Year	PFC14 (CF ₄)	PFC116 (C ₂ F ₆)	PFC218 (C ₃ F ₈)	Total CO ₂ eq.
1990	463.7	19.1	0.0	
1991	430.2	18.0	0.0	
1992	467.4	36.2	0.0	503.5
1993	416.5	31.0	0.0	447.6
1994	321.6	21.4	0.0	343.0
1995	324.3	20.6	0.0	344.9
1996	286.9	18.3	0.0	305.1
1997	283.3	18.1	0.0	301.4
1998	258.5	16.2	0.0	274.7
1999	229.9	15.1	0.0	245.0
2000	209.8	13.3	0.0	223.0
2001	196.2	12.3	0.0	208.5
2002	186.4	11.6	0.0	197.9
2003	187.5	11.9	0.0	199.4
2004	201.3	14.0	0.0	215.3
2005	125.6	10.1	0.0	135.7
2006	122.1	9.4	0.0	131.5
2007	116.7	7.6	0.0	124.3
2008	102.1	8.6	0.0	110.7
2009	111.7	10.3	0.0	122.0
2010	104.7	10.0	0.0	114.7
2011	49.8	5.8	0.0	55.6

Source Statistics Norway/Climate and Pollution Agency

2.2.5 Sulphur hexafluoride (SF₆)

Up till 2006 the largest source of SF₆ emissions in Norway was magnesium production. The consumption of SF₆ was reduced through the 1990s due to improvements in technology and process management and reduced production. In 2011, the SF₆ emissions were more than 97 per cent lower than in 1990. The reduction in the SF₆ emissions is due to the closing down of production of cast magnesium in 2002. There have also been improvements in the GIS-sector and an almost end in the use of SF₆ as tracer gas.

The main other use of SF₆ 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, and were about 43 per cent lower in 2011 than in 2002.

Table 2.8 SF₆ emissions (tonnes) in Norway 1990-2011.

Year	GIS	Magnesium and Aluminium Industry	Other	Total
1990	2.2	89.7	0.1	92.0
1991	2.4	84.5	0.1	87.0
1992	2.7	26.7	0.1	29.5
1993	3.0	27.8	0.1	30.9
1994	3.3	33.1	0.3	36.7
1995	3.6	21.3	0.5	25.4
1996	3.7	19.8	0.5	24.0
1997	3.8	18.3	2.1	24.3
1998	3.9	24.4	2.2	30.4
1999	4.0	30.4	2.2	36.6
2000	4.5	32.4	2.3	39.1
2001	3.8	27.0	2.3	33.1
2002	3.4	5.9	0.6	10.0
2003	1.7	7.2	0.6	9.5
2004	2.3	8.6	0.6	11.6
2005	2.3	10.0	0.7	13.1
2006	3.1	5.0	0.8	8.9
2007	2.5	0.0	0.6	3.2
2008	2.1	0.0	0.7	2.7
2009	1.9	0.0	0.7	2.6
2010	2.5	0.0	0.7	3.2
2011	2.0	0.0	0.6	2.5

Source Statistics Norway/Climate and Pollution Agency.

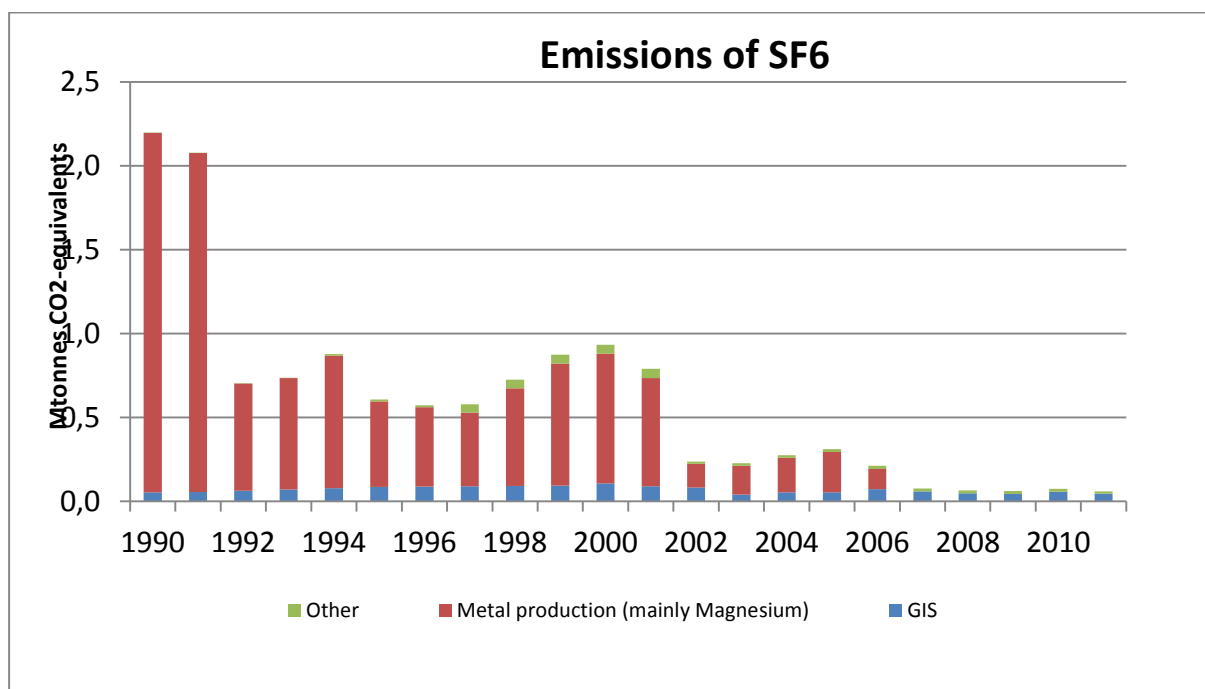


Figure 2.12. Emissions of SF₆ (Mtonnes CO₂ eq.) in Norway 1990-2011.

Source: Statistics Norway/Climate and Pollution Agency

2.2.6 Hydrofluorcarbons (HFCs)

The total actual emissions from HFCs used as substitutes for ozone depleting substances amounted to 0.95 million tonnes of CO₂ equivalents in 2011. Compared to the emissions in 2010, this represents an increase of almost 4 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. Figure 2.13 displays the development of the emissions of HFCs in the period 1990-2011. Table 2.9 shows the actual emissions of different HFCs over the same period. The figure shows that emissions increases year by year. This is due to the strong demand for substitution of ozone depleting substances. The emissions, however was expected to increase even more before the tax on HFCs was introduced in 2003.

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Table 2.9 Actual emissions of HFCs (tonnes) and total (Mtonnes CO₂-eq.) in Norway 1990-2011 calculated using the Tier 2 methodology.

Year	HFC23	HFC32	HFC125	HFC134	HFC134a	HFC143	HFC143a	HFC152a	HFC227ea	Total in Mtonnes CO ₂ eq.
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.00
1991	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.6	0.0	0.01
1992	0.0	0.1	0.1	0.0	13.6	0.0	0.0	0.8	0.0	0.02
1993	0.0	0.2	0.2	0.0	21.3	0.0	0.0	0.8	0.0	0.03
1994	0.0	0.3	1.4	0.0	28.9	0.6	0.0	0.9	0.0	0.04
1995	0.0	0.4	5.2	0.0	38.3	4.1	0.0	1.3	0.0	0.08
1996	0.0	0.6	9.0	0.0	46.2	6.8	0.0	1.4	0.1	0.11
1997	0.1	0.8	15.5	0.0	57.4	11.7	0.0	3.4	0.2	0.16
1998	0.1	1.1	20.6	0.0	70.1	15.4	0.0	6.1	0.2	0.21
1999	0.1	1.5	27.2	0.0	82.1	22.3	0.0	6.6	0.2	0.27
2000	0.1	2.0	34.8	0.0	90.3	28.7	0.0	8.2	0.2	0.33
2001	0.1	2.6	44.0	0.0	99.6	38.2	0.0	10.5	0.4	0.40
2002	0.1	3.3	54.8	0.0	115.8	47.2	0.0	10.6	1.4	0.49
2003	0.1	4.2	51.6	0.0	122.1	43.2	0.0	10.7	1.0	0.48
2004	0.1	5.1	55.0	1.1	128.6	46.0	0.0	22.9	1.1	0.51
2005	0.1	6.0	57.0	0.8	139.2	44.6	1.1	30.5	1.0	0.52
2006	0.1	7.9	63.0	0.8	158.3	47.9	1.9	34.0	0.9	0.58
2007	0.1	10.0	64.0	0.7	184.7	46.2	1.6	35.9	1.1	0.61
2008	0.1	12.4	68.6	2.8	218.3	51.7	1.4	35.0	0.8	0.69
2009	0.1	15.9	73.6	2.2	244.9	50.1	1.3	35.3	0.9	0.74
2010	0.1	19.6	94.1	1.9	280.0	69.2	1.1	39.6	0.7	0.91
2011	0.2	22.4	98.8	1.8	305.7	64.7	1.0	40.2	2.1	0.95

Source Statistics Norway/Climate and Pollution Agency

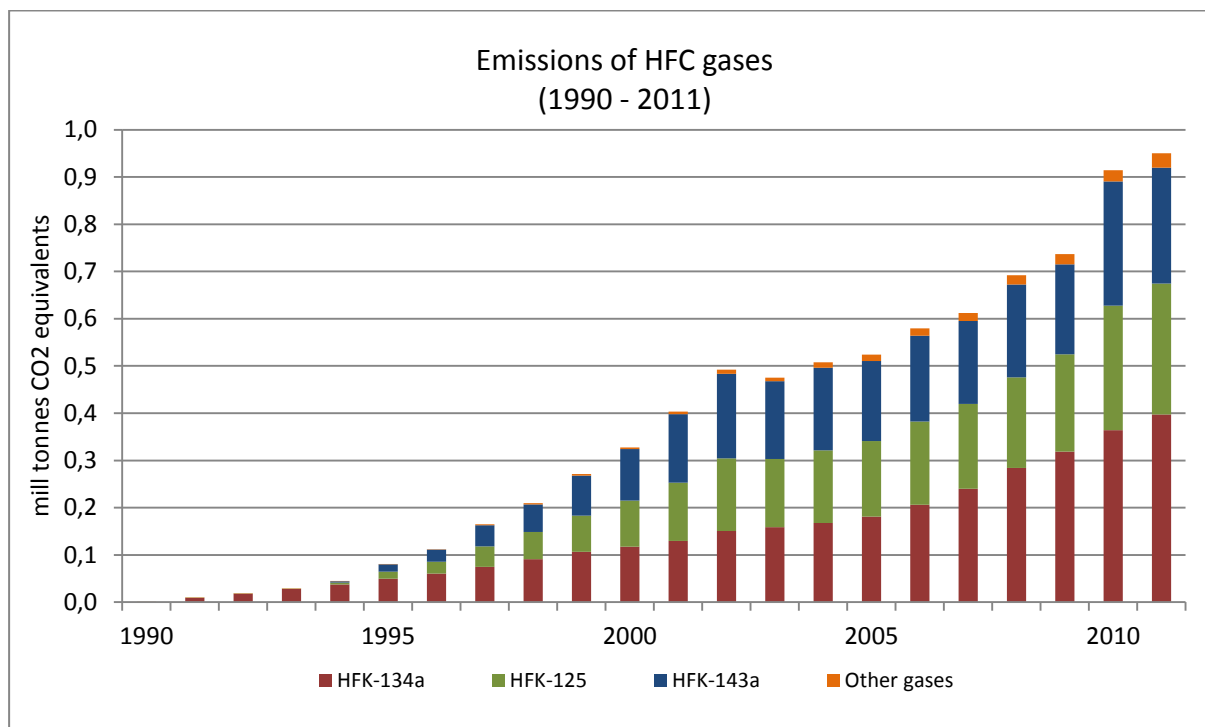


Figure 2.13. Actual emissions of HFCs (Mtonnes CO₂-eq.) in Norway 1990-2011.

Source: Statistics Norway/Climate and Pollution Agency

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 2011 in IPCC classification of sources. The Energy sector is by far the most important, contributing with 74.6 per cent of the total emissions.

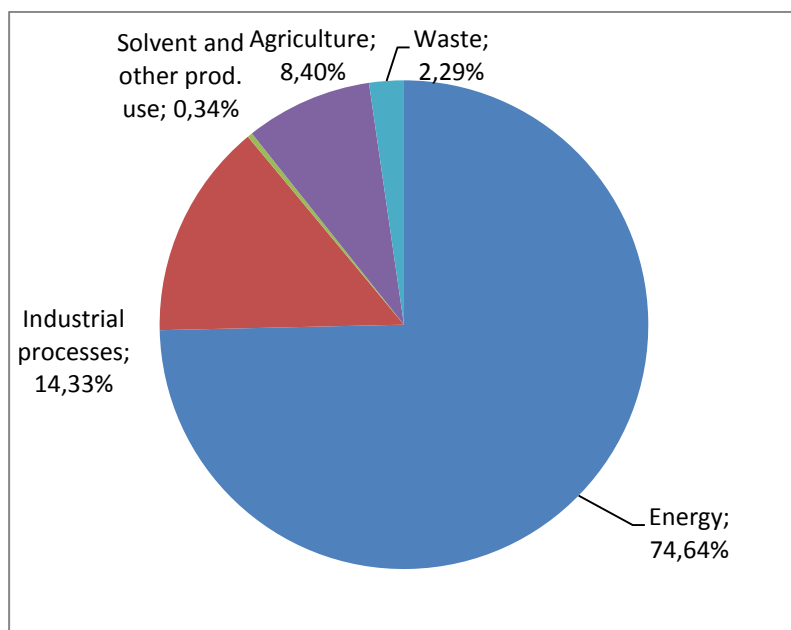


Figure 2.14. Total emissions of GHG in Norway in 2011 by sources.

Source: Statistics Norway/Climate and Pollution Agency

Figure 2.15 shows the changes in greenhouse gas emissions by sectors in the period 1990 to 2011. 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.

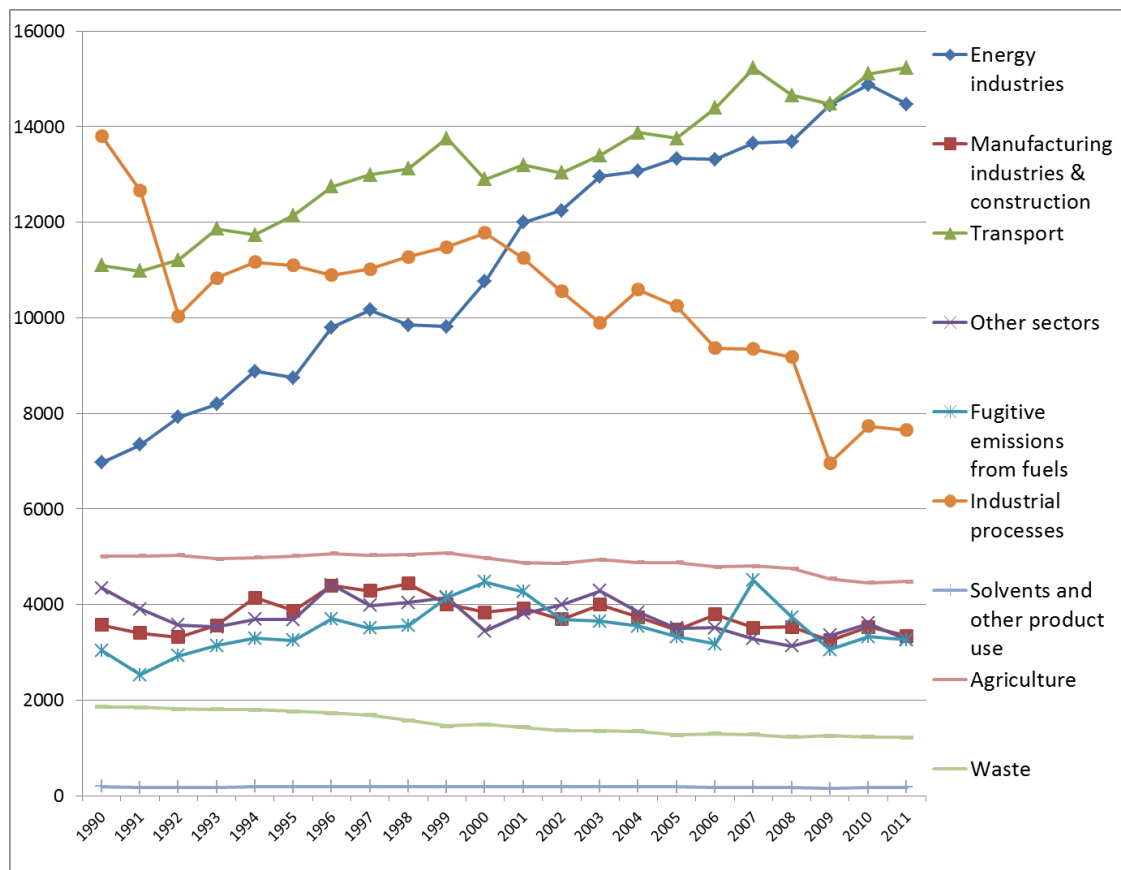


Figure 2.15. Development of emissions of all GHG (Mtonnes CO₂ eq.) from the different sectors.

Source: Statistics Norway/Climate and Pollution Agency

2.3.2 Energy

Figure 2.16 displays the distribution of GHG emissions in 2011 on the main sub categories within the energy sources.

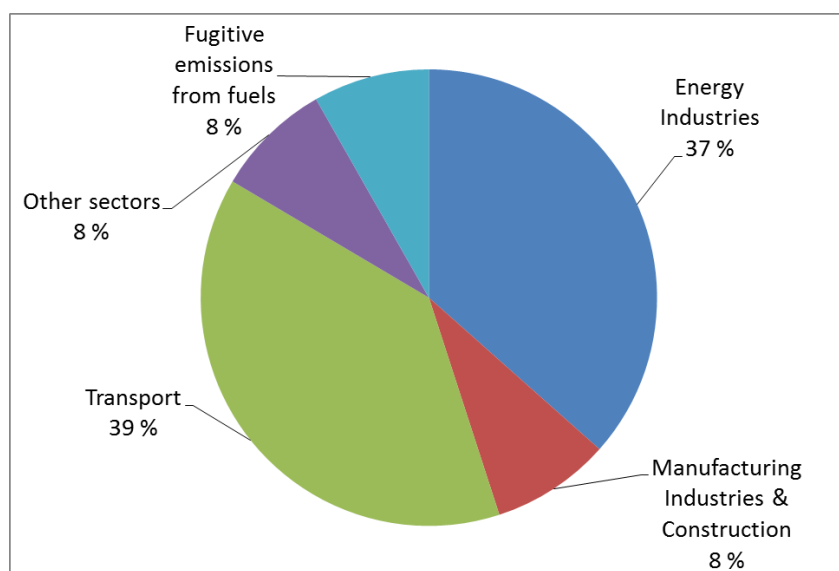


Figure 2.16. Greenhouse gas emissions in 2011 from the energy sector distributed on the different source categories.

Source: Statistics Norway/Climate and Pollution Agency

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.

In 2011 emissions from the energy industries contributed to 36.6 per cent of the sectors emissions, while the transport contributed with 38.5 per cent. Emissions from energy industries origins almost completely from fuel combustion in the oil and gas extraction and related activities.

The total emissions of greenhouse gases from the energy sector over the period 1990-2011 are listed in Table 2.10. The emission changes detected in the various source categories in the energy sector between 1990 and 2011 compared to the 1990 level, are illustrated in Figure 2.17 and discussed in the following.

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Table 2.10. Total emissions of greenhouse gases (Mtonnes CO₂-eq.) from the energy sector in Norway 1990-2011.

Year	Energy Industries	Manufacturing Industries & Construction	Transport	Other sectors¹	Fugitive emissions from fuels	Total
1990	7.0	3.6	11.1	4.3	3.0	29.5
1991	7.3	3.4	11.0	3.9	2.5	28.6
1992	7.9	3.3	11.2	3.6	2.9	29.5
1993	8.2	3.6	11.9	3.5	3.1	30.7
1994	8.9	4.1	11.7	3.7	3.3	32.3
1995	8.7	3.9	12.1	3.7	3.3	32.2
1996	9.8	4.4	12.7	4.4	3.7	35.5
1997	10.2	4.3	13.0	4.0	3.5	35.4
1998	9.9	4.4	13.1	4.0	3.6	35.4
1999	9.8	4.0	13.8	4.1	4.2	36.3
2000	10.8	3.8	12.9	3.4	4.5	35.6
2001	12.0	3.9	13.2	3.8	4.3	37.5
2002	12.2	3.7	13.0	4.0	3.7	37.1
2003	13.0	4.0	13.4	4.3	3.7	38.5
2004	13.1	3.7	13.9	3.8	3.5	38.4
2005	13.3	3.5	13.8	3.5	3.3	37.7
2006	13.3	3.8	14.4	3.5	3.2	38.5
2007	13.7	3.5	15.2	3.3	4.5	40.4
2008	13.7	3.5	14.7	3.1	3.7	39.0
2009	14.5	3.3	14.5	3.4	3.1	38.9
2010	14.9	3.5	15.1	3.6	3.3	40.7
2011	14.5	3.3	15.2	3.3	3.3	39.8

Source: Statistics Norway/Climate and Pollution Agency

¹ Includes 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).

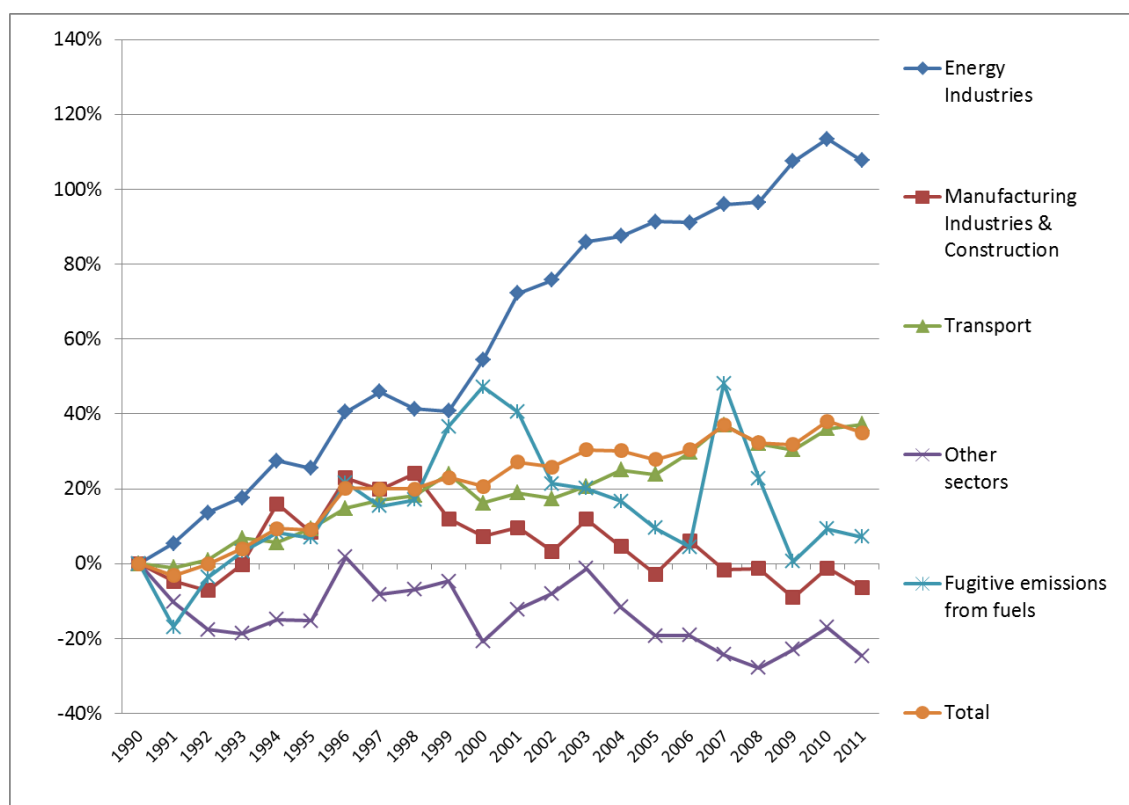


Figure 2.17. Changes in emissions in the various source categories in the energy sector between 1990 and 2011 compared to the 1990 level.

Source: Statistics Norway/Climate and Pollution Agency.

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. The GHG emissions in the energy sector increased by about 35 per cent from 1990 to 2011, primarily due to increased activity in the sectors of oil and gas extraction and transport, specifically road transport. The energy sector's emissions decreased by almost 1 per cent from 2010 to 2011. There were short, temporary emission reductions in 1991, 1995, 2000, 2002, 2005 followed by new growth. In 2008 and 2009 emissions went down again. The reduction in 1991 was caused by a period with 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 almost 2 per cent lower than in 2004. The small decrease in 2005 was due to reduced use of heating oil. The decrease in 2008 and 2009 was caused by economic recession.

Emissions from fuel combustion in **Energy industries** is almost 108 per cent higher in 2011 than in 1990. Emissions decreased, however with 3 per cent from 2010 to 2011. The decrease in 2011 was mainly due to 0.2 million tons emission reductions from energy production offshore. This is by far the main emission source in the Energy industries. 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 2011 the emissions from energy use in offshore oil and gas extraction contributed with more than 18 per cent of the total GHG emissions in Norway. In 1990 the corresponding contribution was 10 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 and transition from oil to gas.

Public generation of electricity is almost completely dominated by hydroelectric generation. Important exceptions are gas fired electricity power plants, waste incineration power plants and a small coal combustion plant (6 MW) on the island of Spitsbergen.

Industrial emissions related to fuel combustion² 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 by 6.5 per cent from 1990 to 2011, while the decrease from 2010 to 2011 also was more than 5.4 per cent.

Emissions from **Transport** showed an overall increase by more than 33 per cent from 1990 to 2011, while the emissions increased by more than almost 1 per cent from 2010 to 2011. The share of transport in the total GHG emissions has increased from 22 per cent in 1990 to about 29 per cent in 2011. Road transportation accounts for 66 per cent of the total mobile emissions, while emissions from navigation and civil aviation accounts for some 14 and 8 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, and it has increased by 119 per cent in the period 1990-2011.

Emissions of GHG from road traffic increased by almost 30 per cent from 1990 to 2011 and contributed to the total national GHG emissions by almost 19 per cent 2011. This trend is mainly due to increased activity in goods transport and taxi industry, as a response to higher economic activity. From 2010 to 2011 however, emissions decreased by 0.4 per cent. The decrease in emissions from 2007 to 2009 and from 2010 to 2011 could in addition to decreased activity also be explained by switching from petrol to diesel driven personnel cars due to the CO₂ differentiated tax on new personnel cars that was implemented in 2007. In addition the consumption of bio diesel and bioethanol increased and hence the CO₂ emission.

Emissions from navigation increased by around 22 % per cent from 1990 to 2011, mainly because of increased activity related to the oil- and gas extraction sector. Navigation contributed to the total national GHG emissions by almost 4 per cent in 2011.

Emissions from civil aviation have increased by 77 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 more than 2 per cent in 2011. The average annual growth in emissions in the period 1990-2011 was 2.7 per cent and between 1990-2000 and 2000-2011 4.5 and 0.3 per cent, respectively. This indicates that the growth in emissions from domestic aviation was substantially higher in the 90ies than it has been the last ten years.

² Includes 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.

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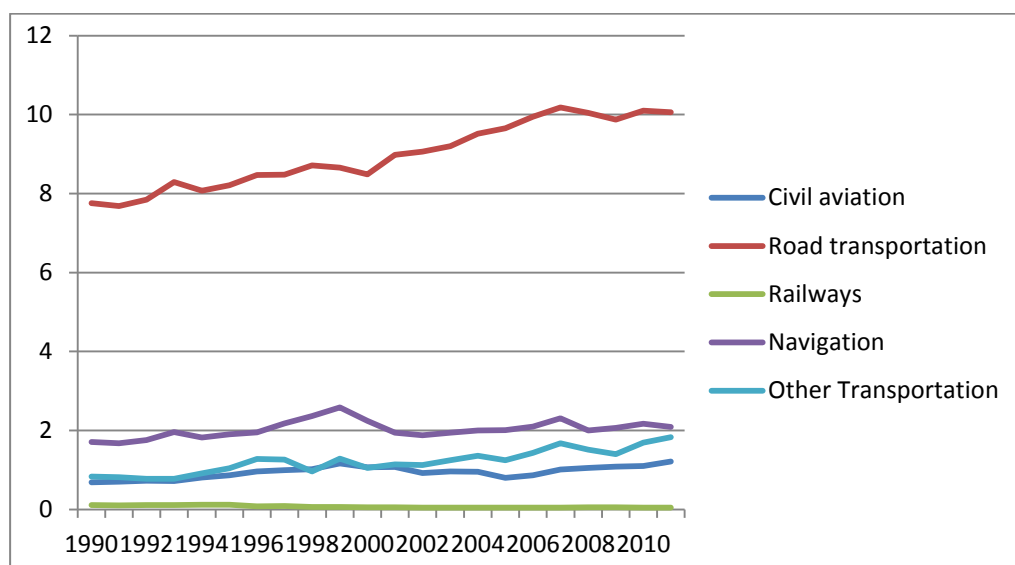


Figure 2.18. Changes in CO₂-emissions from different modes of transport in 1990-2011.

Source: Statistics Norway/Climate and Pollution Agency.

Table 2.11. Total emissions of greenhouse gases from the transport sector in Norway 1990-2011. Million tonnes CO₂ equivalents.

	Civil Aviation	Road transportation	Railways	Navigation	Other transportation	Total Transport
1990	0.69	7.76	0.11	1.71	0.84	11.10
1991	0.70	7.68	0.10	1.67	0.82	10.98
1992	0.73	7.85	0.11	1.76	0.77	11.21
1993	0.72	8.29	0.12	1.96	0.78	11.87
1994	0.81	8.07	0.12	1.82	0.92	11.73
1995	0.87	8.21	0.12	1.90	1.05	12.15
1996	0.97	8.47	0.08	1.95	1.28	12.75
1997	0.99	8.48	0.08	2.18	1.26	13.00
1998	1.02	8.71	0.06	2.36	0.97	13.12
1999	1.17	8.66	0.06	2.59	1.28	13.76
2000	1.07	8.48	0.05	2.24	1.05	12.90
2001	1.07	8.98	0.05	1.94	1.14	13.20
2002	0.92	9.06	0.05	1.88	1.12	13.03
2003	0.96	9.20	0.05	1.94	1.24	13.40
2004	0.96	9.51	0.05	2.00	1.36	13.88
2005	0.80	9.66	0.05	2.01	1.24	13.76
2006	0.87	9.94	0.05	2.10	1.43	14.40
2007	1.01	10.18	0.05	2.31	1.67	15.23
2008	1.05	10.04	0.05	2.00	1.52	14.66
2009	1.08	9.88	0.05	2.07	1.40	14.48
2010	1.10	10.10	0.04	2.17	1.69	15.11
2011	1.21	10.06	0.04	2.09	1.83	15.24

Source: Statistics Norway/Climate and Pollution Agency

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 emissions from this sector was 3.3 million tonnes CO₂ equivalents in 2011. The emissions decreased by almost 25 percent from 1990 to 2011 and by about 9 percent during 2011. The latter was due to decreased fuel consumption from residential and commercial/institutional sources. Fuel combustion in agriculture, forestry and fisheries decreased by almost 1 per cent in 2011 and accounts for about 60 per cent of the emissions of this sector.

Greenhouse gas emissions from residential sources accounted in 2011 for about 22 per cent of this sector's total. Emissions were about 61 per cent less in 2011 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 2008 the emissions from residential sources decreased by 46 per cent, while from 2008 to 2010 the emissions increased with almost 18 per cent. This can be explained by increasing electricity prices and cold winter. From 2010 to 2011 emissions decreased by almost 23 per cent.

Emissions from commercial/institutional sources make up the last 2 per cent of this category. There has been about 12 per cent decrease from 1990 to 2011, and an increase of around 17 per cent from 2010 to 2011.

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 CO₂ emissions from NMVOC emitted during the loading and unloading of oil tankers are also accounted for in this category. Fugitive emissions from fuels contribute some 6 per cent to the total GHG emissions in Norway in 2011 and with 8 per cent of the GHG emissions in the energy sector. The emissions in the sector decreased by about 2 percent from 2010 to 2011.

The reduced emissions from flaring since 1990 are partly explained by the introduction of tax on gas flared off shore from 1991 and implemented technical measures. The amount of gas flared may fluctuate from year to year due to variation of startups, maintenance and interruption in operation.

2.3.3 Industrial processes

The industrial process sector accounted for more than 14 per cent of the national greenhouse gas emissions in 2011. The emissions from this source category have decreased by 45 per cent from 1990 to 2011 and decreased by 1.2 per cent from 2010 to 2011.

Metal production is the main source of process related industrial emissions for both CO₂ and other greenhouse gases such as SF₆ (magnesium foundries) and PFCs (aluminium production), contributing with about 56 per cent of the total emissions from Industrial processes. The other main contributing sectors in 2011 were Chemical Industry, Consumption of Halocarbons and SF₆ and Mineral Product with 14.6, 13.2 and 13.8 1 and 12.0 per cent, respectively, of the total GHG emissions in this sector.

Figure 2.19 shows the variation in the different industries contribution to greenhouse gas emissions from 1990 to 2011. Table 2.11 provides figures for the total greenhouse gas emissions from the Industry sector for the same period.

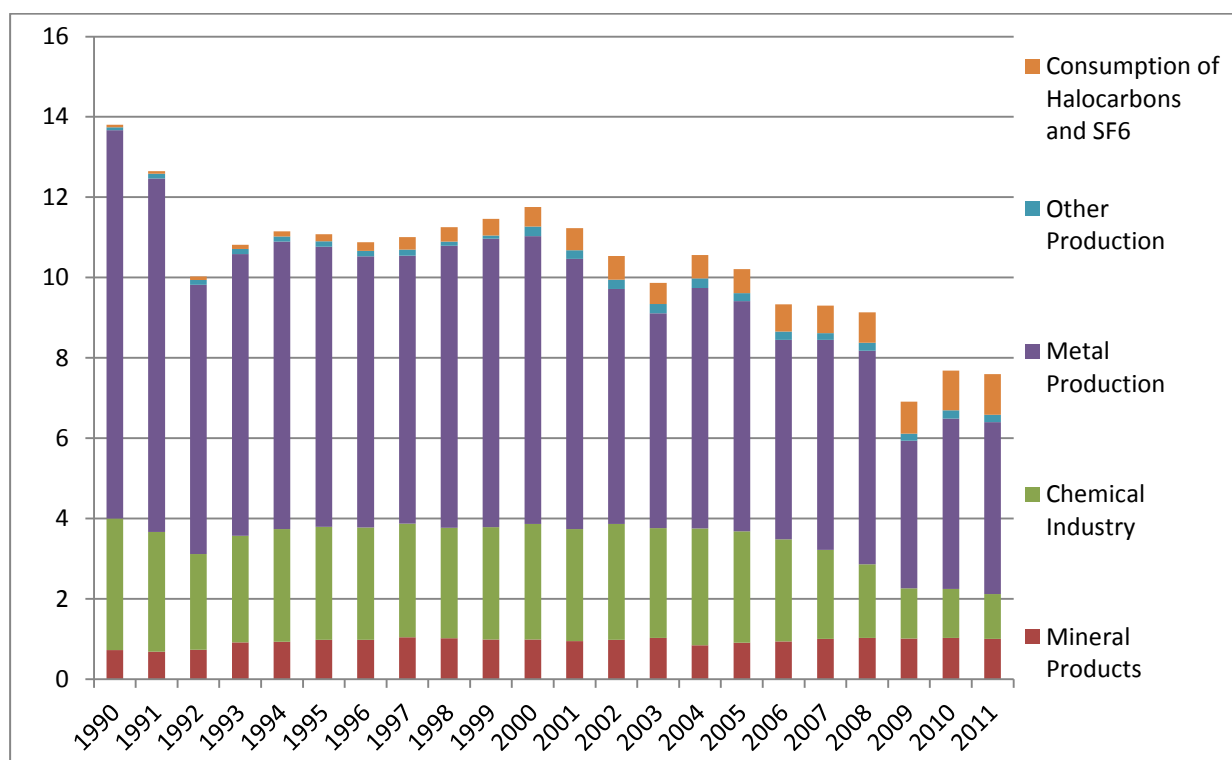


Figure 2.19. Total greenhouse gas emissions (Mtonnes CO₂-eq.) in the industrial source categories in Norway during the period 1990-2011. Source: Statistics Norway/Climate and Pollution Agency

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 ferroalloys. The main energy source has always been hydroelectricity. However, fossil fuels have been used as reducing agents or raw materials. Greenhouse gases are emitted as process related gases.

Approximately 8 per cent of total GHG emissions in Norway were from **Metal Production** in 2011, and the total emissions from this source increased by more than 1 per cent from 2010 to 2011. From 2009 to 2010 a large increase in emissions, reflects low production levels for ferroalloys in 2009 due to lower economic activity, and economic recession. The emissions from metal production contributed with approximately 56 per cent of the emissions from Industrial Processes. The largest contributor to the GHG emissions from Metal Production in 2011 is aluminium production and ferroalloys.

There are seven plants in Norway producing aluminium. PFCs emissions from production of aluminium contributed in 1990 to more than 6 per cent of the total GHG emissions in Norway. The share of the total in 2011 is reduced to around 0.4 per cent. Emissions of PFCs have decreased with more than 93 per cent from 1990 to 2011 and between 2010 and 2011 the emissions have increased by 10 per cent.

Production of ferroalloys is the second most important source within the metal production category. Norway is a major producer of ferroalloys with 12 plants in operation in 2011.

The GHG emissions (CO₂, CH₄ and N₂O) from ferroalloy production accounted for more than 5 per cent of the national total GHG emissions in 1990 and 4 per cent in 2011, a decrease by more than 11 per cent since 1990. From 2010 to 2011 GHG emissions from ferroalloys increased by approximately some 4 per cent.

Table 2.12. Total greenhouse gas emissions (Mtonnes CO₂-eq.) from the industry sector in Norway 1990-2011.

Year	Mineral Products	Chemical Industry	Metal Production	Other Production	Consumption of Halocarbons and SF ₆	Total
1990	0.7	3.3	9.7	0.1	0.1	13.8
1991	0.7	3.0	8.8	0.1	0.1	12.7
1992	0.7	2.4	6.7	0.1	0.1	10.0
1993	0.9	2.7	7.0	0.1	0.1	10.8
1994	0.9	2.8	7.2	0.1	0.1	11.2
1995	1.0	2.8	7.0	0.1	0.2	11.1
1996	1.0	2.8	6.7	0.1	0.2	10.9
1997	1.0	2.8	6.7	0.2	0.3	11.0
1998	1.0	2.7	7.0	0.1	0.4	11.3
1999	1.0	2.8	7.2	0.1	0.4	11.5
2000	1.0	2.9	7.2	0.2	0.5	11.8
2001	1.0	2.8	6.7	0.2	0.5	11.3
2002	1.0	2.9	5.8	0.2	0.6	10.6
2003	1.0	2.7	5.3	0.2	0.5	9.9
2004	0.8	2.9	6.0	0.2	0.6	10.6
2005	0.9	2.8	5.7	0.2	0.6	10.2
2006	0.9	2.5	5.0	0.2	0.7	9.4
2007	1.0	2.2	5.2	0.2	0.7	9.3
2008	1.0	1.8	5.3	0.2	0.8	9.2
2009	1.0	1.3	3.7	0.2	0.8	7.0
2010	1.0	1.2	4.2	0.2	1.0	7.7
2011	1.0	1.1	4.3	0.2	1.0	7.6

Source: Statistics Norway/Climate and Pollution Agency

SF₆ from magnesium foundries accounted in 1990 for around 4 per cent of the national total GHG emissions, but since then the emissions have decreased. The reduction in the SF₆ emissions is mainly due to improvements in the production processes early in the 90ies, and to the closing down of production of cast magnesium in 2002, improvements in the GIS-sector and an almost end in the use of SF₆ as tracer gas.

Production of Mineral products contributed in 1990 by more than 1 percent of the total GHG emissions in Norway and this share has increased to almost 2 per cent in 2011. The emissions from the sector increased with about 28 per cent from 1990-2011, mainly due to increased production of clinker and lime. Emissions decreased by 2.5 per cent from 2010-2011. Cement is produced in two plants in Norway, releasing CO₂ emissions from coal and waste used in direct fired furnaces, and from carbon in limestone. In 2011, the CO₂ emissions from cement production accounted for more than 1 per cent of the total national GHG emissions and approximately 10 per cent of the GHG emissions in the sector. Emissions have increased by 18 per cent from 1990 to 2011 due to increased production of clinker, but decreased by almost 1 per cent from 2010 to 2011

The chemical industry accounted for almost 15 per cent of the emissions in this sector. The emissions decreased with 66 per cent in the period 1990-2011. From 2010 to 2011 the emissions decreased by almost 9 per cent. In Norway, this category includes primarily

production of fertilizers and silicon carbide. These processes release N₂O (from nitric acid production) and CO₂ (from production of ammonia and carbides). The N₂O emissions from production of nitric acid accounted for 0.5 per cent of the total GHG emissions in 2011, and approximately 4 per cent of the GHG emissions in sector Industrial processes. The N₂O emissions have decreased by 86 per cent from 1990 to 2011 while the production of nitric acid increased by more than 25.3 per cent. The emission reduction is due to improved technology in the nitric acid production. Corresponding changes from 2010 to 2011 was a decrease in N₂O emissions by almost 19 per cent and 1 per cent increase in production. The large increase in production from 2009 to 2010 came after a decrease in production of 26 per cent from 2008 to 2009 reflecting the lower economic activity due to economic recession.

Refrigeration and air conditioning equipment is the most important application category related to emissions of hydro fluorocarbons (HFCs) under the category **Consumption of halocarbons and SF₆**. The emissions constitute more than 13 per cent of the emissions from the industry sector, and from 2010 to 2011 the emissions increased by some 2 per cent. The tax on HFCs introduced in 2003 has moderated this growth somewhat (Statistics Norway (2007b)). Electrical switchgears and the use of SF₆ as trace gas are the most important sources of non-process emissions of SF₆. Norway does not manufacture halocarbons or SF₆.

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 CO₂.

In 2011, the total emissions from solvents and other product use were about 0.2 million tonnes CO₂ equivalents. This represented approximately 0.3 per cent of the total GHG emissions in 2011. The emissions have decreased by around 6 per cent compared to 1990 and have increased by almost 6 per cent from 2010.

2.3.5 Agriculture

In 2011, about 8 per cent of the total Norwegian emissions of greenhouse gases (GHG) originated from agriculture. This corresponds to approximately 4.5 million tonnes CO₂ equivalents. The emissions from agriculture are relatively stable with minor fluctuations. The emissions are about 11 per cent lower in 2011 than in 1990, and 0.6 per cent lower than in 2010.

The sectors clearly largest sources of GHGs are “agricultural soils” (N₂O) from domestic animals, contributing with 45 per cent, and “enteric fermentation” (CH₄), also contributing with 45 per cent of the sectors emissions. Manure management contributes with 10 per cent. These sources are also key categories.

Enteric fermentation contributed with almost 2 million tonnes CO₂ equivalents in 2011, which is approximately 4 per cent of the national GHG emissions. Enteric fermentation constitutes 87 per cent of the overall CH₄ emissions from agriculture.

CH₄-emissions due to **manure management** amounted to 0.3million tonnes CO₂ equivalents, and N₂O-emissions due to manure management amounted to 0.1 million tonnes CO₂ equivalents in 2011. In 2011, manure management emitted 1 per cent of the Norwegian emissions of GHGs. Emissions of GHGs from manure management increased by more than 2 per cent in the period 1990-2011 and increased by 1 % from 2010 to 2011.

The emissions of N₂O in Norway from **agricultural soils** amounted to 2 million tonnes, calculated in CO₂ equivalents. They accounted for about 65 per cent of the total Norwegian N₂O emissions in 2011 or about 3.7 per cent of the total Norwegian GHG emissions that year.

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Emissions of N₂O from agricultural soils are a key category because of uncertainty, both in level and trend. During the period 1990-2011 emissions decreased by almost 11 per cent. From 2010 to 2011 the emissions increased by 4 per cent.

Table 2.13. Total greenhouse gas emissions (Mtonnes CO₂-eq.) from the agricultural sector in Norway 1990-2011.

Year	Enteric Fermentation	Manure Management	Agricultural Soils	Field Burning of Agricultural Residues	Total
1990	2.32	0.45	2.22	0.03	5.01
1991	2.32	0.47	2.21	0.02	5.02
1992	2.35	0.47	2.21	0.01	5.03
1993	2.31	0.46	2.17	0.02	4.96
1994	2.35	0.47	2.16	0.01	4.98
1995	2.34	0.48	2.18	0.01	5.02
1996	2.37	0.48	2.20	0.01	5.07
1997	2.34	0.48	2.20	0.01	5.03
1998	2.35	0.48	2.20	0.01	5.05
1999	2.42	0.48	2.16	0.01	5.08
2000	2.32	0.48	2.16	0.01	4.98
2001	2.29	0.48	2.10	0.01	4.87
2002	2.29	0.47	2.10	0.01	4.87
2003	2.33	0.46	2.14	0.01	4.94
2004	2.27	0.46	2.15	0.01	4.88
2005	2.26	0.46	2.15	0.01	4.88
2006	2.21	0.45	2.12	0.00	4.79
2007	2.19	0.46	2.15	0.00	4.80
2008	2.16	0.47	2.12	0.00	4.76
2009	2.08	0.47	2.00	0.00	4.55
2010	2.07	0.47	1.92	0.00	4.46
2011	2.02	0.46	2.00	0.00	4.48

Source: Statistics Norway/Climate and Pollution Agency

2.3.6 Waste

The waste sector, with emissions of 1.2 million tonnes CO₂ equivalents in 2011, accounted for 2 per cent of the total GHG emissions in Norway.

The sector includes emissions from landfills (CH₄), wastewater handling (CH₄ and N₂O) and small scale waste incineration (CO₂ and CH₄). 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 88 per cent of the sector's total emissions. Wastewater handling accounts for 12 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 2011 the emissions were about 34 per cent lower than in 1990. The total amount of waste generated has increased by about 39 per cent from 1995 to 2011, 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 and therefore the methane emissions has decreased.

Due to lower economic activity the amount of waste generated in 2011 was 5 per cent higher than in 2010. In 2009, for the first time since 1995, when the waste account first was produced, the amount waste generated was reduced.

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

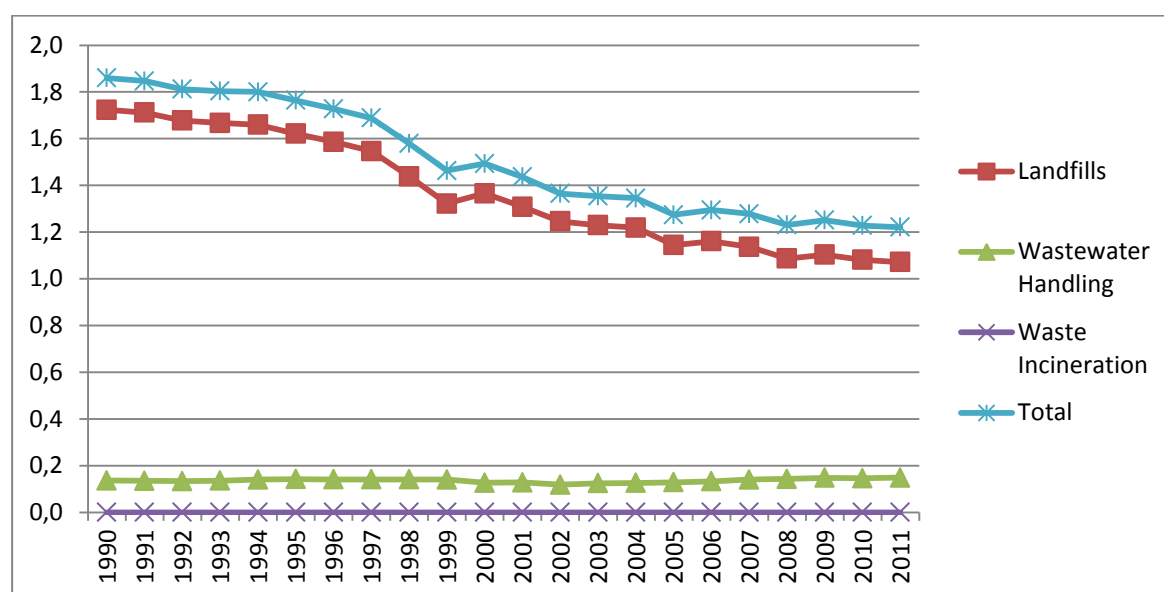


Figure 2.20. Total emissions of greenhouse gases (Mtonnes CO₂-eq.) in Norway from the waste sector 1990-2011. Source: Statistics Norway/Climate and Pollution Agency

Figure 2.20 shows that the general trend is that emissions of methane have decreased since 1998. The reduction is due to a smaller amount of waste disposed at disposal sites. This again 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.

Table 2.14. Emissions (Mtonnes CO₂-eq.) from the waste sector in Norway 1990-2011.

Year	Landfills	Wastewater Handling	Waste Incineration	Total
1990	1.7	0.1	0.0	1.9
1991	1.7	0.1	0.0	1.8
1992	1.7	0.1	0.0	1.8
1993	1.7	0.1	0.0	1.8
1994	1.7	0.1	0.0	1.8
1995	1.6	0.1	0.0	1.8
1996	1.6	0.1	0.0	1.7
1997	1.5	0.1	0.0	1.7
1998	1.4	0.1	0.0	1.6
1999	1.3	0.1	0.0	1.5
2000	1.4	0.1	0.0	1.5
2001	1.3	0.1	0.0	1.4
2002	1.2	0.1	0.0	1.4
2003	1.2	0.1	0.0	1.4
2004	1.2	0.1	0.0	1.3
2005	1.1	0.1	0.0	1.3
2006	1.2	0.1	0.0	1.3
2007	1.1	0.1	0.0	1.3
2008	1.1	0.1	0.0	1.2
2009	1.1	0.1	0.0	1.3
2010	1.1	0.1	0.0	1.2
2011	1.1	0.1	0.0	1.2

Source: Statistics Norway/Climate and Pollution Agency

2.4 Land Use Change and Forestry

In 2011 the net sequestration in the LULUCF sector was 27.6 million CO₂ equivalents, which would offset around half of the total greenhouse gas emissions in Norway that year. The average annual net sequestration from the LULUCF sector was about 20.4 million tonnes CO₂ equivalents for the period 1990-2011.

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

The calculated land-use categories for Norway in 1990 and 2011 are shown in Figure 2.21.

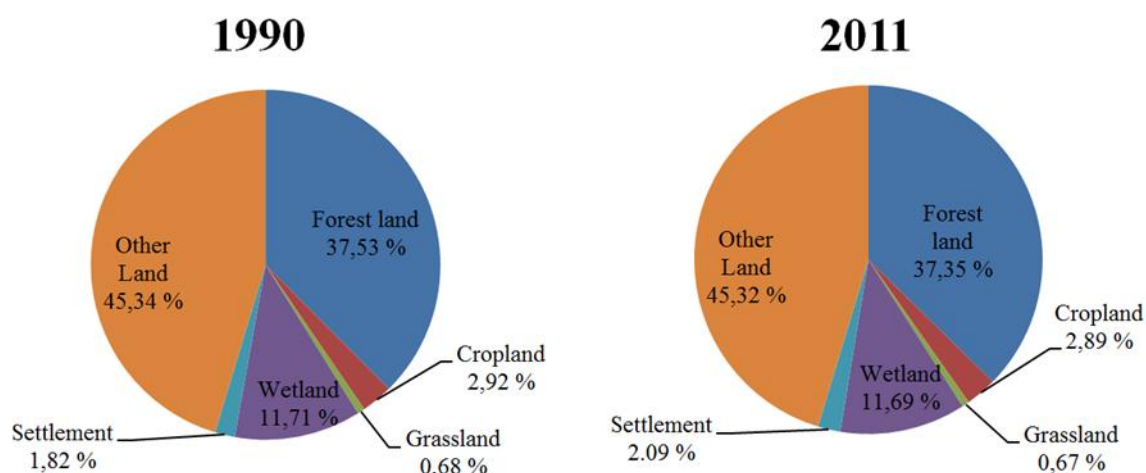


Figure 2.21. Area (%) distribution between the IPCC land-use categories, 1990 and 2011.

Source: The Norwegian Forest and Landscape Institute.

Land use changes in Norway from 1990 to 2011 are very small; only the area settlements has increased slightly, while the other land use categories have decreased.

In 2011 the land-use category forest land remaining forest land was the major contributor to the total amount of sequestration with 31.7 million tonnes CO₂, while land converted to forest land contributed with 0.7 million tonnes CO₂. From 1990 to 2011 the total net sequestration of CO₂ from forest land increased by 79 per cent. The explanation for this growth is an increase in standing volume and gross increment, while the amount of CO₂ emissions due to harvesting and natural losses has been quite stable. The increase in living carbon stock is due to an active forest management policy over the last 60–70 years. The combination of the policy to re-build the country after the Second World War II and the demand for timber led to a great effort to invest in forest tree planting in new areas.

Figure 2.22 illustrates the change in carbon stocks in forest land, dead organic matter and soil between 1990 and 2011.

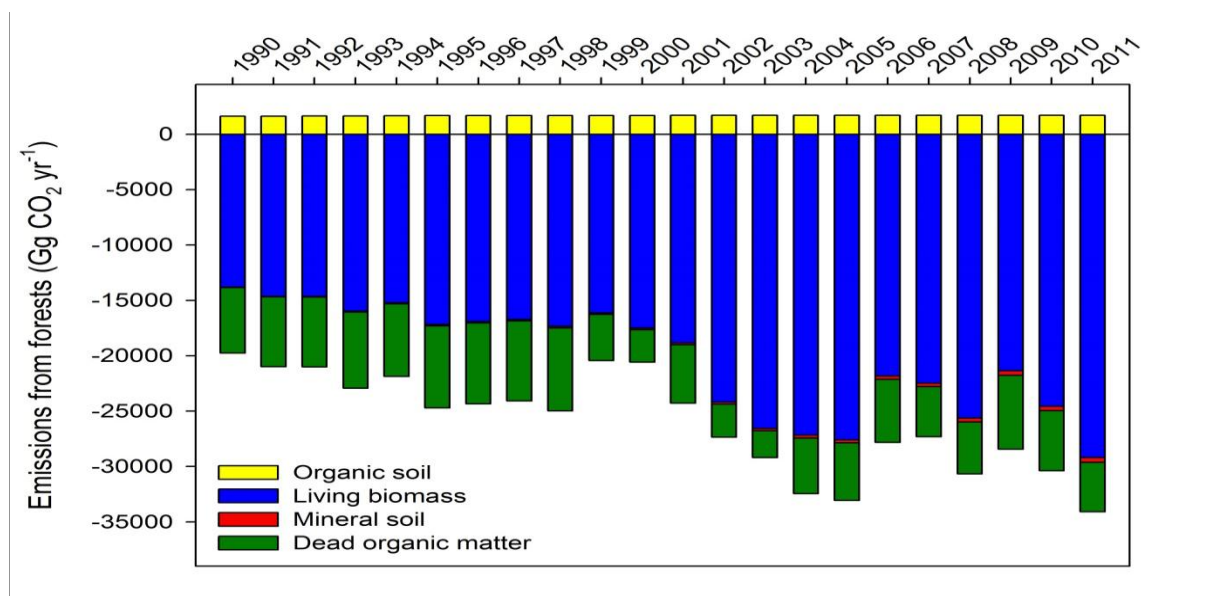


Figure 2.22. Emissions and removals of CO₂ (Gg CO₂ per year) on forest land from organic and mineral soil, dead organic matter (DOM), and living biomass, 1990–2011.

Source: The Norwegian Forest and Landscape Institute.

All land-use categories other than forest land remaining forest land and wetlands showed net emissions in 2011. In total the emissions were calculated to 4.9 million tonnes CO₂ equivalents. Emissions from settlements have become more than five times greater from 1990 to 2011, and are now responsible for the largest emissions from the LULUCF sector, with 2 704 Gg CO₂ in 2011.

2.5 Emission trends for indirect greenhouse gases and SO₂

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 (SO₂) also has an indirect impact on climate, as it increases the level of aerosols with a subsequent cooling effect. Therefore, emission trends of these gases are to some extent included in the inventory.

The overall **NO_x emissions** have decreased with approximately 8 per cent from 1990 to 2011. This can primarily be explained by stricter emission regulations with regard to road traffic, which has given a reduction of almost 43 per cent since 1990. These reductions counteracted increased emissions from e.g. oil and gas production. From 2010 to 2011 the total NO_x emissions decreased by almost 6 per cent.

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 64 per cent from 2001 to 2011, and are now 53 per cent lower than in 1990. From 2010 to 2011 the emissions of NMVOC have decreased by 3.5 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 approximately 58 per cent over the period 1990-2011. This is explained primarily by the implementation of new emission standards for motor vehicles.

SO₂ emissions were reduced by 64 per cent from 1990 to 2011. 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.

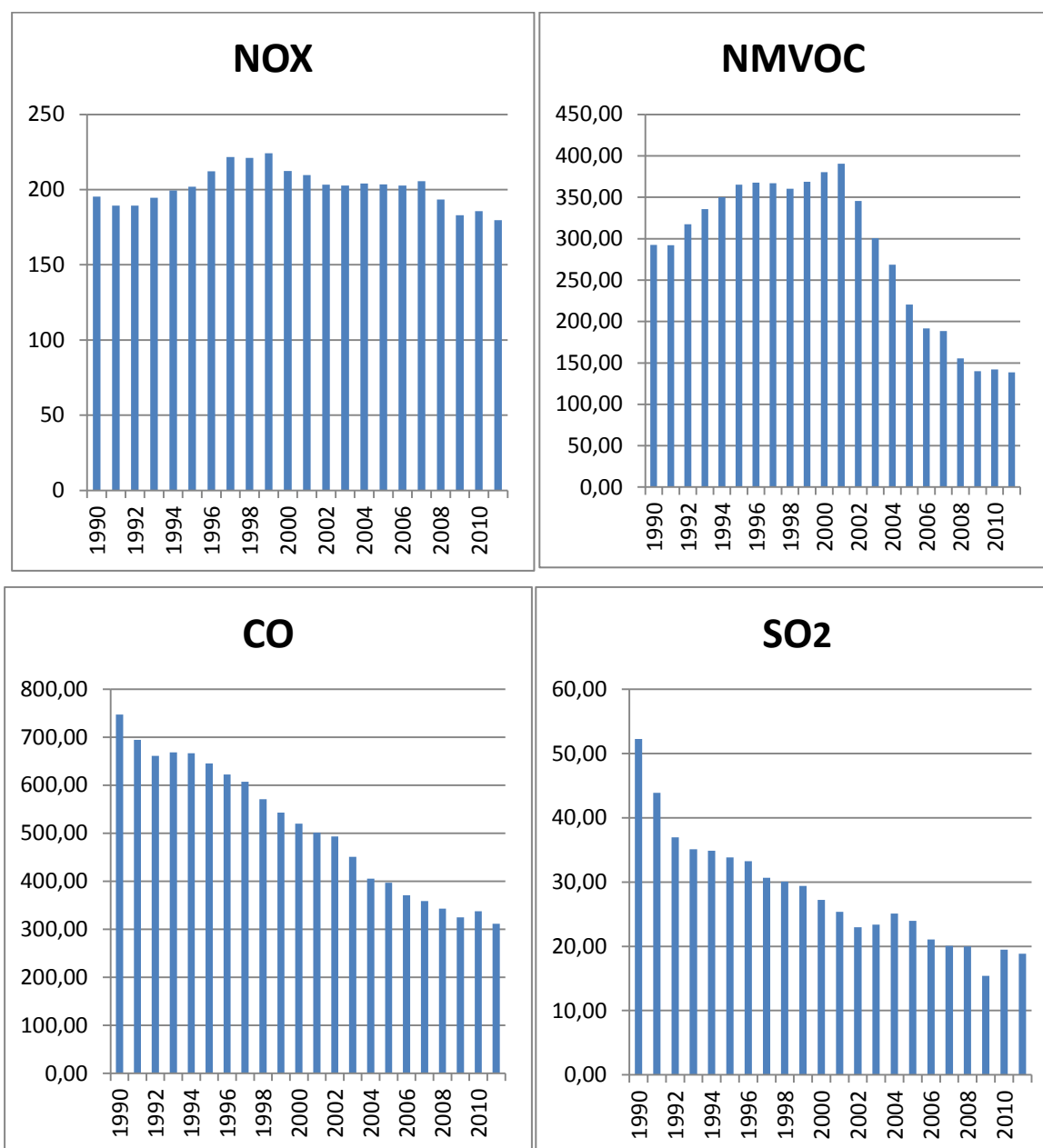


Figure 2.23. Emissions (Ktonnes) of NO_x, NMVOC, CO and SO₂ in Norway 1990-2011.

Source: Statistics Norway/ Climate and Pollution Agency

3 Energy

3.1 Overview

The Energy sector included fugitive emissions accounted for 74.6 per cent of the Norwegian greenhouse gas emissions in 2011 that is a minor decrease from 75.0 per cent in 2010. In 1990 the Energy sector's share of the total greenhouse gas emissions was 58.6 per cent. Road traffic and offshore gas turbines (electricity generation and pumping of natural gas in pipelines) are the sector's largest single contributors to the sector's emissions and the latter is the sector that has increased most since 1990. Other important sources in the Energy sector 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.

The GHG emissions in the Energy sector have increased by 35.1 per cent from 1990 to 2011, primarily due to increased activity in the sectors of oil and gas extraction and transport, specifically road transport. Between 1990 and 2011 there have been temporary emission reductions in the sector in e.g. 1991, 2005 and in 2009. The energy sector's emissions decreased by 3.8 per cent from 2007 to 2009 and by 2.2 per cent from 2010 to 2011. Despite these reductions the sector's 2009 emissions were the third highest in history and the 2010 emissions is all-time high for the sector. The growth in emissions from 2009 to 2010 was mainly due to increased emissions from gas fired power plant and district heating. The latter due to increase used of fuel oils. The emission reduction from 2010 to 2011 is mainly due to reversed trends in the same sector. Other sectors that contributed with more than 10 per cent to the reduction were the oil and gas industry, production of pulp and paper, and stationary combustion in commercial, institutional sectors and household. Sectors that contributed with an increase in emissions were civil aviation, motorized equipment, and fugitive emissions from coal mining and handling.

Figure 3.1a and b below shows the trend and relative change since 1990 in emissions in different Energy sectors. From the figure you can see that emissions from Energy Industries (combustion in oil and gas production, refineries, electricity production and district heating) were in 2009 for the first time since 1990 higher than total emissions in the Transport sector (civil aviation, road transportation, railways, navigation, off road vehicles and other machineries). In 2011 the emissions in the Transport sector was again highest.

Transport

The transport sector's total emissions in CO₂ equivalents was in 2011 15.2 million tonnes whereas civil aviation contributed to 8, road transportation 66, railways 0.3, navigation 13.7 and off road vehicles and other machineries 12 per cent. The latter sectors share of total emissions from transport have increased from 7.5 per cent in 1990. Aviation and other transportation (machineries used in e.g. construction and mining industry) are the sectors with highest percentage growth in emission since 1990. See Figure 3.2. GHG emissions from the sector other transportation is largely following the economic activity in the building and construction sector. This is illustrated e.g. by the decreased emissions from 2007 to 2009 as a consequence of the financial crisis and subsequent increase in 2010 and 2011. See more data in Section 3.2.5 about how road transportation has developed since 1990.

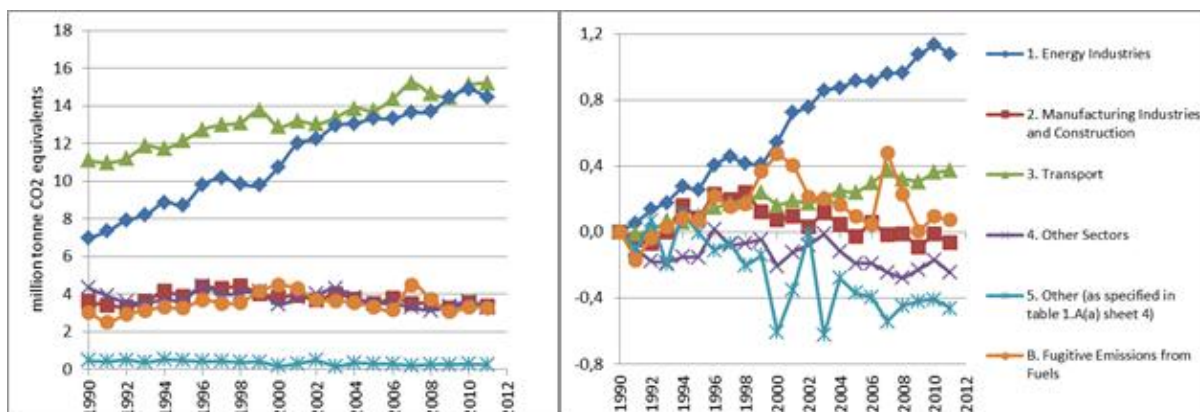


Figure 3.1a. Greenhouse gas emissions from energy sectors and fugitive emissions. 1990-2011. mill tonne CO₂ equivalents. Source: Statistics Norway and Climate and Pollution Agency.

Figure 3.1b. Relative change in GHG emissions in the Energy sector and fugitive emissions. 1990=0. Source: Statistics Norway and Climate and Pollution Agency.

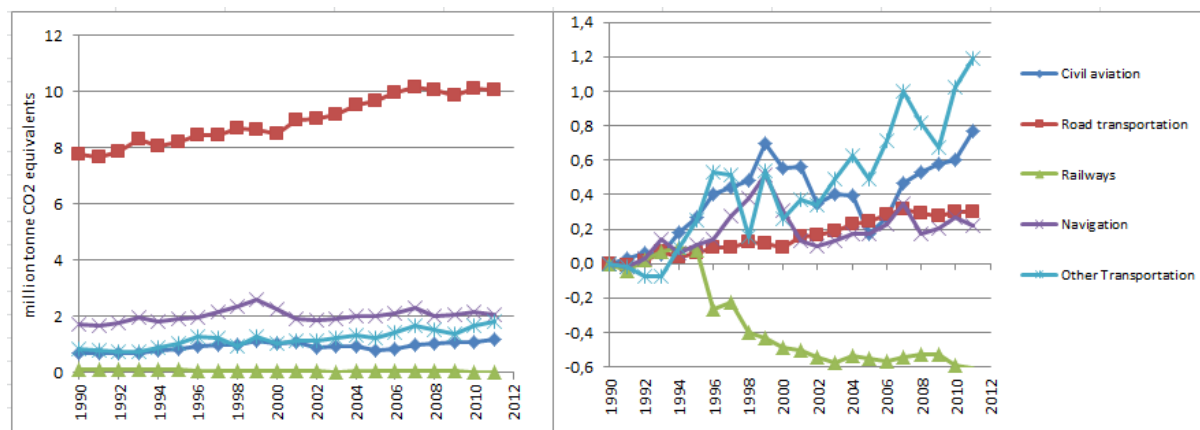


Figure 3.2a. Greenhouse gas emissions from energy sectors and fugitive emissions. 1990-2011. mill tonne CO₂ equivalents. Source: Statistics Norway and Climate and Pollution Agency.

Figure 3.2b. Relative change in GHG emissions in the most important transport sectors. Civil aviation, road transportation, navigation and other transportation. 1990=0. Source: Statistics Norway/Climate and Pollution Agency.

Key source categories

As indicated in Section 1.5, the Tier 2 key category analysis performed for the years 1990 and 2011 has revealed that in terms of total level and/or trend uncertainty the *key categories* in the Energy sector for 1990 and/or 2011 are, in CRF order, the following:

- Stationary Fuel Combustion, Solid Fuels – CO₂ (1A1-1A2-1A4)
- Stationary Fuel Combustion, Liquid Fuels – CO₂ (1A1-1A2-1A4)
- Stationary Fuel Combustion, Gaseous Fuels – CO₂ (1A1-1A2-1A4)
- Stationary Fuel Combustion, Other Fuels – CO₂ (1A1-1A2-1A4)
- Stationary Fuel Combustion, Biomass – CH₄ (1A1-1A2-1A4)
- Other sectors, Mobile Fuel Combustion – CO₂ (1A4)
- Civil Aviation – CO₂ (1A3a)
- Road Transportation – CO₂ (1A3b)
- Navigation – CO₂ (1A3d)
- Navigation – CH₄ (1A3d) ok
- Other Transportation – CO₂ (1A3e)
- Other Transportation – N₂O (1A3e)
- Fugitive Emissions from Oil – CO₂ (1B2a)
- Fugitive Emissions from Oil – CH₄ (1B2a)
- Fugitive Emissions from Natural gas – CH₄ (1B2b)
- Venting and Flaring – CO₂ (1B2c)
- Venting and Flaring – CH₄ (1B2c).

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

- Military, mobile – CO₂ (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 CO₂ emissions at the offshore oil and gas field Sleipner Vest and Hammerfest LNG (Snøhvit gas-condensate field). These unique operations are discussed in detail in Section 3.5.

Emission allocation

Generally energy combustion for energy purposes is reported in 1.A Fuel Combustion Activities while energy combustion not for energy purposes is reported in 1.B Fugitive Emissions from Fuels. 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 reported in 1.B.2c Flaring and described in Sections 3.4 Fugitives Emissions from Oil and Natural Gas due to that this is energy combustion not for energy purposes. Emissions from burn off of coke at catalysts at refinery is reported in 1.B.2.a iv for the same reason as for flaring. 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 general description of emissions from the energy combustion sources (Section 3.2), followed by a description of fugitive emissions (Section 3.3 and 3.4) and a discussion on the capture and storage of CO₂ emissions at the oil and gas field Sleipner Vest and Hammerfest LNG (Snøhvit gas-condensate field) (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 CO₂ emissions from CH₄ and NMVOC

Finally, the memo items of international bunker fuels and CO₂ 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). 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 general methodology for 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 GHG emissions from fuel combustion (1A) accounted for 68.5 per cent of national total emissions in 2011. The emissions increased by 38.3 per cent between 1990 and 2011, primarily due to activity growth in oil and gas extraction that is the major part of energy industries sector and transport, mainly road transportation. The emissions from source category 1A increased by 4 per cent from 2009 to 2010 and decreased 2.2 per cent 2010 to 2011. While the emission from nearly all source categories within sector 1A increased in 2010 except Petroleum Refining and Railways, almost all sectors decreased its emissions in 2011. The change in 2011 was dominated by decreased activity in Public Electricity and Heat Production (gas fired power plants and district heating), oil and gas extraction, and Manufacturing Industries and Construction (specifically non-ferrous metal). Emissions from transport on the other hand increased with almost 1 percent due to increased emissions from Civil Aviation and Other Transportation

The fuel combustion sector is dominated by the emissions of CO₂ which in 2011 contributed 96 per cent to the totals of this sector (1A).

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 sections.

As Table 3.3 shows a large share of GHG emissions from Energy industries and Manufacturing Industries and Construction included in the Norwegian GHG Inventory are from annual reports sent by each plant to the Climate and Pollution Agency (Klif).³ Such annual reports are:

- reports as required by their regular permit
- reports as required by the permit under the EU emission trading system (EU ETS)
- reports as required by a voluntary agreement.

Annex IX QA/QC Point sources NIR 2013 include references to documents that in detail describe requirement for measuring and reporting, specifically for the EU ETS and the voluntary agreement.

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 traffic and aviation where more detailed estimation models are used; involving additional activity data (see Sections 3.2.5 and 3.2.4. respectively). The total amount of fuel consumption is taken from the Norwegian energy balance (see Annex III). The mean theoretical energy content of fuels and their density are listed in Table 3.1.

The general method for calculating emissions from energy consumption is

³ Former Norwegian Pollution Control Authority.

$$(2.1) \quad \text{Emissions (E)} = \text{Activity level (A)} \cdot \text{Emission Factor (EF)}$$

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

$$(2.2) \quad \text{Emissions (E)} = [(A - A_{PS}) \cdot EF] + E_{PS}$$

where A_{PS} and E_{PS} are the activity and the measured emissions at the point sources, respectively. Emissions from activity for which no point source estimate is available ($A - A_{PS}$) are still estimated with the default emission factor. See section 1.4.2 for more information about the main emission model.

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 (dry gas) ¹	35.5 GJ/1000 Sm ³	0.74 kg/Sm ³ (domestic use)
Natural gas (rich gas) ¹	40.3 GJ/1000 Sm ³	0.85 kg/Sm ³ (off shore)
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	12.0 GJ/tonne	..

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

¹ Sm³ = standard cubic meter (at 15 °C and 1 atmospheric pressure).

Source: Energy statistics, Statistics Norway and Climate and Pollution Agency.

For some major manufacturing plants (in particular offshore activities, refineries, gas terminals, cement industry, production of plastics, ammonia production, methanol), emissions of one or more compounds reported by the plants to the Climate and Pollution Agency are used instead of figures calculated as described above. See Table 3.2 below. 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. See Table 3.2 below where an overview of the type of emissions (i.e. estimated and/or reported) used in the inventory for the different sectors is given for the greenhouse gases CO₂, CH₄ and N₂O.

The reports are from the mandatory reporting obligation that is a part of the plants permits given by the authorities and from 2005 the emission data is from the emission trading system. The ETS was first a voluntary system, 2005-2007, and then as a part of EU ETS since 2008. From 1997 there have been different voluntary agreements between national authority and the industry. The agreement from 1997 covered the aluminum producers and included from 2005 industry not included in the ETS. The industry has in the different voluntary agreements committed themselves to reduce their greenhouse gas emissions as a group. As part of the agreements the industry has every year reported detailed AD and emissions to the Climate and Pollution Agency. The voluntary agreement has involved industry i.e. ferro alloy, aluminum, ammonia. Figures on energy use are based on data reported from the plants to Statistics Norway. Some of the energy figures used to calculate reported emissions may deviate from the figures in the energy balance. This may in some cases cause inaccuracies in IEFs, but, generally, this should not be regarded as an important issue.

Table 3.3 shows the share of the emissions of CO₂, CH₄ and N₂O in the different energy sectors that is based on either estimated or reported emissions in 2011. In 2011 92 per cent of the CO₂ emissions from Energy Industries (oil and gas extraction and production, refineries, gas terminals, gas fired power plants and district heating plants) were based on reported emissions and 53 per cent of the CO₂ emissions from Manufacturing Industries and Construction. The table is a result from an advice from the ERT reviewing Norway's 2010 submission.

The guidelines for estimating and reporting emissions are lengthy and in Norwegian, so instead of attaching these to the NIR URLs are provided below. Annex XI describe QA/QC performed for plant specific emission data use in the inventory.

EU ETS:

<http://www.klif.no/no/Tema/Klima-og-ozon/CO2-kvoter/--MENY/Skjema-og-innrapportering/>

Environmental web (offshore activities)

http://www.google.no/url?sa=t&rct=j&q=veiledning%20til%20den%20%C3%A5rlige%20utslippsrapporteringen%20olf%202007&source=web&cd=1&ved=0CC0QFjAA&url=http%3A%2F%2Fwww.norskoljeoggass.no%2FPageFiles%2F6542%2FVeiledning%2520til%2520utslippsrapportering%25202009.pdf&ei=qLleUZPBElNk4ATpnYCYBw&usg=AFQjCNH_gQhyHemDnyAMv7TlBlmwSIP25g&bvm=bv.44770516,d.bGE

Annual normal permit:

www.klif.no/publikasjoner/3012/ta3012.pdf

Voluntary agreement:

<http://www.klif.no/skjema/Regler%20for%20beregning%20og%20måling%20av%20klimagasutslipp%20fra%20avtalebedriftene.pdf>

National Inventory Report 2013 - Norway

Table 3.2. Overview of estimated and reported greenhouse gases CO₂, CH₄ and N₂O for energy combustion activities.*

	CO ₂	CH ₄	N ₂ O
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 (snow scooters, boats, motorized equipment, pipeline transport)	E	E	E
4. Other Sectors			
a. Commercial/Institutional	E	E	E
b. Residential	E	E	E
c. Agriculture/Forestry/Fisheries	E	E	E
5. Other (Military)	E	E	E

* 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).

National Inventory Report 2013 - Norway

Table 3.3. Share of total CO₂, CH₄ and N₂O emissions in the energy sector based on estimated and reported emission estimates for 2011.

	CO ₂		CH ₄		N ₂ O	
	<i>Estimated</i>	<i>Reported</i>	<i>Estimated</i>	<i>Reported</i>	<i>Estimated</i>	<i>Reported</i>
A. Fuel Combustion Activities (Sectoral Approach)	58 %	42 %	76 %	24 %	97 %	3 %
1. Energy Industries	8 %	92 %	15 %	85 %	88 %	12 %
a. Public Electricity and Heat Production	43 %	57 %	100 %		68 %	32 %
b. Petroleum Refining	0 %	100 %	76 %	24 %	100 %	0 %
c. Manufacture of Solid Fuels and Other Energy Industries	2 %	98 %	1 %	99 %	100 %	0 %
2. Manufacturing Industries and Construction	47 %	53 %	88 %	12 %	83 %	17 %
a. Iron and Steel	10 %	90 %	100 %	0 %	100 %	
b. Non-Ferrous Metals	100 %		100 %		100 %	
c. Chemicals	10 %	90 %	96 %	4 %	75 %	25 %
d. Pulp, Paper and Print	100 %		78 %	22 %	77 %	23 %
e. Food Processing, Beverages and Tobacco	100 %		100 %		100 %	
f. Other (Oil drilling, construction, other manufacturing)	54 %	46 %	100 %		100 %	
3. Transport	100%		100%		100%	
a. Civil Aviation	100%		100%		100%	
b. Road Transportation	100%		100%		100%	
c. Railways	100%		100%		100%	
d. Navigation	100%		100%		100%	
e. Other Transportation (Snow scooters, boats, motorized equipment, pipeline transport)	100%		100%		100%	
4. Other Sectors	100%		100%		100%	
a. Commercial/Institutional	100%		100%		100%	
b. Residential	100%		100%		100%	
c. Agriculture/Forestry/Fisheries	100%		100%		100%	
5. Other (Military)	100%		100%		100%	

Source: Statistics Norway, Climate and Pollution Agency

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 territory. 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 1990-2011 are presented in Annex III 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 the Climate and Pollution Agency and Norwegian Petroleum Directorate 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 four gas terminals onshore. However, as explained above emission figures of CO₂ from the largest gas consumers e.g. off shore activities, gas terminals, petro chemical industry are figures reported by the plants. The data are of high quality, due to the Norwegian system of CO₂ 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. However, the total emissions from the refineries included in inventory are equal to emissions reported from the plants and is regarded being of high quality. Emissions from energy combustion for energy purposes are reported in 1A1b, emissions from flaring in 1B2c Flaring and emissions from cracker is reported in 1B2a.iv. Chapter 3.4.2.2 (Refining/Storage – 1.B.2.a.iv) describes the estimation methodology for emissions from cracker. The distribution of emissions from combustion at refineries to different categories is done by using same proportion for all years in the time series. This is of course not a very exact method but comparisons we have made, and reported in previous NIRs and answers submitted during reviews, shows quite good accordance with what is reported by the plants.

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 of gases are reported to Statistics Norway. Two ferroalloy plants sell excess gas (CO gas) some other plants (one producer of ammonia, a district heating plant, iron and steel producers and mineral industry), 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 CO₂ 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 statistics⁴. 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.

However, since the late 1990s the distribution in the sales statistics between different middle distillates has not been in accordance with the bottom-up estimated consumption of the products. In particular, the registered sales of light fuel oil have generally been too low, and it is known that some auto diesel also is used for heating. In order to balance the accounts for the different products, it has since 1998 been necessary to transfer some amounts between products instead of using the sales figures directly. The most important transfer is from auto diesel to light fuel oil, but in addition some auto diesel has also been transferred to heavy distillate.

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. 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.

Bio fuels

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 of wood. 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 balance), is the average of the survey figures from the year in question and the following year. For the years after 2005 the figures are based on responses to questions relating to wood-burning in Statistics Norway'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.

⁴ The statistics are corrected for direct import by other importers or companies.

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. Data on use of peat for energy purposes is not available, but according to the Energy Farm, the center for Bioenergy in Norway, such use is very limited (Hohle, E.E. ed. 2005).

The amount of bio fuels (biodiesel and bioethanol) for road transportation are from the 2013 submission reported separately in CRF and Figure 3.4 shows the consumption of bio fuels. The amount of fuels sold is collected from the fuel marketing companies.

Waste

District heating plants and incineration plants annually report combusted amounts of waste (boilers) to Statistics Norway and the Climate and Pollution Agency. 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 SO₂, NO_x, CO, NH₃, particles, heavy metals and dioxins, and the amount of waste incinerated to the county governor. The county governor then reports this information to the Climate and Pollution Agency. 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 1990-2011 are presented in Annex III.

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 III are now presented in a way that displays a greater level of disaggregation than that of previous reports. The numbers are in PJ with three digits as ask for by the ERT reviewing the 2012 submission. This more detailed presentation concerns, in particular, the years 1992-2011. 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.

The consumption of natural gas in the sector is divided among three flows in the energy balance:

- 8.3 - Thermal power plants: Auto producer generation (only segregated for 2007-)
- 10 – Losses: Flaring
- 13 - Net consumption in manufacturing: Remaining natural gas.

Figures from the energy sources balance sheet are reported to international organizations such as the OECD and the UN. The energy balance sheet should therefore usually be 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

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

CO₂

Emission factors for CO₂ are independent of technology and are based on the average carbon content of fuels used in Norway. The general emission factors for CO₂ used in the emission inventory are listed in Table 3.4, followed by a more detailed description of the factors used for offshore operations and gas terminals.

Note that the standard factor for natural gas (dry gas) used outside the energy sector has been changed from 2.34 kg/Sm³ to 1.99 kg/Sm³ in the current inventory and hence the emissions for the time series have been recalculated. The factor 2.34 kg/Sm³ is the default factor for rich gas combusted in turbines at offshore installations. However, the latest years and specifically after ETS was introduced field specific EFs are used in the estimation of CO₂ emissions from combustion of rich gas. More information is given below under *Offshore operations*.

Table 3.4. General emission factors for CO₂.

	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	3.20
Natural gas (dry gas) (kg/Sm ³)	1.99 ¹ (land)
Natural gas (rich gas) (kg/Sm ³)	2.34 ¹ (off shore)
LPG	3.00
Refinery gas	2.80
Blast furnace gas	1.571
Fuel gas	2.50
Landfill gas	0
Biogas	(2.75) ²
Fuel wood	(1.8) ²
Ethanol	(1.91) ²
Biodiesel	(2.85) ²
Wood waste	(1.8) ²
Black liquor	(1.8) ²
Municipal waste	0.5417
Special waste	3.20

¹ The emission factor for natural gas used in the emission inventory varies as indicated in Tables 3.5 and 3.6.

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

Source: Norwegian Petroleum Industry Association, SFT (1990), SFT (1996), Climate and Pollution Agency (2011b), Wikipedia 2013.

Offshore operations

For all years up to 2002 emissions of CO₂ from gas combustion off shore are calculated by Statistics Norway on the basis of activity data reported by the oil companies to the Norwegian Petroleum Directorate and the Climate and Pollution Agency and the emission factors shown in Table 3.5. For the years 2003-2011 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 the Norwegian Petroleum Directorate and the Climate and Pollution Agency.

The CO₂ 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).

From 1999 and onwards the emission factors employed reflect increasingly field specific conditions as individual emission factors have been reported directly from fields. The measurement frequency varies among the installations. An increasing number uses continuous gas chromatography analysis. Table 3.5 displays the time series of such emission factors, expressed as averages, and based on data reported in Environmental Web. That is the database where the field operators report their emissions data etcetera.

From 2008 off shore gas combustion is included in the Norwegian emission trading system.

Table 3.5. Average emission factors of CO₂ from the combustion of natural gas in turbines at offshore gas and oil fields.

		1990-1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Gas turbines offshore	kg CO ₂ /Sm ³ natural gas burned	2.34	2.29	2.3	2.3	2.31	2.5	2.48	2.47	2.45	2.46	2.43
		2005	2006	2007	2008	2009	2010	2011				
Gas turbines offshore	kg CO ₂ /Sm ³ natural gas burned	2.45	2.43	2.4	2.38	2.36	2.36	2.36				

Source: Climate and Pollution Agency/Norwegian Petroleum Directorate/Environmental Web

Gas terminals

There are four gas terminals in Norway. The eldest started up in before 1990, and then one started up in 1996 and two in 2007.

The CO₂ emission factors for combustion of natural gas on gas terminals are based on continuous or daily plant-specific measurements.

The terminals are from 2005 included in the emission trading system. The average CO₂ emission factors for fuel gas at one gas terminal are shown in Table 3.6. The natural 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. The gas terminal also uses gas from the CO₂ Removal and increased ethane recovery unit (CRAIER) as fuel in a boiler for production of steam. The boiler is connected to a gas treatment unit. The CRAIER unit makes it possible for the gas terminal to receive gas with high content of CO₂ and reduce the CO₂ content in the sales gas to a level that is low enough for the gas market. The CO₂ content in the CRAIER gas burnt in the boiler was in 2008, 2009, 2010 and 2011 respectively 1.71, 1.69, 1.62 and 1.63 tonne CO₂/tonne gas.

Emission factors for two of the other gas terminals lie within the same range as for the one shown in Table 3.6 while the emission factor for natural gas consumed at the fourth terminal in 2011 was 2.47 tonne CO₂ per tonne. It should be born in mind that the emission figures used in the inventory for gas terminals are those reported directly by the plants to the Climate and Pollution Agency. From 2005 the emission data is from the ETS and before that from the mandatory annual report from the plants to the Climate and Pollution Agency (see also Section 3.2.1).

Table 3.6. Average emission factor for CO₂ from the combustion of fuel gas at one gas terminal.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Average content of CO ₂ in natural gas	t CO ₂ /t gas	2.7	2.82	2.94	2.79	2.93	2.93	2.84	2.77	2.73	2.69	2.73
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Average content of CO ₂ in natural gas	t CO ₂ /t gas	2.68	2.68	2.68	2.68	2.67	2.67	2.66	2.65	2.66	2.65	2.64

Source: Climate and Pollution Agency

CH₄ and N₂O

For CH₄ and N₂O, information on emission factors is generally very limited, because, unlike the CO₂ 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.

Offshore operations

The general CH₄ and N₂O emission factors used in the emission inventory for this source are listed in Tables 3.7 and 3.9, respectively. Tables 3.8 and 3.10a display the cases where emission factors other than the general ones were used in the calculations.

Table 3.7. General emission factors for CH₄, stationary combustion. Unit: kg CH₄/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 3.8.

Source: IPCC (1997b), SFT (1996), SINTEF (1995) and OLF (2008).

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Table 3.8. Exceptions from the general factors for CH₄, stationary combustion.

Emission factor (kg CH₄/tonne fuel)	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

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Table 3.9. General emission factors (kg N₂O/tonne fuel) for N₂O, stationary combustion.

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 3.10a.

Source: IPCC (1997b), SFT (1996) and OLF (1998).

Table 3.10a. Exceptions from the general factors for N₂O, stationary combustion.

Emission factor (kg N ₂ O/1000 Sm ³ natural gas)	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.

The ERT has in the ARR2011 (§19) and in the draft ARR2012 (§25) asked for the rationale for the low uncertainty estimates for the AD used to estimate the CO₂ emissions from the energy sector.

The background for these questions is assumed to be the large differences between the Reference and Sectoral Approaches might indicate a large uncertainty in energy consumption.

The current method is based on uncertainty estimates for the individual source categories. The main categories are:

- *Use of oil products.* Total amounts are given by the petroleum sales statistics. The uncertainty for total sales are considered to be low due to reliable and complete sales statistics, CO₂ -tax and other taxes. The project undertaken for the RA&SA also underlines that this statistics is reliable. However, the allocation of the total consumption to individual sources is more uncertain.
- *Reported emissions from other fuels,* primarily natural gas. Uncertainty data for emissions and energy use are provided in ETS reports. A comparison undertaken as part of the RA&SA project shows that there is good correspondence between the energy consumption by plants covered by the EU ETS and the voluntary agreement and Statistics Norway's own statistics. This also indicates that the energy use in manufacturing industry in the inventory is reliable.

These groups comprise today of about 95 per cent of CO₂ from energy, in 1990 88 per cent.

The analyses have not uncovered any major completeness problems in the consumption data. Thus, we have chosen to use the within-source uncertainties in the uncertainty analysis, and to discuss the RA/SA problems in a separate section.

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 and in Annex IX QAQC_Point sources NIR 2013. Three documentation reports have been published describing the methodologies used for road traffic (SFT 1999c) (previous model for road transportation), aviation (Statistics Norway 2002a) and navigation (Statistics Norway 2001a).

Plant specific emission data included in the greenhouse gas inventory are as explained above based on three different reports. First, the annual report that each plant that has a permit from the Climate and Pollution Agency has a legal obligation to submit. This report covers all activity at the plant. Emissions data from the largest plants are included in the national greenhouse gas inventory. Then 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 the Climate and Pollution Agency also receive emission data through a voluntary agreement first established in 1997 between the authority and the industry. From 2005 the agreement covers sectors that are not yet included in the ETS. Data received by the Climate and Pollution Agency through the different reporting channels described above are controlled very thoroughly by the Climate and Pollution Agency and Statistics Norway. Especially the emission data plants included in the ETS and in the voluntary agreement are verified extensively. See Annex XI QAQC_Point sources NIR 2013.

3.2.1.6 Recalculations

Most of the recalculations in the Energy sector have been performed for 2010, because the energy figures for 2010 used in the 2012 submission were preliminary. There will always be some changes in the energy figures, e.g. some figures on energy use in manufacturing

industries will be adjusted, which will lead to adjustments in other sectors, as total use of oil products must sum up to national sales. Now the final figures for energy use are available and are used in the emission calculations. 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 was in 2012 started a project with the aim to improve consistency between different sources for energy data and between estimated emissions of greenhouse gases and energy balance. A summary of the project is described in section 3.2.3.5.

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 and production 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. It is important to specify that it is emissions from energy combustion for energy purposes that is included in section 3.2 Energy combustion in general and therefor also in the source category 1A1. Emissions from combustion not for energy purposed e.g. flaring is included in section 3.3 and 3.4.

Emissions from drilling at moveable offshore installations are included here. The emissions are reallocated from navigation in this inventory cycle. Emissions from these installations while not in operation (during transport, etc.) are included with 1A3d Navigation.

GHG emissions from the energy industries accounted for 36.0 per cent of the sectoral totals and 27 per cent of the total emissions in Norway in 2011. The increase that took place during the period 1990-2011 is as high as 107.6 per cent and is attributed primarily to the increased activity in the oil and gas extraction sector. In 2010, however, the increase was due to approximately one million ton higher CO₂ emissions from gas fired electricity power plants , while the 2.7 per cent reduction in 2011 mostly is the result of decreased emissions from the same sector.

According to the Tier 2 key category analysis for 1990 and 2011, this sector is, in conjunction with sectors 1A2 and 1A4, a key category with respect to:

- Emissions of CO₂ from the combustion of liquid and gaseous fuels in both level and trend uncertainty
- Emissions of CO₂ from the combustion of Other fuels in level in 2011 and trend uncertainty and solid fuels are key category in level in 1990
- Emissions of CH₄ from the combustion of biomass in level in 1990 and 2011.

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 and (Statistics Norway 2013b). However, most of the reported emissions in this source category are from the annual report from the entities to the Climate and Pollution Agency and the Norwegian Petroleum Directorate. The guidelines for estimating and reporting emissions are lengthy and in Norwegian, so instead of attaching these to the NIR URLs are provided in section 3.2.1.1 and in Annex XI.

In the case of waste incineration, further specifications on the methodology are given below.

Oil refineries

The emissions from oil refineries are based on annual report from each refinery to the Climate and Pollution Authority. The reports up to 2004 are from the mandatory reporting obligation that is a part of the plants permits given by the authorities and from 2005 the emission data is from the emission trading system. The distribution of the emissions between flaring and energy utilisation of refinery gas in the whole period 1990-2009 is based on plant and year specific figures. The emission from energy utilization is reported in 1A1b and from flaring in 1B2c. One of the refineries has a catalytic cracker. The emissions from the burn off of coke on the catalyst at the cracker is, since the emissions from that combustion is not emissions for energy utilization, reported in 1B2a Fugitive Emissions from Oil.

Waste incineration – CO₂ and CH₄

Net CO₂ emissions from wood/ biomass burning are not considered in the Norwegian inventory, because the amount of CO₂ released during burning is the same as that absorbed by the plant during growth. Carbon emitted in compounds other than CO₂, e.g. as CO, CH₄ and NMVOC, is also included in the CO₂ emission estimates. This double counting of carbon is in accordance with the IPCC guidelines (IPCC 1997b).

Waste incineration – N₂O

Emissions of N₂O are derived from the emissions of NO_x which are reported from each plant to the Climate and Pollution Agency. More specifically, an estimated amount of 2.5 per cent of this NO_x is subtracted and reported to UNFCCC as N₂O (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 Climate and Pollution Agency, see Table 3.10b. The data are considered to be of high quality.

Table 3.10b. Amount of waste combusted at waste incineration plants. 1990-2011. 1000 tonne

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Amount of waste incinerated	385	399	390	429	431	448	442	458	468	513	587
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Amount of waste incinerated	598	604	730	741	733	743	802	830	793	902	1,023

Source: Statistics Norway, Climate and Pollution Agency

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 CO₂ tax on fuel combustion. The activity data are used for 1990-2002. From 2003 onwards, reported emission figures from the field operators reported into the database Environmental Web 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 four gas terminals, where natural gas from the Norwegian continental shelf is landed, treated and distributed. Annual figures on natural gas combusted in turbines and flared are reported to the Climate and Pollution Agency and the Norwegian Petroleum Directorate. Emissions included in inventory for this category are from the gas terminals annual report to the Climate and Pollution Agency.

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 the Climate and Pollution Agency. Emissions from the catalytic cracker at one refinery are reported in 1.B.2.a.iv Refining/Storage.

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 CO₂, CH₄ and N₂O are displayed in Tables 3.4, 3.7 and 3.9, respectively. Emission factors for CH₄ have been calculated by (SFT 1996).

CO₂ emission factor for the fossil part of waste combusted in waste incineration plants in Norway was revised last year (Climate and Pollution Agency 2011b). The new factor is based on that there are 2.708 tonne CO₂ per tonne plastic combusted, 20 per cent of combusted waste is fossil (Avfall Norge 2006) and is used from 1996 and until today and about 9 per cent before 1996. The energy content in combusted waste used in the calculation is in average 12 GJ per tonne waste (Avfall Norge 2006) and (PROFU 2006). The latter energy content is used from 1996 and before that 10.5 GJ per tonne waste (Statistics Norway 2013b).

The factor 2.708 tonne CO₂ per tonne plastic combusted is based upon the same composition of polymers combusted as in (Denmark NIR 2010). Denmark has in their inventory based their calculation on that 13 per cent of combusted waste is of fossil origin.

The content of fossil waste of 20 per cent is from (Avfall Norge 2006) and is based on surveys of the composition of waste combusted in 2004 and before. In the mid 90ies there

were conducted surveys of the composition of waste combusted and the conclusion was then that the content of fossil waste in combusted waste was about 9 per cent (SFT 1996). Due to lack of data we have chosen to use the two factors as constants for two periods. While we assume that it is more reasonable to believe that there is a more gradual increase in the content of fossil waste. We will consider looking further into this subject in the coming years.

Extraction of oil and natural gas

The CO₂ emission factor for gas combustion offshore that has been 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).

The carbon content of gas burnt varies considerably between the various oil and gas fields. These changes are reflected in the reported emissions. Up to the early 1990s, most of the gas was used in the Ekofisk area, which has a below average carbon content. From around 2000, fields with higher carbon content came into production. In the last few years, there has again been a shift towards fields with somewhat lower carbon content.

Oil refineries

The CO₂ emission factor for combustion of refinery gas is based on daily or weekly plant-specific measurements. The refinery gas consists of hydrogen and various hydrocarbons. The composition is variable, leading to changing emissions factors measured as tonne CO₂/tonne fuel or tonne CO₂/TJ. High hydrogen content leads to low emission factors as measured in tonne CO₂/TJ. As an example, a gas with 40 % hydrogen and 60 % hydrocarbons with an average carbon number of 2 give an emission factor of 50 tonne CO₂/TJ. In the Norwegian inventory, the emission factor varies in the range 45-60 tonne CO₂/TJ.

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 CO₂, 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 CH₄ and N₂O 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 and in Annex IX QAQC_Point sources NIR 2013.

The source specific QA/QC described in section 3.2.1.5 is also valid for Energy Industries.

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 CO₂ 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

- Improved completeness. Use of bio-oil has been included for 2010. Increased emissions for all components, except CO₂.
- Correction of error. N₂O from district heating plants were previously double counted for 1996-2010. Removal of this double counting has reduced the emissions somewhat.
- Correction of error. CH₄ figures for 2010 for a thermal power plant located at the same place as an oil refinery, are included in reported figures for the latter and registered under 1A1b Petroleum refining. An additional factor estimation of emissions from the thermal power plant, registered under 1A1a, caused a double counting in the previous submission, and this has now been removed. Hopefully, the plants will report separate emission figures for CH₄ in the future.
- Correction of error. A small amount of natural gas previously erroneously registered as used for production of electricity in 2006 has been removed. This causes minor reductions in emissions of CH₄ and N₂O.
- Consistency. As the ERT has pointed out, previous IEFs for CO₂ from gaseous fuels fluctuated remarkably for the latest years in the time series. A thorough examination of the energy figures used has led to revisions for five gas-fired power plants in 2007-2010. In addition to a minor revision of emission figures for another plant in 2004 and 2005, this has given far more reasonable IEFs.

3.2.2.8 Planned improvements

There is a continuous activity going on to improve the inventory for the sector and activity continues also up to the 2014 submission. Some of the planned work is described in section 9.4.

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

3.2.3.1 Description

A description of the general method used for estimation of emissions from fuel combustion is given in Section 3.2.1.1 and in (Statistics Norway 2013b). Emissions from 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 (e.g. ammonia, methanol, plastics), 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 6.3 per cent to the national GHG total in 2011. Emission from the sector has decreased by 6.5 per cent from 1990 to 2011. Between 2010 and 2011 1A2's sectoral emissions decreased by 5.4 per cent, about 192 Gg CO₂ equivalents. All sub-sectors in 1A2 have decreased emissions in 2011, save chemical industry and other industry which have increased emissions by 2.8 and 0.7 per cent respectively. The largest reductions come from Iron and steel industry and pulp and paper industry with reduced emissions by 51 per cent, 74 Gg CO₂ equivalents and 24.2 per cent, 94 Gg CO₂ equivalents respectively.

According to the Tier 2 key category analysis for 1990 and 2011, this sector is, in conjunction with sectors 1A1 and 1A4, a key category with respect to:

- Emissions of CO₂ from the combustion of liquid and gaseous fuels in both level and trend uncertainty
- Emissions of CO₂ from the combustion of Other fuels in level in 2011 and trend uncertainty and solid fuels are key category in level in 1990
- Emissions of CH₄ from the combustion of biomass in level in 1990 and 2011.

3.2.3.2 Methodological issues

A description of the general method used for estimation of emissions from fuel combustion is given in Section 1.2.1.1. For a few plants the emission figures are based on reported figures from the plants to the Climate and Pollution Agency. However, in 2011 these plants account for approximately half (53 per cent) of the CO₂ 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 the Climate and Pollution Agency in this sector. The guidelines for estimating and reporting emissions are lengthy and in Norwegian, so instead of attaching these to the NIR URLs are provided in section 3.2.1.1 and in Annex XI.

Ammonia production

Emissions from production of ammonia is reported in this section as far as emissions from combustion from energy utilization is concerned while emissions from production of hydrogen from wet gas is reported in section 2B1, see Section 4.3.1.1. Emissions included in the inventory are from the plant's annual report to the Climate and Pollution Agency.

The emissions from fuel combustion included in this section are liquid petroleum gas of different composition and CO rich blast furnace gas from a producer of ferro alloy. The activity data and emission factors for the different fuels combusted are shown in Section 3.2.3.4.

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.

Ammonia

The LPGs used as fuels in the ammonia production is mainly a mix of propane/butane with the emission factor 3.01 tonne CO₂ /t gas and ethane the emissions factor 2.93 tonne CO₂ /tonne. Then a small amount of a light fuel gas (composition of 60 per cent H₂ and 40 per cent CH₄) from a producer of plastic is used a few years with an emissions factor of 2.4 t CO₂ per tonne gas.

The blast furnace gas used as fuel has an emission factor of 0.714 t CO₂ per tonne gas. This gas is sold from a metal producer and is mainly used as fuel in ammonia production and is reported under solid fuels. This lead to emission factors in the range of 190-264 tonne CO₂/TJ for solid fuels in source category 1A2c Chemical industry. The default emission factor for blast furnace gas in the 2006 guidelines is 70.8 tonne C/TJ, or 260 tonne CO₂/TJ.

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

QC of plant specific data performed by the inventory compilers in Klif before handing over the data to SN to be included in the inventory is quite extensive. The QC is described in Section 1.6 of the NIR and also in Annex IX QAQC_Point sources NIR 2013, section 5 Current QA/QC procedures and data sources. This is an annual QC.

This year SN has had an extensive QC of energy consumption data in the Manufacturing industries and construction sector (Statistics Norway 2013c unpublished). This is an answer to the ERT's recommendation to compare the plant-specific AD collected under the EU ETS with data from other sources (e.g. statistical data and the national energy balance). The QC is based on energy data collected by SN and Klif as described in Table 10c.

Table 3.10c. Amount of waste combusted at waste incineration plants. 1990-2011. 1000 tonne

Differences	SN	Klif - reports from plants with regular permit	Klif – reports from EU ETS
Mandatory	Yes	Partly	Yes
Deadline	May 1	March 1	March 1
Confidential	Yes	No	No
Who reports	Sample of mining and construction industry	Reports as required by regular permit and required by the voluntary agreement	All entities included in EU ETS
Number of entities covered by this QC	2 500	100	50

Source: Statistics Norway

Annually SN collects consumption data for energy use in industry. The survey covers all energy carriers used in industry for production, lightning, heating and transport. The data is important input in the estimation of energy consumption in Energy balance and Energy accounts that is important data in the GHG inventory.

Klif collects each year energy consumption data from all entities included in EU ETS, mandatory reporting by plants with a permit and plants covered by the voluntary agreement.

The aim for the project was to evaluate if energy data from Klif can be used to

- Regular QC of the largest entities when preparing and analyzing the statistics for use of energy in the industry
- Verify the data used to estimate the energy balance and the GHG emissions from industry.

The summary of the evaluation is:

- Fuel oils; the reporting of consumption of fuel oils to SN and Klif are comparable. There is no important differences between the two datasets
- Waste oil; There is no important differences between the two datasets
- Natural gas; there is a challenge that there is different units used in the reporting to SN and Klif and that it not always quite clear if the gas is used for energy production or as feedstock The consumption of LNG when reported to Klif match with SN data. There is some major LNG consumers not found in the dataset from Klif
- LPG; there is a challenge when comparison the data that Klif data not always differentiate between LPG used as fuel or as feedstock
- Other gases; fuel gas, CO-gas, refinery gas and other purchased and own generated. There is a challenge that there are different units used in the reporting to SN and Klif. But due to there is a limited numbers of entities the comparison is easy to perform. However, there are a few problematic plants and these have to be control strict each year. Common for the plants is that they have integrated energy production connected to the production. The energy data from Klif is still important to verify the data collected by SN
- Coal and coke; the dataset collected by Klif are lacking some major consumers of coal and coke. This is mainly due to that data collected by Klif in the voluntary agreement are not stored in Forurensning and therefore not included in this project. The data for coal and coke should therefore be checked

- Statistical differences; in spite of potential errors in the data the conclusion is that based on the 2011 data there is no reason to assume that the errors have any importance for the statistical differences in the energy balance.

3.2.3.7 Recalculations

1A 2 a Iron and steel

- Correction of error. Previously, combustion emissions from coal at one plant in 2010 were estimated, although the amount in question actually was used as a reducing agent. The removal of this coal amount has resulted in a reduction in emissions of CH₄ and N₂O, which are factor estimated. As reported emission figures (in this case CO₂) are distributed between different energy goods relatively to the use of the goods, the removal of coal has caused larger emissions for other energy goods, i.e. light fuel oil, LPG and blast furnace gas.
- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³.

1A 2 b Non-ferrous metals

- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³.

1A 2 c Chemicals

- Correction of error. A previous double counting of CO₂ from one plant in 2007 has been removed.
- Correction of error/reallocation/revised data. The figure on use of natural gas in 2002 at one plant has been corrected and this has led to an increase in factor estimated emissions, i.e. CH₄ and N₂O. At the same time, there has for the same plant been both a revision of total emission figures for CO₂ and a reallocation between combustion with energy utilisation (1A2c) and flaring, registered as process emissions (2B5.5 Methanol), all years 1997-2010. The revised figures are based on data from the emission trading system (ETS). There are decreases all years in 1A2c, ranging between 22 and 44 ktonnes CO₂.
- Correction of error. For one plant, reported CH₄ emissions 2005-2010 were previously erroneously registered both as combustion emissions in 1A2c Chemicals and process emissions in 2B5 Plastic, and thus causing a double counting. The figures have now been split between the two groups, and this has led to minor reductions in both (less than 1 tonne CH₄).
- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³.
- Revised data/reallocation. For one plant, there has been a reallocation between 1A2c Chemicals and 2B5 Plastic for CO₂ emissions in 1990-2005. Previously, all emissions prior to 2006 were registered as emissions from combustion in boilers, whereas flaring, which is registered under 2B5, now has been separated for all years, as previously was the case only from 2006. There have also been many revisions for total emission figures, causing changes also for the years from 2006. This has caused a decline for CO₂ in 1Ac. Factor estimated emissions (CH₄ and N₂O) have also been influenced by these changes

- Reallocation. For one plant there, has been a reallocation between 1A2c Chemicals and 2B5 Plastic for CO₂ 2001-2005. Previously all emissions were registered in 1A2c.

1A 2 d Pulp and paper

- Correction of error. Marginal change in reported CH₄ from one plant in 2010. Assumed typing error.
- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³.

1A 2 f Other

- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³
- Revised data. For 2002-2010, figures for combustion of wood waste, waste and special waste at two plants have been changed. Reported consumption figures in tonnes from the plants are used in factor estimations. Previously, reported figures in GWh were converted to tonnes via another conversion to toe. This results in minor emission changes for CH₄ and N₂O.

3.2.3.8 Planned improvements

There is a continuous activity going on to improve the inventory for the sector and activity continues also up to the 2014 submission. Some of the planned work is described in section 9.4.

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

3.2.4.1 Description

In 2011 emissions from this source category were 8 per cent of the total emissions from transport and 2.3 per cent of the GHG national total. From 1990 to 2011 these emissions increased by 76.7 per cent due to activity growth. Emission fluctuations over time have been dictated by the activity growth rates. The GHG emissions from aviation in 2011 were 10.3 per cent higher (113 Gg CO₂ equivalents) than in 2010. The average annual growth in emissions in the period 1990-2011 was 2.7 per cent and between 1990-2000 and 2000-2010 4.5 and 0.3 per cent, respectively. This indicates that the growth in emissions from domestic aviation was substantial higher in the 90ies than it has been the last nine years.

Civil aviation is a key category with respect to CO₂ emissions in level in 1990 and 2011 and in trend. Emissions of CH₄ and N₂O from this source category are insignificant.

3.2.4.2 Methodological issues

The calculation methodology applied is described in Statistics Norway (2002a). 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 kilometers flown and is more uncertain (Statistics Norway 2002a). 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 3.11-3.12.

The Norwegian Petroleum Industry Association provides emission factors for CO₂ for the combustion of jet fuel and gasoline (Statistics Norway 2002a). The CO₂ emission factor used for aviation gasoline is 3.13 tonne CO₂/tonne fuel and has been applied to all small aircraft. All other aircraft use jet fuel (kerosene) with an emission factor of 3.15 tonne CO₂/tonne fuel.

For N₂O a default emission factor is used for all aircraft (IPCC) and is valid for both LTO and the cruise phase. EEA (2001) and IPCC (2000) suggest using an emission factor for CH₄, 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/tonne 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 Statistics Norway 2002a) 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.

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Table 3.11. General emission factors for aviation. Unit: CO₂: tonne/tonne fuel, CH₄ and N₂O: kg/tonne fuel.

Source	CO ₂		CH ₄		N ₂ O
	Aviation gasoline	Jet kerosene	Aviation gasoline	Jet kerosene	Aviation gasoline/Jet kerosene
Charter/scheduled flights					
<i>Domestic</i>					
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
<i>Foreign</i>					
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

¹Jet kerosene used on aircraft in the Defence Air Forces has an emission factor of 0.35 kg CH₄/tonne.

Source: IPCC (2001) and (Statistics Norway 2002a)

Table 3.12 Time series of variable CH₄ 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).

Sector	Source	CH ₄ Emission Factor (kg/tonne fuel)		
		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

Source: IPCC (2001) and (Statistics Norway 2002a)

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 (Statistics Norway 2000). In a recent study on emissions from aircraft (Statistics Norway 2002a), 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 CO₂ emission factors is ± 3 per cent. The uncertainty in the emission factors for CH₄ and N₂O 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 (Statistics Norway 2002a). 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

No recalculations performed this year.

3.2.4.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2014.

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

Road traffic accounted for 66 per cent of the total GHG emissions from transport and for 18.9 per cent of the national GHG total in 2011.

During the period 1990-2011 an increase in emissions of 29.7 per cent took place in road transportation.

CO₂ emissions from PC petrol were reduced by 40 per cent and PC diesel increased its emissions 14 times in the period 1990-2011. In 2011 total CO₂ emissions from PC petrol decreased its emissions by 9 per cent and emissions from PC diesel increased by 8 per cent. All changes mainly due to the shift from petrol to diesel driven PCs because of the different CO₂ tax on new cars differentiated after fuel consumption.

The annual average growth in CO₂ emissions from road transportation in the period 1990-2011 was 1.4 per cent. Between 1990-2000 and 2000-2010 the annual average growth were 1.6 and 1.1 per cent, respectively.

Passenger cars (PC). Figure 3.3a shows that the total emissions from both petrol and diesel – driven PCs have been stable all years from 1990 till 2001. From 2001 to 2006 the CO₂ emissions from all PCs slightly increased by 7 per cent. From 2006 to 2007 the emissions increased by 3 per cent. From 1990 emissions from PCs have increased by 8 percent while vehicle kilometers have increased by 44per cent and the number of PCs has grown by 47 per cent, see Figure 3.3g. The percentage difference between growth in emission and driven kilometers is explained by more fuel efficient vehicles in the period, see Figure 3.3e and f, and switching from petrol to diesel driven personnel cars in all years. But specifically from 2007 due to the CO₂ differentiated tax on new personnel cars that was implemented that year. In addition the consumption of bio diesel and bioethanol increased since 2006, see Figure 3.4, and hence the CO₂ emission decreased.

Figure 3.3e and f shows the change in absolute emissions per kilometer and relative change. This is the core emission factors that are included in the HBEFA model. In addition there are emissions related to driving conditions like e.g. gradient, air conditioning. The gross emissions factor is therefor higher than those in the figure and in Table 3.14.

Emissions from **light commercial vehicles (LCV)** and **heavy duty vehicles (HDV)** have increased with 104 and 41 per cent, respectively, in the period 1990-2011. See Figure 3.3c.

PC's contribution to total CO₂ emissions from road traffic has decreased from 66 per cent in 1990 to 57 per cent in 2011. While light commercial vehicles (LCV) and heavy duty vehicles (HDV) have increased their contribution to total emissions for road traffic from 9 and 15 percent and 24 and 28 per cent, respectively, in 1990 and 2011.

The increase in LCV's share of the total emissions from road traffic illustrates that the transport of goods has increased since 1990 as a consequence of increased trade and consumption of goods due to economic growth. HDVs consist of trucks and buses. It is specifically emissions from trucks that have increased (almost doubled) from 1990. This growth due to economic growth that has led to increased activity in the building and construction sector but also to the fact that the trucks has larger motors and is heavier in general.

The summing up of this short deep dive into road transportation is that the number of PCs has the highest growth rate and that the growths in vehicle kilometers are in the same order but a little lower. The increase in CO₂ emissions from PCs from 1990 to 2011 is low and this can be explained mainly by more energy efficient PCs. There is an indication that some of the

profit from switching to more fuel efficient motor technology is lost due to the fact that the motor volume in diesel-powered PCs is increasing. According to the Tier 2 key category analysis for 2011, road transportation is a key category with respect to: emissions of CO₂ in terms of uncertainty in level in 1990 and 2011 and in trend.

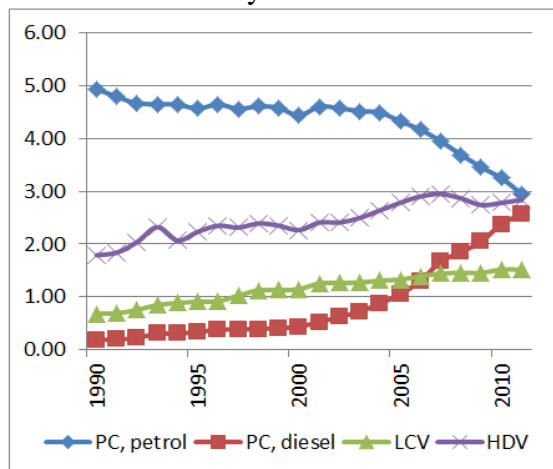


Figure 3.3a. Emissions of CO₂. PC petrol and diesel, LCV and HDV

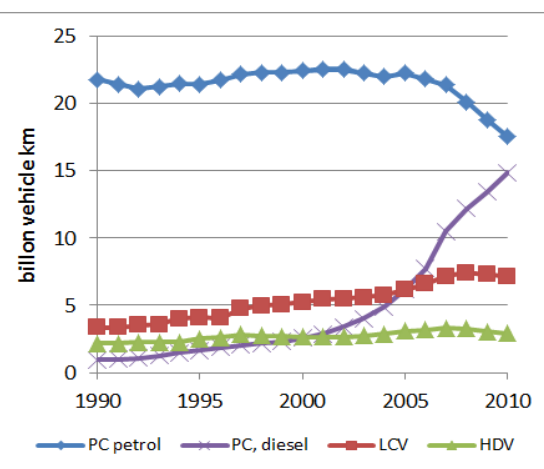


Figure 3.3b. Vehicle kilometre. PC petrol and diesel, LCV and HDV

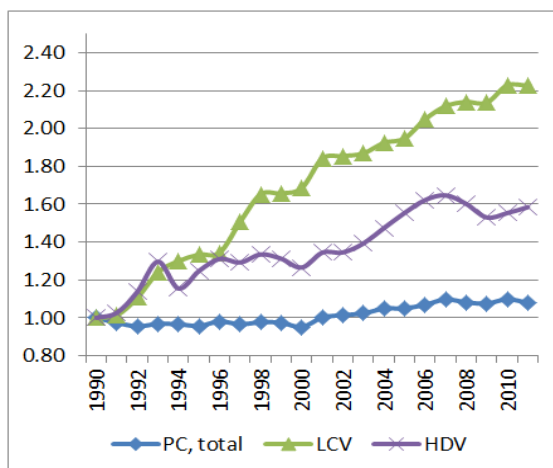


Figure 3.3c. Relative change in total CO₂ emissions from PC, LCV and HDV. 1990=1

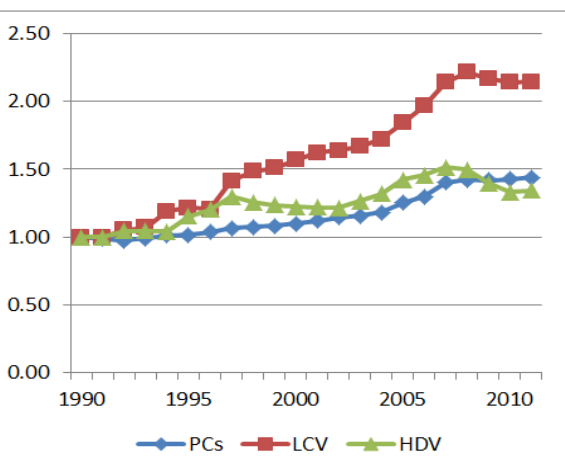


Figure 3.3d. Relative change in total vehicle km. PC, LCV and HDV. 1990=1

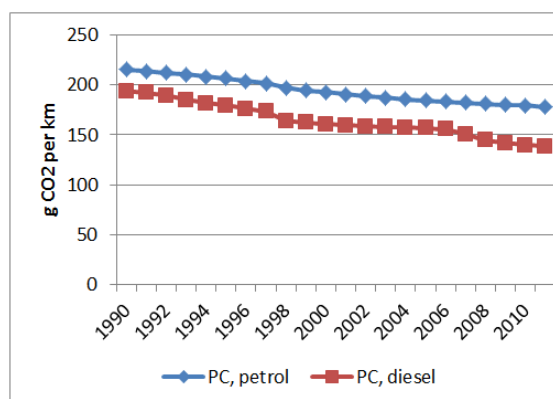


Figure 3.3e. Emissions of CO₂. mill tonn. PC petrol and diesel

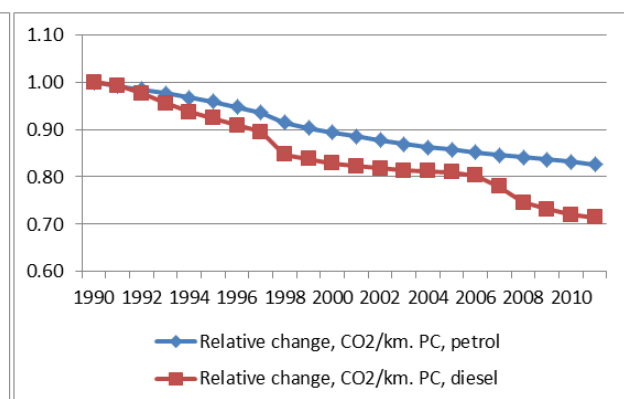


Figure 3.3f. Relative change in CO₂ emission per km. PC petrol and diesel.

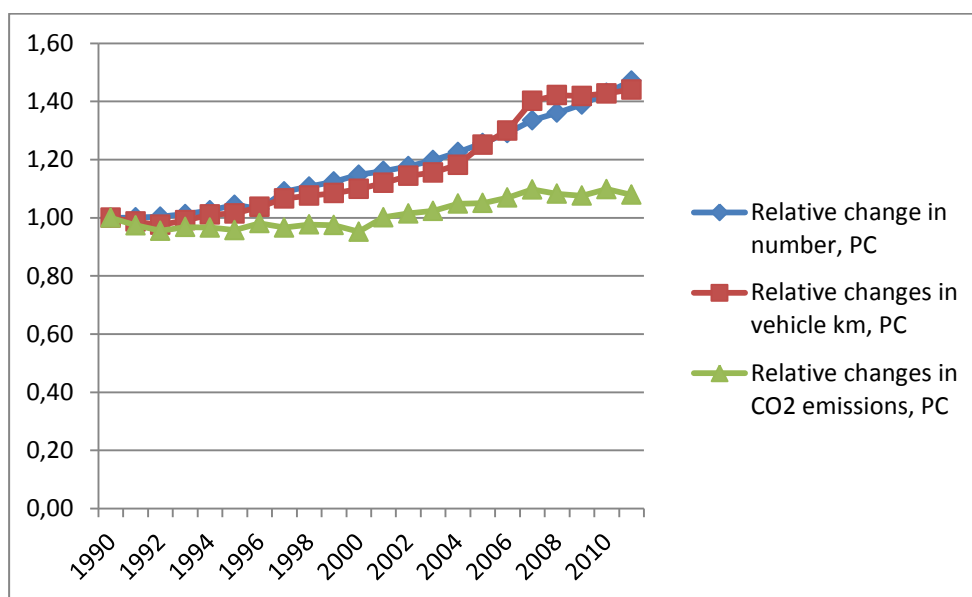


Figure 3.3g. Relative change in number of PCs and CO₂ emissions and vehicle kilometers.

3.2.5.1 Methodological issues

Total emissions of CO₂ are estimated directly from total consumption of each fuel. The consumption of gasoline for road traffic is estimated as total sales minus consumption for other uses, i.e. a top-down approach. Other uses for gasoline are e.g. small boats, snow mobiles and motorized equipment. For auto diesel, the total consumption in road traffic is all auto diesel charged with auto diesel tax, with two per cent addition for assumed tax free auto diesel used in road traffic. For the years prior to 1997 the auto diesel taxation was incomplete, and the consumption of auto diesel to road traffic was calculated as for gasoline, by subtracting the consumption for other uses. Other uses of auto diesel are e.g. motorized equipment in agriculture and construction. CNG and LPG are estimated by bottom-up approaches. The total consumption of each fuel is attributed to different vehicle classes based on results from the emission model of the Handbook of Emission Factors (HBEFA; (INFRAS 2009)).

Estimates of emissions of other pollutants than CO₂ are estimated by the emission model of the Handbook of Emission Factors (HBEFA; (INFRAS 2009)). The model uses a mileage approach:

$$\text{Emissions} = \text{mileage} * \text{emission per km}$$

The model results are used directly without any adjustment for discrepancies between estimated consumption in the model and registered fuel sale.

The HBEFA model provides emission factors and possibilities for calculating emissions for segments and sub-segments for six vehicle class: passenger cars, light commercial vehicles, heavy commercial vehicles, urban buses, coaches and motorcycles (including mopeds). The segments are based on engine volume for passenger cars and motorcycles, total weight for heavy commercial vehicles, urban buses and coaches, and gross weight for light commercial vehicles. The segments are further disaggregated into sub segments based on fuel type and technology type (e.g. Euro-1 – Euro-5). The segments used for Norway in the HBEFA model are given in Table 3.13.

The model combines the number of vehicles within each segment with driving lengths for the same segments to produce annual national mileage per sub segment. For heavy goods vehicles, the vehicle number is corrected for vehicles driving with trailers, and the driving is split into three load classes (empty, half loaded and fully loaded).

The annual national mileage is split between shares driven in different traffic situations. The traffic situations are a combination of area (urban/rural), road type (e.g. trunk road and access road), speed limit and level of service (free flow, heavy, saturated, and stop and go). The traffic situations are further disaggregated by gradients, where it for each traffic situation is specified the amount of driving on roads with slopes ranging from -6 per cent to 6 per cent is specified for each traffic situation.

Hot emission factors are provided on the disaggregated level of sub segments and traffic situations with different gradients, and the emissions are estimated after these steps of disaggregation.

The HBEFA model provides emission factors for cold emissions and evaporative emissions (soak, running losses and diurnal), in addition to hot emission factors. In order to calculate cold and evaporative emissions, information on diurnal variation in curves of traffic, trip length distributions, parking time distributions and driving behaviour distributions must be provided, in addition to variation in mean air temperature and humidity.

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Table 3.13. Segments used for Norway in the HBEFA.

Vehicle class	Segment	Fuel type	Segment split based on
Passenger car	PC petrol <1,4L	Petrol	Engine volume
	PC petrol 1,4-<2L	Petrol	Engine volume
	PC petrol >=2L	Petrol	Engine volume
	PC diesel <1,4L	Diesel	Engine volume
	PC diesel 1,4-<2L	Diesel	Engine volume
	PC diesel >=2L	Diesel	Engine volume
	PC LPG	LPG	-
Light commercial vehicles	LCV petrol M+N1-I	Petrol	Tare weight
	LCV petrol N1-II	Petrol	Tare weight
	LCV petrol N1-III	Petrol	Tare weight
	LCV diesel M+N1-I	Diesel	Tare weight
	LCV diesel N1-II	Diesel	Tare weight
	LCV diesel N1-III	Diesel	Tare weight
Heavy goods vehicles	RT petrol	Petrol	-
	RigidTruck <7,5t	Diesel	Gross weight
	RigidTruck 7,5-12t	Diesel	Gross weight
	RigidTruck >12-14t	Diesel	Gross weight
	RigidTruck >14-20t	Diesel	Gross weight
	RigidTruck >20-26t	Diesel	Gross weight
	RigidTruck >26-28t	Diesel	Gross weight
	RigidTruck >28-32t	Diesel	Gross weight
	RigidTruck >32t	Diesel	Gross weight
	Tractor for AT <=7,5t	Diesel	Gross weight
	Tractor for AT>7,5-14t	Diesel	Gross weight
	Tractor for AT>14-20t	Diesel	Gross weight
	Tractor for AT>20-28t	Diesel	Gross weight
	Tractor for AT >34-40t	Diesel	Gross weight
	Tractor for AT >40-50t	Diesel	Gross weight
	Tractor for AT >50-60t	Diesel	Gross weight
	Tractor for AT >60t	Diesel	Gross weight
Coach	Coach Std <=18t	Diesel	Gross weight
	Coach 3-Axes >18t	Diesel	Gross weight
Urban bus	Ubus Midi <=15t	Diesel	Gross weight
	Ubus Std >15-18t	Diesel	Gross weight
	Ubus Artic >18t	Diesel	Gross weight
	Ubus Std >15-18t CNG	CNG	Gross weight
	Ubus Artic >18t CNG	CNG	Gross weight
Motorcycles and mopeds	Moped <=50cc (v<50kmh)	Petrol	Engine volume
	MC 2S <=150cc	Petrol	Engine volume
	MC 2S >150cc	Petrol	Engine volume
	MC 4S <=150cc	Petrol	Engine volume
	MC 4S 151-250cc	Petrol	Engine volume
	MC 4S 251-750cc	Petrol	Engine volume
	MC 4S >750cc	Petrol	Engine volume

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. Many of the data sources are less comprehensive for the earliest years in the inventory. The sources of activity data are listed below:

- *Total fuel consumption*: the total amounts of fuels consumed are corrected for off-road use (in boats, snow scooters, motorized equipment, etc.). These corrections are estimated either from assumptions about the number of units, annual operation time, and specific fuel consumption, or from assumptions about and investigations of the fraction of consumption used off-road in each sector. Statistics Norway's sales statistics for petroleum products supplies the data for total fuel consumption (Statistics Norway Annually). See Figure 3.4 where the fuel consumption is split between fossil petrol and diesel and biofuels (biodiesel and bioethanol). Consumption of biofuels is included in the inventory from 2006. In 2011 93 per cent of bio fuels used was biodiesel and the rest (7 per cent) was bioethanol. More than 90 per cent of the consumption of biofuels was blend fuels in 2011 (about 98 for biodiesel and 90 per cent for bioethanol).
- *Number of vehicles*: the number of vehicles in the various categories and age groups is taken from the statistics on registered vehicles, which receives data from the official register of the Norwegian Directorate of Public Roads. The model input is number of vehicles per vehicle class for each inventory year, and the share of vehicles for any given combination of segment and fuel type. These data are combined with information on the introduction of technology classes to provide number of vehicles within each sub segment. The information on introduction of technology classes are for recent years based on information from the official register of the Norwegian Directorate of Public Roads and on legislation for the years in which the information in the register is insufficient.
- The HBEFA model distinguishes between two types of buses: urban buses mainly used for urban driving, and coaches, mainly used for rural and motorway driving. Due to lack of specific information to make this split in the national vehicle register, the distinction between urban buses and coaches are based on a methodology used in Sweden (Swedish environmental protection agency 2011), where the split is made based on the ratio p/w . Here, p is equal to the maximum allowed number of passengers (number of seats plus number of allowed standing passengers), and w is equal to the gross vehicle weight. These data are available from the national vehicle register. Buses with a p/w -value above 3.7 are classified as urban buses, whereas buses with a p/w -value below 3.75 are classified as coaches.
- *Average annual mileage*: Mileages for passenger cars, light commercial vehicles, heavy goods vehicles, coaches and urban buses are from 2005 onwards based on odometer readings taken during annual or biannual roadworthiness tests. The readings are collected by the Directorate of Public Roads and further processed by Statistics Norway (Statistics Norway 2010a). For earlier years, most figures are determined from surveys by Statistics Norway or the Institute of Transport Economics. In some instances assumptions are needed.
- The statistics on number of vehicles depict the vehicle fleet per December 31st of the inventory year, while the statistics on mileages represents annual driving for the entire year, including vehicles that have been scrapped or in other ways been in the vehicle fleet for only parts of the inventory year. To adjust for this discrepancy for the years 2005-2011, mean annual driving lengths for each vehicle category have been adjusted upwards in such a way that the totals correspond to the total annual traffic activity from the statistics on annual driving lengths.
- The average annual mileages vary as a function of age, with older vehicles generally driving shorter annual distances than newer vehicles. The correction of driving as a function of vehicle age is based on odometer readings taken during the roadworthiness test. The functions are calculated as the mean of the years 2005-2011, and the same correction curve is used for all years.

- Motorcycles and mopeds are not subject to roadworthiness tests in Norway. Average annual mileage are taken from a report on transport volumes in Norway (Vågane og Rideng 2010). Due to lack of data, corrections of annual mileage as a function of age for motor cycles and mopeds are taken from a Swedish survey (Bjørketun og Nilsson 2007) under the assumption that annual mileage as a function of age are comparable in Norway and Sweden.
- *Load data* are taken from the Road goods transport survey (Statistics Norway 2010b).
- *Transformation patterns* are calculated using information from Statistics Norway' Road goods transport survey on use of trailers and trailer size (Statistics Norway 2010b).
- *Traffic situations*: 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, road type, area type (urban/ rural), and vehicle size (small/ large). Traffic on municipal roads (104odel 1. 15 per cent) is estimated by Statistics Norway based on road lengths, detailed population data, traffic on adjoining roads, etc. The HBEFA model has emission factors for different situations of traffic flow (free flow, heavy traffic, saturated traffic, and stop and go). Assumptions have been made as to this distribution for the different combinations of area type, road type and speed limits for Norway. Effects of road gradients are included, based primarily on Swiss data supplied to the HBEFA.
- *Ambient conditions* (air temperature and humidity) are included in the model to calculate cold and evaporative emissions. An average of five larger Norwegian cities has been used for spring, summer, autumn and winter separately. The data are based on measurements from the Norwegian meteorological institute.
- *Trip length and parking time distributions* are calculated from the Norwegian Travel survey (Institute of transport economics 1993). The distributions are given on hourly basis.

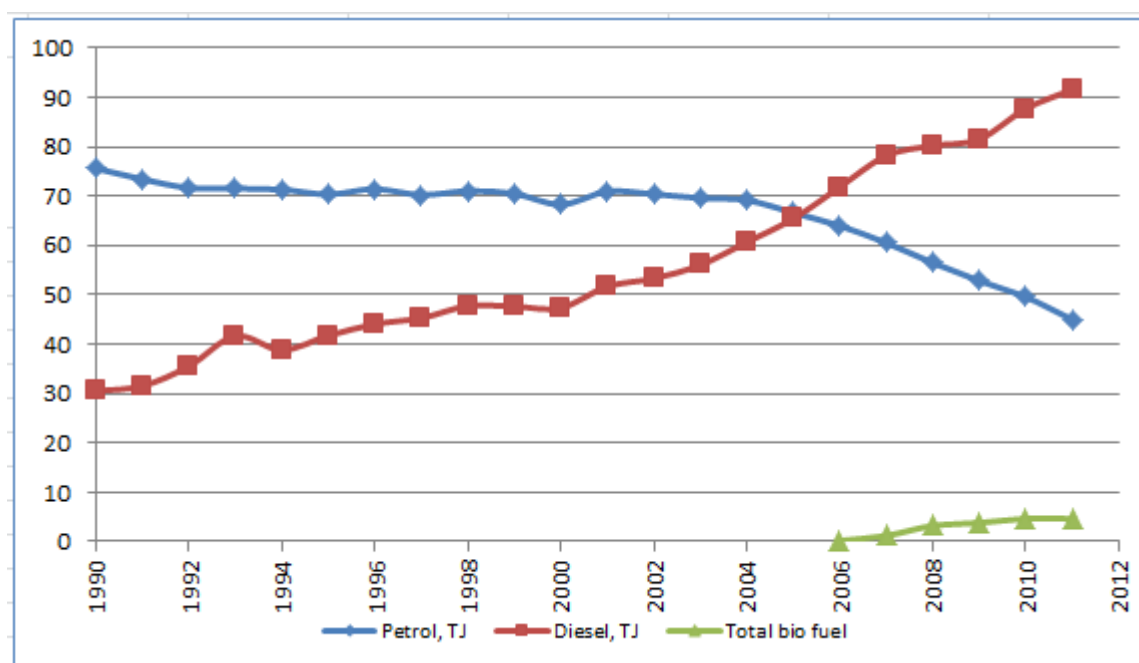


Figure 3.4. Consumption of gasoline, auto diesel and bio fuel for road transportation. 1990-2011. TJ.

Source: Statistics Norway

3.2.5.3 Emission factors

Emission factors (except CO₂) are taken from the Handbook of Emission Factors (HBEFA). Factors are given as emission per vehicle kilometres for detailed combinations of sub segments and traffic situations.

The CO₂ factors used for ethanol is 1.91 kg CO₂ /kg and for biodiesel 2.85 kg CO₂ /kg.

CO₂

Table 3.14. Average CO₂ emission from different vehicle classes, including cold start emissions and evaporation. 1990-2011. Unit: g/km.

	Motor gasoline				Auto diesel		
	Passenger car	Light commercial vehicle	Heavy duty vehicles	Motorcycle	Passenger car	Light commercial vehicle	Heavy duty vehicles
1990	215	185	489	71	194	215	834
1991	214	186	489	72	192	216	837
1992	212	186	488	73	189	217	839
1993	211	187	488	74	185	217	804
1994	208	187	488	76	182	217	820
1995	207	188	488	77	179	217	794
1996	204	189	488	79	176	216	791
1997	202	189	488	81	174	215	775
1998	197	192	488	82	164	217	802
1999	195	192	489	83	162	216	817
2000	193	191	489	84	161	215	810
2001	191	189	489	84	159	213	810
2002	189	188	489	83	159	210	810
2003	187	186	489	82	158	208	812
2004	186	185	489	82	157	205	825
2005	185	184	490	82	157	203	850
2006	183	183	489	82	156	200	867
2007	182	183	489	82	151	195	875
2008	181	182	489	82	145	190	862
2009	180	182	488	83	142	189	860
2010	179	182	488	83	140	188	860
2011	178	181	488	83	138	189	875

Source: The Norwegian road emission model that is operated by Statistics Norway.

CH₄ and N₂O

In HBEFA (INFRAS 2009) the CH₄ emission factor for passenger cars using LPG is zero. While buses using CNG has zero for both CH₄ and N₂O.

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Table 3.15. General CH₄ and N₂O emission factors from use of natural gas and LPG for passenger cars and heavy duty vehicles

Source	Fuel	CH ₄ kg/tonne	N ₂ O kg/tonne
Passenger cars	Natural gas	0.261	0.0255
	LPG	0	0.052
Heavy duty vehicles	Natural gas	0	0

Source: HBEFA, (INFRAS 2009)

Table 3.16. Average N₂O emission factors from road traffic including cold start emissions and evaporation. Unit: g/km.

	Motor gasoline					Auto diesel		
	Passenger car	Other light duty cars	Heavy duty vehicles	Moped	Motorcycle	Passenger car	Other light duty cars	Heavy duty vehicles
1990	0.099	0.109	0.043	0.052	0.057	0	0	0.029
1991	0.105	0.109	0.044	0.052	0.057	0	0	0.028
1992	0.110	0.111	0.044	0.052	0.058	0	0	0.026
1993	0.117	0.117	0.044	0.052	0.058	0	0	0.022
1994	0.125	0.123	0.044	0.053	0.058	0	0	0.025
1995	0.135	0.134	0.044	0.053	0.058	0.003	0.005	0.026
1996	0.146	0.143	0.044	0.052	0.057	0.009	0.012	0.026
1997	0.155	0.158	0.045	0.053	0.059	0.018	0.020	0.029
1998	0.153	0.161	0.044	0.052	0.057	0.027	0.026	0.028
1999	0.154	0.168	0.043	0.052	0.057	0.036	0.034	0.028
2000	0.160	0.180	0.045	0.053	0.059	0.045	0.041	0.029
2001	0.156	0.188	0.043	0.051	0.057	0.049	0.043	0.027
2002	0.156	0.204	0.043	0.051	0.057	0.056	0.046	0.026
2003	0.152	0.179	0.042	0.050	0.056	0.061	0.049	0.025
2004	0.147	0.178	0.042	0.050	0.056	0.065	0.052	0.024
2005	0.087	0.168	0.043	0.052	0.058	0.072	0.057	0.024
2006	0.083	0.165	0.044	0.052	0.059	0.076	0.060	0.023
2007	0.081	0.164	0.045	0.054	0.060	0.082	0.064	0.025
2008	0.077	0.155	0.045	0.054	0.060	0.086	0.065	0.028
2009	0.073	0.146	0.045	0.053	0.060	0.086	0.064	0.033
2010	0.067	0.132	0.044	0.052	0.059	0.082	0.061	0.042
2011	0.062	0.126	0.045	0.053	0.059	0.084	0.061	0.056

Source: The Norwegian road emission model that is operated by Statistics Norway.

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Table 3.17 Average CH₄ emission factors from road traffic including cold start emissions and evaporation. Unit: g/km.

	Motor gasoline					Auto diesel		
	Passenger car	Other light duty cars	Heavy duty vehicles	Moped	Motorcycle	Passenger car	Other light duty cars	Heavy duty vehicles
1990	1.863	2.178	0.570	12.901	3.360	0.111	0.101	0.083
1991	1.821	2.184	0.574	12.988	3.106	0.107	0.099	0.082
1992	1.772	2.150	0.575	13.015	2.870	0.098	0.093	0.078
1993	1.721	2.080	0.577	13.055	2.615	0.078	0.077	0.068
1994	1.660	1.996	0.578	13.092	2.412	0.086	0.089	0.074
1995	1.592	1.888	0.581	13.153	2.253	0.083	0.085	0.071
1996	1.450	1.730	0.572	12.949	2.016	0.079	0.080	0.066
1997	1.392	1.674	0.588	13.303	1.952	0.081	0.082	0.066
1998	1.264	1.512	0.571	12.929	1.684	0.077	0.074	0.056
1999	1.164	1.410	0.568	12.871	1.594	0.074	0.070	0.052
2000	1.106	1.347	0.583	13.209	1.542	0.070	0.067	0.049
2001	0.976	1.176	0.559	12.682	1.428	0.060	0.058	0.043
2002	0.890	1.077	0.558	12.662	1.398	0.053	0.053	0.040
2003	0.804	0.996	0.552	13.142	1.408	0.048	0.049	0.038
2004	0.719	0.917	0.544	14.292	1.426	0.042	0.044	0.035
2005	0.682	0.896	0.568	16.233	1.522	0.038	0.041	0.034
2006	0.628	0.844	0.574	17.502	1.505	0.033	0.036	0.032
2007	0.601	0.814	0.590	18.939	1.475	0.029	0.032	0.029
2008	0.564	0.768	0.591	19.745	1.370	0.025	0.027	0.026
2009	0.532	0.730	0.588	20.220	1.324	0.022	0.023	0.022
2010	0.497	0.690	0.578	20.289	1.270	0.019	0.020	0.017
2011	0.480	0.686	0.585	20.895	1.265	0.018	0.018	0.015

Source: The Norwegian road emission model that is operated by Statistics Norway.

NO₂ from gasoline fuelled PC: The N₂O EF in the HBEFA is from the COPERT IV model. In addition to the "normal" reduction of the EF according to the Euro-classes the N₂O EF is influenced by the sulphur content. The sulphur content in petrol was in 2004 0.3 per cent and in 2005 0.05 per cent. This sharp drop in sulphur content explains the decrease in N₂O EF between 2004 and 2005. See Table 3.16. Similar development in the N₂O EF has also e.g. Switzerland and Sweden that also use the HBEFA model. The change in the IEF is linked to a lower sulphur content of gasoline which leads to a reduced deactivation of the catalyst and reduced N₂O formation. This finding is backed up by several international peer-reviewed papers.

CH₄ and N₂O from biofuels/biomass in road transport: The IEFs for bio fuels changes substantially between 2009-2010 and 2010-2011, and specifically for CH₄. In the inventory we use the same EFs for CH₄ and N₂O for bio fuels as for corresponding fossil fuels.

- CH₄: The CH₄ EF from gasoline is about 30 times higher than the EF for auto diesel. The CH₄ IEFs in the CRF is weighted average of the IEFs for methanol and bio diesel. Due to that the share of bioethanol is increasing and that the CH₄ EF for bioethanol is much higher than EF for diesel the average IEF for CH₄ will increase. This even if the share of bioethanol is as low as described in section 3.2.5.2. However, this explains why the CH₄ IEF increases from 0.804 kg/TJ in 2009 to 2.342 kg/TJ in 2011 (+191 per cent).
- N₂O: The EF for gasoline and auto diesel is in the same order. Due to that the consumption of bio diesel is much higher than consumption of bioethanol the EF for bio diesel will dominate the average IEF. The increasing trend of the EF for both gasoline and auto diesel the same. The EF for biomass in t/TJ is 17-19 per cent higher

than the factor for auto diesel and this is due to that the auto diesel contains 17 per cent more energy per unit than bio diesel. Again, this explains why the N₂O IEF only increases from 1.571 kg/TJ in 2009 to 1.875 kg/TJ in 2011 (+19 per cent).

3.2.5.4 Uncertainties

The uncertainty in the activity data and the CO₂ emissions from road transportation is found to be ± 5 per cent and ± 3 per cent of the mean, respectively. In the case of CH₄ and N₂O the uncertainty in the emission factors lies on ± 45 and ± 65 , respectively (Gustafsson 2005). 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 HBEFA emission model for road traffic also makes bottom up estimates of consumption, which can be compared with the top down data. The estimated fuel consumption from HBEFA deviates from the top-down estimate by approximately 5-15 per cent per year, with the higher value for auto diesel. The causes are uncertainties in the amount of non-road use on one hand, and uncertainties in mileage and specific consumption in road transport.

However, the total consumption of auto diesel, and hence the CO₂ emission from this fuel, is well known. The uncertainty connected to consumption of auto diesel in road traffic is the share illegal use diesel without road tax. For CH₄ and N₂O the total emission may be sensitive to the allocation due to different emission factors.

3.2.5.6 Recalculations

1A 3 b i-iii Road transport

There have been two significant corrections to activity data within road transport, and one minor adjustment. In total, these three adjustments have had no effect on totals for CO₂ because the total fuel consumption figures have not been changed, only the allocation between different vehicle categories. The time series of CH₄ has been adjusted upwards by 0-6.9 per cent annually, while N₂O emissions are reduced by 0.8- 0 per cent annually in the 1993-2004 time period, and increased by approximately 1.4 per cent in 1990-1992 and 5.8 to 7.6 per cent annually in 2005-2010.

- Correction of activity data 1990-1992: Traffic activity for a segment of heavy duty vehicles has previously been omitted in the calculations in HBEFA. This traffic activity has now been included, leading to a reallocation of traffic activity within road transport. This reallocation has led to an increase in N₂O emissions of approximately 1.5 per cent each year, and a negligible reduction in CH₄ emissions.
- Corrections of coupling between activity data sets in HBEFA 2005-2010: Previously, there has been a direct coupling between statistics on number of vehicles, which have the vehicle population per December 31 of the inventory year, and statistics on driving lengths, which has had data on mean driving lengths for the average vehicle for each inventory year. This has led to an underestimation of total traffic activity data. This error has been addressed by adjusting mean annual driving lengths in such a way that the totals now represent annual traffic activity. For CO₂, this has only lead to a reallocation of emissions between vehicle categories, while it has led to an increase in both CH₄ emissions (4-6 per cent) and N₂O emissions (5-7 per cent).

- New coupling of age distributions and introduction schemes of new technologies has led to different traffic activities being coupled to different sub segments (with different emission factors). N₂O emissions are reduced by less than one per cent annually. The reduction is due to that a larger proportion of driving is calculated to having been performed by older vehicles without a catalyst. CH₄ emissions have increased in the same order of magnitude.

Additional recalculations for road transport:

- Correction of error: Emission factors for CNG vehicles are adjusted to 74% of the previous values. The previous factors were by mistake calculated as emissions per kg fuel, whereas the activity data are given in Sm³. The correction only affects emissions originally calculated in the road traffic emission model from activity data in vehicle kilometres (N₂O and CH₄). Emissions calculated from the fuel composition (CO₂) are not affected.
- Reallocation: Energy consumption and emissions for biofuels in 1A3b Road Transportation are now reported under *Biomass. Liquid Fuels\Gasoline* og *Liquid Fuels\Diesel* now has only the fossil fuel fraction.
The reallocation has no effect on total emissions. Emissions of CO₂ from *Liquid Fuels* are unchanged. Emissions of CO₂ from *Biomass* are now included, but do not enter the totals. Emissions of CH₄, N₂O, and precursors from biofuels use the same emission factors as for regular fuels.
The reallocation currently does not include all consumption of biofuels. Ethanol in gasoline used for non-road purposes in 1A3e, 1A4, etc, is still included with *Liquid fuels* in these sectors. Approximately 700 tonnes of ethanol was used for non-road purposes in 2011.

3.2.5.7 Planned improvements

The evaluation of the Norwegian road emission model started in 2008 and the new HBEFA model was implemented as a part of the Norwegian greenhouse gas emission inventory in the 2011 submission. However, there will always be room for elaborating different aspect of the model as a part of the continuous process for improving and correcting the inventory and the documentation of the methodologies employed. We assume that this is mainly valid for improving the accuracy of the emissions estimates for other gases than the greenhouse gases. There are today no specific parts of the calculation model we will look into before the 2014 submission. The documentation report for the new model is still planned to be prepared.

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 etcetera). There is also a minor consumption of coal in museum railways. The greenhouse gas emissions from this source category accounted for 0.3 per cent of the total emissions from transport in 2011. The emissions decreased by 60.4 per cent from 1990 to 2011.

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. Consumption of coal is estimated based on information from different museum railways; the same figure is used for all years from 1990.

3.2.6.4 Emission factors

The emission factors used in this source category are displayed in Table 3.4 for CO₂ and Table 3.19 for CH₄ and N₂O.

Emission factors for NO_x, HC, CO, and PM₁₀ were estimated by Bang (1993) based on a literature survey and data on Norwegian usage profiles. The HC factor of 4 g/kg was used directly for NMVOC.

The other emission factors are the same as for diesel machinery in mining and quarrying (see section 3.2.4.7.4), with the following exceptions:

- N₂O: 1.2 g/kg vs 1.3 g/kg for machinery (IPCC Guidelines)
- NH₃: 0 g/kg vs 0.005 g/kg for machinery.

General emission factors for coal are used in the calculations.

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 CO₂ is ± 3 per cent of the mean, whereas for CH₄ and N₂O 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

1 A 3 c Railways

- Completeness. Emissions from coal used in museum railways have previously not been estimated. The inclusion of these emissions causes a minor rise in all emissions from this source. Due to lack of exact data on consumption, the same amount is used for all years in the period from 1990. This gives 353 tonnes CO₂ annually.

3.2.6.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2014.

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.

Greenhouse gas emissions from navigation constituted 3.9 per cent of the national GHG total in 2011 and 13.7 per cent of emissions from transport. The emissions from shipping have increased by 22 per cent from 1990 to 2011. The changes are mainly due to increased activity in the oil and gas extraction sector. GHG emissions in 2011 were 3.8 per cent higher than those of 2010. The average annual growth in GHG emissions from navigation from 1990 to 2011 was 1 per cent. Between 1990-2000 and 2000-2010 the annual average growth were 2.7 and – 0.3 per cent, respectively. The increased emissions in the 90ies can to a large extent be explained by the growing activity in the oil and gas sector in general but especially by the fast growing production of crude oil and hence the increasing demand for ships transporting the oil from the oil fields to land. Due to the decreasing production of crude oil since 2001 the demand for transport of crude oil has been reduced. But this reduction has been counteracted by growth in demand in other segments of transport.

Navigation is a key category with respect to CO₂ emissions in level in 1990 and 2011 and trend uncertainty and for CH₄ in trend.

3.2.7.2 Methodological issues

Emissions from navigation are estimated according to the Tier 2 IPCC methodology. Emissions from moveable installations used in oil and gas exploration and extraction are split between 1A1 – energy industries (Section 3.2.2) and navigation: Emissions from drilling are reported under 1A1, while emissions from transport and other activities are reported under navigation. Emissions from international marine bunkers are excluded from the national totals and are reported separately (see Section 3.7.1), 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 (Statistics Norway 2001a), 2004 and 2007 emissions have also been estimated based on a bottom up. 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, passenger vessels, fishing vessels, 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.

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 the ship categories in the bottom up analysis is mainly given by data from the Business Sector's NO_x-fund for 2007 and by earlier Statistics Norway analyses for 1993 and 1998 (Statistics Norway 2001a), and 2004. Data on fuel consumed by public road ferries are available from the Directorate of Public Roads.

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 etcetera, is taken from the oil

companies' reports to the Climate and Pollution Agency and the Norwegian Petroleum Directorate. These reports are found in the *Environmental Web*, a database operated by the Norwegian Oil Industry Association (OLF), Norwegian Petroleum Directorate and the Climate and Pollution Agency.

For marine gas oil, the amount used for navigation is equal to total sales figures except bunkers, after the deduction of estimated stationary use, mainly in oil and gas extraction, but also some minor use in manufacturing industries and construction.

Use of natural gas in navigation, which was introduced in 2000 and has increased considerably from 2007, is based on sales figures reported to Statistics Norway from the distributors.

3.2.7.4 Emission factors

CO₂

For CO₂ 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

CH₄ and N₂O

For liquid fuels the general/standard emission factors for CH₄ and N₂O used in the emission inventory are taken from IPCC/OECD: 0.23 kg CH₄/tonne fuel and 0.08 kg N₂O/tonne fuel.

In the case of oil drilling, the employed factors are as follows:

- CH₄: 0.8 kg/tonne marine gas oil/diesel; 1.9 kg/tonne heavy fuel oil
- N₂O: 0.02 kg/tonne marine gas oil/diesel.

Some natural gas is combusted in ferry transportation and offshore supply; the CH₄ emission factors used are based on the emission factors in Table 3.18. From the year 2000, when the first vessel that used LNG as fuel started operating, a mean factor for all skips weighted after consumption data for the different ship categories (ferries and supply ships) are calculated. Ferry consumption data used in the calculations are given by the Directorate of Public Roads (Norrdal 2010).

Table 3.18. Methane emission factors for vessels using LNG as fuel.

Vessel category	Methane emission factor (kg CH ₄ / tonne LNG)	Methane emission factor (kg CH ₄ / 1000 Sm ³ LNG)
Ferry (currently lean burn engines only)	44	32
Offshore supply (Currently dual fuel engines only)	80	59

Source: Marintek (2010), and estimations from Statistics Norway.

3.2.7.5 Uncertainties

An important source of uncertainty is assumed to be estimation of fuel used by fishing vessels. There is also an uncertainty connected to the fuel use for other domestic sea traffic

due to uncertainty in the sale statistics for petroleum products. Important sources of uncertainty are also delimitation of national sea traffic and the emission factors.

The uncertainty in the activity data for navigation is assessed to be ± 20 per cent. With regard to emission factors the uncertainty for ships and fishing vessels is ± 3 per cent of the mean for CO₂. For CH₄ and N₂O 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

As mentioned, emission estimates for ships have been made bottom up for 1993 and 1998 (Statistics Norway 2001a) and for 2004 and 2007. These results have been compared with top down data (from sales) on fuel consumption used in the annual estimates. The outcome showed that data from sales were only 1 per cent higher than data from reported consumption in 2007. For 2004 the sales data were 27 per cent higher than the consumption data in the bottom up analysis. 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. Another element, which not has been taken into account, is possible changes in stock. For the years 1993 and 1998 a deviation of -12 and -15 per cent respectively has been found. In the calculations, sales figures are used, as they are assumed to be more complete and are annually available.

3.2.7.7 Recalculations

1A 3d National navigation

- Reallocation. In 2009, 26 ktonnes marine gas oils have been transferred from 1A4c Agriculture/forestry/fishing to 1A3d Navigation. This results in corresponding changes in emissions (83 700 tonnes CO₂).

3.2.7.8 Planned improvements

The Norwegian Coastal Administration started in 2011 a project with the aim to use the Automatic Identification System (AIS) to estimate the supply of polluters from ships to sea. The Climate and Pollution Agency is co-financing the project. The opportunity to use data from this project in the greenhouse gas inventory has been investigated. There were an option to use data directly to estimate emissions from the sector and include the estimates in the inventory or the data could be used to verify the calculated emissions.

We have also look into the possibility to use data from the National Account to allocate consumption of fuels between international and domestic shipping.

The conclusion from the investigation described above is that there is today no plan to use data from the AIS in the GHG inventory.

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

3.2.8.1 Description

This source category includes emissions from motorized equipment only.

3.2.8.2 Pipelines

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. However, energy generation for pipeline transport also takes place at the production facilities. Specific data on consumption for transport are not available. Thus, the consumption at the two pipeline

facilities does not give a correct picture of the activity in this sector. As a consequence, all emissions from pipelines are reported under 1A1 Energy Industries.

3.2.8.3 Motorized equipment

3.2.8.3.1 Description

Emissions from this sector were 3.4 per cent of the national GHG total emissions in 2011. In the period 1990-2011, these emissions increased by 119.2 per cent. In 2011 emission levels were 8.5 per cent higher than in 2010.

The category *motorized equipment* comprises all mobile combustion sources except road, sea, air, and railway transport. Equipment used in agricultural and construction sector is 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.

According to the Tier 2 key category analysis for 1990 and 2011, 1A4 Other sectors – Mobile fuel combustion is a key category with respect to emissions of CO₂ of level in 1990 and 2011. 1A3e Other (snow scooters, boats, motorized equipment) is key category with respect to emissions of CO₂ in level in 1990 and 2011 and trend and with respect to N₂O in level in 2011 and trend.

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/m³. 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 balance. Auto diesel used in off road vehicles has no road tax from 1993. Total use of auto diesel in motorized equipment is

given as the difference between total sales tax free diesel and estimated use for railway transportation. It is important to bear in mind that the total consumption of auto diesel in motorized equipment from 1993 is considered being of good quality since there is from 1993 no road tax on this part of the auto diesel. There is CO₂ tax on the auto diesel used for motorized equipment as well as for road traffic.

3.2.8.3.4 Emission factors

The emission factors used are given in Tables 3.19-3.20.

Table 3.19. General emission factors for other mobile sources

		CH ₄ kg/tonne	N ₂ O 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 3.16-3.17.

Bold figures have exceptions for some sectors, see Table 3.20.

Sources: Bang (1993), SFT (1999c) and Statistic Norway (2002).

Table 3.20. 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 ₂ O	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

No recalculations performed this year.

3.2.8.3.8 Planned improvements

Norway started late spring 2012 a project with the aim to consider and improve the methodology, activity data etcetera used to calculate emissions from motorized equipment. The total consumption of auto diesel in this sector is as explained above considered being of high quality so it is the allocation between source categories and equipment that will be focus in the project. The allocation is important when we calculate emissions of e.g. NO_x where the emissions are dependent of technology. The project was publicly announced for consultants' application late in November 2011. Consultant to perform the project was chosen and the projected started late spring in 2012. Due to some unlucky circumstances we did not manage to finalize the project before publishing this year inventory. We now plan to finalize the project so the result can be included in the 2014 submission.

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 fishing vessels and boats.

Fuel combustion in agriculture, forestry and fisheries accounts for more than half of the emissions of this source category. This share of the sectors emissions decreased by 3.5 percent from 1990 to 2011 and increased in both 2010 and 2011, the latter year by 0.8 percent. In 2011 the emissions from the whole sector were 3.3 million tonne CO₂-equivalents and constitute of 6.1 per cent of national total GHG that year. The sectors emissions decreased by 24.7 percent from 1990 to 2011 and by 9.3 percent during 2011 and the latter was due to decreased activity in fisheries, combustion and motorized equipment. Throughout the period 1990-2011, emissions have fluctuated although with a decreasing trend. The decreasing trend is mainly due to reduced consumption of fuel oil in the commercial, institutional and households sectors.

According to the Tier 2 key category analysis for 1990 and 2011, this sector is, in conjunction with sectors 1A1 and 1A2, a key category with respect to:

- Emissions of CO₂ from the combustion of liquid and gaseous fuels in both level and trend uncertainty
- Emissions of CO₂ from the combustion of Other fuels in level in 2011 and trend uncertainty and solid fuels are key category in level in 1990
- Emissions of CH₄ from the combustion of biomass in level in 1990 and 2011.

3.2.9.2 Activity data

Motorized equipment

Activity data are as described in Section 3.2.8.3.

Households

Use of wood in households for the years after 2005 is based on responses to questions relating to wood-burning in Statistics Norway's Travel and Holiday Survey. The figures in the survey refer to quantities of wood *used*. The survey quarterly gathers data that cover the preceding twelve months. The figure used in the emission calculations is the average of 5 quarterly surveys. For the years before 2005 figures are based on the amount of wood burned from the annual survey on consumer expenditure. The statistics cover purchase in physical units and estimates for self-harvest. The survey figures refer to quantities *acquired*, which not necessarily correspond to *use*. The survey gathers monthly data that cover the preceding twelve months; the figure used in the emission calculations (taken from the energy accounts), is the average of the survey figures from the year in question and the following year. Combustion takes place in small ovens in private 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. Use of natural gas is based on sales figures reported to Statistics Norway from the distributors.

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. For bio fuels and LPG figures are interpolated for years not included in surveys. 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. Use of natural gas in agriculture, which has increased considerably since it first was registered in 2003, is based on sales figures reported to Statistics Norway from the distributors.

Fishing

Figures on the use of marine gas oil, heavy distillate and heavy fuel oil are identical with the registered sales to fishing vessels in the sales statistics for petroleum products. 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.

Use of natural gas is based on sales figures reported to Statistics Norway from the distributors.

Calculated emissions from combustion of biogas at a sewage treatment plant are included for all years since 1993.

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 ± 20 per cent of the mean for solid and liquid fuels, and ± 30 per cent of the mean for biomass and waste. For natural gas the amount is considered to be known with ± 10 per cent (see Annex II).

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: Stationary

- Revised activity data. For one plant, previously not registered with use of coal coke in 2005 and 2006 and petrol coke in 2009 and 2010 has been included. This results in higher emissions of CO₂, CH₄ and N₂O. For CO₂ the emissions amount to 383, 3088, 4272 and 6843 tonnes in, 2005, 2006, 2009 and 2010, respectively.

1A 4 b Residential

- Revised activity data. For 2009 the amount of wood burned in holiday houses have been revised due consistency in the routine of imputation of data. Minor decrease for all components apart from CO₂.

1A 4 c Agriculture/Forestry/Fishing

- Reallocation. In 2009, 26 ktonnes marine gas oils have been transferred from 1A4c Agriculture/forestry/fishing to 1A3d Navigation. This results in corresponding changes in emissions (83 700 tonnes CO₂).

3.2.9.7 Planned improvements

See Section 3.2.8.3.8.

3.2.10 Other (CRF source category 1A5)

This source includes solely emissions from fuel use in military stationary and mobile activities. Emissions of CO₂ 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 1990-2008 are listed in Table 3.21.

There have been large variations in annual sales of military aviation kerosene; as stock changes are not taken into account. The actual annual use of kerosene and hence emissions is therefore uncertain.

3.2.10.1 Recalculations

1A 5 Other

Reallocation. Due to new information, military use of natural gas in 2010 has been reallocated from stationary to mobile use (ships). As the emission factor for CH₄ from natural gas in ships is considerably higher than the factor for boilers which previously was used, CH₄ emissions in 1A5b Mobile in 2010 are ten times higher (increased by 90 tonnes CH₄) in the 2013 submission than in the 2012 submission. In addition to this reallocation, which is less remarkable for other emissions, emission changes in 1A5 are mainly caused by revised emission factors for CH₄ and N₂O from vehicles, in addition to revised consumption figures from the energy statistics for 2010.

3.2.10.2 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2014

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Table 3.21. Stationary and mobile emissions from military activities. 1990-2011.
CO₂ in 1000 tonne, CH₄ and N₂O in tonne.

	CO ₂	CH ₄	N ₂ O
1990			
1A5A Military – stationary	62.445	7.860	0.591
1A5B Military – mobile	393.744	15.895	19.238
1991			
1A5A Military – stationary	53.252	6.700	0.504
1A5B Military – mobile	352.502	14.451	17.893
1992			
1A5A Military – stationary	60.076	7.203	0.569
1A5B Military – mobile	426.836	18.188	25.477
1993			
1A5A Military – stationary	44.328	5.573	0.420
1A5B Military – mobile	322.462	13.835	16.027
1994			
1A5A Military – stationary	50.979	6.428	0.482
1A5B Military – mobile	456.670	14.116	21.594
1995			
1A5A Military – stationary	48.063	6.054	0.455
1A5B Military – mobile	406.123	11.449	21.489
1996			
1A5A Military – stationary	62.444	7.877	0.591
1A5B Military – mobile	344.156	10.909	15.470
1997			
1A5A Military – stationary	73.637	9.233	0.697
1A5B Military – mobile	350.932	10.509	20.343
1998			
1A5A Military – stationary	49.628	6.175	0.470
1A5B Military – mobile	309.941	11.402	25.484
1999			
1A5A Military – stationary	50.294	6.343	0.476
1A5B Military – mobile	341.269	10.684	19.798
2000			
1A5A Military – stationary	40.635	5.126	0.385
1A5B Military – mobile	137.526	7.686	11.647
2001			
1A5A Military – stationary	54.359	6.858	0.514
1A5B Military – mobile	240.552	12.761	12.839
2002			
1A5A Military – stationary	44.070	5.532	0.417
1A5B Military – mobile	409.161	9.638	14.222
2003			
1A5A Military – stationary	58.250	7.349	0.551
1A5B Military – mobile	114.205	6.554	4.324
2004			
1A5A Military – stationary	45.433	5.731	0.430
1A5B Military – mobile	284.715	8.526	10.023
2005			
1A5A Military – stationary	37.298	4.705	0.353
1A5B Military – mobile	251.854	5.300	8.893

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	CO ₂	CH ₄	N ₂ O
2006			
1A5A Military – stationary	38.747	4.887	0.367
1A5B Military – mobile	238.887	6.198	8.511
2007			
1A5A Military – stationary	32.296	4.073	0.306
1A5B Military – mobile	177.225	4.788	6.796
2008			
1A5A Military – stationary	31.655	4.184	0.415
1A5B Military – mobile	220.846	9.623	12.886
2009			
1A5A Military – stationary	36.064	5.680	0.720
1A5B Military – mobile	227.533	10.162	13.217
2010			
1A5A Military – stationary	36.825	8.305	1.471
1A5B Military – mobile	230.005	101.213	13.872
2011			
1A5A Military – stationary	29.958	6.981	1.236
1A5B Military – mobile	212.225	102.057	12.735

3.3 Fugitive Emissions from Coal Mining and Handling – 1B1a – CH₄ (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 at Pyramidene in a 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. There was also a fire in the Russian mine still in operation in 2008 and therefore the production has been minor from that mine also in 2009-2010. The production increased substantially in 2011. This explains partly why the total national GHG emissions from coal mines were reduced in 2008 and years after. The main explanation for decreased emissions is that the emissions in the Norwegian mines are falling. The emissions decreased by 31 per cent in 2008, 22 per cent in 2009, 11 per cent in 2010 and then increased by 24 per cent in 2011. However, the emissions from mining are still low and were in 2011 44 Gg CO₂ equivalents.

Figure 3.5 illustrate that the production of coal at Svalbard increased 31 per cent from 1990 to 2000. In 2001 the production was about 80 per cent higher than in 2000. There was a peak in the production in 2007 when the production was almost five times higher than in 1990. In 2009 the coal production was reduced to being three times higher than in 1990. The production of coal in 2011 was 15.1 per cent lower than in 2010.

In 2005 there was a fire in one the Norwegian coal mines and this caused that the production was almost halved from 2004 to 2005 as Figure 3.5 illustrate. The emissions from this fire in 2005 are included in the inventory. The CO₂ emissions from the fire are estimated to approximately 3,000 tonne.

CH₄ 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 lower than IPCC's default factors.

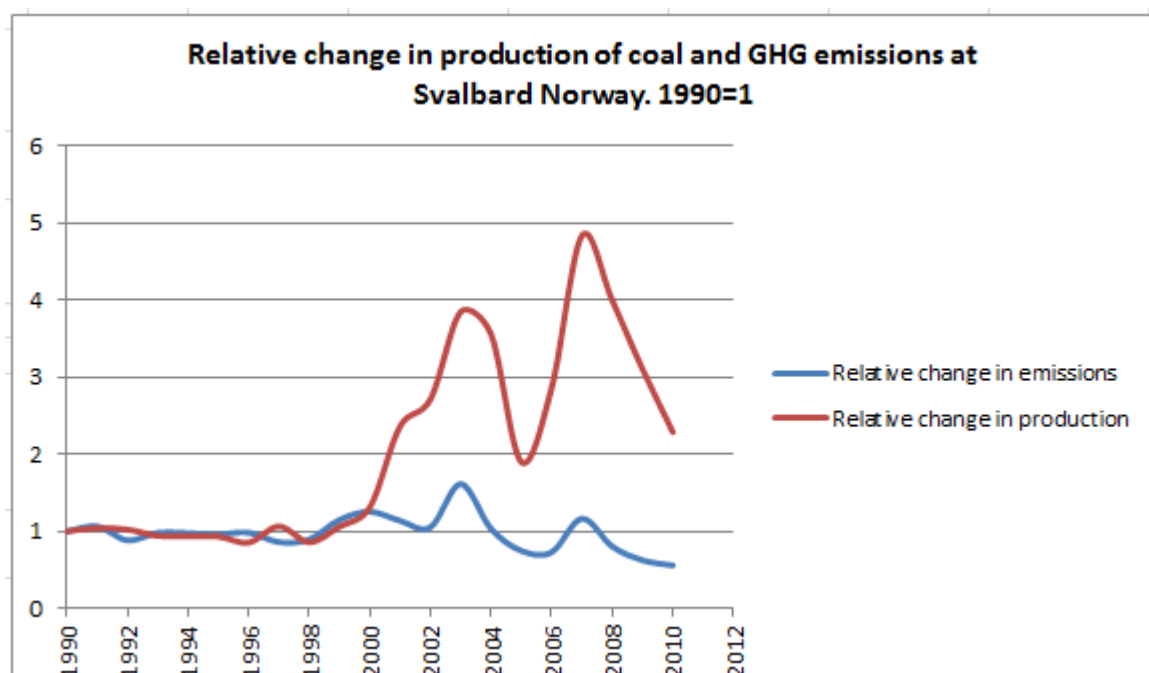


Figure 3.5. Coal productions in Norway. Relative change in production and GHG emissions. 1990-2011.

Source: Statistics Norway and Climate and Pollution Agency

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 (see Section 3.6.3 for more information about 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 analyzed (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 m³ methane per tonne coal derived from an average content of 0.79 m³ 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 m³ 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 CH₄ 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 the Climate and Pollution Agency 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 2012.

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 approaches 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 but have so far not prioritized issue.

3.4 Fugitive Emissions from Oil and Natural Gas – 2B

3.4.1 Overview

Production of oil and gas on the Norwegian continental shelf started on 15 June 1971 when the Ekofisk field came in production, and in the following years a number of major discoveries were made. The Ekofisk field is still in production and is expected to produce oil for many years to come. This illustrates the huge amount of gas and oil in that field. There has been almost a quantum jump in the development of the production technology in the off shore sector since the production activity started. An illustration of this is that the expected recovery factor at Ekofisk was 17 per cent when the production started and today they expect the recovery to be approximately 50 per cent. In 2011 there were 70 fields in production on the Norwegian continental shelf and additional 7 fields are being developed and all will start production in the nearest years.

Figure 3.6 below shows the net sale production of oil, gas and NGL and condensate in the period 1974-2011. Maximum production of oil, gas and NGL and condensate was reached in 2004 and the production was then approximately 264 mill Sm³ oil equivalents. This was an increase since 1990 of 111 per cent. In 2011 the total production has decreased by 18 per cent compared to the all-time high production in 2004 and 4.4 per cent since 2010. The maximum production of oil was reached in 2000. Production data show that the production of gas in 2010 was then for the first time higher than the production of oil and in 2011 the sale gas production was about 4 per cent higher than the sale production of oil. For more information about the Norwegian petroleum sector see the report Facts 2012 – The Norwegian petroleum sector published by the Ministry of Petroleum and Energy together with the Norwegian Petroleum Directorate (OED/NPD 2012).

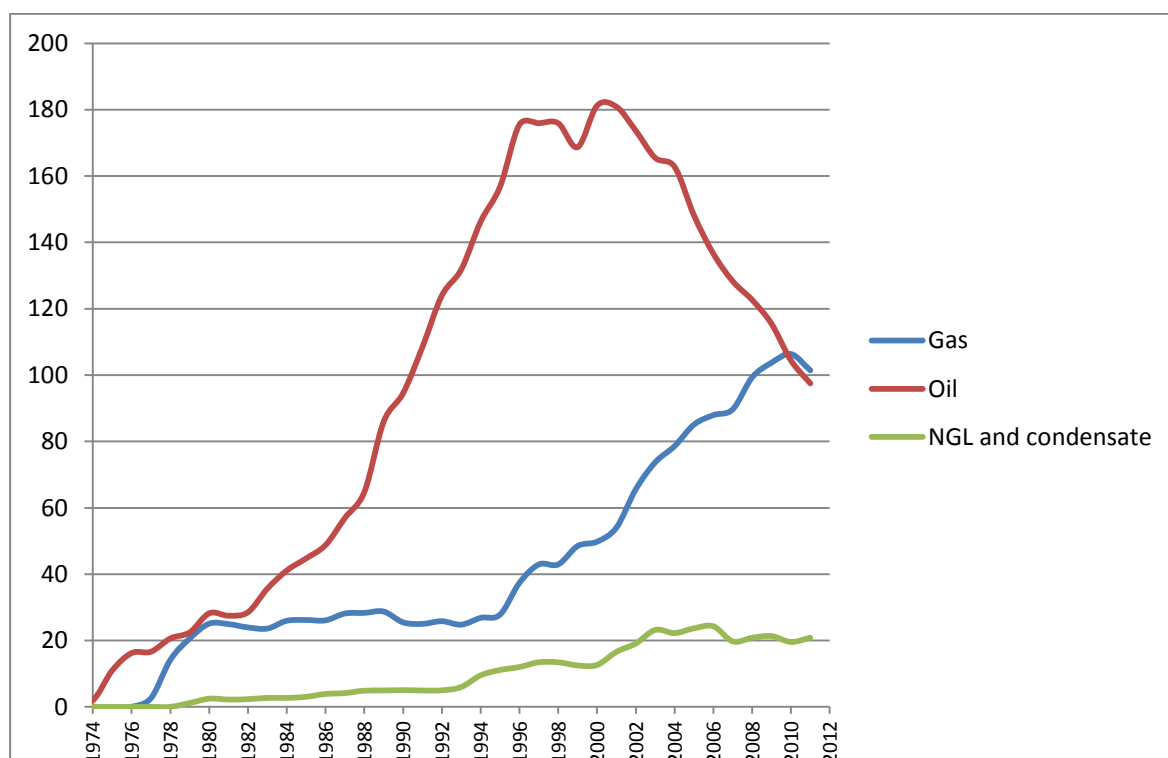


Figure 3.6. Net sale production of oil, gas and NGL and condensate. mill Sm³ oe.

Source: Statistics Norway.

As response to the 2009 annual review report sale production of oil, NGL and condensate are from the 2010 submission included in the CRF in source category 1.B2.A.2 Production oil and sale production of gas in 1.B2.B.2 Production/processing gas. The emissions from combustion for energy purposes at off shore installations and gas terminals are as in previous submissions reported in source category 1.A.c. This is emissions from combustion of natural gas and diesel in turbines, motors and boilers. Fugitive emissions included emissions from flaring in oil and gas exploration and production, gas terminals and refineries are as in previous submissions included in source category 1.B.2.c. The reporting is from our understanding in accordance with the reporting guidelines.

Fugitive emissions from oil, natural gas and venting and flaring contribute 6.0 per cent to the total GHG emissions in Norway in 2011 and with 8.0 per cent of the total GHG emissions in the energy sector. This includes emissions from burn off of coke on the catalysts at one refinery. Without this emissions fugitives emissions from what we more or less can define as oil and gas exploration and production contribute 4.1 per cent to the total GHG emissions in Norway in 2011 and with 6.0 per cent of the total GHG emissions in the energy sector. Fugitive emissions from oil and gas exploration and production's share of total GHG emissions in Norway have fluctuated between 3.6 (1991) and 6.3 (2000) per cent. The average share has been 4.8 per cent.

Figure 3.7a below shows the trend in fugitive emissions from oil and gas production, venting and flaring while Figure 3.7b shows relative change in emissions for the same emission sources. The total sector emissions increased by 8.0 per cent from 1990 to 2011 and decreased by 2.3 per cent in 2011. The fugitive emissions that are closely connected to oil and gas exploration and production increased by 1.3 per cent between 1990-2011 while the production of oil and gas increased by 76 per cent. The different development in emissions and

production is mainly explained by measures taken that have given reduction in emissions from storage and loading of crude oil offshore and onshore and that flaring of gas is for most of the years are lower than in 1990. More information about flaring off shore is explained below. The emissions in the total sector were decreased by 2.3 per cent from 2010 to 2011.

From Figure 3.7a you can also see that the total emissions from the source category increased substantially from 2006 to 2007-08 and that the emissions now are back to the 2006 level. The peak emissions in 2007-08 were due to that the LNG plant that started up in 2007 had some start-up problems that gave high emissions. From 2009 the plant came into more regular production.

CO₂ emissions from the burn off of coke at catalytic cracker in sector 2.B.2.a.iv

Refining/Storage increased by nearly 30 per cent in 2009 due to increased production. And from 2009 the emissions raised with additional 9.3 per cent.

In Figure 3.7a you will see the emissions from four source categories in absolute values and in Figure 3.7b the relative change in emissions compared to 1990. The two source categories with highest emissions, flaring and fugitives from oil (Figure 3.7a), have been almost at same level (Figure 3.7b) in the period 1990-2011. While emissions from venting have increased in orders of magnitude from 1990 and especially from 2002 but the emissions are still not more than about 0.5 million CO₂ equivalents.

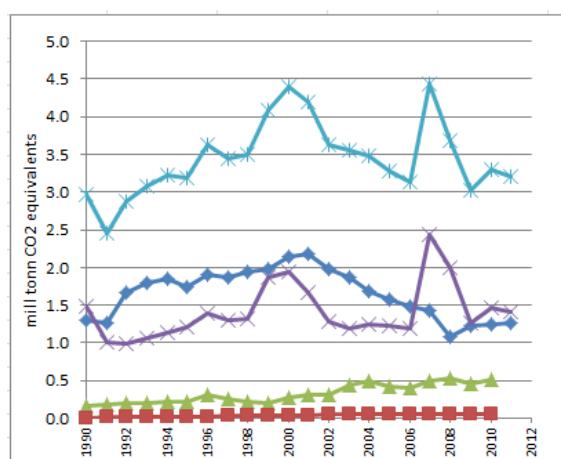


Figure 3.7a. Fugitive emissions from oil and gas production. Million tonne CO₂ equivalents. Source: Statistics Norway and Climate and Pollution Agency

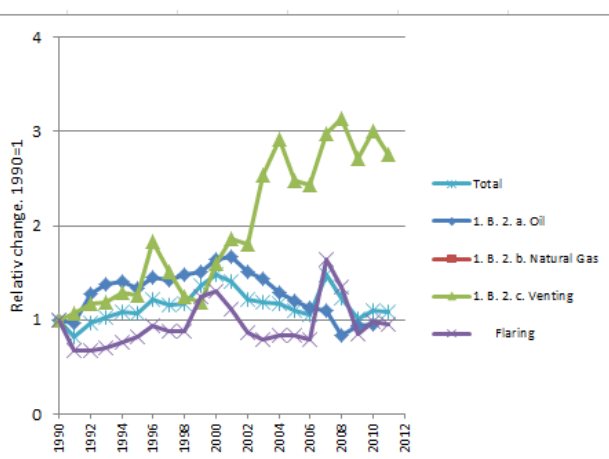


Figure 3.7b. Relative change in fugitive emissions in CO₂ equivalents from oil and gas production. 1990=1. Source: Statistics Norway and Climate and Pollution Agency

In 2011 CO₂ from flaring off shore contributed with 1.9 per cent to the total GHG emissions in Norway. The CO₂ emissions from flaring off shore were 21.9 per cent lower in 2011 than it was in 1990 while the oil and gas production were about 76 per cent higher, see Figure 3.8a. The reduced emission from flaring is partly explained by 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. In principle it is allowed to flare from safety reasons only. To minimize emissions from venting and flaring technical measures have been implemented. The venting rate is low due to strict security regulations. The giant leap in emissions from flaring in 1999-2001 was due to that several oil/gas fields came into production in that period.

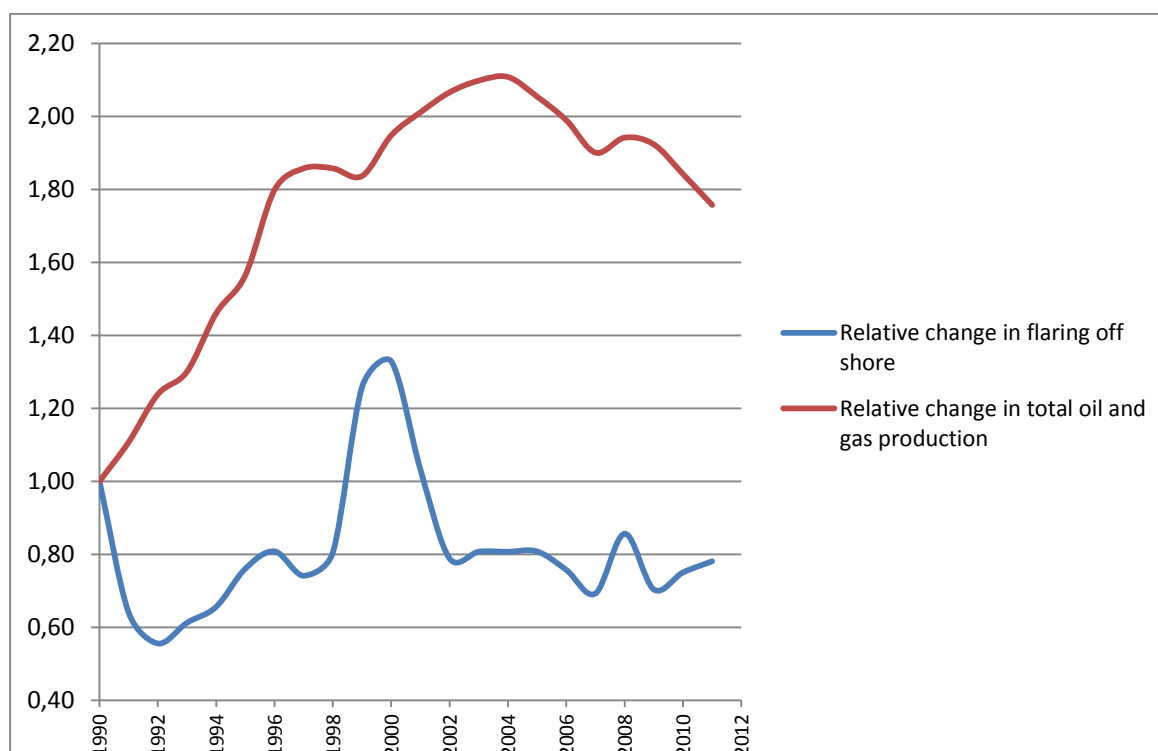


Figure 3.8a. Relative change in CO₂ emissions from flaring off shore and total production of oil and gas. 1990=1. Source: Statistics Norway and Climate and Pollution Agency

Figure 3.8b shows the number of exploration wells on the Norwegian continental shelf in the period 1990-2011. The activity has been high most of the year with 1994, 1999, 2002-2004 and especially 2005 as years with low activity. In average 34 exploration wells have been started each year from 1990.

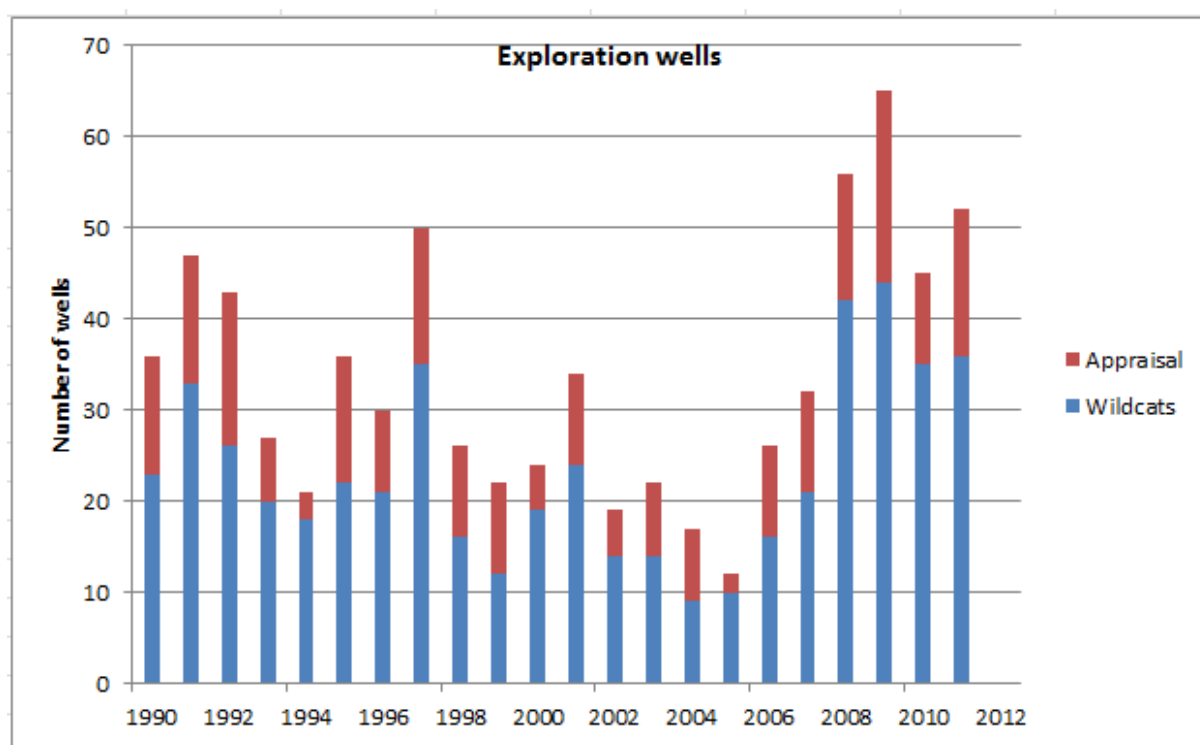


Figure 3.8b. Exploration wells. Number of wildcats and appraisal wells started. 1990-2011.
Source: Norwegian petroleum directorate

Overall description of methodology

Table 3.22a gives an overview over methodology (tier), EF and AD for each source category within the sector used in the calculations of the fugitive emissions of CO₂, CH₄, N₂O and NMVOC. The table shows if the EF and AD used in the calculation are CS or PS. The notation R/E in the table indicates that emission estimates is based on reporting from the entities (R) or calculated (E) 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.

Emissions from the following processes are reported as IE: exploration and production of oil, exploration, production/processing and transmission of gas, venting in oil and gas and flaring in combined. All emissions from venting and flaring from the processes listed in the previous sentence are included in 1B2c Venting iii Combined, 1B2c Flaring Flaring i Oil (well testing), 1B2c Gas and oil fields, Gas terminals or Refineries..

Table 3.22b shows the shares of total CO₂, CH₄ and N₂O emissions in the sector that is based on estimated and reported estimates in 2011. From the table you see that for CO₂ and CH₄ more than 90 per cent of the emissions in the sector are based on reports from the plant, mainly off shore installations. N₂O is based on estimates performed by Statistics Norway.

Sector 1.B.2.a Oil:

- CO₂: 87 per cent is based on reports that are from catalytic cracker at one oil refinery and indirect CO₂ emissions from loading and storage of crude oil. The emissions from the latter source category are estimated based on reported emission of NMVOC and CH₄.
- CH₄: 100 per cent is based on reports from refineries and oil and gas installations

1.B.2.b Natural gas:

- CO₂: 100 per cent is estimated and is indirect CO₂ based on mostly reported CH₄ emissions from gas terminals
- CH₄: 99 per cent of the emissions is based on reported emissions from gas terminals

1.B.2.c Venting and flaring

- CO₂: 93 per cent of the emissions are based on reports mostly from the oil and gas installations. In addition the reports from refineries. And is indirect CO₂ based on mostly reported CH₄ emissions from gas terminals
- CH₄: 99 per cent of the emissions are based on reported emissions from the oil and gas installations.

National Inventory Report 2013 - Norway

Table 3.22a. Fugitive emissions from oil and natural gas. Emission sources, compounds, methods, emission factors and activity data included in the Norwegian GHG Inventory.

B Fugitive emissions from fuels	CO₂	CH₄	N₂O	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	Tier II	IE	IE
ii. Production/Processing	IE	IE	NO	IE	Tier II	IE	IE
iii. Transmission	IE	IE	NO	IE	Tier II	IE	IE
iv. Distribution	E	E	NO	IE	Tier II	OTH	CS/PS
v. Other leakage							
<i>industrial plants, power stations</i>	E	R	NO	R	Tier II	CS	PS
<i>residential/commercial sectors</i>	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	E	E	R/E	Tier II	CS	PS
ii. Gas	NO	NO	NO	NO			
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, OTH=Other.

Table 3.22b. Fugitive emissions from oil and natural gas. Share of total CO₂, CH₄ and N₂O emissions in the sector based on estimated and reported emission estimates for 2011.

	CO ₂		CH ₄		N ₂ O	
	Estimated	Reported	Estimated	Reported	Estimated	Reported
B Fugitive emissions from fuels	10 %	90 %	3 %	97 %	100 %	0 %
1B1a a Coal Mining	100 %	-	46 %	54 %	-	-
1.B.2.a Oil	13 %	87 %	0 %	100 %	-	-
1.B.2.b Natural gas	100 %	0 %	1 %	99 %	-	-
1.B.2.c Venting and flaring	7 %	93 %	99 %	1 %	100 %	0 %

3.4.2 Fugitive Emissions from Oil – CO₂, CH₄ – 1.B.2.a (Key Category)

3.4.2.1 Description

1.B.2a covers emissions from loading and storage of crude oil, refining of oil and distribution of gasoline.

Included in the inventory is emission from loading and storage of crude oil produced at the Norwegian continental shelf. This means also those oil fields that is on both the Norwegian and UK continental shelf and is loaded on the Norwegian side of the shelf is included as a whole in the Norwegian inventory and opposite.

Loading, unloading and storage of crude oil on the oil fields offshore and at oil terminals on shore causes direct emissions of CH₄ and indirect emissions of CO₂ from oxidized NMVOC and CH₄. Non-combustion emissions from Norway's two oil refineries (a third was closed down in 2000) include CO₂, CH₄ and NMVOC. It is important to have in mind that included in source category 1.B.2.a.iv is CO₂ from burn off of coke on the catalyst at the catalytic cracker at one refinery, see Section 3.2.2.2. Gasoline distribution causes emissions of NMVOC, which lead to indirect CO₂ emissions.

Indirect emissions of CO₂ from loading and storage of crude oil, distribution of gasoline, direct CO₂ emissions from burn off of coke on catalytic cracker at a refinery are *key category* in level in both 1990 and 2011 and in trend according to the Tier 2 key category analyses due to uncertainty in emission factors. The source category is defined as key in level in 2011 for CH₄ emissions. 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

Emissions of CH₄ and NMVOC from loading and storage of crude oil shuttle tankers are calculated by multiplying field based on the field specific amounts of crude oil loaded and stored multiplied with field specific emission factors.

For the years 1990-2002 the emissions of CH₄ and NMVOC is calculated by Statistics Norway. The calculation is based on the field specific amounts of crude oil loaded and stored multiplied with field specific emission factors. Field specific activity data and emission factors (the latter only to the Climate and Pollution Agency) used in the calculation were annually reported by the field operators to Statistics Norway and the Climate and Pollution

Agency. 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 the Climate and Pollution Agency and used in the QC of the calculated Statistics Norway emission figures.

From 2003, emission of CH₄ 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 emissions factors with and without VRU are reported from each field operator into the database Environmental Web. The database is operated by the Norwegian Petroleum Directorate, the Climate and Pollution Agency and ¹The Norwegian Oil Industry Association. The method for calculating the emissions is the same as for 1990-2002.

An agreement was established 25 June 2002 between the Norwegian Pollution Control Authority (now Climate and Pollution Agency) and VOC Industrisamarbeid (a union of oil companies operating on the Norwegian continental shelf) aiming to reduce NMVOC emissions from loading and storage of crude oil off shore. So in addition, *also from 2003*, the emission of CH₄ and NMVOC from loading and storage of crude oil on shuttle tankers is reported annually to the Climate and Pollution Agency by the "VOC Industrisamarbeid" in the report "VOC Industrisamarbeid. NMVOC reduksjon bøyelasting norsk sokkel" (VOC Cooperation. Reduction of NMVOC from buoy loading on the Norwegian continental shelf). The report include e.g. details of ships buoy loading and which oil fields the oil has been loaded /stored at, amount of oil loaded, EFs with and without VRU. The method for calculating the emissions is the same as for 1990-2002.

Norway considers that the method for calculating the CH₄ and NMVOC emissions from loading and storage of crude oil is consistent for the period 1990-2011.

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 the Climate and Pollution Agency. At one of the terminals VRU for recovering NMVOC was installed in 1996. The calculation of the emissions of CH₄ 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 CO₂ emissions from the oxidation of CH₄ 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 CO₂, CH₄ and NMVOC included in the inventory are reported by the refineries to the Climate and Pollution Agency. There is however one exception and that is CH₄ emissions from the largest refinery. The CH₄ emissions from that refinery are estimated by the Climate and Pollution Agency 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 direct CO₂ emissions reported in this sector originate from the burn off of coke on the catalyst and from the coke calcining kilns at one refinery. The emissions from the catalytic cracker are included in the Norwegian ETS and the emissions reported in source category

1.B.2.a. iv is from the ETS and is therefore regarded being of high quality. The CO₂ emissions from catalytic cracker and calcining kilns are calculated from the formula:

$$(2006) \text{ tonne CO}_2 \text{ per year} = ((\text{Nm}^3 \text{ RG per year} * \text{volume\% CO}_2) / 100 * (\text{molar weight of CO}_2 / 22.4)) / 1000$$

- the amount of stack gas (RG) is measured continuously
- the density of the stack gas is 1.31 kg/Nm³
- volume percentage of CO₂ is based on continuously measurements. However, if the refinery can document that the volume percentage of CO₂ is not fluctuating more than 2 per cent from last year report it is not mandatory to have continuous measurements.

The indirect CO₂ from oxidized CH₄ 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 the Climate and Pollution Agency and the Norwegian Petroleum Directorate. 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 Norwegian Petroleum Directorate. The data from each field are reported monthly by the field operators to the Norwegian Petroleum Directorate on both a mass and a volume basis. The allocation of the amount of crude oil loaded at shuttle tankers and stored at storage vessels with or without VRU is from the annually report the field operators are committed to deliver to the Climate and Pollution Agency and the Norwegian Petroleum Directorate.

The amount of oil loaded at on shore oil terminals is also reported to the Climate and Pollution Agency and the Norwegian Petroleum Directorate.

The amount of crude oil buoy loaded and loaded from storage tankers off shore and crude oil loaded and unloaded at on shore oil terminals is reported for all years in source category 1.B.2.a.iii, as recommended by ERT in previous review reports.

Refining – 1.B.2.a.iv

The crude oil refined included in the CRF is crude oil converted in refineries from the Energy balance.

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

From 1990 to 2002 emission factors used in the calculation of CH₄ and NMVOC emissions from loading and storage of crude oil offshore and on shore are field/plant specific and were reported to the Climate and Pollution Agency and the Norwegian Petroleum Directorate in an annual report. The Climate and Pollution Agency forwarded the emission factors to Statistics Norway that calculated the emissions.

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 CH₄ content of the VOC evaporated is also measured so that total emissions of VOC are split between CH₄ and NMVOC.

The emission factors that the field operator use in their calculations is reported to the Climate and Pollution Agency and the Norwegian Petroleum Directorate. They report emissions factor with and without VRU and the split between CH₄ and NMVOC. The emission factors are reported by the field operators into the database Environmental web.

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 CO₂ emissions from the burn off of coke from the catalytic cracker are calculated as described above under Methodological issues. The CO₂ IEF in CRF is calculated from the emissions from catalytic cracker at one refinery and the amount of crude oil refined at three refineries up to 2002 and thereafter two refineries. This may indicate a low IEF compared to other party's IEF and if so its explain the low IEF,

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 Norwegian Petroleum Directorate. This data is reported monthly by the field operators to the

Norwegian Petroleum Directorate. The activity data are quality controlled by comparing them with the figures reported in the field operator's annual report to the Climate and Pollution Agency and the Norwegian Petroleum Directorate. We have not found any discrepancy of significance between the data from the two data sources.

Statistics Norway's calculated emissions for 1990-02 are compared with the emission data that the field operators report to the Climate and Pollution Agency and the Norwegian Petroleum Directorate. We have not found any discrepancy of significance between the two emission calculations.

From 2003 the Climate and Pollution Agency annual compare data annually reported into the EW by the oil field operators with data from the report VOC Cooperation. Reduction of NMVOC from buoy loading on the Norwegian continental shelf. If discrepancies are found between the two sets of data they are investigated and corrections are made if appropriate. If errors are found, the Climate and Pollution Agency contacts the plant to discuss the reported data and changes are made if necessary.

3.4.2.7 Recalculations

1B 2a v Distribution of oil products

- Improved consistency. Previously, a lower emission factor for NMVOC from refuelling of petrol at stations belonging to one petroleum company was used in the period 1993-2010, due to supposed emission reducing measures at these stations. Uncertainties regarding this lower emission factor has caused that the same factor now is used for all refuelling. This has given somewhat higher indirect CO₂ emissions for all years 1993-2010, ranging from 32 to 267 tonnes annually.

3.4.2.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2014.

3.4.3 Fugitive Emissions from Natural Gas – CH₄ – 1.B.2.b (Key Category)

3.4.3.1 Description

Sector 1.B.2.b covers fugitive emissions of CH₄ and NMVOC and indirect emissions of CO₂ from the two gas terminals and emissions from *distribution* of natural gas. For 1.B.2.b.i Exploration and ii Production/Processing, see section 3.4.1.

CH₄ 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

Gas terminals

Fugitive emissions of CH₄ and NMVOC from gas terminals are annually reported from the terminals to the Climate and Pollution Agency.

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.

Gas distribution

CH₄

The Norwegian gas system has two main parts: The extraction and export sector, including processing terminals and transmission pipelines handling large gas volumes, and a much smaller domestic network. Emissions from transmission, distribution and storage within the main extraction/export system is reported in 1.B.2.b v Other leakage. Emissions from the domestic system is reported in 1.B.2.b iv Distribution.

Emissions of CH₄ from three different subgroups of distribution of natural gas are estimated:

- High pressure transmission pipelines: Large diameter pipelines that transport gas long distances from field production and processing areas to distribution systems or large volume customers such as power plants or chemical plants. Emissions are calculated by multiplying pipeline distance with an emission factor.
- Low pressure distribution pipelines: Distribution pipelines which take the high-pressure gas from the transmission system at “city gate” stations, reduce the pressure and distribute the gas through primarily underground mains and service lines to individual end users. Emissions are calculated by multiplying pipeline distance with an emission factor.
- Storage: Emissions from end users’ storage. Emissions are calculated by multiplying the amount of gas consumed with an emission factor.

3.4.3.3 Activity data

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

Gas distribution

In the estimation of CH₄ emissions from storage, figures on use of natural gas from the energy statistics are used. Emissions from transmission and distribution are based on data on pipeline distances collected from gas distributors.

3.4.3.4 Emission factors

Gas distribution

Since country specific emission factors for Norway not are available, Austrian factors are used in the estimations. The factors for both storage and transmission may be too high.

The domestic system is fairly simple. Processing and storage is mainly taking place at units within the extraction sector. We considered that the combined emission factor in the IPCC 1996 GL for “Emissions from Processing, Distribution, and Transmission” did not reflect Norwegian conditions. In a literature survey, the Austrian report offered a simple method using activity data that were available. It was assumed that Austria and Norway had fairly similar gas distribution systems.

Table 3.23. Emission factors for gas distribution.

	CH ₄	
	Emission factor	Unit
High pressure transmission pipelines	0.475	tonnes per km pipeline
Low pressure distribution pipelines	0.013	tonnes per km pipeline
Storage	0.005145	tonnes per mill. Sm ³ gas consumed

Source: Austria 2010

3.4.3.5 Uncertainties

The emission factors for both storage and transmission of natural gas are uncertain, since Austrian factors are used in lack of country specific Norwegian factors.

3.4.3.6 Source-specific QA/QC and verification

Reported emissions are compared with previous years' emissions.

3.4.3.7 Recalculations**1B 2b Natural gas – gas distribution**

- Revised activity data. Revised figures of use of natural gas 2008-2010 causes marginal changes in emissions of CH₄ from gas distribution.

3.4.3.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2014.

3.4.4 Fugitive Emissions from Venting and Flaring – CO₂, CH₄ – 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 from extraction and production, at gas terminals and at refineries and the emissions is reported in sector 1.B.2.c.ii. Emission of CO₂, CH₄ and N₂O from flaring of oil when well testing is reported in sector 1.B.2.c.i.

Sector 1.B.2.c *Venting* includes emissions of CO₂, CH₄ and NMVOC from exploration and production drilling of gas and oil and reinjection of CO₂ at the Sleipner oil and gas field and Hammerfest LNG (Snøhvit gas-condensate field). The major source is cold vent and leakage of CH₄ and NMVOC from production drilling.

The sector 1.B.2.c *Venting* includes emissions of CH₄ and NMVOC and hence indirect CO₂ emissions from cold venting and diffuse emissions from extraction and exploration of oil and gas. Since most oil and gas production occur at combined production fields of oil and gas it is not appropriate to split the emissions between oil and gas production. To divide the emissions from venting between gas and oil production will improve the accuracy of the inventory.

CO₂ emissions vented to the atmosphere when the injection of CO₂ has to stop for maintenance etcetera is reported in this sector. See Section 3.5 and Annex IV CO₂ capture and storage at the oil and gas production field Sleipner Vest and Hammerfest LNG (Snøhvit gas-condensate field) for further description of this source. Amount of gas vented or injected in Table 3.24.

Table 3.24. Amount of gas vented or injected 1996-2011.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Vented, mill tonne CO ₂	0.081	0.029	0.004	0.009	0.008	0.003	0.008	0.024	0.021	0.006	0.002	0.077	0.107	0.054	0.095	0.089
Injected, mill tonne CO ₂	0.070	0.665	0.842	0.971	0.933	1.009	0.955	0.914	0.750	0.858	0.820	0.921	1.011	1.168	1.203	1.332
Vented, GJ gas	1.6	0.6	0.1	0.2	0.2	0.1	0.2	0.5	0.4	0.1	0.1	1.6	2.2	1.1	1.9	1.8
Injected, GJ gas	1.4	13.5	17.1	19.7	18.9	20.4	19.3	18.5	15.2	17.4	16.6	18.7	20.5	23.6	24.4	27.0

Source: Climate and Pollution Agency.

Most of the emissions in sector *1.B.2.c Flaring* come from flaring of natural gas offshore (during both well testing, extraction, production 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 the Norwegian Petroleum Directorate and the Climate and Pollution Agency.

CO₂ and CH₄ from venting and flaring is *key category* with respect to level in 1990 and 2011 and only CH₄ is key category 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 CH₄ and NMVOC from cold venting and diffuse emissions for each field are reported annually to the Climate and Pollution Agency from the field operator. The emissions are calculated by multiplying the amount of gas produced with an emission factor. The indirect CO₂ emissions are calculated by Statistics Norway.

The vented CO₂ at Sleipner Vest and Hammerfest LNG (Snøhvit gas-condensate field) are measured. Section 3.5 and Annex IV CO₂ capture and storage at the oil and gas production field Sleipner Vest and Hammerfest LNG (Snøhvit gas-condensate field) for details

Flaring

The CO₂, CH₄ and N₂O 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 3.22). From 2003, emissions of CO₂ and CH₄ from flaring offshore reported by the oil companies to the Norwegian Petroleum Directorate and the Climate and Pollution Agency are used in the inventory. The same method is used in the calculation of emission from flaring of gas by well testing. We consider that the method is consistent for all year.

Emissions of CH₄ and N₂O from flaring of oil in well testing is estimated for all years by Statistics Norway based on the amount of oil well tested reported annually by the field

operators to the Norwegian Petroleum Directorate and the Climate and Pollution Agency. The same emission factors are used for the whole period.

Emissions of CO₂ from flaring at the four gas terminals that is included in the inventory are reported from the plant.

The refineries reports annually CO₂ emissions from flaring to the Climate and Pollution Agency. The emissions are calculated by multiplying the amount of gas flared with plant specific emission factors. See additional information section 3.2.1.2.

3.4.4.3 Activity data

Venting

Amount of gas produced or handled at the platforms are reported from the Norwegian Petroleum Directorate to Statistics Norway and used in the QC of the reported emissions.

Flaring

Amounts of gas flared at offshore oil and gas installations are monthly reported by the operators to the Norwegian Petroleum Directorate. Amounts flared at the four gas terminals are reported to the Norwegian Petroleum Directorate and the Climate and Pollution Agency.

Amounts of refinery gas flared are found by distributing the total amounts of refinery gas 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 3.21 or field specific factors. Some of the EFs in the table are more accurate (more decimals) than those given in this table in previous submissions. The reference for the default factors is Aker Engineering (1992).

Table 3.25. 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/Sm ³]	[g/Sm ³]	
Glycol regeneration	0.065	0.265	Tonne per start up
Gas dissolved in liquid from K.O. Drum	0.004	0.0025	
Gas from produced water system	0.03	0.03	
Seal oil systems	0.015	0.010	
Leaks through dry compressor gaskets	0.0014	0.0012	
Start gas for turbines ⁵	0.4	0.36	
Depressurization of equipment	0.005	0.016	
Instrument flushing and sampling	0.00021	0.00005	
Purge and blanket gas ¹	0.032	0.023	
Extinguished flare	0.014	0.015	
Leaks in process	0.007	0.022	Tonne per well
Depressurization of annulus	0.000005	0.000005	
Drilling	0.550	0.250	

¹ The gas source is standard fuel gas.

Source: Aker Engineering (1992).

Flaring

CO₂: For the years 1990-02, average emission factor are used, except for one field, for which a field specific factor is used for all years. From 2003, more and more field specific EFs have been accessible. Especially from 2008 when CO₂ from the oil and gas sector was included in the EU ETS field specific EFs have become more and more available. This is due to that the general rule in the EU ETS is that is mandatory to use field specific EF for gas flared or gas combusted for energy purposes. The default EF in EU ETS is 3.73 kg CO₂ / Sm³ natural gas that is considerably higher than almost all field specific factors. From Table 3.24 you will see that the average EF are increasing and that specifically in 2010 and 2011 the average EFs were high.

⁵ The gas source is standard fuel gas.

In Table 3.24, the CO₂ emission factors for flaring off shore and at one gas terminals are shown. The CO₂ emissions from the gas terminal were in 2011 less than 50,000 tonne. The flared gas in 2011 are from three different gas fields where the carbon content in one of the gas streams were about 10 per cent higher than in the two other gas streams in 2011. This explains why the average EF for flaring is 4 per cent higher in 2011 compared to 2010. The average emission factor for the three types of flares (high pressure, low pressure, maintenance flare) at one of the other gas terminal was in 2009, 2010 and 2011 respectively 2.50, 2.55 and 2.64 tonne CO₂/tonne gas flared. For the third gas terminal the average emissions factor for flared gas in 2009, 2010 and 2011 were respectively 1.94, 1.77 and 1.47 tonne CO₂ per tonne gas.

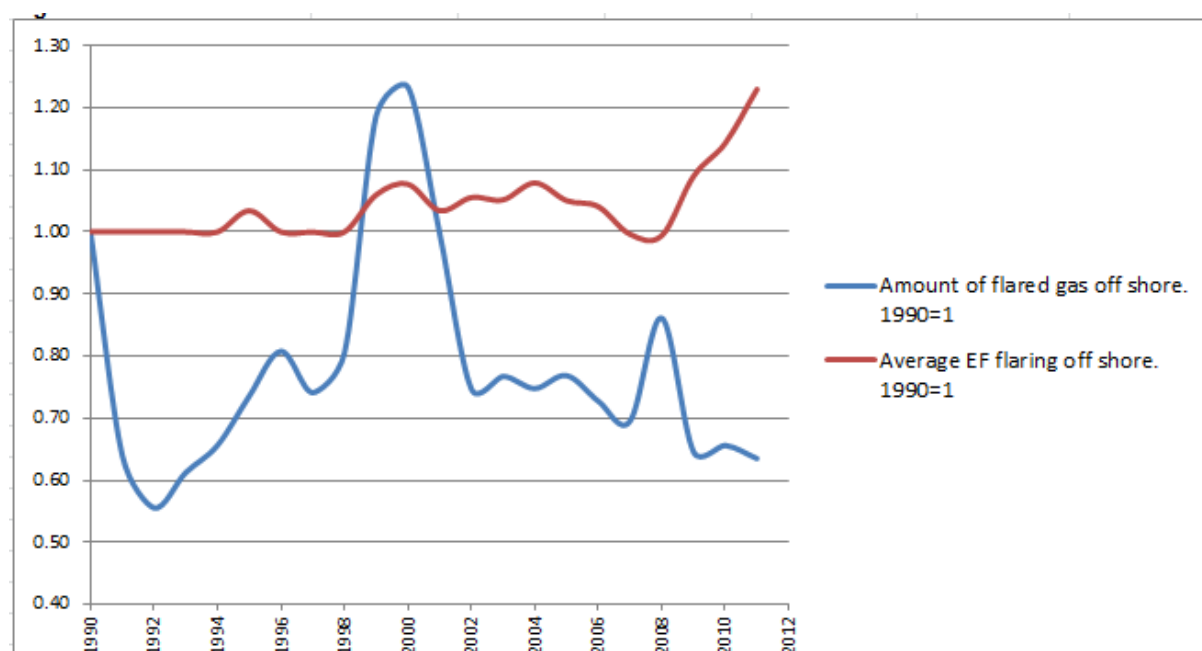
Emission factors used in the calculations for well testing are shown in Table 3.25. During the review of the 2008 inventory submission the expert review team raised question to that CH₄ and N₂O from well testing off shore were not included in the inventory. Norway then estimated the emissions of CH₄ and N₂O and presented the result for the expert review team. The emission estimates was for the first time included in the inventory in the 2010 submission.

Table 3.26. Emission factors for flaring of natural gas at off shore oil fields and one gas terminal on shore.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Average emission factor for flaring at one gas terminal	tonne CO ₂ /tonne natural gas	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Average emission factor for flaring off shore	kg CO ₂ / Sm ³ natural gas	2.34	2.34	2.34	2.34	2.34	2.42	2.34	2.34	2.34	2.48	2.52
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Average emission factor for flaring at one gas terminal	tonne CO ₂ /tonne natural gas	2.7	2.7	2.7	2.7	2.7	2.69	2.67	2.67	2.67	2.65	2.76
Average emission factor for flaring off shore	kg CO ₂ / Sm ³ natural gas	2.42	2.47	2.46	2.52	2.46	2.44	2.33	2.33	2.55	2.67	2.88

Source: Climate and Pollution Agency/Norwegian Petroleum Directorate/Statistics Norway

Table 3.8c. Emission factors for flaring of natural gas at off shore oil fields and one gas terminal on shore.



Source: Climate and Pollution Agency/Norwegian Petroleum Directorate/Statistics Norway

Table 3.27. 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)	3.20	(SFT 1990)	2.34	(SFT 1990)
CH ₄ (tonnes)	0.0004 ¹	Same factors as for fuel oil used for boilers in manufacturing	0.00024	(IPCC 1997b)
N ₂ O (tonnes)	0.00003 ¹		0.00002	(OLF 2009)
NM VOC (tonnes)	0.0033	(OLF 2009)	0.00006	(OLF 2009)
CO (tonnes)	0.018	(OLF 2009)	0.0015	(OLF 2009)

¹The Norwegian Oil Industry Association

3.4.4.5 Uncertainties

The uncertainty in the amount of gas flared is in (Statistics Norway 2000) regarded as being low, ± 1.4 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 (Norwegian Petroleum Directorate 2001). The uncertainty in the CO₂ emission factor for flaring is ± 10 (Statistics Norway 2000).

The uncertainty in the amount of gas flared is in regarded as being low, ± 1.4 per cent, based on data reported in the emission trading scheme (Climate and Pollution Agency 2011a) and assumptions in (Statistics Norway 2000). The uncertainty in the CO₂ emission factor for flaring is ± 4.5 (Climate and Pollution Agency 2011a) and (Statistics Norway 2000).

The uncertainty in CH₄ and NM VOC emissions from venting and, hence, in the indirect emissions of CO₂, 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 gathers activity data used in the calculation from the Norwegian Petroleum Directorate. The figures are quality controlled by comparing them with the figures reported in the field operators annually report to the Climate and Pollution Agency and the Norwegian Petroleum Directorate and time series are checked.

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

Statistics Norway and the Climate and Pollution Agency 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. The Norwegian Petroleum Directorate has a thorough control of the amount of gas reported as flared. The oil and gas sector is included in the EUETS from 2008.

3.4.4.7 Recalculations

1B 2c2ii Flaring of gas

- Correction of error. Reported emissions of CO₂ from one plant onshore in 2010 were previously erroneously registered as 2, instead of 24 446 tonnes.

1B 2c Venting and flaring

- Correction of error: The activity data for well testing of oil and gas for 2010 were erroneous and have been corrected. CO₂ emissions were increased by 89 000 tonnes.

3.4.4.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2014. However, we intend to look into the inventory for flaring off shore but the schedule for this work is not yet set.

3.5 CO₂ capture and storage at oil and gas production fields (Key Category)

3.5.1 CO₂ capture and storage at the oil and gas production field Sleipner Vest

3.5.1.1 Description

The natural gas in the Sleipner Vest offshore gas-condensate field contains about 9 per cent CO₂. The CO₂ content has to be reduced to about 2.5 per cent before transported to the consumers onshore. The CO₂ to be removed amounts about 1 million tonnes per year.

When this North Sea field was planned around 1990 the considerations were influenced by the discussions about strategies to reduce greenhouse gas emissions and a possible national tax on CO₂-emissions (introduced in 1991 and extended in 1996). It was therefore decided that the removed CO₂ 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 CO₂. 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 CO₂ should be stored under high pressure – preferably more than 800 meters below the surface. Under these conditions CO₂ is buoyant and less likely to move upwards than CO₂ 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 CO₂ 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 CO₂ leakage, see figure 3.9 below.

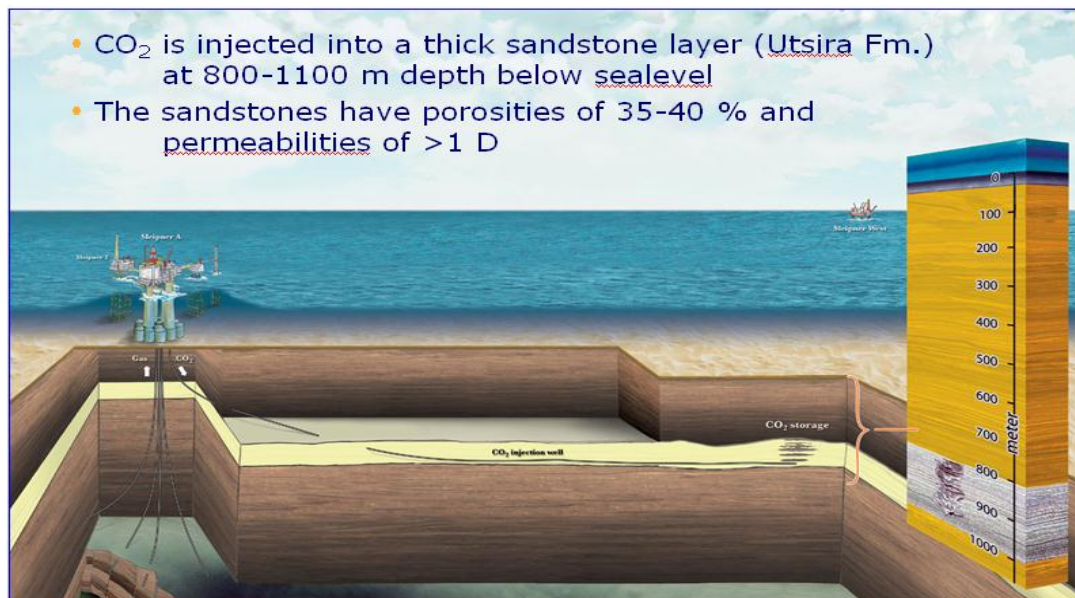


Figure 3.9. CO₂ capture from Sleipner Vest well stream and storage at Sleipner. Source: Statoil.

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 CO₂ 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 CO₂ 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 IV) with the CO₂ expected to migrate vertically to the sealing shales and horizontally along the saddle point of the structure. This will take the CO₂ away from other wells drilled from the Sleipner platform. A more detailed description of the reservoirs suitability for long term CO₂ storage is given in Annex IV.

The field and the injection program have been in operation since 1996. Statoil monitors the injected CO₂ with respect to leakages.

Investigations carried out so far show that the injected CO₂ has been kept in place without leaking out. In case unexpected CO₂ movements take place beyond the capture rock in the future it can be registered by the monitoring techniques. Table 3.28 below gives the amount of CO₂ injected since the project started in 1996.

Table 3.28. CO₂ from the Sleipner field injected in the Utsira formation.

Year	CO₂ (ktonnes)	Year	CO₂ (ktonnes)
1996	70	2004	750
1997	665	2005	858
1998	842	2006	820
1999	971	2007	921
2000	933	2008	814
2001	1 009	2009	860
2002	955	2010	743
2003	914	2011	929

Source: The Climate and Pollution Agency.

When the injection has to stop for maintenance etc. the CO₂ is vented to the atmosphere. The amount vented to the atmosphere is included in the greenhouse gas inventory reported under 1B2c – see 3.4.4. In 2011 this emission amounted to 2409 tonnes CO₂. The figures for the other years are given in Table 3.29.

Table 3.29. Emissions of CO₂ vented from the Sleipner Vest CO₂–injection plant due to inaccessibility of the injection facility.

Year	CO ₂ (ktonnes)	Year	CO ₂ (ktonnes)
1996	81 000	2004	21 377
1997	29 000	2005	6 191
1998	4 195	2006	2 471
1999	9 105	2007	6 413
2000	8 318	2008	13 569
2001	3050	2009	4 595
2002	7 567	2010	932
2003	23 910	2011	2 409

Source: The Climate and Pollution Agency

The status by 1.1.2012 is that 13 million tonnes CO₂ has been injected into the Utsira Formation and 0,222 million tonnes CO₂ has been vented. Figure 3.10 shows the yearly injected and vented volumes for the entire injection period on Sleipner.

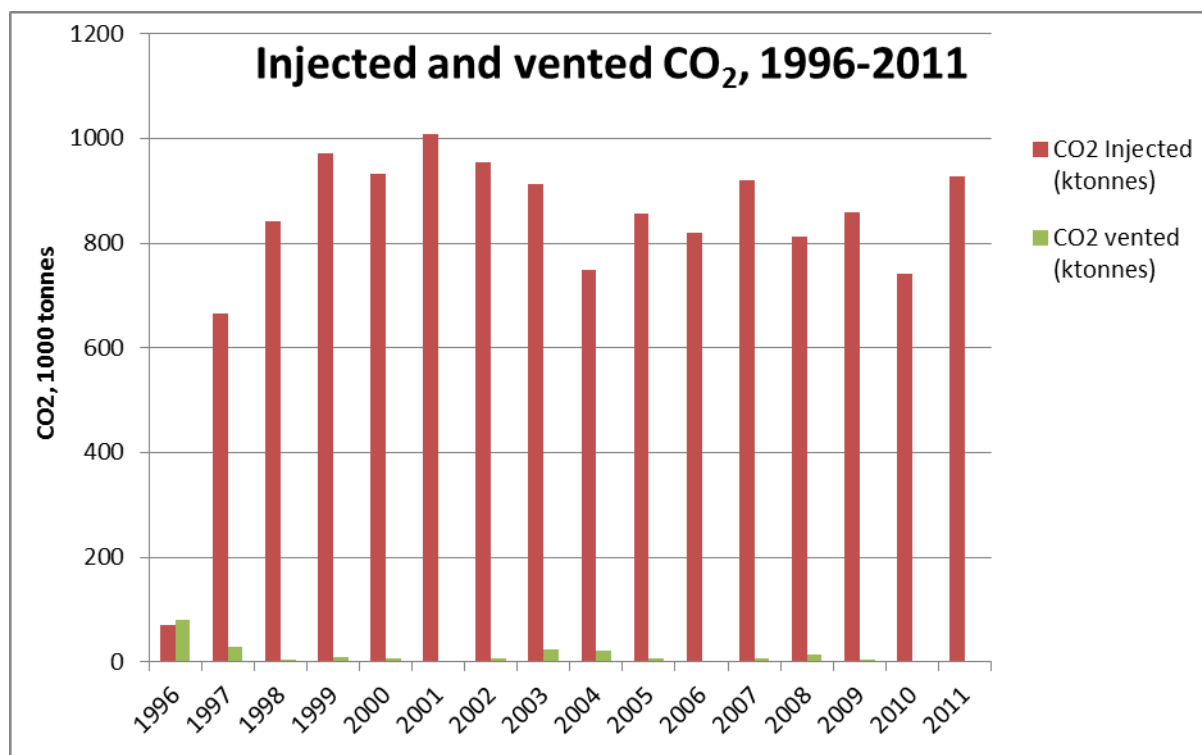


Figure 3.10. Injected and vented CO₂ at Sleipner Vest.

Source: Climate and Pollution Agency

3.5.1.2 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 CO₂ which are injected in the Utsira formation are based on continuous metering of the gas stream by orifice meter. The composition of the CO₂-stream is stable, about 98% CO₂ and the remaining 2% mainly methane and heavier hydrocarbons.

The Sleipner CO₂-injection project is considered as the first industrial-scale, environmentally driven CO₂-injection project in the world. In order to document what happens with the CO₂ 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-co-funded 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 CO₂ had been injected into the reservoir. This was followed by seismic surveys in 1999, 2001, 2002, 2004, 2006, 2008 and 2010. The monitoring methodology and the results of the monitoring are described in Annex V written by Statoil.

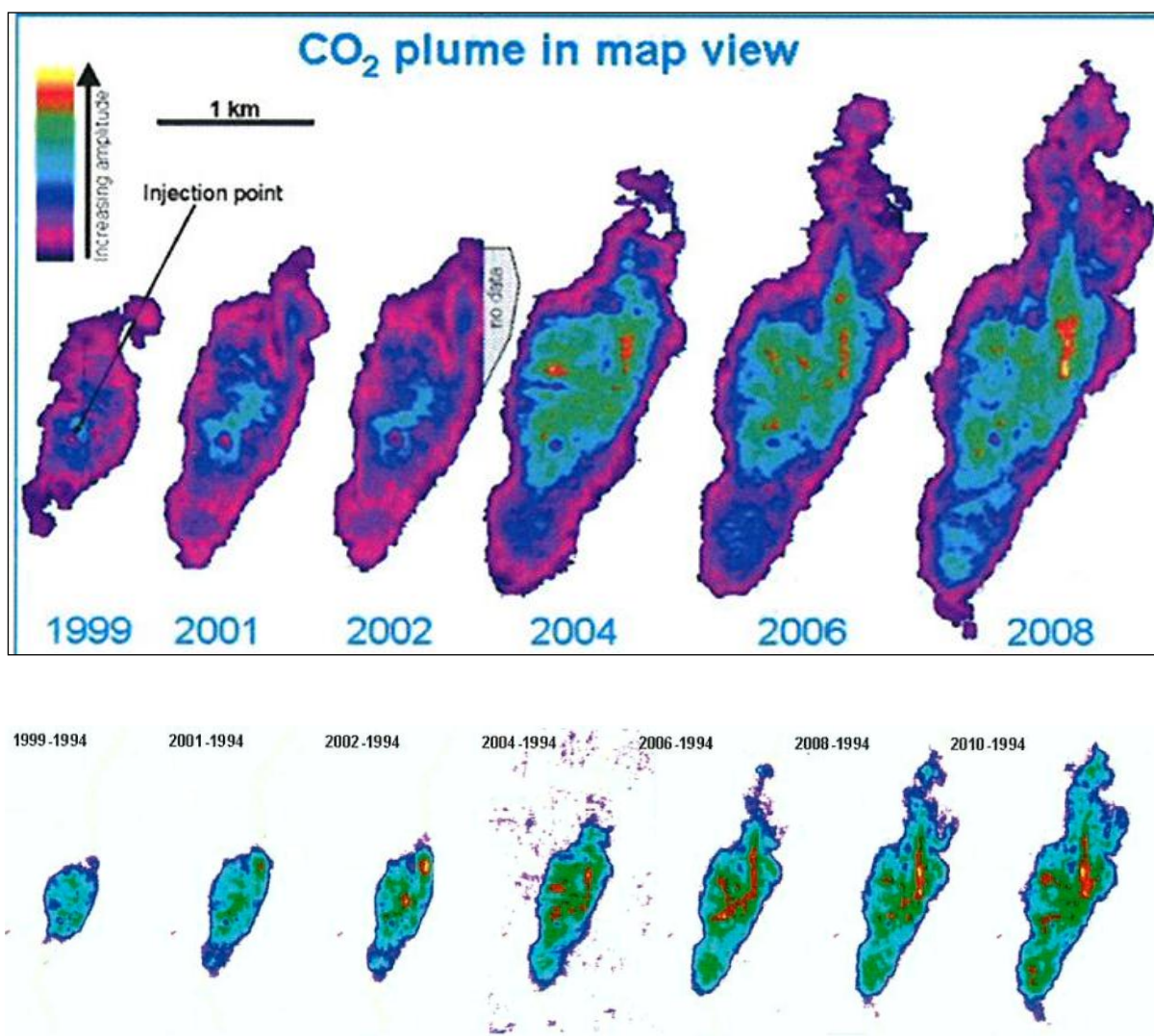


Figure 3.11. Results of seismic monitoring Sleipner Vest, 1998-2010.

Source: Statoil

The stored CO₂ 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 CO₂ above the top of Utsira Formation.

Results from the projects are also given in several reports and articles such as: “Final Technical 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 CO₂-injection site” published at 7th Greenhouse Gas Control Technologies Conference (GHGT7), Vancouver 2004, Chadwick, R.A.; Arts, R.; Eiken, O.; Kirby, G.A.; Lindeberg, E.; Zweigel, P. 2004 4D

seismic imaging of an injected CO₂ plume at the Sleipner Field, central North Sea. In: Davies, Richard J., (ed.) *3D seismic technology: application to the exploration of sedimentary basins*. London, UK, Geological Society of London, 311-320. (Geological Society of London Memoir, 29). And Chadwick, R.A., R.Arts & O. Eiken, 2005, 4D seismic quantification of a growing CO₂ plume at Sleipner, North Sea. In; DORÉ, A.G & VINING, B.A (eds) *Petroleum Geology: North-West Europe and Global Perspectives*, Proceedings of the 6th Petroleum Geology Conference, 1385-1399.

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 CO₂ deep inside the Utsira formation migrates (see Figure 5 in Annex IV). 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 CO₂ within the reservoir, both as high amplitude reflections and as a pronounced velocity pushdown (see Figure 3.11 and Figure 4 in Annex IV).

The data also resolve a vertical CO₂ chimney, which is regarded the primary feeder of CO₂ in the upper part of the bubble.

Flow simulation models, which match the 4D seismic data reasonably well, have been used to predict the CO₂ behaviour, see figure 3.12.

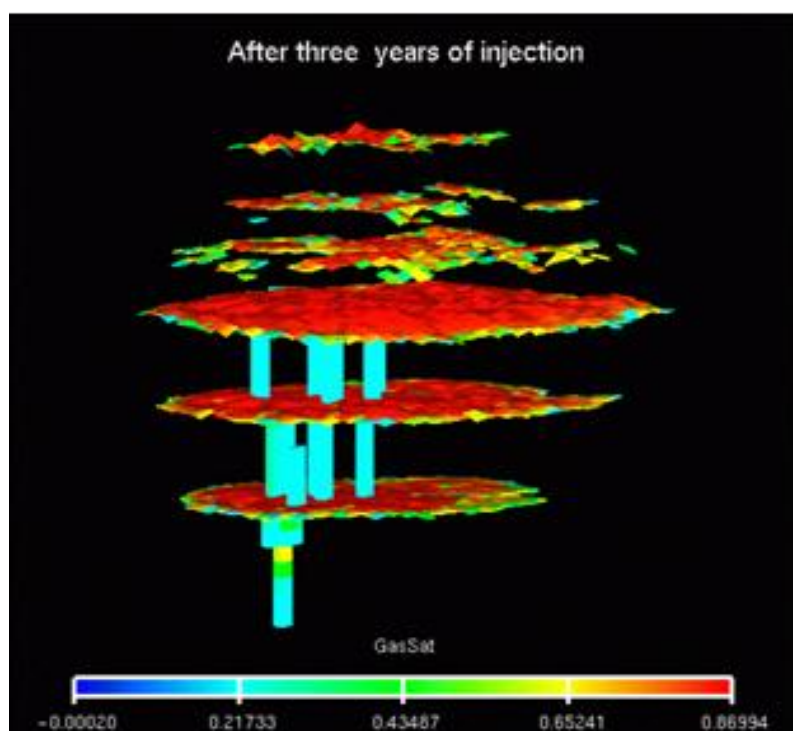


Figure 3.12. Flow simulation of CO₂ Sleipner Vest.

Source: Statoil

The results from the simulations indicate that the cap rock shales provide a capillary seal for the CO₂ 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 CO₂ plume, and also have been used to calculate the amount of CO₂ 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 CO₂, gravimetric monitoring, pressure measurements and well monitoring. For more details see Annex V.

3.5.1.3 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 CO₂ injected in the Utsira formation have ± 3 per cent accuracy. So far there have not been detected any leakage from the storage.

3.5.1.4 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 CO₂ is included in the emission licence for the Sleipner Vest field. According to the license Statoil is obliged to monitor the CO₂-storage. Furthermore Statoil reports the amount of CO₂ emitted and the amount injected every year to The Climate and Pollution Agency. The injected CO₂ 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 CO₂-tax for the emissions. From 2013 these emissions are also included in the EU-ETS. These emissions are reported to the Norwegian Petroleum directorate. In this national emissions inventory this amount of CO₂ vented is reported under 1B2c.

3.5.1.5 Planned improvements

No specific planned improvements.

3.5.2 CO₂ capture and storage at Hammerfest LNG/the gas-condensate production field Snøhvit

3.5.2.1 Description

The natural gas in the Snøhvit gas-condensate subsea field contains about 5-7.5 % CO₂. Prior to the LNG production process at Hammerfest LNG, the CO₂ in the feed gas has to be removed as the gas is liquefied to LNG and stored at -163 °C. The CO₂ removed from the well stream is compressed and reinjected into the geological formation. Until March 2011 CO₂ was injected into Tubåen formation and from March 2011, after an intervention performed in the CO₂ injection well, the injection is into Stø. About 0.73 Mtonnes CO₂ are removed from the feed gas every year at full production. A total of about 23 million tonnes CO₂ will be separated from the feed gas during the field's lifetime.

Reservoir

In the Snøhvit area, several structures of interest were evaluated for disposal of CO₂. Four structures were identified as possible candidates for CO₂ storage. These were Marcello, 7122/2-1 structure, 7122/7-1 Goliath and the water bearing Tubåen Formation on the Snøhvit and Albatross fields. Marcello and the 7122/2-1 structure are immature as CO₂ storage for the Snøhvit CO₂ storage project because the reservoir data was not sufficiently detailed and there are no current plans for exploration drilling. (ref: Plan for Development and Operation).

Hammerfest LNG (former Snøhvit LNG Statoil) was granted a permit pursuant to the Pollution Control Act to inject 730 000 tonnes of CO₂ per year into a geological formation. The permit was issued on Sept. 13, 2004 by the Climate and Pollution Agency. Tubåen was expected to be able to store the expected amount of CO₂, but from March 2011, injection point was moved from Tubåen to Stø, due to lower injectivity in Tubåen than expected.

The Snøhvit Fields are not very complex structurally. Two well-defined fault directions, E-W and N-S, define most of the major structures. Minor internal faulting is present within the major structures.

Tubåen formation is a saline aquifer lying around 100-200 metres below the gas cap at Snøhvit. Tubåen formation is water filled and has a thickness between 45 and 75 metres. Core samples show that the formation consists of relatively pure quartz sand. The porosity and permeability are 10-16% and 200-800 md, respectively. The formation is bounded by large faults on all sides. Formation depth is 2600 m below sea level.

Stø water zone formation, which is the bottom of the current producing gas reservoir, was perforated for injection. The water zone has a thickness of 42 metres. Core samples show that the formation consists of relatively sand. The porosity and permeability are 15% and 400md, respectively (table 3.30) Formation depth is 2450 m below sea level.

The geophysical, geological and petrophysical evaluations are based on 19 exploration wells and 10 development wells within the area. The data available from these wells are generally of good quality, including logs, core data and pressure data.

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

Table 3.30. Key parameters for injection well F-2 H and Tubåen reservoir at the Snøhvit field. Stø reservoir pressure is being depleted by field production.

Key parameteres	
Initial reservoir pressure	288 Bar
Initial temperature	98 ° C
Porosity Tubåen	10-16 %
Permeability Tubåen	200-800 md
Depth Tubåen reservoir	2600 m
Water depth at F-template	330 m
Length pipeline from Melkøya	152 km

Location of the CO₂ injection well F-2 H.

The CO₂ injection well is located at the F-segment at the western part of the Snøhvit reservoir (figure 3.13).

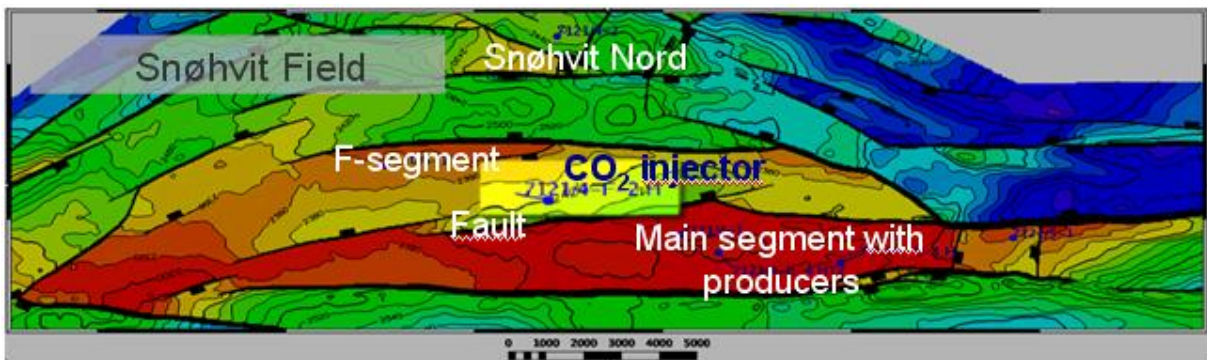


Figure 3.13. Location of the CO₂ well at the Snøhvit field.

Source: Statoil

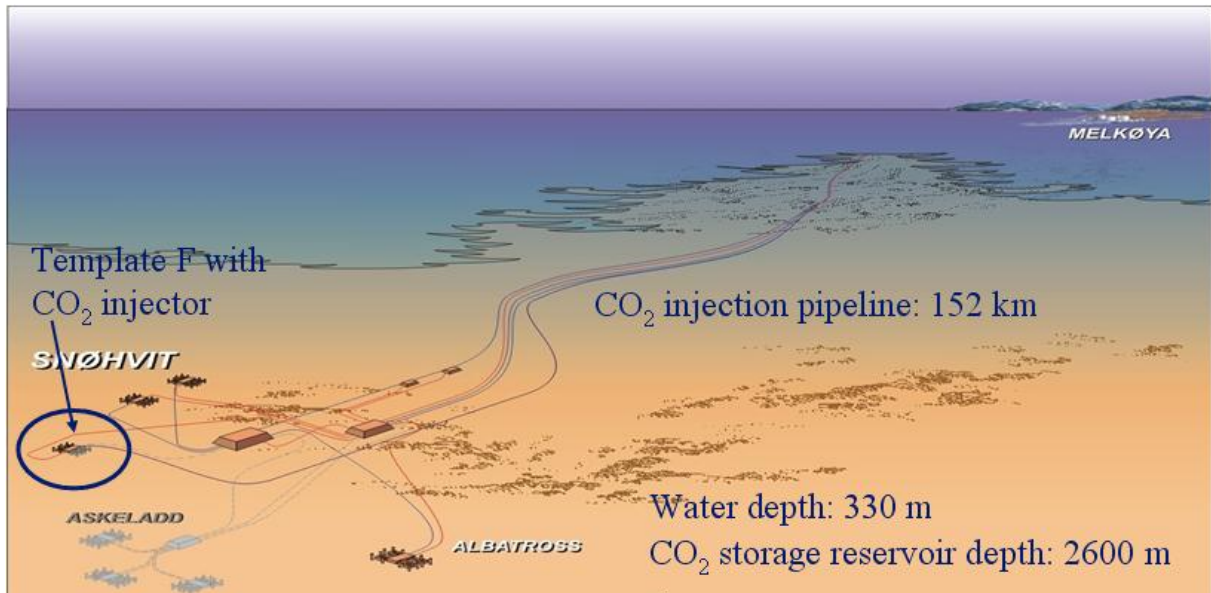


Figure 3.14. Snøhvit Field overview. The injection pipeline is 152 km long (Figure 3.14).) Source: Statoil

At the beginning, to keep the CO₂ as deep as possible, it was decided to perforate the mid and lower part of Tubåen as shown in figure 3.15. Since injection was changed to Stø, additional perforations were done in the bottom of Stø as shown in figure 3.15.

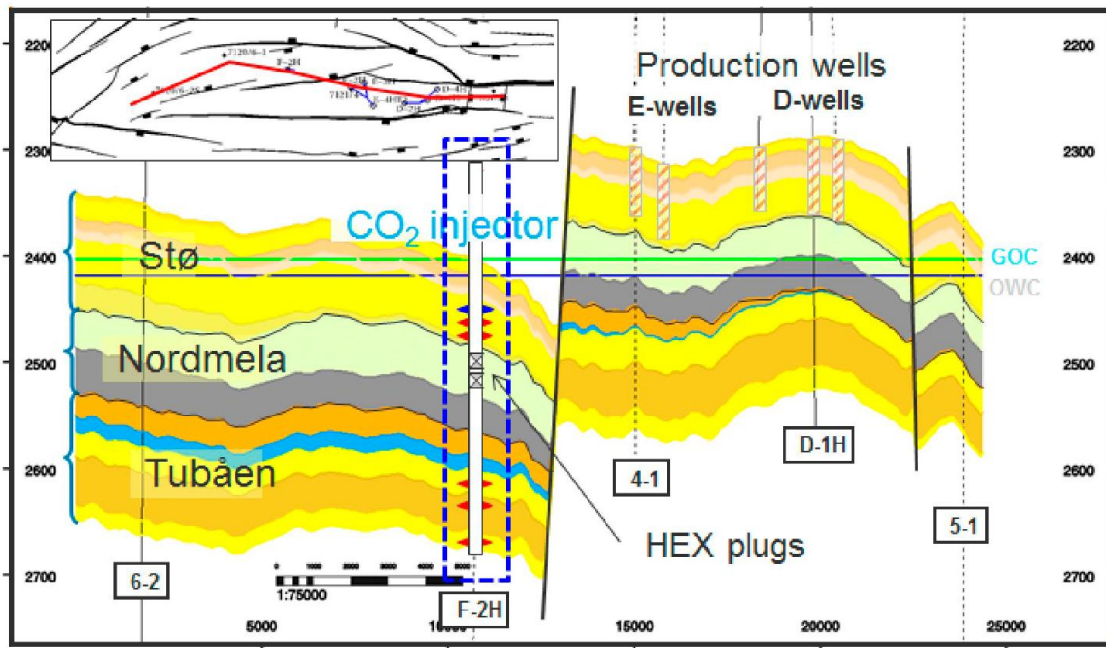


Figure 3.15. Cross-section of F-segment where CO_2 is injected, Snøhvit field formation.

Source: Statoil

CO_2 injection well specification

The completion design basis for the CO_2 injector at Tubåen/Stø depth, is a perforated 7" liner. A downhole pressure and temperature gauge is installed.

CO_2 re-injection system

At Snøhvit, all facilities for separation and injection of CO_2 are placed onshore at the Hammerfest LNG process plant at Melkøya. CO_2 in the feed gas (natural gas) are removed to avoid it freezing out in the downstream liquefaction process. An amine absorption unit performs this operation. The recovered CO_2 is condensed and recompressed before re-injected into Tubåen/Stø (current). A schematic of the CO_2 re-injection system is shown in figure 3.16.

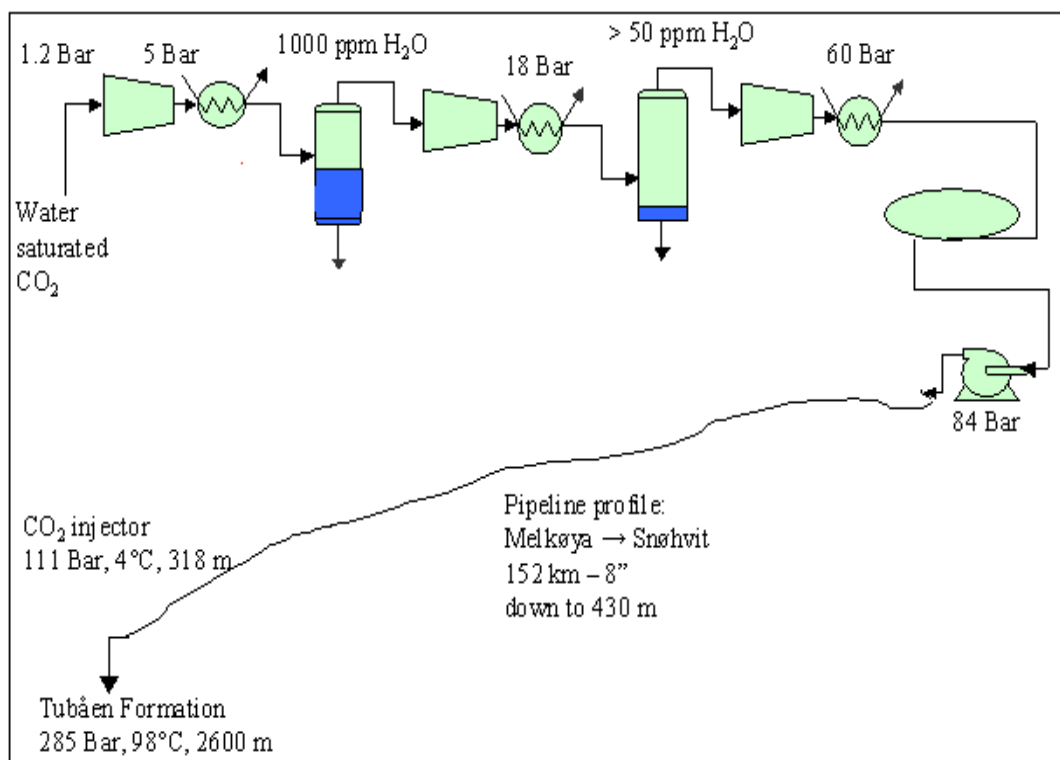


Figure 3.16. Schematic of the CO₂ injection system in the Snøhvit area.

Source: Statoil

CO₂ is most likely re-injected as a single phase (liquid condition in the pipeline from the export pump to the well head, transformed to supercritical condition in the reservoir where the temperature is higher).

CO₂ well stream specification

- >99% CO₂
- max 100 ppm (mol) H₂S
- max 50 ppm (wt) H₂O
- traces of HC and N₂

CO₂ venting to atmosphere

CO₂ venting is foreseen in case of shut down of the CO₂ reinjection system. The maximum vent rate is almost equal to the CO₂ removal flow rate. A separate vent stack for the CO₂ is provided at the plant.

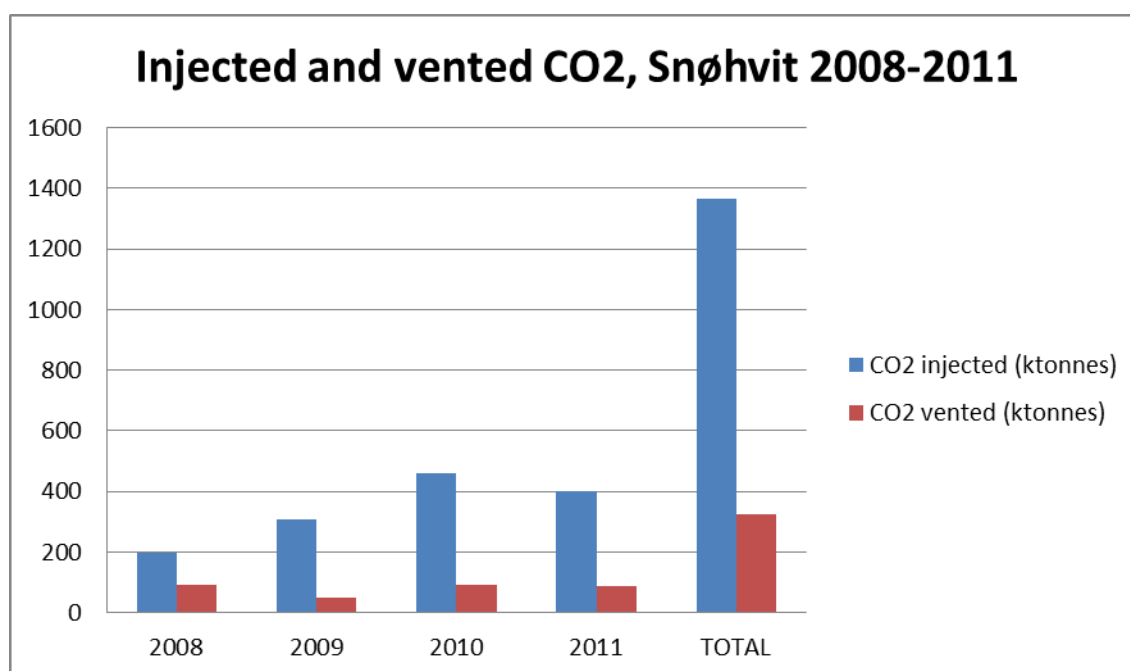
3.5.2.2 CO₂ injection and vented CO₂

The status by 1.1.2012 is that 1087ktonnes CO₂ has been injected into the Tubåen Formation and 282 ktonnes has been injected into the Stø Formation. 394 ktonnes CO₂ has been vented (Table 3.31).

Table 3.31. Injected and vented CO₂ Hammerfest LNG/Snøhvit field

	2008	2009	2010	2011	TOTAL
CO ₂ injected (ktonnes)	196	308	460	403	1370
CO ₂ vented (ktonnes)	93	49	94	87	394

The following Figure 3.17 shows the yearly injected at in the Tubåen /Støformation at the Snøhvit field and vented volumes for the injection period at Hammerfest LNG. These figures are reported to the Climate and Pollution Agency on yearly bases.

Figure 3.17. Injected and vented CO₂ at the Snøhvit field and Hammerfest LNG

Source: Statoil

3.5.2.3 Methodological issues and uncertainties in measurements

The reported data covers CO₂ emissions to the atmosphere, e.g. when the injection system is out of operation. These emissions are measured by a venture flow meter with an uncertainty of 5, 8 % (CMR-13-F14029-RA-3 2013).

Flow metering of the well stream to the CO₂ injector is measured by an orifice meter with an uncertainty of 3-5%.

Gas composition of injected or vented gas from the CO₂ injector is controlled by analyses. This is primarily done as a quality assurance of the CO₂ removal system (system 22). For environmental reporting, the following values are used: 99.549 weight % CO₂, 0.0066 weight % H₂S, 0.331% CH₄ and 0.088 weight % nmVOC and the analysis performed on a regular basis from April 2010 to September 2010 confirm these values. Weekly analyses are taken in addition.

3.5.2.4 Reservoir monitoring

Seismic monitoring

A 3D/4D seismic monitoring survey was shot in August 2011 to monitor CO₂ movement in the Stø and Tubåen formations. A clear response is seen on the seismic that was according to the predictions. The results from 2011 seismic data analysis are shown in figure 3.18 and figure 3.19.

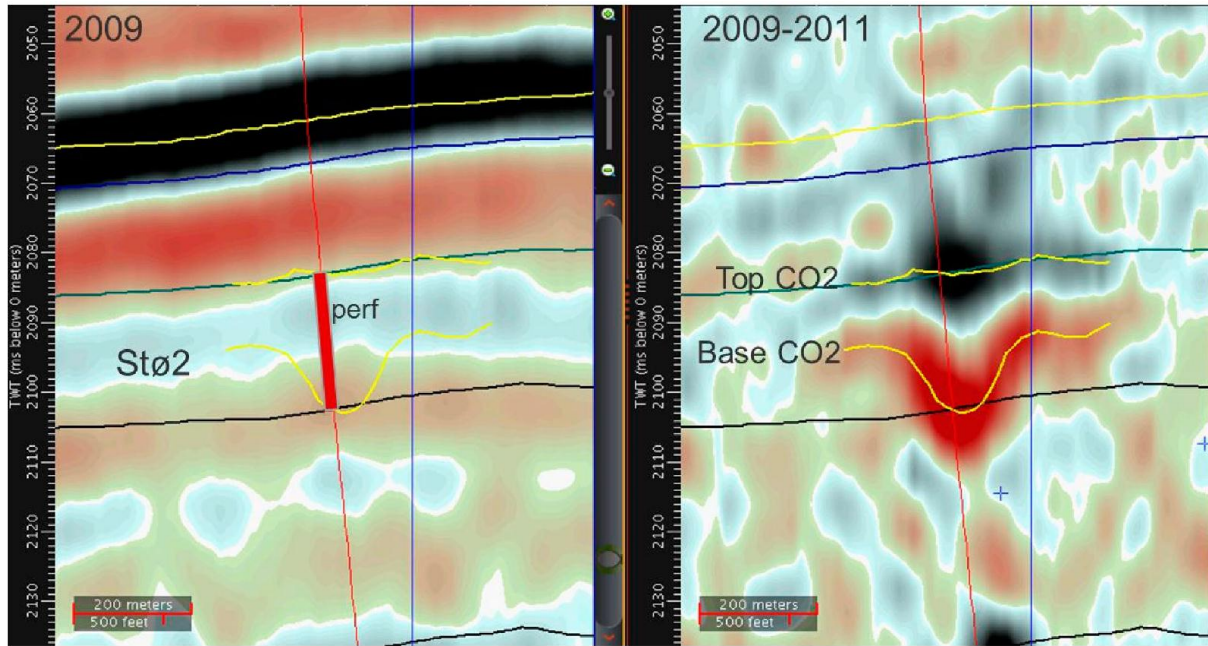


Figure 3.18. Seismic section from 2009 (left) and difference section, between 2009 and 2011 (right) showing the clear response of CO₂ injection in Stø formation (Source: Statoil).

Figure 3.19. Shows the seismic 4D effect between 3D surveys acquired in 2003 and 2009 at Snøhvit CO₂ storage project, indicating pressure and CO₂ plume.

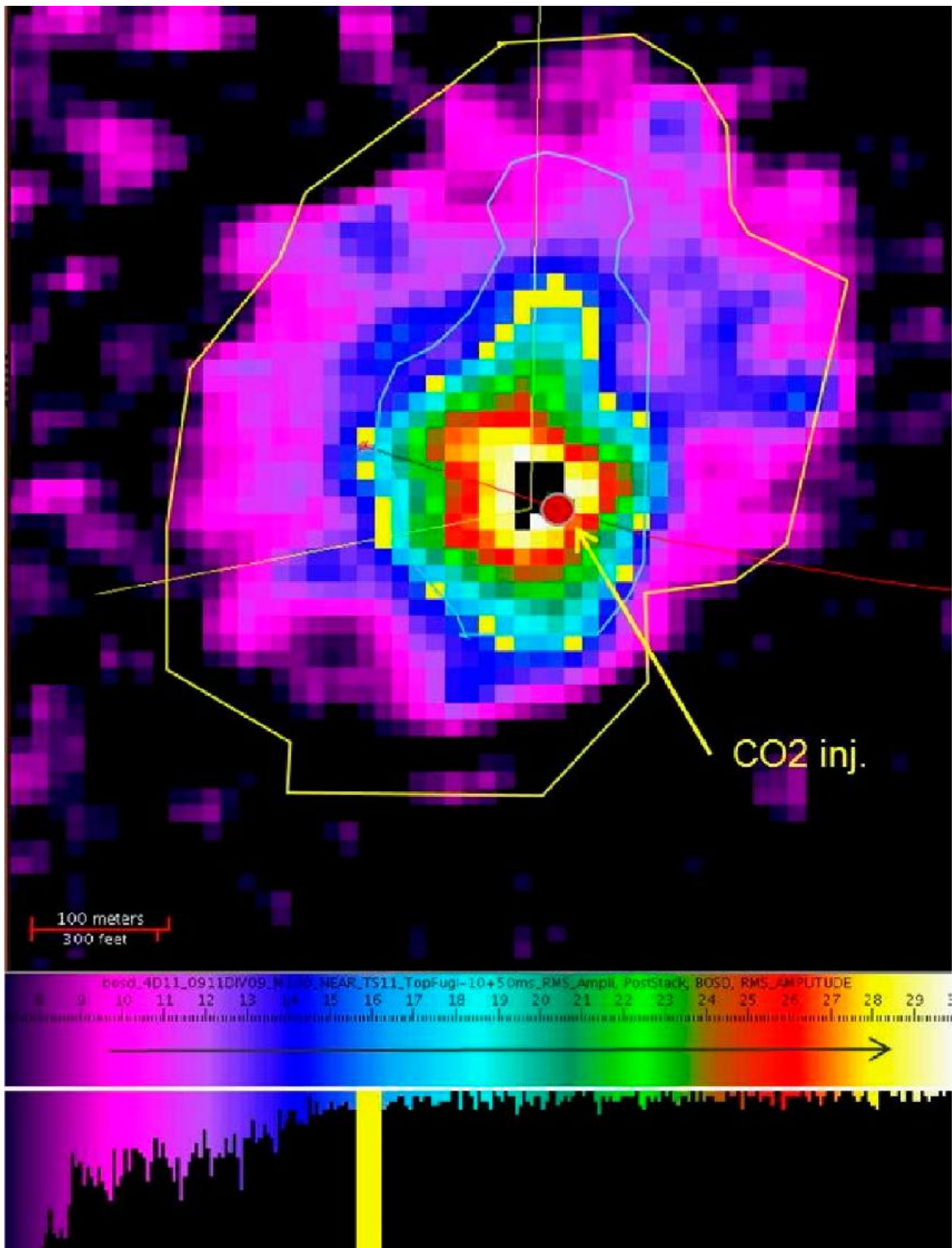


Figure 3.19. Seismic 4D amplitude map from 2011, showing a clear anomaly around the CO₂ injector Pressure/temperature gauge, reservoir modeling and prediction of reservoir performance in Tubåen.

The pressure development in the injection well is monitored on a daily basis by using data from the pressure and temperature (PT) gauge installed in the well, 800 meters above the reservoir. Due to problems during drilling there is diameter restriction in the well and the PT gauge had to be installed about 600 m above the reservoir. Actual bottom hole pressure is estimated based on gauge measurements and CO₂ PVT (pressure, volume, temperature). An Eclipse 100 (“black oil”) simulation model is used for prediction pressure development in the well. In this model CO₂ is injected into the water filled Stø reservoir. Using this model, it has proven to be easy to match the CO₂ plume size/shape geometry in this model with time-lapses seismic data. A weakness of the model is that it does not include temperature and other advanced simulation physical effects. Temperature effects are likely in the near well area as CO₂ at 21 °C is injected into a reservoir of initially 90 °C.

Since mid 2011 CO₂ in liquid phase have been injected to Stø water saturated formation. Injectivity have been stable and monitored every week.

As can be seen from Figure 3.20, the reservoir pressure (red line) has depleted since May 2011. This is due to production of the gas zone above the water zone in the same formation.

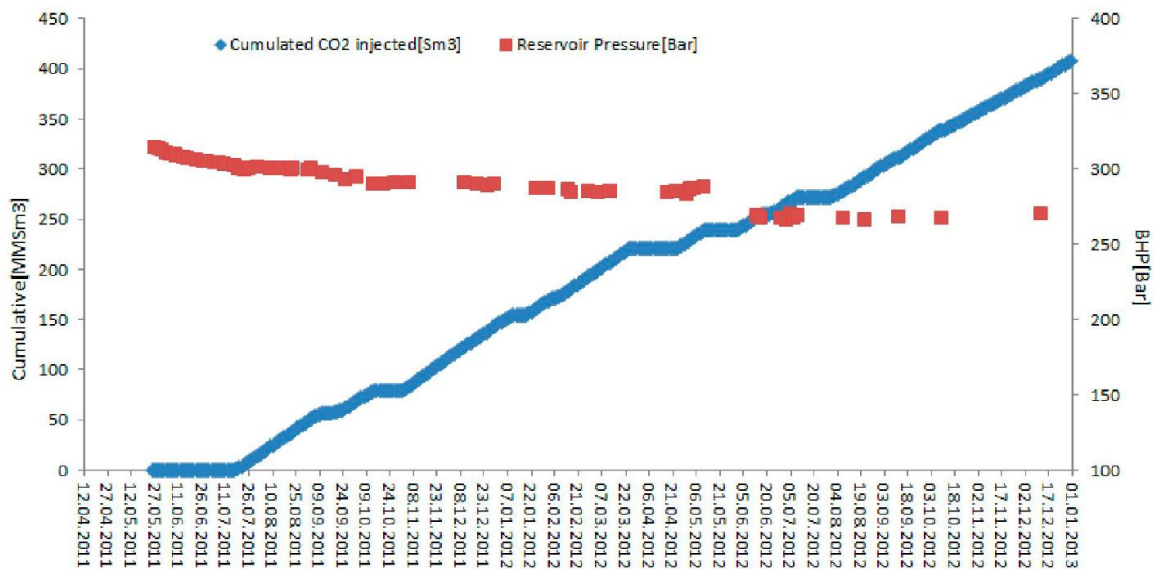


Figure 3.20. History pressures and volume injection into Stø formation Source: Statoil

Further in this report is described an intervention operation done in the CO₂-well. Since mid 2011 CO₂ is injected in liquid form to Stø water saturated formation. The reservoir pressure has depleted since May 2011, due to production of the same formation above the water zone, from the gas zone.

Gravimetric monitoring

A baseline gravity and seafloor subsidence monitoring survey was carried out over the Snøhvit and Albatross fields in June 2007. The closest is 419 m from the CO₂ injection well. A total of 76 sea floor benchmarks were deployed at the start of the survey, and relative gravity and depth was measured. A new gravity monitoring was carried out in spring 2011. Comparison of 2011 and 2007 gravity measurements confirmed the prognoses.

3.5.2.5 Activities and future plans

A 3D/4D seismic data will be carried out in 2012. Stø formation was perforated in April 2011 and is currently injecting in this zone. Injection has been monitored every week by a fall-off test performed during stable conditions.

Injection of CO₂ has been stable and there are no well integrity issues related to operation of the well.

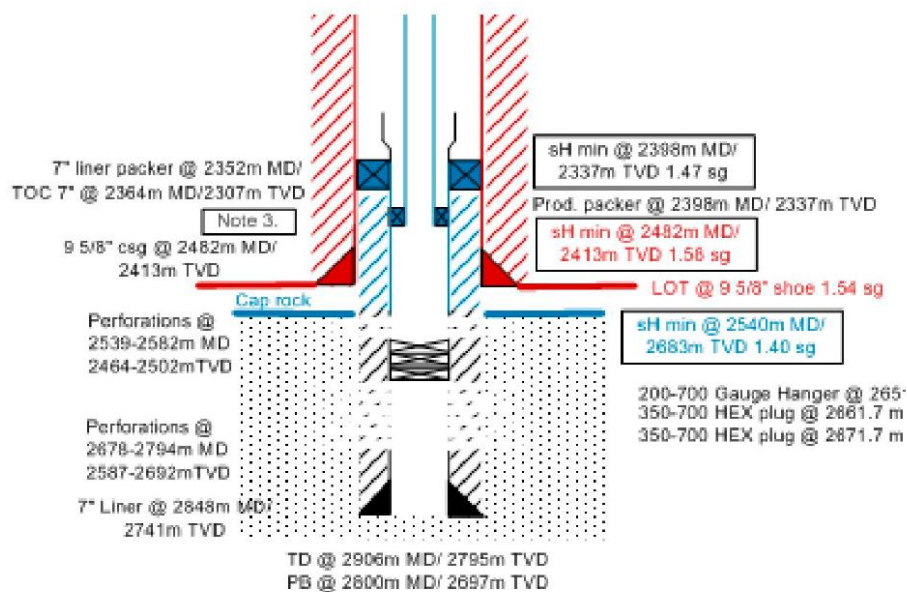


Figure 3.21. CO₂ injector current completion (Source: Statoil)

Two Hex plugs are installed between Tubåen and Stø. A seismic survey was run in September 2011, data is still being analysed. Weekly fall off tests are performed for surveillance performance of CO₂ injector well.

The challenge of production CO₂ from Snøhvit field has led to a great effort to find solutions that makes the CO₂ injection as robust as possible. The authorities have been kept informed about the situation and the activities and measures planned. A monitoring program covering the period 2011-2020 has been submitted to the environmental authorities.

The main ongoing activity is planning for a possible new injector well.

The situation that occurred at Tubåen, with pressure build-up in the early phase of injecting into Tubåen was described in the documentation report on Snøhvit CO₂-model-compositional simulations, 2004. If no HC is available, and F-2 connects a reservoir-volume of 330 MRm³, fracture pressure would be reached after 150 days of injection.

The documentation from 2004, supported by compositional simulation, indicates what will happen if CO₂ is injected into bottom of Stø in present well location. A figure from this document is copied below and indicates how CO₂ moves if injected into Stø.

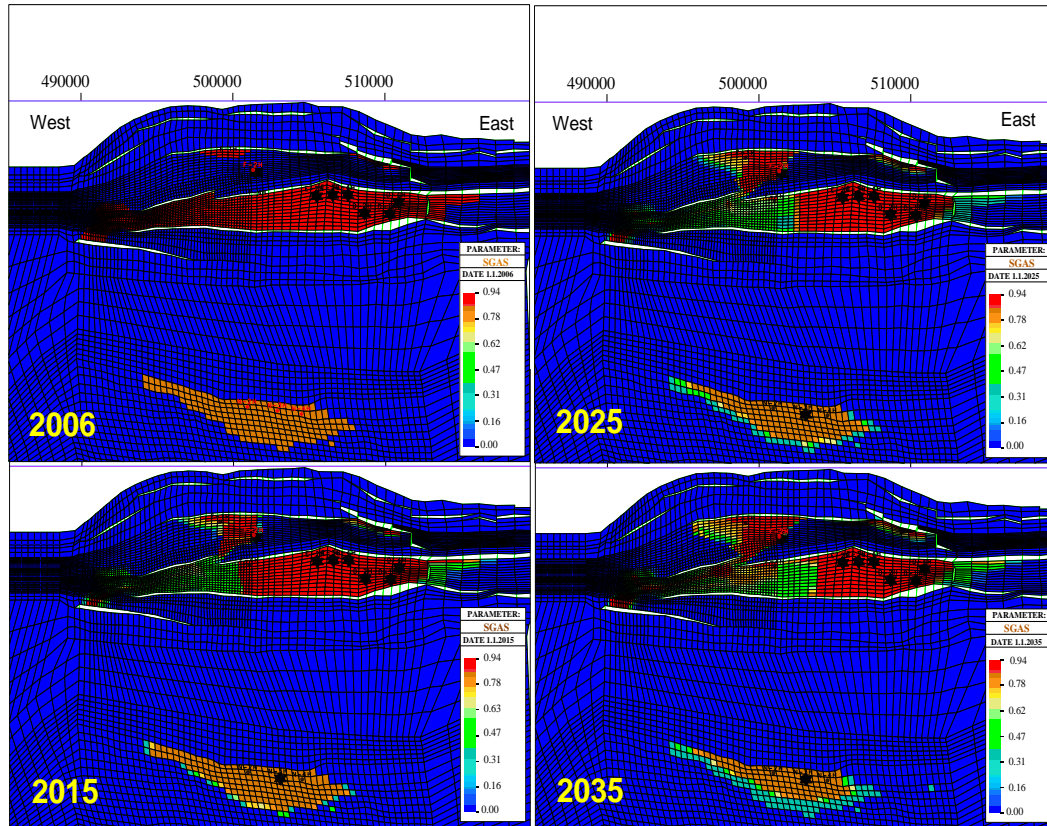


Figure 3.22. Lateral extent of the re-injected CO₂ and the remaining hydrocarbon gas at bottom Stø level, option 1 location, at four different times.

Source: Statoil

Based on above Figure 3.22, injecting CO₂ into the Stø formation is safe. In 2012 3D/4D seismic will be carried out in 2012. More simulations and studies will be performed.

3.5.2.6 Source specific QA/QC and verification

Storage projects like the injection at the Snøhvit area have to apply for a permit after the Pollution Control Act. According to the permit Statoil has implemented system for monitoring the CO₂-storage. So far there is no sign of emissions to the water column or the atmosphere from the injected CO₂. Hence the CO₂ injected is not reported as emissions in the emission inventory. Statoil has to pay a CO₂-tax for the emissions when the injection facility is out of operation due to maintenance etc. These emissions are reported to the Norwegian Petroleum directorate. In the national emissions inventory this amount CO₂ vented at Hammerfest LNG (Snøhvit CO₂ storage project) – is reported 1B2c.

Statoil reports the amount of CO₂ emitted and the amount injected every year to The Climate and Pollution Agency. From 2013 carbon capture and storage is included in the EU-ETS (applies in Norway).

In addition Statoil perform internal QA/QC for the ongoing CO₂ studies.

3.5.2.7 CO₂ projects outside Statoil ASA using Snøhvit data

The EU project CO2ReMoVe plans to perform a complete performance and risk assessment for the Snøhvit project by complementing the work done under the CASTOR umbrella. Particular attention will be paid to potential vertical CO₂ migration to the upper gas field and lateral migration, potential flow through deteriorated wells and through undetected faults. The geochemical interaction between CO₂, fluids and rock and coupling with geomechanical effects will be investigated.

Data from Snøhvit is released to the FME SUCCESS Centre (Centre for Environmental Friendly Energy Research; Subsurface CO₂ Storage- Critical Elements and Superior Strategy). Based on this information, specific research tasks may be defined.

3.6 Cross-cutting issues

3.6.1 Sectoral versus reference approach

In the reviews of the Norwegian greenhouse gas inventory submitted in 2011 and 2012 the ERTs raised potential problems with non-inventory elements of Norway's annual submission under the Kyoto Protocol. In the review of the 2011 inventory Norway was asked to explain the difference between Reference Approach (RA) and Sectoral Approach (SA). An analysis included in the 2012 NIR concluded that the difference was mainly due to statistical differences in the energy balance. In the 2012 review Norway was asked to analyze and improve the statistical balance.

Norway has in this year NIR calculated energy consumption and CO₂ emissions from energy combustion based on Reference Approach (RA) and Sectoral Approach (SA). The supply side in the RA is from the national energy balance that is included in Annex III in the NIR. The national energy balance differs from energy balance data reported to the IEA with respect to delimitations, definitions, and revision level.

Sectoral versus reference approach. The result of the estimation with the two methods is shown in Table 3.32. There are large differences between the output from RA and SA, both for the energy consumption data and the CO₂ emissions. The difference between the *fuel consumption* in the RA and SA ranges from about -14 per cent to + 45 per cent. The deviations for CO₂ emissions are generally around 5 percentage points higher. The highest discrepancy for CO₂ is in 1999-2001 and in 2004-2006. For 2011, the difference for CO₂ is 9 per cent. The large discrepancies are primarily due to statistical differences in the energy balance, as shown below.

A detailed analysis of the relationship between the RA and SA and the energy balance is given in annex XI. The main results are shown in Table 3.33. The analysis in the CRF tables is shown in the left part of the table. Further corrections are included in the following columns.

The main conclusion is that the difference between the energy consumption in RA and SA is primarily due to statistical differences in the energy balance (column *b*). In addition, a number of other smaller differences were identified. The remaining difference between RA and SA after adjusting for these items is within +/- 2 per cent for all years except 1991, where it is -3 per cent.

National Inventory Report 2013 - Norway

Table 3.32 Comparison of fuel consumption and CO₂ emission data between the Reference Approach (RA) and the Sectoral Approach (SA). 1990-2011.

Year	Fuel consumption			CO ₂ emissions		
	RA, apparent consumption (PJ)	SA (PJ)	Difference RA-SA (%)	RA (Gg)	SA (Gg)	Difference RA-SA (%)
1990	335	384	-12.8	24 090	25 870	-6.9
1991	400	381	5.0	28 455	25 479	11.7
1992	379	388	-2.3	26 646	25 965	2.6
1993	378	403	-6.4	26 496	26 952	-1.7
1994	404	424	-4.8	28 646	28 348	1.1
1995	431	422	2.1	30 307	28 267	7.2
1996	397	460	-13.6	28 066	31 085	-9.7
1997	450	464	-3.1	31 704	31 171	1.7
1998	508	464	9.5	35 526	31 183	13.9
1999	566	463	22.1	39 883	31 449	26.8
2000	654	453	44.3	45 941	30 487	50.7
2001	611	478	27.7	41 695	32 565	28.0
2002	509	484	5.1	35 409	32 753	8.1
2003	546	504	8.2	37 797	34 110	10.8
2004	647	509	27.2	45 833	34 147	34.2
2005	598	498	20.2	42 584	33 704	26.3
2006	637	519	22.7	45 766	34 616	32.2
2007	501	529	-5.3	34 505	35 166	-1.9
2008	580	526	10.4	40 389	34 543	16.9
2009	555	538	3.2	38 871	35 080	10.8
2010	653	554	17.8	44 532	36 598	21.7
2011	561	540	3.9	39 095	35 774	9.3

Source: Statistics Norway/Climate and Pollution Agency

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Table 3.33. Relationship between the Reference and Sectoral approaches and the energy balance. PJ. 1990-2011

Unit: PJ	Consumption data from CRF Table 1.A(c)					Additional adjustments in RA consumption			Remaining difference RA-SA	
	RA: Apparent consumption (incl non- energy use and feedstocks)	SA: Consumption (incl Other fuels)	Correction for non-fuel use and feedstocks in CRF	Difference RA (adjusted)- SA, PJ	Difference RA-SA, per cent of SA	Statistical differences	Other corrections	Other fuels in SA excluded from comparison	Remaining difference RA-SA, PJ	Remaining difference RA-SA, per cent of SA
Notes			a			b	c	d		
1990	431	384	96	-49	-13 %	-42	8	-4	-11	-2.8 %
1991	486	381	86	19	5 %	22	7	-4	-6	-1.7 %
1992	465	388	86	-9	-2 %	-9	10	-4	-5	-1.4 %
1993	470	403	93	-26	-6 %	-28	10	-5	-3	-0.7 %
1994	500	424	96	-20	-5 %	-20	7	-5	-3	-0.6 %
1995	534	422	103	9	2 %	14	5	-5	-5	-1.3 %
1996	500	460	103	-63	-14 %	-59	5	-5	-4	-1.0 %
1997	564	464	114	-15	-3 %	-11	4	-5	-3	-0.6 %
1998	629	464	121	44	9 %	43	5	-5	1	0.2 %
1999	683	463	118	102	22 %	103	4	-6	1	0.1 %
2000	773	453	119	201	44 %	200	7	-6	-0	-0.1 %
2001	743	478	132	132	28 %	128	4	-7	8	1.6 %
2002	631	484	122	25	5 %	29	2	-7	1	0.1 %
2003	676	504	130	42	8 %	47	-1	-8	4	0.9 %
2004	776	509	129	139	27 %	150	0	-8	-3	-0.6 %
2005	721	498	123	100	20 %	109	1	-9	-1	-0.1 %
2006	756	519	119	118	23 %	126	-0	-9	1	0.2 %
2007	625	529	125	-28	-5 %	-27	6	-9	2	0.3 %
2008	711	526	130	55	10 %	62	3	-10	-1	-0.2 %
2009	666	538	111	17	3 %	25	4	-9	-3	-0.5 %
2010	768	554	115	99	18 %	95	6	-11	8	1.5 %
2011	681	540	120	21	4 %	31	5	-13	-2	-0.4 %

Notes

- a) Difference between "Reference approach" and "Apparent energy consumption" in CRF table 1.A(c), equal to the total from non-fuel use in table 1.A(d),
b) Energy balance items "Statistical differences" *plus* balance of non-combustion transformation items (consumption in blast furnaces, petroleum refineries and other conversion *minus* production of derived energy bearers).
c) Energy balance item "Losses"; petrol coke/CO gas burnt in refineries and reported as fugitive emissions in the inventory; correction for different NCV values used for condensate in energy balance and in the RA.
d) *Other fuels* are currently not included in the reference approach. Further explanations and more details are found in appendix XI.

The reference approach may be an important tool for verification of the sectoral approach used in the inventory. The analyses undertaken in the present and the previous NIR have shown that the difference between RA and SA is mainly due to the statistical difference in the energy balance, and that important parts of the consumption block in the EB are unlikely to have major completeness issues. If the statistical differences are due to problems in the supply block of the balance, then resolving these problems will only affect the RA, but not the SA and the reported emissions. An analysis of the statistical differences in the energy balance is given in appendix XII and a summary from the analyze is section 3.6.2.

3.6.2 Action plan for quality controls within reference and sectoral approach

The statistical differences in the energy balance are the main reasons for large differences between the reference and the sectoral approach in the Norwegian emission inventory. As a response to the Saturday paper from the in-country review in the fall of 2012, an action plan was developed. The aim of this action plan was quality controls of important data sources and calculations within the energy balance and, if possible, reduction of the statistical differences for dominant energy products.

There is a close cooperation between the producers of the energy statistics and the emission inventory compilers in Norway, and the requirements of the emission inventory are continuously taken into account in the production of the energy balance. Considerable resources are allocated to the production of the energy balance and the emission inventory and appurtenant improvement projects every year. Allocations are however always a result of priorities between different needs and demands.

The quality controls of the energy balance, pursuant to the action plan presented to the expert review team (ERT) in November 2012, have included examinations of both the supply side (roughly comparable to the reference approach) and of the consumption side of the energy balance (roughly comparable to the sectoral approach).

The *supply side* has been examined through contact with the Norwegian Petroleum Directorate (NPD) and the division for external trade at Statistics Norway. The production data are found to be of high quality. NPD also possesses detailed data on shipments, from which export data can be extracted. The NPD export data have been found to be consistent with the production data, and should be evaluated as an alternative data source in the external trade statistics (ETS).

The ETS data on petroleum export consists of several data sources, which need to be sewed together. It has earlier been demonstrated that shipping agents misclassify petroleum products. This may lead to under- and over-coverage in the ETS export, which in turn causes statistical differences. There are also examples that new fields and pipelines have been missing in the ETS export. This illustrates the risk when new facilities are not automatically included in the input data.

We recommend a project to be set down to evaluate the NPD export data as an alternative data source for unrefined petroleum products (excl. natural gas transported by the Gassled system), in order to avoid the inconsistencies and automatically cover new facilities.

On the *consumption side*, the statistics on energy use in the manufacturing sector has been controlled by comparing input data from individual entities with energy consumption figures from the same entities reported to the Climate and Pollution Agency in the annual report as

required under the EU ETS and under the regular permits. The overall consistency and coherence with this other data source is acceptable.

The statistics on deliveries of petroleum products have undergone changes in the methodologies for the annual petroleum statistics. Previously, annual figures were based on adding up the monthly figures. In the pilot project, Statistics Norway collected additional annual information from the oil companies to help improve the quality of placing the deliveries into the correct purchaser groups. When the total volume in the annual and the monthly figures were compared, there were only small differences in the figures. In the monthly figures for 2012 total sales amounted to 9.488 billion liters. In the annual figures the total deliveries came to 9.555 billion liters.

Data on energy goods used as raw materials are collected annually from the largest consumers, with a more complete survey on use of raw materials in all manufacturing industries being carried out less frequently. The latest thorough survey carried out for the reference years 2009, 2010 and 2011 has been used as a quality control for the raw material figures used in the energy balance, and the control did not reveal any significant use of energy as raw materials not already covered in the energy balance.

Although comprehensive quality controls have been performed during the past few months according to the action plan, further work is still needed. This primarily concerns the supply side of the energy balance, where further work on export figures needs to be performed. In addition, a project to improve consistence with the national accounts is in the planning phase, and an improved production system of the energy balance is under development. This will result in a more robust system and increased transparency. More focus on cooperation between divisions at Statistics Norway will be developed as a result of this and other ongoing projects. Such cooperation will contribute to better statistics and reduced statistical differences.

Statistics Norway maintains the position that a large statistical difference relative to national consumption is not unreasonable in Norway, given the large production and export share. This project has not revealed any major shortcomings of the consumption data of the energy balance, and it is likely that the main sources of statistical differences are to be found on the supply side of the equation. It is not feasible to set a fixed level of statistical difference that is considered acceptable. It could be determined as a percentage of production or consumption, but the actual level will depend on the production, export and consumption level, and the relationship between them, for each energy product. The level of statistical difference will continue to be evaluated, but it is unlikely that a strict rule can be determined.

3.6.3 Feedstocks and non-energy use of fuels

Emissions from the use of feedstock 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 and fuel gas from ethylene cracking that is sold and combusted are accounted for and reported under the energy sector.

3.6.4 Indirect CO₂ emissions from CH₄ 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 released into the atmosphere indirect CO₂ emissions are formed. The emissions of CH₄ and NMVOC from some sources will partly be of fossil origin and should therefore be included. Indirect CO₂ emissions originating from the fossil part of CH₄ 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 CO₂ emissions from oxidized CH₄ 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 CO₂/kg CH₄ and 3.0 kg CO₂/kg NMVOC, calculated on basis of mass of molecules.

The EF 3.0 kg CO₂ per kg NMVOC are mainly based on information from the report Norwegian Pollution Control Authority (SFT, now Climate and Pollution Agency) Report 1152/1995 (ISBN-nummer 82-7655-271-4) Løsemiddelbalanse for Norge – utslipp, forbruk og metode (Solvent balance – emission, consumption and methodology). In the Revised 1996 IPCC Guidelines there is no factor for this emissions source. In IPCC 2006 they propose a default fraction of carbon in NMVOC by mass of 0.6 i.e. 2.20 kg CO₂ per kg NMVOC. The IPCC 2006 includes no information of what the default factor is based on. The EF used by Norway is based on Norwegian old data. Our assumption is that the EF we use is in the upper level of what is reasonable to believe is the fraction of carbon in NMVOC. We therefore consider it being GP not changing the factor until we have information available about speciation of the NMVOC in Norway.

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 3.34.

In 2011 CO₂ emissions from ships and aircraft in international traffic bunkered in Norway amounted to a total of 2.7 million tonnes, which corresponds to 5.0 per cent of the total Norwegian CO₂ emissions. The CO₂ emissions from bunkers have increased by 26 per cent from 1990 to 2011.

During the period 1990-2011, emissions of CO₂ from marine bunkers increased by 0.2 per cent. The emissions have varied greatly in this period and reached a peak in 1997. Thereafter there has been a descending trend in emissions and the emissions decreased by more than 50 per cent in the period 1997-2011.

The CO₂ emissions from international air traffic bunkered in Norway was in 2011 1.2 million tonne. These emissions have been on its highest level from 2006-2011 when the emissions were more doubled compared to 1990. However, as aircraft engines are improving their fuel-efficiency, 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 2005-2008. In 2009 the emissions from international aviation decreased by 5 per cent as we assume was an effect of the financial crises. In 2010 the emissions increased again and then by 19 per cent and in 2011 emissions decreased by 10 per cent.

Table 3.34. Emissions from ships and aircraft in international traffic bunkered in Norway, 1990-2011. 1000 tonnes. CO₂ in Mtonnes.

Marine	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂	1.5	1.3	1.6	1.7	1.8	2.3	2.5	3.0	2.9	2.7	2.6
CH ₄	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
N ₂ O	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
NO _x	26.4	22.3	28.0	29.9	32.9	40.1	44.5	54.2	51.7	47.8	47.3
CO	1.4	1.2	1.5	1.6	1.8	2.2	2.4	2.9	2.6	2.4	2.4
NM VOC	1.1	0.9	1.2	1.3	1.4	1.7	1.9	2.3	2.2	2.0	2.0
SO ₂	9.9	9.7	12.3	13.5	14.0	13.7	15.4	18.8	14.5	12.4	10.6

Marine	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO ₂	2.6	2.1	2.1	2.0	2.3	2.3	2.1	2.1	1.8	1.5	1.5
CH ₄	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1
N ₂ O	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0
NO _x	47.2	37.2	36.7	35.0	39.8	39.5	35.7	33.7	26.6	20.2	18.2
CO	2.4	1.9	1.9	1.8	2.1	2.1	1.9	1.9	1.6	1.3	1.3
NM VOC	2.0	1.6	1.6	1.5	1.7	1.7	1.6	1.6	1.3	1.1	1.1
SO ₂	12.8	7.0	8.0	7.8	8.6	5.1	5.5	6.1	4.7	4.7	4.9

Aviation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO ₂	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.8	0.8	0.9	0.9
CH ₄	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N ₂ O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO _x	2.1	1.9	2.1	2.3	2.2	2.1	2.5	2.8	3.0	3.4	3.3
CO	0.9	0.9	1.1	1.2	1.3	1.3	1.4	1.4	1.3	1.3	1.0
NM VOC	0.3	0.3	0.4	0.5	0.6	0.6	0.6	0.6	0.5	0.4	0.2
SO ₂	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Aviation	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO ₂	0.8	0.7	0.7	0.8	1.1	1.2	1.2	1.2	1.1	1.3	1.2
CH ₄	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N ₂ O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO _x	3.0	2.6	2.7	3.0	3.9	4.5	4.1	4.1	3.9	4.7	4.2
CO	0.9	0.8	0.8	1.0	1.2	1.4	1.3	1.3	1.2	1.5	1.3
NM VOC	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
SO ₂	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Statistics Norway/Climate and Pollution Agency.

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 fuelled 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 2011 were about 18.2 ktonnes, which equals 10.2 per cent of the national Norwegian NO_x emissions. During the period from 1990 to 2011, NO_x emissions from international shipping bunkered in Norway decreased by 31 per cent.

NO_x emissions from international aviation amounted to 4.2 ktonnes in 2011. That is an decrease of about, 10 per cent from 2010.

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 CO₂ 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 CO₂ emissions are not

included in the national total in the Norwegian emission inventory but are reported as memo items in the CRF.

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 emissions from industrial processes included in the Norwegian GHG Inventory are from annual reports sent by each plant to the Climate and Pollution Agency (Klif).⁶ Such annual reports are:

- reports as required by their regular permit;
- reports as required by the permit under the EU emission trading system (EU ETS);
- reports as required by the voluntary agreement.

A specific QA/QC was carried out in 2006 (SFT, 2006) for the whole time series for the industrial processes sector. The QA/QC covered the GHG emissions from the largest industrial plants to be included in the inventory. The methodology was previously presented as an Annex to the National Inventory Reports in the years following the QA/QC exercise, but not in 2011 and 2012. The ERT of the 2012 NIR concluded (draft ARR12, §34) that Norway during the review provided the ERT with comprehensive information on the QA/QC procedures applied to plant-specific data, which showed that the QA/QC procedures are robust and comprehensive. The ERT however, found that the information provided in the NIR is partly outdated and recommended that the Norway includes a summary of this information in its next annual submission. Annex IX therefore describes the approach for QA/QC of GHG emissions from industrial point sources.

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.

Indirect emissions of CO₂ from some source categories are calculated by Statistics Norway and are based on the emissions of CH₄ and NMVOC. As explained in chapter 3.6.2, the indirect CO₂ emissions from oxidized CH₄ and NMVOC are calculated from the content of fossil carbon in the compounds. The EFs used are 2.74 kg CO₂/kg CH₄ and 3 kg CO₂/kg NMVOC. The GHG emissions from Industrial processes in 2011 were 7.6 million tonnes CO₂-equivalents, or 14.3 per cent of the total GHG emissions in Norway. The corresponding percentage in 1990 and 2010 were 27.4 and 14.2 per cent respectively. The emissions from this source category have decreased by 44.6 per cent from 1990 to 2011 and by 1.2 per cent from 2010 to 2011. The decrease from 1990 to 2011 is mainly due to reduced PFC emissions from production of aluminium and SF₆ from production of magnesium. There was a reduction in the PFC emissions by 93.3 per cent even if the production of aluminium in the period 1990-2011 has increased by 28.7 per cent. The reduction in the SF₆ 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 SF₆ as tracer gas. In June 2006 also the magnesium recycling foundry was closed down. In addition, N₂O emissions from nitric acid production have decreased by 86.1 per cent since 1990.

⁶ Former Norwegian Pollution Control Authority.

Metal production contributed to 56.0 per cent of the total GHG emissions from Industrial Processes in 2011, mainly from production of ferro alloys and aluminium, and in 1990 the contribution from metal production was 70.0 per cent. The other main contributing sectors in 2011 were Chemical Industry, Consumption of Halocarbons and SF₆ and Mineral Product with 14.6, 13.2 and 13.1 per cent, respectively, of the total GHG emissions in this sector.

The Tier 2 key category analysis performed for 1990 and 2011 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, 2A2, 2B1, 2B5, 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
2A2	Lime production	CO ₂	Tier 1	Tier 2
2B1	Ammonia Production	CO ₂	Tier 1	Tier 2
2B2	Nitric Acid Production	N ₂ O	Tier 2	Tier 2
2B4	Silicon carbide	CO ₂	Tier 2	Tier 2
2B5	Other Chemical Industry	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 CO₂ emissions in the source categories cement production, lime production, limestone and dolomite use, other uses of soda ash and glass and glassfibre production.. Table 4.2 shows that the CO₂ emissions from the sector category are mainly based on figures reported by the plants to Klif, that a Tier 2 methodology is used for nearly all sources and whether the sources are key category or not.

The CO₂ emissions from this sector category were 1.0 million tonnes in 2011, this accounts for 1.9 per cent of the total GHG emissions in Norway and 13.1 per cent of the total emission from the sector Industrial processes.. The emissions from this sector has increased with 37.9 per cent from 1990-2011, mainly due to increased production of clinker and lime in more recent years. The emissions from this sector have decreased by 2.5 per cent from 2010 to 2011.

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

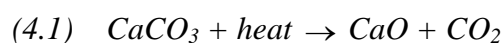
	CO ₂	Tier	Key category
2A1. Cement production	R	Tier 2	Yes
2A2. Lime production	R	Tier 2	Yes
2A3. Limestone and dolomite use	R	Tier 2	No
2A4. Other use of soda ash	E	Tier 1	No
2A7. Glassworks	R	Tier 2	No

R = Figures reported by the plant to Klif

4.2.1 Cement Production – CO₂ – 2A1 (Key Category)

4.2.1.1 Description

Two plants in Norway produce cement and they are covered by the EU ETS. Production of cement gives rise to both non-combustion and combustion emissions of CO₂. The emission from combustion is reported in Chapter 3 Energy. The non-combustion emissions originate from the raw material calcium carbonate (CaCO₃). The resulting calcium oxide is heated to form clinker and then crushed to form cement



In 2011, the CO₂ emissions from cement production were about 0.75 million tonnes, this is 1.4 per cent of the total national GHG emissions and 9.8 per cent of the GHG emissions in the sector Industrial processes. The emissions from cement production have increased with 18.1 per cent from 1990, due to increased production of clinker. The CO₂ emissions have decreased by 0.7 per cent from 2010 to 2011.

CO₂ from cement 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 CO₂ from clinker production included in the GHG inventory are reported by the two producers in their annual report under their regular permit and under the EU ETS to Klif. Emissions are estimated by multiplying the annually clinker production, including 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 that the plants use in their calculation is reported each year from the plants to Klif. The time series for the AD used for the calculations are reported in the CRF. Table 4.3 shows the clinker production for some of the years in the time series.

Table 4.3. Norwegian clinker production (ktonnes) in 1990, 1995, 2000, 2005, 2010 and 2011.

1990	1995	2000	2005	2010	2011
1 244,1	1 682,9	1 656,2	1 460,7	1 433,8	1 415,4

Source: Klif

4.2.1.4 Emission factors

CO₂

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. Prior to entering the EU ETS, the emission factors were more or less constant as one plant used the factor 0.530 tonne CO₂ per tonne clinker (Norcem 2006) and the other producer used the emission factor 0.541 tonne CO₂ per tonne clinker as recommended by (SINTEF 1998a). The IPCC default emission factor is 0.5071 tonne CO₂/tonne clinker. Since entering the EU ETS, the emission factors vary from one year to another. This explains the inter-annual variations in the IEF in the end of the time series.. 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 to the 2010 NIR. The plants are covered by the EU ETS and their emissions are verified annually. Klif's inventory team tracks emissions, AD and IEFs for both plants.

Statistics Norway occasionally calculates alternative emission figures for CO₂ and compares them with the emission figures reported by the plants to the Climate and Pollution Agency to check if they are reasonable. The calculations are based on the clinker production (reported annually from the plants to the Statistic Norway). The calculated emission figures have agreed quite well with emissions figures reported by the plants.

4.2.1.7 Recalculations

There has been no recalculation since NIR 2010.

4.2.1.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.2.2 Lime Production – CO₂ - 2A2 (Key category)

4.2.2.1 Description

Three plants that produce lime in Norway reported CO₂ emissions from processes to Klif and all three plants are covered by the EU ETS. In 2011, the CO₂ emissions from lime production were about 0.2 million tonnes, this is 0.4 per cent of the total national GHG emissions and 2.9

per cent of the GHG emissions in the sector Industrial processes. The CO₂ emissions from lime production have increased with 348.5 per cent from 1990. This is due to increased production at existing plants and the establishment of a new plant in 2007 with large production. The CO₂ emissions have decreased by 9.6 per cent from 2010 to 2011.

CO₂ from lime production is according to a Tier 1 key category analysis defined as key category due to contribution in level to total GHG emission.

4.2.2.2 Methodological issues

All three plants calculate the emissions of CO₂ based on actual production volumes of lime and plant specific emission factors for CO₂ from limestone and dolomite respectively. The emissions are reported to the Klif. For one of the plants, Klif has estimated the emissions for 2002-2004 based on activity data and plant specific emission factors. Klif has also interpolated the emissions for the years 1991-1997 for the same plant.

4.2.2.3 Activity data

The activity data is the input of limestone and dolomite and the the plants report the annual amounts to Klif. For two of the plants, the input of limestone is determined by adding up the production volumes of lime (weighed on a scale for trucks). Analysis of the contents of CaO in lime is then used to calculate the input of limestone. For the third plant, the amounts of limestone and dolomite going into the production process are weighed in batches. The weights of these batches are then added to get an annual figure. Nearly all production in Norway consists of quicklime but there is also some dolomitic lime. The time series consistency for the IEF was improved in the 2012 NIR due to the revised data.

The ERT of the 2011 NIR acknowledged that Norway uses an approach that results in more accurate emission estimates than those produced using the IPCC default method. Since Norway earlier has reported the consumption of limestone and dolomite as AD in the CRF rather than the amount of lime produced, the ERT pointed out that the CO₂ IEFs for lime production over the time series are very low compared with the default IPCC EF (0.785 t/t for quicklime). To assist with comparability across Parties, the ERT therefore encouraged Norway to report final lime production values in CRF sectoral background table 2(I).A-G and include the necessary explanations in the NIR. Norway has followed up the ERT's recommendation and now reports final lime production values in the CRF. Table 4.4 shows the lime production for some of the years in the time series. Note that the emissions are still calculated on the basis of limestone and dolomite consumption.

Table 4.4. Norwegian lime production (ktonnes) in 1990, 1995, 2000, 2005, 2010 and 2011.

1990	1995	2000	2005	2010	2011
62.0	86.8	84.6	102.6	315.2	294.4

Source: Klif

Figure 4.1 shows that the change of AD in the CRF results in IEFs closer to the default IPCC EF. However, this change results in a less stable IEF as it varies more than the previously used IEF.

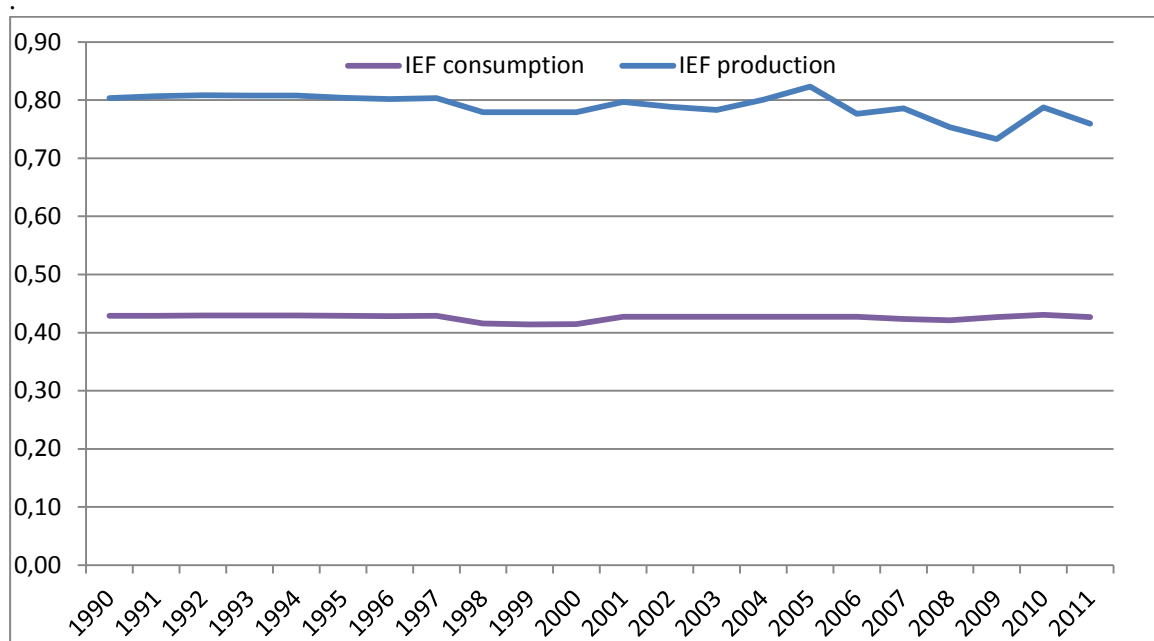


Figure 4.1. IEF (tonne CO₂ per tonne limestone) using consumption and production as AD

Source: Klif

4.2.2.4 Emission factors

The plants use emission factors in the range of 0.4254 to 0.437 tonnes CO₂ per tonne limestone and 0.474 tonnes CO₂ per tonne dolomite used.

4.2.2.5 Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.2.2.6 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 IX. The plants are covered by the EU ETS and their emissions are verified annually. Klif's inventory team tracks emissions, AD and IEFs for all the plants.

4.2.2.7 Recalculations

There has been no recalculation since NIR 2012.

4.2.2.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.2.3 Limestone and Dolomite Use – CO₂ - 2A3

4.2.3.1 Description

Limestone and dolomite are used and reported in several source categories. Table 4.5 shows the balance for the limestone and dolomite use in 2010 and 2011 and where the emissions are reported.

Table 4.5. Balance in tonnes for the limestone and dolomite use in 2010 and 2011.

Limestone	2010	2011
2A1 - Cement production	1 713 704	1 702 109
2A2 - Lime production	533 959	474 542
2A3 - Limestone and dolomite use	55 364	50 248
2C2 - Production of ferroalloys	93 964	247 017
Total limestone	2 396 991	2 473 916
Dolomite		
2A2 - Lime production	38 905	45 357
2A7 - Glassworks	4 512	5 239
2C2 - Production of ferroalloys*	48 537	40 138
Total dolomite	91 954	90 734
Total limestone and dolomite	2 488 945	2 564 650

* In the production of ferroalloys, a total of 19 619 tonnes in 2010 and 5 556 tonnes is not specified and is for the purpose of this table placed under dolomite.

Source: Climate and Pollution Agency and Statistics Norway

Norway has included CO₂ emissions from limestone and dolomite consumption in ferroalloy production under the category ferroalloys production (2C2). This allocation of emissions is the one set out in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, which encourage all emissions from carbonate consumption to be reported under the category in which they are consumed. The ERT of the 2009 NIR agreed that such a calculation approach leads to accurate estimates of emissions from ferroalloys but recommended to report the emissions under 2A3 in order to facilitate transparency and comparability among reporting Parties. The ERT of the 2010 NIR noted the recommendation made in the previous review report, but recommended that Norway continue with its current reporting. Therefore, see category 2C2 (ferroalloys production) for more information.

For reporting in this source category, three plants report emissions from limestone and dolomite use to Klif and two of these plants are covered by the EU ETS. One plant neutralizes sulphuric acid waste with limestone and fly ash and this produces CO₂. The use of fly ash decrease the CO₂ emissions compared with when limestone is used. The second plant is a brick producer and uses limestone in its production. The third plant produces calcium oxide and magnesium oxide from limestone and dolomite.

In 2011, the CO₂ emissions from limestone and dolomite use reported in this source category were about 23 600 tonnes, this is 0.04 per cent of the total national GHG emissions and 0.3 per cent of the GHG emissions in the sector Industrial processes. The CO₂ emissions from this source category have decreased with 0.5 per cent from 1990 by 9.3 per cent from 2010 to 2011. The ERT of the 2012 NIR asked if Flue Gas Desulfurization (FGD) is used to control SO₂ emissions in Norway, and if that is the case if the production of hydrated lime is considered under source category 2A3. During the review, Norway answered that we did not have any information that FGD is used in Norway and we therefore do not report such emissions in this source category.

4.2.3.2 Methodological issues

The plants report emission figures of CO₂ to Klif. The emissions are calculated by multiplying the amount of sulphuric acid and limestone with emission factors.

4.2.3.3 Activity data

The amount of limestone and dolomite that the plants use in their calculation is reported each year from the plants to Klif. The ERT of the 2009 NIR recommended that missing AD should be included in the CRF tables. Norway has included the AD in the CRF tables.

4.2.3.4 Emission factors

The EF for the plant that neutralizes sulphuric acid waste has been calculated by Klif based on reported emissions and amounts of acid neutralized. The EF of 0.44 tonnes CO₂ per tonne limestone used by the brick producing plant is the standard EF used in the EU Emission Trading System (EU ETS) for limestone. The plant producing calcium oxide and magnesium oxide has used EF equal to the standard EF used in the EU ETS for limestone before it entered the EU ETS and uses plant specific EFs after it has entered the EU ETS. The plant does not use limestone every year, but the EFs for 2006, 2009 and 2010 are 0.41, 0.44 and 0.4504. The EF for the dolomite used by the plant producing calcium oxide and magnesium oxide is equal to the standard EF used in the EU ETS (0.44) for before it entered the EU ETS and uses plant specific EFs after it has entered the EU ETS. The plant does not use dolomite every year, but the EFs for 2005-2007 are 0.45, it is 0.46 in 2008 and 0.477 in 2009.

4.2.3.5 Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.2.3.6 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 IX. Two of the plants are covered by the EU ETS and their emissions are verified annually. The third plant's reports emissions under its regular permit and are checked both by the case handler and by Klif's inventory team.

4.2.3.7 Recalculations

The reported 2009 figure for CO₂ from one plant has been altered from 23 300 to 21 000 tonnes. This is due to revised data from the plant.

4.2.3.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.2.4 Other use of soda ash – CO₂ - 2A4

4.2.4.1 Description

Soda ash is used and reported in several source categories. Table 4.6 shows the total balance for the use of soda ash for the period 1990-2011 and in which source categories Norway reports these emissions. Glass wool production (emissions reported under 2A7) and nickel production (emissions reported under 2C5) report emissions due to use of soda ash. The soda ash use at two plants producing glass wool and the nickel production plant amounts to approximately 60-80 per cent of the net import. In addition, some soda ash is used in the chemical industry where consumption is assumed to be non-emissive.

The net import of soda ash is higher than the sum of the amounts consumed in these industries. Therefore, CO₂-emission from other use of soda ash is estimated and reported here

under 2A4. There are no data on soda ash in Norway in production statistics (PRODCOM) from Statistics Norway.

Table 4.6. Soda ash use balance for Norway, 1990-2011 (tonnes)

Year	Net import	2A4 (Soda ash production and use)	2A7 (Glassworks)	2C5 (Nickel production)
1990	41 456	18 396	4 743	18 317
1991	44 365	16 967	4 743	22 655
1992	42 740	13 505	5 146	24 089
1993	35 201	6 299	4 198	24 704
1994	49 565	14 339	4 859	30 367
1995	51 321	21 247	4 744	25 330
1996	57 606	25 222	5 126	27 258
1997	51 846	15 805	5 433	30 608
1998	48 556	5 838	4 638	38 080
1999	48 830	8 458	4 944	35 429
2000	45 426	14 295	5 343	25 788
2001	46 364	15 390	5 427	25 547
2002	51 463	17 547	5 477	28 439
2003	54 016	16 577	5 384	32 054
2004	52 975	13 737	5 979	33 259
2005	61 046	19 508	5 406	36 132
2006	53 699	14 377	3 393	35 929
2007	50 732	14 532	3 540	32 659
2008	56 057	20 266	3 492	32 299
2009	39 970	1 375	3 461	35 134
2010	37 153	-	3 518	33 635
2011	47 568	10 440	3 585	33 543

Source: Statistics Norway and Climate and Pollution

In 2011, the CO₂ emissions from soda ash use reported in this source category were about 4 300 tonnes, this is 0.01 per cent of the total national GHG emissions and 0.06 per cent of the GHG emissions in the sector Industrial processes. The CO₂ emissions from this source category have decreased with 71.6 per cent from 1990. There were no emissions from this source category in 2010.

4.2.4.2 Methodological issues

The emission figures for CO₂ are estimated by multiplying the activity data by an emission factor.

4.2.4.3 Activity data

The activity data is net import in tonnes, minus consumption in glass wool, nickel production and the chemical industry.

4.2.4.4 Emission factors

The emission factor for soda ash use of 0.41492 tonnes CO₂/tonne soda ash from table 2.1 in the IPCC Guidelines 2006 is used.

4.2.4.5 Uncertainties

As we have not been able to obtain sufficient information to determine where the rest of the imported soda ash has been consumed, there is some uncertainty as to whether all soda ash consumption in fact is emissive. There is also some uncertainty associated with the foreign

trade statistics, as well as with the assumption that the CO₂ is emitted the same year as the soda ash are imported. According to the IPCC Guidelines 2006, there is negligible uncertainty associated with the emission factor, given that the correct emission factor is applied.

4.2.4.6 Source specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. However, when the calculation first was included in the inventory, a comparison was made between figures on net import of soda ash in foreign trade statistics and in the Norwegian Product Register. Import figures from the Product Register for the period 2000-2011 never constituted more than 41 % of the amounts imported according to foreign trade statistics. Thus, it was assumed that the net import in the foreign trade statistics is a good proxy for the total quantity of soda ash used in Norway.

4.2.4.7 Recalculations

Emissions from other use of soda ash has for the first time been included under 2A4. The tonnes as shown in the third column of table 4.6 result in the emissions as shown in table 4.7.

Table 4.7. Recalculations for 2A4 due to the inclusion of emissions from other use of soda ash.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Tonnes CO ₂	15233	16440	5604	2614	5949	8816	10465	6558	2422	3509	5931
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Tonnes CO ₂	6386	7281	6878	5700	8094	5965	6030	8409	570	-	

Source: Statistics Norway

4.2.4.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014. We might examine further what these other uses of soda ash actually might be in order to confirm whether they are emissive or not.

4.2.5 Glassworks – CO₂ - 2A7

4.2.5.1 Description

Three plants producing glass or glass fibre are included in the emission inventory, based on emission reports to the Climate and Pollution Agency. All three plants are covered by the EU ETS. The CO₂ emissions from this source category amounted to about 4 700 tonnes CO₂ in 2011. This is an increase of 13.1 per cent from 2010 and a decrease of 15.7 per cent from 1990.

4.2.5.2 Methodological issues

Two plants producing glass wool and one plant producing glass fibre report emission figures on CO₂ to the Climate and Pollution Agency. The two glass wool production plants report

emissions from the use of soda ash, limestone and dolomite, while the glass fibre producer reports emissions from the use of limestone and dolomite.

4.2.5.3 Activity data

The activity data is use of soda ash, limestone and dolomite. For years where reported emission figures are not available, the AD has been estimated based through interpolation.

4.2.5.4 Emission factors

The emission factors used are 0.41492 tonnes CO₂/tonne soda ash, 0.477 tonnes CO₂/tonne limestone and 0.44 tonnes CO₂/tonne dolomite.

4.2.5.5 Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.2.5.6 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 IX. The plants are covered by the EU ETS and their emissions are verified annually. Klif's inventory team tracks emissions and AD for all plants.

4.2.5.7 Recalculations

Additional emissions from the use of soda ash and limestone/dolomite at two point sources are included for the first time. Table 4.8 gives the resulting increase in emissions of CO₂.

Table 4.8. Additional emissions (tonnes CO₂) from use of soda ash and limestone/dolomite in 2A7.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Tonnes CO ₂	5 576	5 576	5 831	5 231	5 682	5 589	5 839	6 019	5 815	5 010	5 390
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Tonnes CO ₂	6 010	5 259	5 149	5 643	5 001	4 301	3 940	4 456	4 090	4 152	

Source: Climate and Pollution Agency and Statistics Norway

4.2.5.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.3 Chemical Industry – 2B

In the Norwegian inventory, there are different activities included under chemical industry. Nearly all emissions figures from this industry included in the inventory are reported figures from the plants to Klif. Table 4.9 shows the GHGs that are emitted from which industry, tier of methodology and if the source category is key category or not.

The GHG emissions from this sector category were 1.1 million tonnes in 2011, this is 2.1 per cent of the total GHG emissions in Norway and 14.6 per cent of the total emission from the

sector Industrial processes. The emissions from this sector has decreased with 66.0 per cent from 1990-2011, mainly due to lower emissions from the production of nitric acid, ammonia and carbide. The emissions have decreased by 8.6 per cent from 2010 to 2011.

Table 4.9. Chemical industry. Components emitted and included in the Norwegian inventory.

	CO ₂	CH ₄	N ₂ O	NMVOC	Tier	Key category
2B1. Ammonia	R	NA	NA	NA	Tier 2	Yes
2B2. Nitric acid	NA	NA	R	NA	Tier 2	Yes
2B4. Silicon carbide	R+E	R/E	NA	NA	Tier 2	Yes
2B4. Calcium carbide	R	NA	NA	R	Tier 1	No
2B5. Methanol	E	R	NA	R	Tier 2	No
2B5. Plastic	R+E	R	NA	R	Tier 2	No
2B5. Titanium dioxide production	R	R	R	NA	Tier 2	Yes

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 – CO₂ – 2B1 (Key category)

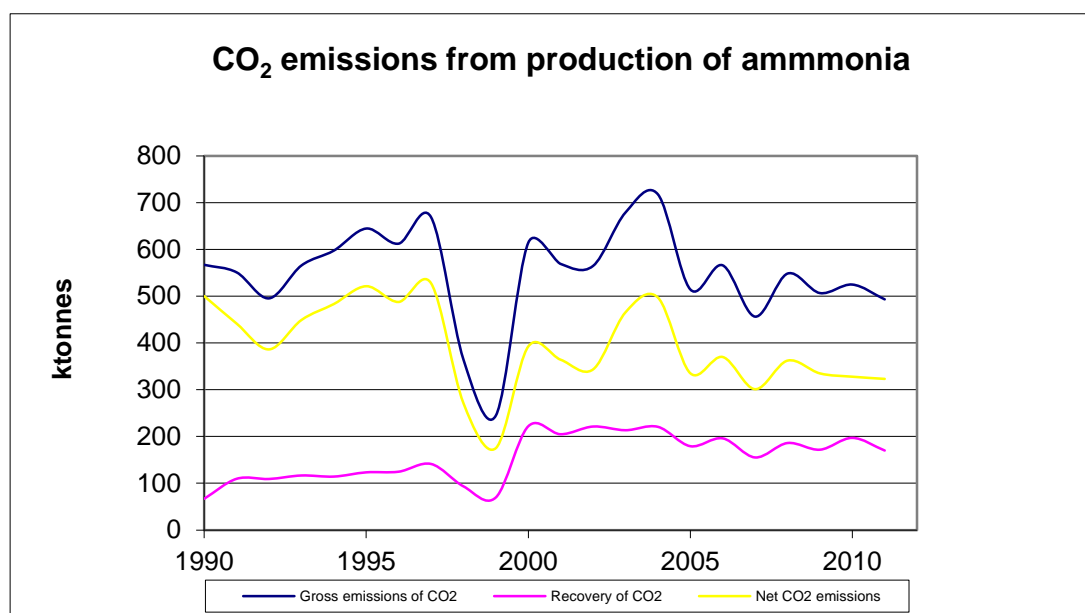
4.3.1.1 Description

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 in the production of fertilizers. Hydrogen is needed to produce ammonia, and wet fuel gas is the basis for the production of hydrogen. A substantial amount of CO₂ is recovered from the production process.

The net CO₂ emissions from the production of ammonia were about 323 000 tonnes in 2011, this accounts for 0.6 per cent of the total GHG emissions in Norway and 4.2 per cent of the total emission from the sector Industrial processes.

The gross CO₂ emissions from the production process were 13.0 per cent lower in 2011 compared to 1990 while the net emissions decreased by 35.4 per cent in the same period. The reduction in the net emissions is due to that the amount of recovered CO₂ increased by about 154.2 per cent. From 2010 to 2011 the gross CO₂ emissions increased by 6.0 per cent, the net emissions decreased by 1.4 per cent while the recovered CO₂ decreased by 13.7 per cent. In 2011 170 ktonnes CO₂ were captured and sold, see Figure 4.2.

According to the Tier 1 key category analysis ammonia production is defined as key category due to contribution in level and trend.

Figure 4.2. CO₂ emissions from production of ammonia.

Source: Climate and Pollution Agency

4.3.1.2 Methodological issues

The CO₂ 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 CO₂, 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 CO₂ 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 Klif. As a part of the official Industrial statistics, gas consumed is also reported to Statistics Norway that uses 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 calculated based on the composition of the gases consumed. The plant states that the composition is based on daily analysis and that the composition of the gases is stable.

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 IX. The plant reports as required by the voluntary agreement.

The figures reported from the plant are occasionally compared to calculations done by Statistics Norway based on total amount of gas consumed and an emission factor on 3 tonne CO₂/tonne LPG recommended by IPCC (1997b). The calculated emissions figures have agreed quite well with emissions figures reported by the enterprises.

4.3.1.7 Recalculations

The reported CO₂ figure for 2010 has been reduced by 25 200 tonnes due to new information provided by the plant. Previously used 2009 figures are replaced by actual 2010 figures.

4.3.1.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.3.2 Production of Nitric Acid –N₂O – 2B2 (Key Category)

4.3.2.1 Description

There are two plants in Norway where nitric acid is produced and these plants are covered by the EU ETS. Nitric acid is used as a raw material in the manufacture of nitrogenous-based fertilizer. The production of nitric acid (HNO₃) generates nitrous oxide (N₂O) and NO_x as by-products of high temperature catalytic oxidation of ammonia (NH₃).

In 2011, the N₂O emissions from the production of nitric acid equaled about 289 000 tonnes CO₂-equivalents, this is 0.5 per cent of the total national GHG emissions and 3.8 per cent of the GHG emissions in the sector Industrial processes. The emissions from the production of nitric acid have decreased by 86.1 per cent from 1990 to 2011 and by 18.8 per cent from 2010 to 2011. The large decrease in emissions is explained later.

During the centralized review in 2008, Norway provided additional information regarding the plant-specific production technology and a relative comparison with the technologies described in table 3.3 in the IPCC 2006 Guidelines. A summary of this information is repeated in table 4.10.

Table. 4.10 Production process and default factors for nitric acid production.

Production process	N ₂ O Emission Factor (relating to 100 percent pure acid)
A. Plants with NSCR ⁷ (all processes)	2 kg N ₂ O/tonne nitric acid ±10%
B. Plants with process-integrated or tailgas N ₂ O destruction	2.5 kg N ₂ O/tonne nitric acid ±10%
C. Atmospheric pressure plants (low pressure)	5 kg N ₂ O/tonne nitric acid ±10%
D. Medium pressure combustion plants	7 kg N ₂ O/tonne nitric acid ±20%
E. High pressure plants	9 kg N ₂ O/tonne nitric acid ±40%

Source: van Balken (2005).

The two plants have together five production lines. Four of the production lines are a mix of technology C and D in table 4.10 and the last one is technology B. One production line was

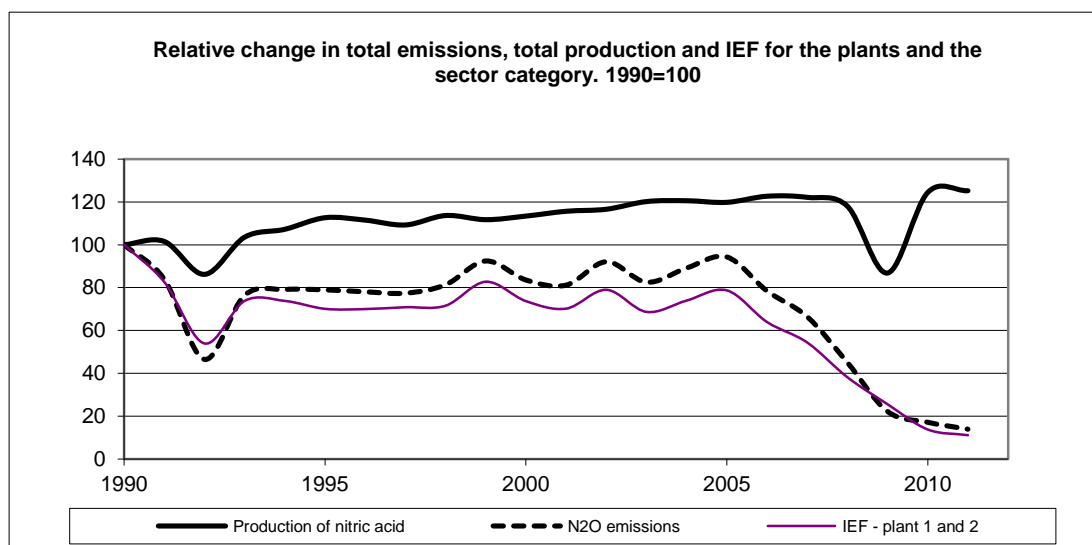
⁷ A Non-Selective Catalytic Reduction (NSCR)

rebuilt in 1991 and in 2006 two lines were equipped with the technology – N_2O decomposition by extension of the reactor chamber. Since then, all production lines have to a certain extent been equipped with this technology. The full effect of implementing the technology will be reached in 2010. Figures 4.3 and 4.4 show that the production specific N_2O emissions were reduced substantially in the early 90ties and again from 2006. The reduced emissions in the early 1990s were due to rebuilding of one production line in 1991 and that a larger part of the production became from that line. The reduced emissions from 2006 are due to the installation of the earlier mentioned technology and explains the downwards trend from 1990.

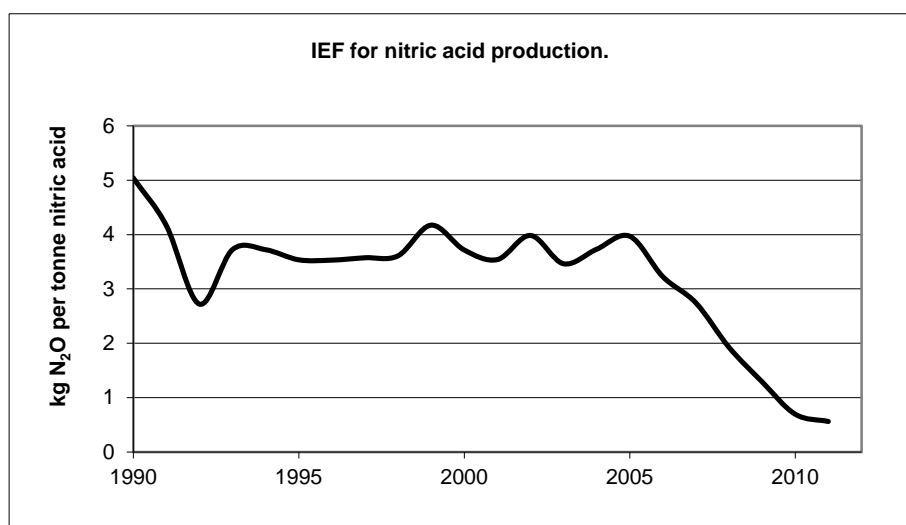
The N_2O emissions from all production lines are from 2008 based on continuous measurements. Previous emissions are based on continuous, monthly and weekly measurements. The inter-annual changes of IEFs are likely to be explained by variations in the level of production between the lines with different IEFs and how the emissions have been measured. The N_2O emissions have decreased by 86.1 percent from 1990 to 2011 while the production of nitric acid increased by 25.2 percent. Corresponding changes from 2010 to 2011 was a decrease in N_2O emissions by 18.8 per cent and a 1.0 per cent increase in production. There was a large increase in production of 43.4 percent from 2009 to 2010 that came after a decrease in production of 26.4 percent from 2008 to 2009. The low production level in 2009 reflects the lower economic activity due to the economic recession. The IEF for nitric acid production has decreased from 5.0 kg N_2O per tonne nitric acid in 1990 to 0.6 kg N_2O per tonne nitric acid in 2011.

Production of nitric acid is defined as key category both in level and trend according to the Tier 2 key category analysis.

Figure 4.3. Relative change in total emissions, total production and IEF for nitric acid production. 1990=100



Source: Climate and Pollution Agency

Figure 4.4. IEF for nitric acid production. Kg N_2O per tonne nitric acid.

Source: Climate and Pollution Agency

4.3.2.2 Methodological issues

N_2O

The two plants report the emissions of N_2O to Klif. 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 Klif.

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 Klif one plant reports that the uncertainty in measurement of N_2O is calculated to $\pm 1-3$ 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 IX. The plants are covered by the EU ETS and their emissions are verified annually. Klif's inventory team tracks the emissions, AD and the IEFs for all production lines as a quality check.

4.3.2.6 Recalculations

There has been no recalculation since NIR 2009.

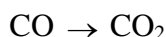
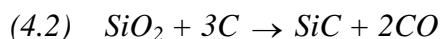
4.3.2.7 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.3.3 Silicon Carbide – CO₂ - 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 (SiO₂) with petrol coke as a reducing agent.



In the production of silicon carbide, CO₂ and CO is released as a by-product from the reaction between quartz and carbon. Methane (CH₄) 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 were about 71 000 tonnes CO₂-equivalents in 2011 and accounted for 0.1 per cent of the total GHG emissions and 0.9 per cent of the GHG emissions in sector Industrial processes. The emissions were reduced by 69.1 per cent in the years 1990-2011 and decreased by 8.1 per cent from 2010 to 2011. The large decrease from 1990 to 2011 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. There was a large production increase from 2009 to 2010 and this is due to a low production level in 2009. The production level in 2009 is also lower than 2008 and reflects the lower economic activity due to the economic recession.

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 CO₂ 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.

CO₂

Emission figures are reported annually by the three plants to the Klif.

CO₂ from process is calculated based on the following equation:

$$(4.3) \quad CO_2 = \Sigma Activity\ data * Emission\ factor$$

The three production sites have used amount of produced crude silicon carbide as activity data in the calculation of CO₂ emissions.

NMVOC

Emission figures are reported to the Climate and Pollution Agency by the plants. The emissions are calculated by multiplying annual production of silicon carbide by an emission factor.

Indirect emission of CO₂ is calculated by Statistics Norway based on the emission of CH₄.

CH₄

The emission of CH₄ from production of silicon carbide is calculated based on the following equation:

$$(4.4) \quad CO_2 = \sum Activity\ data_i * Emission\ factor_i$$

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 CO₂, CH₄ and NMVOC 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. For the calculations of indirect CO₂, the AD is the amount of CH₄.

4.3.3.4 Emission factors

CO₂

All three sites use the country-specific emission factor that is the basis for the IPCC (2006) default factor of 2.62 ton CO₂/ton crude silicon carbides, see Table 4.11.

CH₄

For calculation of methane emissions the country-specific emission factor 4.2 kg CH₄/tonne crude SiC is used, see Table 4.11. Documentation of the choice and uncertainties of the emission factor is given under Uncertainties.

CO

The emission factor is in accordance with the IPCC Guidelines (IPCC 1997b).

Indirect CO₂

The indirect CO₂ emissions from oxidized CH₄ are calculated using the emission factor 2.74 kg CO₂/kg CH₄.

Table 4.11. Emission factor for CO₂, CH₄ 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 kg CH ₄ /tonnes crude SiC	CS
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 one of the plants is stable at around 10.8 t NMVOC/kt SiC while the emission factor at the other plant is less stable and increasing. The concerned plant has responded that the variations are within the expected variations. For previous years, the emission factor for Saint Gobain is more or less constant whereas the emission factor for Washington Mills varies.

4.3.3.5 Uncertainties

CO₂

Activity data: The three productions sites use the amount of produced crude silicon carbide as activity data. The uncertainty of the activity data is related to the uncertainty of the weighing equipment and is calculated to be ± 3 per cent.

Emission factor: The emission factor of 2.62 tonne CO₂/tonnes SiC has an estimated uncertainty range of -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 country specific emissions factors (SINTEF 1998e).

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 CO₂/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 CO₂ /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 CO₂, based on uncertainties in activity data and emissions factor, is calculated to be in the range of -20% to $+10\%$.

CH₄

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 $\pm 3\%$.

Emission factor:

The emission factor of 4.2 kg CH₄/tonne SiC is used, and the uncertainty level is estimated to be $\pm 30\%$.

The calculation of emission factor and the uncertainty level is explained below. The production of SiC is a batch process with duration of about 43 hours. The CH₄-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 CH₄ is peaking in the first hour of the process, giving a CH₄ concentration 10 – 15 times higher than in the last 36 hours of the process. A typical level of the concentration of CH₄ is given in Figure 4.5. If the CH₄-concentration is averaged over the total batch time of 43 hours, this will give an emissions factor of 4.2 kg CH₄/tonne SiC, i.e. 3.5 kg CH₄/tonne petrol coke.

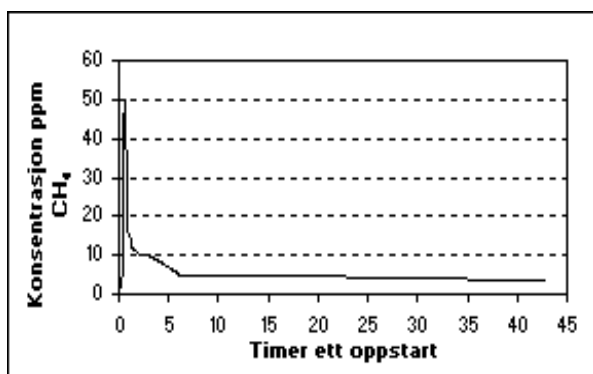


Figure 4.5. Concentration of CH₄ for one batch of SiC.

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 CH₄ is ± 30 per cent.

4.3.3.6 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 IX. The two existing plants report as required by the voluntary agreement and Klif's inventory team tracks emissions and AD for the plants.

4.3.3.7 Recalculations

There has been no recalculation since NIR 2010.

4.3.3.8 Planned improvements

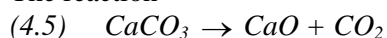
There is no planned activity this year that will improve the data quality for NIR 2014.

4.3.4 Production of Calcium Carbide – 2B4

4.3.4.1 Description

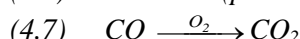
One plant in Norway was producing calcium carbide until 2003 and the emissions from this source were about 178 000 tonnes CO₂ in 1990. The production of calcium carbide generates CO₂ emissions when limestone is heated and when petrol coke is used as a reducing agent.

The reaction



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

The reactions



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

4.3.4.2 Methodological issues

The CO₂ figures in the National GHG emission inventory are based on emission figures reported from the plant to Klif. 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 Klif.

4.3.4.4 Emission factors

The emission factor used by the plants in the calculation of CO₂ has been estimated by (SINTEF 1998e) to be 1.69 tonne/tonne CaC₂. An additional 0.02 t CO₂ /t CaC₂ from fuel is reported in the Energy chapter.

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 IX.

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 and it is covered by the EU ETS. 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. CH₄ and NMVOC are emitted during the production process. Emissions from the combustion of natural gas in the flare from the production of methanol are as recommended by the review team reported under 2B5 and were about 69 000 tonnes CO₂ in 2011. This accounted for 0.1 per cent of the total GHG emissions and 0.9 per cent of the GHG emissions in sector Industrial processes. The emissions have increased by 6.1 per cent from 2010 to 2011. There were no emissions in 1990 since the plant was established in 1997.

The CO₂ emissions from energy combustion are included under 1.A.2.C. Indirect emissions of CO₂ are calculated by Statistics Norway based on the emission of CH₄ and NMVOC, see chapter 3.6.3.

4.3.5.2 Methodological issues

The plant reports emission figures of CO₂, CH₄ and NMVOC to Klif. The reported emissions from flaring are based on the amounts of natural gas flared multiplied by emission factors while the diffuse CH₄ and NMVOC emissions are estimated through the use of the measuring method DIAL (Differential Absorption LIDAR) in the years 2002, 2005, 2008 and in 2011. The plant was divided into various process areas and measurements were taken for at least two days for all process areas. The DIAL method results in an emission factor per operating hour and this forms the basis for the plant's reported diffuse NMVOC and CH₄ emissions from the production of Methanol. The plant's reported diffuse emissions of CH₄ do not appear to be consistent over time as the various measurements differ substantially. Based on the results from the LIDAR measurements done in 2005, we have used the same emission factor (kg CH₄ per operating hour) for the entire time series. Since the number of operating hours is constant, the time series for the CH₄ emissions also becomes constant.

The NMVOC emissions included in the inventory are based on the reported emissions from the plant as these appear to be consistent.

4.3.5.3 Activity data

The annual emissions from flaring are based on the combustion of natural gas in the flare. The activity data used to calculate the indirect CO₂ emissions are the diffuse emissions of CH₄ and NMVOC which are based on the number of operating hours in a year, this is 8 760 hours annually.

4.3.5.4 Emission factors

Emission factors for flare of natural gas are for CO₂: 2 340 tonnes/Sm³ and for CH₄: 0.24 tonnes/Sm³.

For the diffuse CH₄ emissions, we have used a factor of 10.0 kg CH₄ per operating hour. This is based on the results from the LIDAR measurements done in 2005. The emission factor used for calculating the diffuse NMVOC emissions ranges between 7.6 to 28.5 kg NMVOC per operating hour.

For the indirect CO₂ emissions from CH₄ and NMVOC, the EFs used are 2.74 kg CO₂/kg CH₄ and 3 kg CO₂/kg NMVOC.

4.3.5.5 Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.3.5.6 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 IX. The plant is covered by the EU ETS and its emissions are verified annually. Klif's inventory team tracks emissions and AD for the plants.

4.3.5.7 Recalculations

There has been both a revision of total emission figures for CO₂ and a reallocation between combustion with energy utilisation (1A2c) and flaring, registered as process emissions (2B5.5 Methanol), all years 1997-2010. The revised figures are based on data from the emission trading system (ETS). There has been an increase in figures in 2B5.5 all years, varying between 69 100 (1998) and 22 800 (2004) tonnes CO₂.

4.3.5.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.3.6 Production of Plastic 2B5

4.3.6.1 Description

Three plants report emissions under this source category and they are covered by the EU ETS. 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. One plant reports process emissions that stem from dangerous waste being recycled to sulphuric acid in a production process.

CH₄ and NMVOC emissions are from leakages in the process. Direct CO₂ emission is from combustion and is reported in Chapter 3 Energy. One of the plants reports emissions of flaring and these emissions are reported under process. This has been done to follow the same practice as for the production of methanol where we based on the recommendation of the ERT moved the emissions to process.

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.

In 2011, the GHG emissions from the production of plastic equaled about 85 800 tonnes CO₂-equivalents, this is 0.2 per cent of the total national GHG emissions and 1.1 per cent of the GHG emissions in the sector Industrial processes. The emissions have decreased by 4.6 per cent from 1990 to 2011 and by 3.1 per cent from 2010 to 2011.

4.3.6.2 Methodological issues

CO₂, CH₄ and NMVOC

Emission figures are annually reported to Klif. CO₂ from combustion is based on gas specific emissions factors and activity data. CH₄ and NMVOC emissions reported are based on measurements.

Indirect emissions of CO₂ calculated by Statistics Norway are based on the emission of CH₄ and NMVOC and are reported here under industrial processes.

4.3.6.3 Activity data

For direct CO₂, the annual emissions from flaring are based on the combustion of natural gas in the flare and the amount of dangerous waste being recycled to sulphuric acid. The activity data used to

calculate the indirect CO₂ emissions are the diffuse emissions of CH₄ and NMVOC and are based on measurements.

4.3.6.4 Emission factors

For the indirect CO₂ emissions from CH₄ and NMVOC, the EFs used are 2.74 kg CO₂/kg CH₄ and 3 kg CO₂/kg NMVOC.

4.3.6.5 Uncertainties

It is difficult to measure leakages of CH₄ and NMVOC and therefore the uncertainty is regarded as being large. Uncertainty estimates for greenhouse gases are given in Annex II.

4.3.6.6 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 IX. The plants are covered by the EU ETS and their emissions are verified annually. Klif's inventory team tracks emissions and AD for the plant.

4.3.6.7 Recalculations

For one plant, the reported CH₄ emissions 2005-2010 were previously erroneously registered both as combustion emissions in 1A2c Chemicals and process emissions in 2B5 Plastic. The figures have now been split between the two groups, and this has led to minor reductions in both groups (less than 1 tonne CH₄).

For one plant, there has been a reallocation between 1A2c Chemicals and 2B5 Plastic for CO₂ 1990-2005. Previously, all emissions prior to 2006 were registered as emissions from combustion in boilers, whereas flaring, which is registered under 2B5, now has been separated for all years, as previously was the case only from 2006. This has caused a rise for CO₂ in 2B5 ranging between 42 and 73 ktonnes CO₂. There have also been many revisions for total emission figures, causing changes also for the years from 2006. The only noticeable changes for these years are declines in 2007 and 2008, 25 and 18 ktonnes CO₂, respectively.

In the 2012 NIR, some CO₂ emissions previously registered as combustion emissions were reallocated to process emissions. This caused an annual rise in the process emissions of 10-15 ktonnes for all years 1990-2008. The ERT requested that the explanation provided during the review should be included in the next NIR, and this can be found below.

The process emissions stem from a process in which dangerous waste is recycled to sulphuric acid in a production process. For the years 2005-2010, the split was made by comparing the CO₂ emissions reported under the EU ETS and the CO₂ emissions reported in its annual environmental report as required under its "normal" permit. This is because these particular process emissions are not covered by the EU ETS. For the years 1990-2004, we used the process emissions' average percentage of total emissions for the years 2005-2010 (15%) as the basis for estimating the process emissions. The plant in question was split from another plant in 2001 and the totals for 1990-2000 therefore cover both plants. We assumed that the plant in question's share of total emissions for 1990-2000 is the same as the years 2001-2010 (17%).

4.3.6.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.3.7 Titanium dioxide production CO₂ – 2B5 (key category)

4.3.7.1 Description

One plant producing titanium dioxide slag is included in the Norwegian Inventory. The plant also produced pig iron as a by-product. The titanium dioxide slag and pig iron are produced from the mineral ilmenite and coal is used as a reducing agent. Various components included CO₂ are emitted during the production process.

In 2011, the GHG emissions from the production of plastic equaled about 276 500 tonnes CO₂-equivalents, this is 0.5 per cent of the total national GHG emissions and 3.6 per cent of the GHG emissions in the sector Industrial processes. The emissions have increased by 37.5 per cent from 1990 to 2011 and have decreased by 9.4 per cent from 2010 to 2011. According to the Tier 1 key category analysis, titanium dioxide production is defined as key category due to contribution in level.

4.3.7.2 Methodological issues

The method that is used for all years can be defined as a calculation based on carbon balance. This method accounts for all the carbon in the materials entering the process and subtracts the CO₂ captured in the products.

4.3.7.3 Activity data

The carbon inputs are dominated by coal, but there is also some pet coke, electrodes, carbides and some masses. The CO₂ captured in the products is then subtracted in order to estimate the net emissions. Table 4.12 shows the carbon balance for 2010 and 2011.

Table 4.12. Carbon balance for titanium dioxide production in 2010 and 2011

	2010	2011
Coal	300 324	288 563
Green pet coke (tonne dry weight)	3 785	225
Pet coke and antracite (tonne dry weight)	17 325	2 448
Electrode mass (tonne dry weight)	4411.4	3 711.9
Carbides	785.9	617.7
Plug mass	26.8	24.4
Melting mass	139.4	260.8
Gross CO ₂ (tonnes) before sales	326 798	295 851
Corrected CO ₂ -equivalent from CH ₄ (tonn)		5.3
CO ₂ stored in products	21 410	19 260
Net CO ₂ emissions	305 388	276 586

Source: Klif

4.3.7.4 Emission factors

Since a mass balance is used, it is the carbon contents of the carbon materials that go into the mass balance that are used.

4.3.7.5 Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.3.7.6 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 IX. The plant reports as required by the voluntary agreement. Klif's inventory team tracks emissions and AD for the plant.

4.3.7.7 Recalculations

The reported CO₂ figures has been revised for 1990, 1991, 1998-2001 and 2005 due to new information from the plant. The changes vary between a 7 400 tonnes rise in 1998 and a 15 100 tonnes reduction in 2005.

4.3.7.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.4 Metal Production – 2C

Metal production in Norway includes plants producing iron and steel, ferroalloys, aluminum, nickel and also magnesium until spring 2006, see table 4.13. 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 Klif.

8.0 per cent of total GHG emissions in Norway were from Metal Production in 2011, and the sector contributed with 56.0 per cent of the emissions from Industrial Processes. The largest contributor to the GHG emissions from Metal Production in 2011 is Aluminum production and Ferroalloy production.

The emissions from Metal Production decreased by 55.7 per cent from 1990-2011 and increased by 1.1.x per cent from 2010-2011. There was a large increase in emissions from 2009 to 2010, this is mainly due to a low production level for ferroalloys in 2009. The production level in 2009 is also lower than 2008 and reflects the lower economic activity due to the economic recession. The reduction from 1990-2011 is due to decreased PFC and SF₆ that again was due to improvement in technology aluminum production, the close down of a magnesium plant in 2006 and generally lower production volumes.

Table 4.13. Metal production. Components emitted and included in the Norwegian inventory.

	CO ₂	CH ₄	PFCs	SF ₆	Tier	Key category
2C1. Iron and steel ¹⁾	R	NA	NA	NA	Tier 2	No
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 – CO₂ – 2C1

4.4.1.1 Description

Norway includes one plant producing steel that is covered by the EU ETS and the activity data in the CRF is steel produced. The emissions in 2011 from this source category were about 25 500 tonnes CO₂ and accounted for 0.05 per cent of the total GHG emissions and 0.3 per cent of the GHG emissions in sector Industrial processes. The emissions were increased by 107.1 per cent in the years 1990-2011 and by 19.3 per cent from 2010 to 2011.

4.4.1.2 Methodological issues

In the Norwegian GHG Inventory, emission figures of CO₂, annually reported to the Klif, are used. This reporting includes both the reporting under the EU ETS and reporting as required under its regular emission permit. The emission figures are based on mass balance calculations.

The total emissions from steel production cover emissions from industrial processes and from combustion, but only the process emissions are reported in this sub-category.

For the years 1998-2001 and 2005 and onwards we have detailed emission distributed between combustion and processes from the plant. The process emissions in 1990, 1992-1997 have been estimated on the basis of CO₂ emissions per ton steel produced in 1998 multiplied with the actual production of steel. The reason for using the IEF for 1998 is because the plant provided detailed information when it applied for allowances under the EU ETS. For 2002-2004 the same method is used but then we have used the 2005 process emissions per ton steel produced. The reason for using the IEF for 2005 for these years is because this was the first year these emissions were part of the EU ETS and they are considered to be the best data available. The process emissions prior to 2005 have to a large extent therefore been estimated based on the process emissions per ton steel produced in 1998 and 2005, this explains the

increasing variation in the CO₂ IEF for steel after 2005 since the emissions from 2005 and onwards are based on annual reported data from the EU ETS.

4.4.1.3 Activity data

The process CO₂ emissions stem from an Electric Arc Furnace (EAF) where scrap iron is melted with other carbon materials. The emissions from the scrap iron are calculated based on the use of each types of scrap iron and the appurtenant content of carbon in each type of scrap iron. E.g. in 2010 the plant used 10 types of scrap iron. The types of scrap iron are according to the UK steel protocol and the carbon content in the types of scrap used varies from 0.15 per cent up to 4 per cent. The other input materials to the EAF are coal, lime and the metals ferromanganese, ferrosilicon and silicomanganese and electrodes. The outputs are steel, dust and slag. The net emissions from the mass balance are the process emissions.

Since the plant is part of the EU ETS and Norway makes reported data publically available, the mass balances for 2008-2011 can be found through Klif's web pages.⁸

4.4.1.4 Emission factors

Since a mass balance is used, it is the carbon contents of the carbon materials that go into the mass balance that are used. For the scrap iron, all ten types of scrap iron have their own carbon content.

4.4.1.5 Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.4.1.6 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 IX. The plant is covered by the EU ETS and their emissions are verified annually. Klif's inventory team tracks emissions, AD and IEF for the plant.

4.4.1.7 Recalculations

There have been no recalculations since NIR 2012.

4.4.1.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

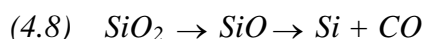
4.4.2 Production of Ferroalloys – CO₂ – 2C2 (Key Category)

4.4.2.1 Description

There were 12 plants producing ferroalloys in Norway in 2011. 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 per cent Si and silicon metal with 98-99 per cent

⁸ <http://www.klif.no/Tema/Klima-og-ozon/CO2-kvoter/Klimakvoter-for-2008/> (In Norwegian)

Si is produced. The raw material for silicon is quartz (SiO_2). SiO_2 is reduced to Si and CO using reducing agents like coal, coke and charcoal.



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 Söderberg 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.

The CO is produced from the production process. In open or semi- closed furnaces the CO reacts with air and forms CO_2 before it is emitted. This is due to high temperature and access to air in the process. In a closed furnace the CO does not reach to CO_2 as there are no access to air (oxygen) in the process. The waste gas are then led from furnace and used as an energy source or flared and is reported under the relevant Energy sectors. The technical specification of the furnaces is irrelevant since emissions are calculated using a mass balance or calculated by multiplying the amount of reducing agents in dry weight with country specific EFs.

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 manganese (FeMn), silicon manganese (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 were about 2.3 million tonnes CO_2 -equivalents in 2011 and accounted for 4.3 per cent of the national total GHG emissions and for 29.7 per cent of the emissions from the Industrial sector in 2011. The emissions from production of ferroalloy decreased by 11.4 per cent from 1990 to 2011 and increased by 4.1 per cent from 2010 to 2011. The large increase in emissions from 2009 to 2010 (50.2 per cent) is due to a low production level for ferroalloys in 2009. The production level in 2009 is also lower than 2008 and reflects the lower economic activity due to the economic recession.

According to the Tier 2 key category analysis CO_2 emissions from production of ferroalloys are key category due to the large share of total emissions.

4.4.2.2 Methodological issues

CO_2

The methods used in the calculation of CO_2 emissions from 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. Emissions are reported by each plant in an annual report to the Klif.

The plants have used one of the two methods below for calculating CO₂-emissions:

1. Mass balance; the emissions for CO₂ 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)

Each plant has for consistency just used one method for the entire time series.

Indirect emissions of CO₂ are calculated based on the emission of CH₄ and NMVOC and are reported in this sub-category.

CH₄ and N₂O

The emissions of CH₄ and N₂O 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 Klif.

Plants producing ferro manganes, silicon manganes and ferrochromium do not emit emissions of CH₄ and N₂O.

NMVOC

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

4.4.2.3 Activity data

CO₂

Calculation of emissions is based on the consumption of gross reducing agents and electrodes in the production of ferroalloys. The activity data include limestone and dolomite and the corresponding emissions are included here under 2C2 and not under 2A3. Based on a recommendation from a previous review, table 4. 14 shows the activity data (including limestone and dolomite consumption) for the years 2010-2011.

Table 4.14. Tonnes of various activity data (dry basis) in the ferroalloys production for 2010 and 2011

Activity data	2010	2011
Coal/anthracite	360 291	441 611
Coke	328 013	332 747
Petrol coke	48 813	45 400
Electrodes	7 793	4 617
Limestone and dolomite	123 623	287 155
Coke powder	9 708	7 799
Carbonate ore	253 980	548 944

Source: Climate and Pollution Agency

CH₄ and N₂O

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*CO₂*

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 1998d) and the factors are listed in Table 4.15.

Table 4.15. Emission factors from production of ferroalloys. Tonnes CO₂/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).

CH₄ and N₂O

Measurements performed at Norwegian plants producing ferro alloys indicate emissions of N₂O in addition to CH₄. The emissions of CH₄ and N₂O 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.

Measurement campaigns at silicon alloy furnaces have been performed since 1995, and these measurements are the base for the values in the BREF document for silicon alloys. The results of the measurements, that the emissions factors in the Norwegian CH₄ and N₂O are based upon, are presented in SINTEF (2004a). A summary of the report is given in the publication "Reduction of emissions from ferroalloy furnaces" by SINTEF (2004b). The main focus for the studies has been NO_x emissions. However, the emissions of CH₄ and N₂O have also been measured.

Full scale measurements have been performed at different industrial FeSi/Si furnaces. The average CH₄ and N₂O concentrations in the ferroalloy process are with some exceptions a few

ppm. For N₂O and CH₄ 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 N₂O emissions goes from around zero to more than 35 ppm. The avalanches are always short in duration. There are also increased N₂O emissions during blowing phenomenon.

The EF used in the inventory represents the longer-term average N₂O and CH₄ 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 4.16. 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 4.16. Emission factors for CH₄ and N₂O 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°C ²	Batch- charging	Sprinkle- charging ¹	Sprinkle- charging and >750°C ²	Batch- charging	Sprinkle- charging ¹	Sprinkle- charging and >750°C 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 ₂ O 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 IX. The plants report as required by the voluntary agreement. Klif's inventory team tracks emissions and AD for the plants.

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 were emissions of CH₄ and N₂O based on EFs shown in Table 4.16. With very few exceptions the AD reported in the CRF is data that the plants have reported to Klif. 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 occasional quality controls (QC) of the emission data on the basis of the consumption of reducing agents they collect in an annual survey and average emission factors.

4.4.2.7 Recalculations

There are minor reductions in the reported CH₄ and N₂O figures for 2005 from one plant due to new information from the plant.

4.4.2.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.4.3 Production of Primary Aluminium –CO₂ 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.

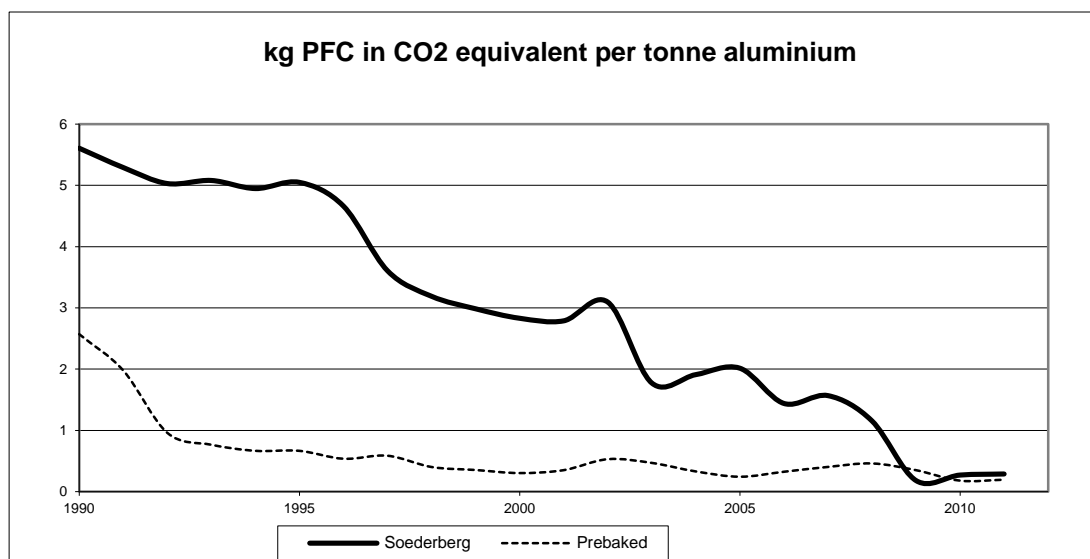
Production of aluminium leads to emission of various components as CO₂, SO₂, NO_x, perfluorocarbons (PFCs), heavy metals and persistent organic pollutants. The emission of CO₂ is due to the electrolysis process during the production of aluminium, while the SO₂ emissions are from the sulphur in the reducing 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.

The GHG emissions from aluminium production were 1.9 million tonnes CO₂-equivalents in 2011 and accounted for 3.6 per cent of the national total GHG emissions and for 24.9 per cent of the emissions from the Industrial sector in 2011. The emissions decreased by 60.2 per cent from 1990 to 2011 and by 2.7 per cent from 2010 to 2011.

There has been a substantial reduction in the total PFC emissions from the seven Norwegian aluminium plants in the period from 1990 to 2011. 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 for Soederberg were 5.61, 5.29 and 5.03. In 2011 the specific PFC emissions for prebaked and Soederberg were 0.19 and 0.29 kg CO₂-equivalent, see Figure 4.6 and table 4.17.

Figure 4.6. kg PFC in CO₂ equivalent per tonne aluminium



Source: Klif

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 92 per cent in 2011. Two new plants with prebaked technology were established in 2002 and plants using Soederberg technology were closed down in the period 2002-2009.

The ERT of the NIR submitted in 2011 encouraged Norway to include a table in the NIR showing the shares of the two technologies and the PCF IEFs for each year of the time series. This is shown in table 4.17.

The PFCs emissions from production of aluminium have decreased by 93.3 per cent from 1990 to 2011. Between 2010 and 2011, the emissions increased by 10.1 per cent.

The PFC emissions per tonne aluminium produced in Norway was 3.88 kg CO₂-equivalent in 1990 and 0.20 kg CO₂-equivalent in 2011. This is a reduction of 94.8 per cent from 1990 to 2011. From 2010 to 2011, the PFC emissions per tonne aluminium produced were increased by 8.3 per cent.

An increase in production capacity is also included in the modernisation, leading to higher total emissions of CO₂. The implied emission factor for CO₂ is relatively stable.

PFCs and CO₂ emissions from aluminium production are both key category in level, PFC also in trend both according to the Tier 2 key category analysis.

Table 4.17. Shares of the technologies used in aluminum production and the PFC IEFs⁹

Year	% of production from Soederberg technology	% of production from pre-baked technology	PFC IEF Soderberg	PFC IEF pre-baked
1990	43 %	57 %	5.61	2.57
1991	43 %	57 %	5.29	1.98
1992	42 %	58 %	5.03	0.96
1993	43 %	57 %	5.08	0.77
1994	40 %	60 %	4.95	0.67
1995	39 %	61 %	5.05	0.67
1996	39 %	61 %	4.66	0.54
1997	40 %	60 %	3.61	0.59
1998	39 %	61 %	3.19	0.40
1999	39 %	61 %	2.99	0.35
2000	39 %	61 %	2.83	0.30
2001	38 %	62 %	2.79	0.35
2002	32 %	68 %	3.09	0.53
2003	23 %	77 %	1.77	0.47
2004	21 %	79 %	1.91	0.33
2005	20 %	80 %	2.01	0.24
2006	19 %	81 %	1.44	0.32
2007	17 %	83 %	1.57	0.40
2008	15 %	85 %	1.15	0.46
2009	8 %	92 %	0.18	0.35
2010	8 %	92 %	0.27	0.18
2011	8 %	92 %	0.29	0.19

Source: Climate and Pollution Agency

4.4.3.2 Methodological issues

CO₂

The inventory uses the emission figures reported to Klif, 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 CO₂-emissions from consumption data provided by the enterprises but now figures reported by the plants to Klif 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 CO₂ emissions separate for each technology. The following methods are used:

⁹ kg PFC in CO₂-equivalents per tonne aluminium

CO₂ from Prebake Cells

$$(4.9) \quad Q = A \cdot C \cdot 3.67$$

Where

Q is the total yearly emissions of CO₂

A is the yearly net consumption of anodes

C is per cent carbon in the anodes

3,67 is the mol-factor CO₂/C

CO₂ from Soederberg Cells

$$(4.10) \quad Q = S \cdot 3.67 \cdot (K \cdot C1 + P \cdot C2)$$

Where

Q is the total yearly emissions of CO₂

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 (CF₄) and hexafluoroethane (C₂F₆), 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 (CF₄) and heksafluorethane (C₂F₆), may be produced in the following reaction:

Reaction 1



Reaction 2



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 4.18, given as kg CF₄/tonne Al/anode effect minutes per cell day, 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:

$$\text{kg CF}_4 \text{ per year} = S_{\text{CF}_4} \cdot \text{AEM} \cdot \text{MP}$$

and

$$\text{kg C}_2\text{F}_6 \text{ per year} = \text{kg CF}_4 \text{ per year} \cdot F_{\text{C}_2\text{F}_6/\text{CF}_4}$$

Where :

S_{CF_4} = “Slope coefficient” for CF₄, (kg PFC/t_{Al}/anode effect minutes/cell day

AEM = anode effect minutes per cell day

MP = aluminium production, tonnes Al per year

$F_{\text{C}_2\text{F}_6/\text{CF}_4}$ = weight fraction of C₂F₆/CF₄

Table 4.18. 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/cell day)		Weight fraction C ₂ F ₆ /CF ₄	
	S_{CF_4}	Uncertainty (±%)	$F_{\text{C}_2\text{F}_6/\text{CF}_4}$	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 Klif.

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 IX. The plant reports as required by the voluntary agreement. Klif's inventory team tracks emissions and AD for the plants.

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 Klif contacts the plant to discuss the reported data and changes are made if necessary.

Klif has annual meetings with the aluminium industry where all plants are represented. This forum is used for discussion of uncertainties and improvement possibilities.

Klif'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.

The emission figures reported by the plants are also occasionally 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.

4.4.3.7 Recalculations

There has been no recalculation since NIR 2012.

4.4.3.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.4.4 Production of Secondary Aluminium – 2C4

4.4.4.1 Description

One open mill in Norway has handled secondary aluminium production, but it closed down in 2001. Minor emissions of SF₆ in the period 1992-2000 are therefore included in the inventory.

4.4.5 Production of magnesium –SF₆ – 2C4 (Key Category)

4.4.5.1 Description

There was previously one plant in Norway producing magnesium. The plant closed down the production of primary magnesium in 2002 and the production of cast magnesium was closed down in 2006. 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 CO₂ and CO emissions. During the calcinations of Dolomite (MgCa(CO₃)₂) to magnesium oxide, CO₂ is emitted. This is reported under category 2C5. During the next step, magnesium oxide is chlorinated to magnesium chloride and coke is added to bind the oxygen as CO and CO₂. SO₂ is emitted due to the sulphur in the reducing agent used.

In the foundry, producing cast magnesium, SF₆ is used as a cover gas to prevent oxidation of magnesium. The Norwegian producers of cast magnesium has assessed whether SF₆ used as 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 SF₆ used as cover gas is emitted to the air.

The SF₆ emissions from magnesium foundries accounted for about 2.1 million tonnes CO₂-equivalents in 1990, this is 4.3 per cent of the national total GHG emissions. The emissions decreased 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 CO₂ emissions from processes. During 2006 also the production of remelting Mg stopped and since then there were no emissions from this source.

SF₆ 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

CO₂

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 CO₂ emissions are therefore calculated by using annually production volume and the emission factor recommended by (SINTEF 1998f).

SF₆

The consumption figures of the cover gas (SF₆) are used as the emission estimates in accordance with the IPCC Guidelines (IPCC 1997a, 1997b). The SF₆ emissions are reported annually to Klif.

Studies performed by the Norwegian producer have assessed that SF₆ used as cover gas is inert. Therefore the consumption of SF₆ is used as the emission estimate in accordance with the IPCC Inventory Guidelines and Good Practice Guidance. The plant reports the emissions each year to Klif.

4.4.5.3 Activity data

In the GHG emission inventory we have used production volumes as activity data in the calculation of CO₂. This method is recommended by (SINTEF 1998f). The plant reported the consumption of SF₆ to Klif.

4.4.5.4 Emission factor

An emission factor of 4.07 tonnes CO₂/tonnes produced magnesium is used to calculate the annual emissions of CO₂ (SINTEF 1998f).

4.4.5.5 Uncertainties

The uncertainty estimates are given in Annex II.

4.4.5.6 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 to the 2010 NIR. The latest reported emission data from the plant were compared with previously reported data and the emissions were compared with the production.

4.4.5.7 Recalculations

There has been no recalculation since NIR 2008.

4.4.5.8 Planned improvements

Since the plant is closed down there is no further planned activity to review historical data.

4.4.6 Production of Nickel – 2C5

4.4.6.1 Description

One plant in Norway produces nickel. During the production of nickel CO₂ is emitted from the use of soda ash.

4.4.6.2 Methodological issues

CO₂

Emission figures are annually reported from the plant to the Klif.

4.4.6.3 Activity data

The activity data is the annual amounts of soda ash used in the production process

4.4.6.4 Emission factors

An emission factor of 0.415 tonnes CO₂/tonne soda ash is used for the calculations.

4.4.6.5 Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.4.6.6 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 IX. The plant reports as required by the voluntary agreement. Klif's inventory team tracks emissions and AD for the plant.

4.4.6.7 Recalculations

The reported CO₂ emissions for 1990 were previously erroneously omitted. This reported figure of 7 600 tonnes CO₂ has now been included in the inventory. The reported figures for the period 1991-1997 have been updated based on new reported figures to Klif. The changes vary between a 2 600 tonnes increase in 1994 and a 600 tonnes reduction in 1991.

4.4.6.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.4.7 Manufacture of Anodes – 2C5

4.4.7.1 Description

Four plants in Norway produce anodes. Three plants produce prebaked anodes and one plant produces coal electrodes. These 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 CO₂.

4.4.7.2 Methodological issues

The emissions of CO₂ from the production of anodes are calculated by each plant and the method is based on the Aluminium Sector Greenhouse Gas Protocol by the International Aluminium Institute (IAI 2005).

The fourth plant produces coal electrodes and Söderberg anodes for ferroalloy production. The emissions are calculated from the consumption of anthracite and petrol coke. In addition pitch is included in production. The calculations of CO₂ from processes are uptime in hours multiplied with EF for each feedstock. When calcinations of anthracite the EF are 167 kg CO₂ per uptime hour and for petrol coke the EF is 238 kg CO₂. In addition there is an emission from energy use that is reported in Energy sector.

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 IX. The plant reports as required by the voluntary agreement. Klif's inventory team tracks emissions and AD for the plants.

4.4.7.5 Recalculations

There has been no recalculation since NIR 2010.

4.4.7.6 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.5 Other Production – 2D

4.5.1 Pulp and paper – 2D1

4.5.1.1 Description

There are CO₂ emissions from non-combustion from two plants in this sector and they are covered by the EU ETS. The emissions originate from the use of limestone. Emissions from combustion are included in Chapter 3.

4.5.1.2 Methodological issues

The CO₂ emissions are calculated by multiplying the amount of limestone by an emission factor. For the years 1990-97 the emissions are calculated by Klif based upon activity data reported to Klif by the plants and emission factor. The emissions in the period 1998-2004 are reported in the plants' application for CO₂-permits within the Norwegian emissions trading scheme. From 2005 and onwards, the plants report the emissions through the annual reporting under the emissions trading scheme.

4.5.1.3 Activity data

Activity data is reported by the plants to Klif. The amount of limestone is calculated from purchased amount, adjusted for the amount of limestone in storage in the beginning and end of the year.

4.5.1.4 Emission factors

The emission factor used in the calculation is 0.44 tonne CO₂ per tonne limestone.

4.5.1.5 Uncertainties

Uncertainty estimates are given in Annex II.

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 IX. The plants are covered by the EU ETS and their emissions are verified annually. Klif's inventory team tracks emissions and AD for the plants.

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 2014.

4.5.2 Food and drink – CO₂ – 2D2

4.5.2.1 Description

This source category includes NMVOC emissions from production of bread and beer, CO₂ from carbonic acid mainly used in breweries, export of captured CO₂ and CO₂ from production of bio protein.

As mentioned in Section 4.3.1 Ammonia Production, some CO₂ from this production is captured and in Norway mainly used as carbonic acid in carbonated beverages but most of the captured CO₂ 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 2011, about 170 ktonnes CO₂ were sold for national use and export.

4.5.2.2 Methodological issues

CO₂

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 CO₂

One plant produced bio protein in the years 2001-2005. Natural gas was used to feed the bacteria cultures that produced the bio protein and this was used as animal fodder. The plant reported emissions of about 2 000 – 11 000 tonnes CO₂ and these 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.

Production of Bio Protein CO₂

The activity data is the amount of natural gas used in the process.

4.5.2.4 Emission factors

NMVOC

The emission factors in Table 4.19 are taken from (EEA 1996).

Table 4.19. 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 are recommended by EEA (1996) and not specific for Norwegian conditions.

CO₂

See the uncertainty in the activity data for the ammonia plant (2B1) in Annex II.

4.5.2.6 Source specific QA/QC and verification

NMVOC and CO₂

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 IX. The plant reports as required by the voluntary agreement.

4.5.2.7 Recalculations

The activity data for calculation of CO₂ from carbonic acid in 2010 has been altered. Previously used 2009 figures are replaced by actual 2010 figures and results in 25 200 more CO₂ in 2010.

4.5.2.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.6 Consumption of Halocarbons and SF₆

4.6.1 HFCs and PFCs from Products and Processes – HFC – 2F (Key Category)

4.6.1.1 Description

HFCs and PFCs are mainly 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 is no production of HFCs and PFCs in Norway. However, PFCs are emitted as a by-product during the production of aluminium, see chapter 4.4.3.1. HFCs and PFCs registered for use in Norway are HFC-23, HFC-32, HFK-125, HFC-134, HFC-134a, HFC-143, HFC-143a, HFC-152a, HFC-227ea and PFC-218. The most significant gases, measured in CO₂ equivalents are HFC-134a, HFC-143a and HFC-125. Due to, i.e., high taxation, the use of PFCs in product-applications has been very low and no emissions are reported for the last three years. The PFC-218 has been used as a commercial cooling agent.

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. The tax and refund are both around 230 NOK (approximately 30 Euro) per tonnes of CO₂-equivalents. In May 2010, EU regulation (EC) No 842/2006 on certain fluorinated greenhouse gases was included in Norwegian legislation..

The GHG emissions from this source category were 0.95 million tonnes CO₂-equivalents in 2011 and accounted for 1.8 per cent of the national total GHG emissions and for 12.4 per cent of the emissions from the Industrial sector in 2011. The emissions have increased from a low level in 1990 and increased by 2.1 per cent from 2010 to 2011.

Recalculations (see later) mean that the misallocation of emissions within commercial and industrial refrigeration reflected in the ARR11 (\$60) has been corrected. The error in the PLFs for HFC-134 and C3F8 reflected in the ARR11 (\$61) has also been corrected.

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 and its maintenance.

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. The ratio between potential (Tier 1b) and actual emissions (Tier 2) has decreased from about 4:1 in the year 1999 to less than 2:1 in 2011.

4.6.1.3 Activity data

There is no production of HFC or PFC in Norway. Hence all emissions of these chemicals originate from chemicals imported in bulk or in products. The methodology requires that annual imported amounts of each chemical are obtained by source category. Various data sources are used:

Amounts of chemicals imported in bulk were up to 2009 obtained from the Norwegian Climate and Pollution Agency. After 2009 bulk data are collected from the Norwegian Directorate of Customs and Excise.

Time series for imported and exported amounts of chemicals in products are based on collected data for some years and data prior to and between these years are estimated. For the years 1995-1997 data were collected through a survey performed in 1999 (SFT 1999a), Data on imports from customs statistics were collected for the years 2005-2006 and 2010-2011. They will be collected annually after 2011.

4.6.1.4 Emission factors

Leakage rates and product lifetimes used in the calculations are shown in Table 4.20.

In the ARR11 (\$59), the ERT recommended that Norway should provide a justification for the 3.5 per cent factor for imported refrigeration equipment. The emission factor of 3.5 per cent is applied to estimate emissions of fluorinated substances in the operating phase (equipment in use) from imported commercial refrigeration equipment. This application category consists of stand-alone units, like moveable refrigerators and freezers typically used for keeping beverages and ice cream cold in supermarkets, office buildings, schools etc. The IPCC 1996 Guidelines recommends the application of an emission factor between 1 and 10 per cent for this application category, and between 0.1 and 0.5 per cent for domestic refrigeration. Because the units imported to Norway are similar to the refrigerators and freezers for domestic use, an emission factor in the lower end of IPCCs recommendation is believed to best reflect the actual emissions. Larger commercial refrigeration equipment is normally built and filled with fluorinated substances on site, and is not included in the above mentioned application category.

National Inventory Report 2013 - Norway

Table 4.20. Emission factors for HFCs from products and lifetime of products

Source category	Lifetime (years)	Production/initial emission (per cent of initial charge)	Lifetime emission (per cent of initial charge/year)
Refrigeration			
Domestic Refrigeration	15 ¹	NO	0,5 ¹
Commercial Refrigeration			
Stand-alone Commercial Applications	10 ¹	NO	3,5 ¹
Medium and Large Commercial Refrigeration	15 ¹	2 ¹	10 ¹
Transport Refrigeration	9 ¹	1 ¹	20 ¹
Industrial Refrigeration	15 ¹	2 ¹	10 ¹
Residential and Commercial A/C, including heat pumps	15 ¹	1 ¹	4 ¹
Mobile Air-Conditioning	12 ¹	NO	NA
Foam			
Hard Foam	20 ¹	5 ¹	4,5 ¹
Soft Foam	NO	NO	NO
Fire protection	15 ¹	2 ²	5 ¹
Aerosols			
Metered Dose Inhalers	2 ¹	NO	50 ¹
Other aerosols	2 ¹	NO	50 ¹
Solvents	2 ¹	NO	50 ¹

¹IPCC 1996

²Country specific SFT 99:03

In the ARR11 (\$60), the ERT recommended that Norway should include in the NIR information on the relative share of imported products for the refrigeration subcategories, which explains the difference between some low PLF values reported in the NIR and the higher values reported in CRF table 2(II).F. Emissions of fluorinated substances from commercial refrigeration are estimated on a more detailed level than what is reported in the CRF. The reasoning behind this is that the life cycle and emission pattern of small, sealed units (stand-alone commercial applications) are different from the larger commercial applications. The smaller units are assumed to have lower leakage rates (emission factors) and are typically retired from use after fewer years than larger equipment. There is no domestic production of the smaller units in Norway, whereas the larger equipment is typically built on

site. In order to provide better transparency, table 4.21 provides information on the relative share of emissions from the two categories.

Table 4.21. Relative share of emissions of HFCs from commercial refrigeration applications, imported and domestically produced products.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Share imported	0.0	0.0	0.0	10.8	6.7	2.9	3.0	3.1	3.3	3.2	3.2
Share made in Norway	100.0	100.0	100.0	89.2	93.3	97.1	97.0	96.9	96.7	96.8	96.8
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Share imported	3.0	2.9	4.3	3.9	4.2	5.3	7.7	9.0	10.3	8.0	10.0
Share made in Norway	97.0	97.1	95.7	96.1	95.8	94.7	92.3	91.0	89.7	92.0	90.0

Source: Statistics Norway

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

In addition to the general QA/QC procedures (see section 1.6), the consistency of time series are checked for both activity data and emissions. The time series are checked for each individual HFC/PFC and application category.

4.6.1.7 Recalculations

The emission estimates of HFCs and PFCs from product use has undergone a major revision. Most importantly, the activity data has been updated to improve accuracy. Old projections of imports of chemicals in products have been replaced by new calculations based on annual data collected from the Norwegian Directorate of Customs and Excise. Some of the emission factors have also been updated in order to be better in line with the recommendations in the IPCC 1996 Guidelines.

In addition, the calculation model set up in 1998 has been upgraded in several ways. In order to improve transparency and provide adequate data, changes have been made to the application categories used in the calculations, and activity data and data on emissions from disposal are now available. Disposal data used to be reported as a part of operating stocks and was therefore not in line with reporting requirements. A slight overestimation of emissions has been removed by the incorporation of data on destruction of used gas and by removing the requirement set by the model that a gas has to be imported every subsequent year after it was first imported. The production process, i.e. the data flow from input to output has been streamlined, both for the dissemination of statistics and for reporting under the UNFCCC.

As a consequence of updated activity data, emission factors (including life times), and the application of a new calculation model, the estimated emissions increased by nearly 168 000 tonnes CO₂ equivalents (up 22 per cent) in 2010. Table 4.22 gives an overview of the changes in emissions for all years, both in tonnes and per cent. The table shows that HFC-134a, HFC-125 and HFC-143a are the chemicals primarily affected.

According to the new calculations, the total emissions have been underestimated for all years in the previous calculations. This is mainly due to changes made in the calculation methodology and emission factors (i.e. reduced life time for some products) resulting in emissions occurring earlier in time. New activity data have pulled in the opposite direction, as the imports of chemicals in general are lower in the current estimate.

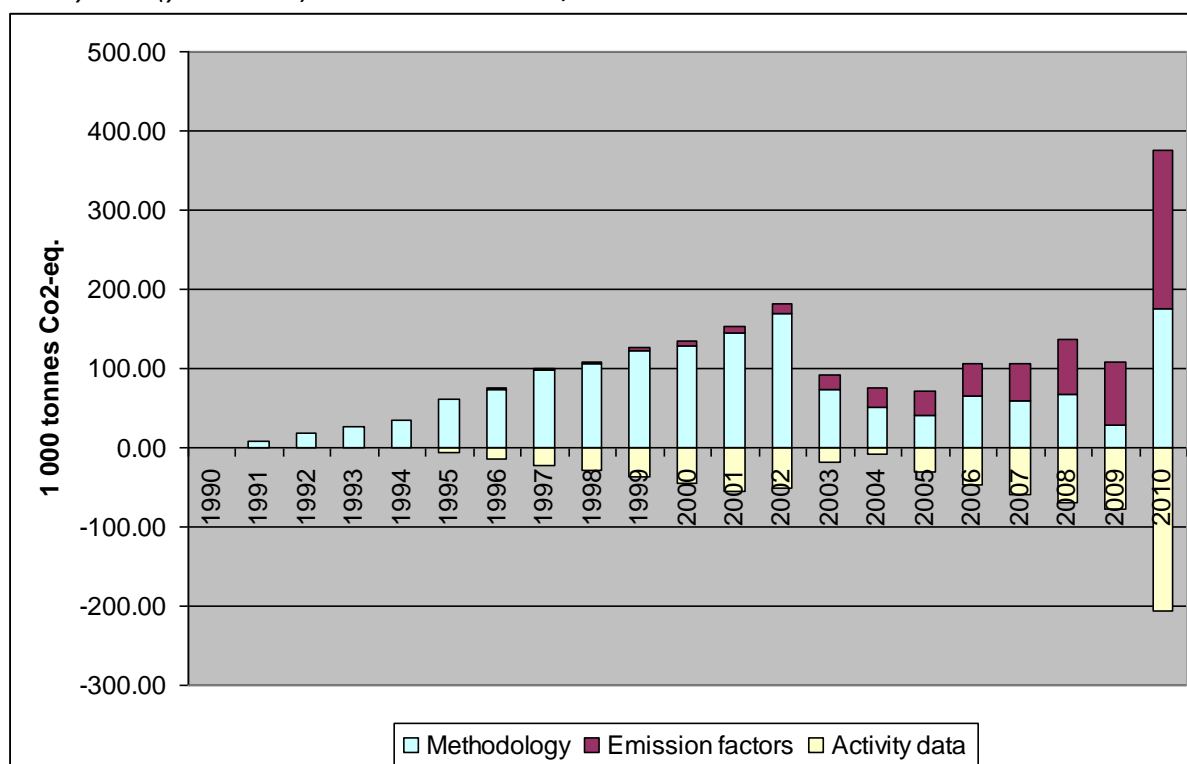
Table 4.22. Difference in emissions after recalculations (current minus previous estimate)

Year	Total (ktonnes CO ₂ -eq)	HFC-23 (tonnes)	HFC-32 (tonnes)	HFC-125 (tonnes)	HFC-134 (tonnes)	HFC- 134a (tonnes)	HFC-143 (tonnes)	HFC- 143a (tonnes)	HFC- 152a (tonnes)	HFC- 227ea (tonnes)	PFC-218 (tonnes)
1990	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00
1991	9.01	0.00	0.03	0.04	0.00	6.72	0.00	0.00	0.21	0.00	0.00
1992	18.12	0.00	0.10	0.10	0.00	13.39	0.00	0.00	0.19	0.00	0.00
1993	26.45	0.00	0.18	0.19	0.00	19.51	0.00	0.00	0.03	0.00	0.00
1994	35.19	0.00	0.29	0.96	0.00	23.44	0.00	0.43	0.04	0.00	0.00
1995	54.35	0.00	0.42	2.82	0.00	28.18	0.00	2.54	0.29	0.00	0.03
1996	60.24	0.01	0.57	3.54	0.00	29.54	0.00	2.91	-0.03	0.06	0.05
1997	77.86	0.03	0.62	5.80	0.00	32.75	0.00	4.85	1.02	0.05	0.04
1998	79.86	0.00	0.74	5.81	0.00	34.40	0.00	4.88	0.51	0.01	0.04
1999	89.89	0.00	0.83	7.20	0.00	31.97	0.00	7.48	-2.10	0.00	0.03
2000	89.45	0.00	0.96	8.64	0.00	25.93	0.00	8.21	-4.17	0.00	0.03
2001	99.21	0.00	1.11	10.68	0.00	20.82	0.00	11.11	-5.79	0.15	0.03
2002	128.94	0.00	1.08	15.60	0.00	20.75	0.00	14.86	-8.69	0.92	0.02
2003	72.31	-0.03	1.16	9.21	0.00	10.38	0.00	8.89	-12.06	0.23	0.02
2004	68.73	-0.05	1.22	9.75	1.03	1.17	0.00	10.09	-3.95	0.15	0.02
2005	42.23	0.03	1.50	9.20	0.75	-9.86	0.70	7.27	-1.12	-0.09	0.01
2006	59.64	0.00	2.53	12.97	0.67	-9.93	0.65	9.22	-4.58	-0.32	0.00
2007	47.29	-0.02	3.54	11.55	0.59	-8.49	-0.14	6.22	0.85	-0.13	0.00
2008	68.13	-0.05	4.79	13.60	2.66	-8.51	-0.29	9.94	-3.12	-0.44	0.00
2009	28.65	-0.06	7.22	16.59	2.07	-36.49	-0.45	6.77	-4.14	-0.40	-0.01
2010	167.62	-0.04	10.33	34.07	1.85	-20.30	-0.60	24.67	-3.31	-0.76	-0.01

Source: Statistics Norway

Figure 4.7 shows the influence on total emissions for each year, by the changes made in methodology (blue bars), emission factors (red bars) and activity data (yellow bars). The figure illustrates that in the beginning of the time series, changes in methodology was responsible for almost 100 per cent of the emission changes in the recalculations. Towards the end of the time series, the three groups of changes are equally important – each causing a change in emissions of about 1/3 of the total change. This means that if only activity data was updated in 2010, the emissions would have been about 207 000 tonnes CO₂ equivalents lower than the previous estimate of 747 000 tonnes. If only emission factors were updated, the emissions would have been about 199 000 tonnes CO₂ equivalents higher than the previous estimates. And equally, if only the methodology had been changed, the emissions would have been about 176 000 tonnes CO₂ equivalents higher than the previous estimates. The net increase in the emissions after performing all three changes was therefore 168 000 tonnes CO₂ equivalents.

Figure 4.7. The influence of change in methodology (blue bars), emission factors (red bars) and activity data (yellow bars) on the recalculations/emission estimates



Source: Statistics Norway

Methodological changes

Accumulated over time, it is the change in methodology that is responsible for the largest share of changes in the recalculation of emissions. An important methodological change is that the *new* model bases the emission estimates on the original amount of chemical filled in to a product. The emission factors are applied to the amount of chemical a product initially contained, even if some of the chemical have leaked out over time. This is in line with the recommendations of the IPCC 1996 Guidelines. The old model applied the emission factors to the amount stored in the products at any given time. For products not being refilled, like household refrigeration and foam products, this will cause the chemicals to be released at a higher pace. It is important to note that this will not lead to a change in the accumulated amount of chemicals emitted over time, but it leads to the emissions occurring earlier in time. For one product group, i.e. mobile air conditioning, the emissions are no longer calculated based on emission factors. A mass balance approach is used, as the emissions are equal to imports of chemicals for refilling. This has also caused the emissions to increase. Of less importance is the fact that the new model takes amounts of destructed chemicals into account. This has slightly lowered the emissions.

Changes in emission factors, including life time

The changes in emission factors have also contributed to higher emissions, but this has mainly had an effect on later years. A reduction in life time for some products has lead emissions to occur earlier in time than what was estimated in the previous model. For some products the emission factors are higher, for some they are lower. These changes will have opposed effects on the emissions. See table 4.23 with new and old emission factors and life times. The effects are accounted for in the red bars in figure 4.7.

Table 4.23 Emission factors used before and after recalculations. Old values shown in bold

Application category	Leakage rates for production of new equipment. Per cent of initial charge	Leakage rates for operating equipment. Per cent of initial charge/year	Lifetime (years)
	New Old	New Old	New Old
Refrigeration			
Domestic Refrigeration	Not occurring	0,5 1	15
Commercial Refrigeration			
Stand-alone Commercial Applications	Not occurring	3,5	10 15
Medium and Large Commercial Refrigeration	2	10	15
Transport Refrigeration	1 2	20	9 15
Industrial Refrigeration	2	10	15
Residential and Commercial A/C, including heat pumps	1 2	4	15
Mobile Air-Conditioning	Not occurring	Not applicable ² 10	12
Foam	5	4,5 and 3 1	20 30/40
Fire protection	2 ¹	5	15
Aerosols			
Metered Dose Inhalers	Not occurring	50	2
Other aerosols	Not occurring	50	2
Solvents	Not occurring	50	2

¹Country specific SFT 99:03²A mass balance approach is used to estimate emissions from mobile air conditioning

Activity data

The yellow bars in figure 4.7 show the effect of updating the activity data. This has overall lead to a decrease in emission figures. The updating of activity data results in a decrease in net consumption caused by lower total imports for the whole period 1990-2010 for HFC-134a and HFC-152a, and less importantly of HFC-143a and HFC-125. Net consumption increased for the other chemicals. As projections based on data collected in mid 90ties were replaced by annual import statistics, the current activity data is believed to be of much higher quality. Projections seem to have been too high especially for imports of chemicals in hard foam products and too low for imports in stationary air conditioning.

4.6.1.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.6.2 Emissions of SF₆ from Products and Processes – 2F

4.6.2.1 Description

SF₆ is used as an insulation medium in high tension electrical equipment including gas insulated switchgear (GIS) and circuit breakers (IPCC 1996 GL). There is no production of SF₆ in Norway. In March 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 producer (one factory) report yearly to the government. This voluntary agreement terminated successfully in 2010, but a continuation is being discussed.

4.6.2.2 Methodological issues

The general methodology for estimating SF₆ emissions was revised in 1999 (SFT 1999d), while the sector specific methodology for GIS has been revised in the 2010 reporting based on new information from the agreement. The current method for GIS is largely in accordance with the Tier 3a methodology in the IPCC Good Practice Guidance (IPCC 2000).

The method for other sources is described in SFT (1999d) and is largely in accordance with the Tier 2 methodology in the IPPC guidelines for emission inventories (IPCC 1997a,b). For tracer gas, production of semiconductors, medical use, and other minor uses, the activity data are annual consumption as estimated in the SFT (1999d) report. However, for tracer gas some major research projects expired in 2001 and 2006, respectively, and the consumption has been reduced. For sound-insulating windows and footwear, the emissions are calculated from estimated stock of SF₆ in the products, and from production of windows. Footwear with SF₆ was imported, and the use ended in 2001. Activity data are annual additions of SF₆ to the product stock, as estimated in the SFT (1999d) report.

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 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 SF₆. 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 SF₆ 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 4.23. Activity data

Data is collected from direct consultations with importers and exporters of bulk chemicals and products containing SF₆, and from companies that use SF₆ in various processes.

4.6.2.3 Emission factors

Leakage rates and product lifetimes used in the calculations are shown in Tables 4.24 and 4.25.

Table 4.24. Yearly rate of leakage of SF₆ 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 4.25. Product lifetimes and leakage rates from products containing SF₆

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).

4.6.2.4 Uncertainties

An uncertainty estimate is given in Annex II. The uncertainty of 60% is an expert judgement from Statistics Norway (2000).

4.6.2.5 Source specific QA/QC and verification

The current methodology was established in SFT (1999d), with emissions from GIS calculated from stock data estimates and leakage factors. It was revised in 2004 when data from the voluntary agreement on GIS became available, with emissions estimated from reported data on refilling (Statistics Norway 2007b).

4.6.2.6 Recalculations

Based on new reporting from one company, the emissions for 2010 were slightly changed, they increased by 0.3 per cent.

4.6.2.7 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

4.7 Paraffin wax use – 2G

4.7.1 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 CO₂.

Emissions from the incineration of products containing paraffin wax, such as wax coated boxes, are covered by emissions estimates from waste incineration.

4.7.2 Methodological issues

Emissions of CO₂ 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:

$$(4.11) \text{ Emissions} = PC * PF * CC_{\text{Wax}} * 44/12$$

Where:

- Emissions = CO₂ emissions from waxes, tonne CO₂
- 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 CO₂/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 CO₂ emissions, using the mass ratio of CO₂/C.

4.7.3 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 these data, net consumption of paraffin waxes and other candle waxes (including stearin) can be calculated.

4.7.4 Emission factors

Parameter values used in the emissions calculations are given in Table 4.26.

Table 4.26. 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.

4.7.5 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.

4.7.6 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.

4.7.7 Recalculations

Due to confidentiality problems, the sales figures for 2008-2010 have been replaced by interpolated figures. This has caused a decrease in CO_2 emissions from this source by 151, 426 and 528 tonnes for 2008, 2009 and 2010, respectively.

4.7.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

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 CO₂.

In addition to solvents emitting NMVOC, there are other products that emit other volatile components. Emissions of N₂O from anesthesia procedures and spray cans are included in the Norwegian inventory.

In 2011, the total emissions from solvents and other product use totaled 0,180 million tonnes of CO₂-equivalents. This represented 0.3 per cent of the total GHG emissions in 2011. The emissions have decreased by 5.6 % compared to 1990 and have increased by 5.7 % from 2010 to 2011.

5.2 Solvent losses (NMVOC) – 3A, 3B, 3C, 3D

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 CO₂, which is included in the total greenhouse gas emissions reported to UNFCCC. As explained in chapter 3.6.2, the indirect CO₂ emissions from oxidized CH₄ and NMVOC are calculated from the content of fossil carbon in the compounds. The EFs used are 2.74 kg CO₂/kg CH₄ and 3 kg CO₂/kg NMVOC.

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 Climate and Pollution Agency 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 Guidelines¹⁰. 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 Climate and Pollution Agency 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 CO₂

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 CO₂, which is included in the total greenhouse gas emissions reported to UNFCCC.

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 2003b), 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 Climate and Pollution Agency 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

¹⁰ "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."

used as raw materials in this sector are excluded from the emission estimates from the Product Register data.

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 Recalculations

3 A 1 and 3 A 3

A correction of error (missing industry code) resulted in 1 tonne NMVOC being reallocated from 3A3 to 3A1 in 2010. This has increased the emissions of indirect CO₂ emissions in 3A1 and a corresponding decrease in 3A3.

3 D 2 Domestic solvent use

Revised sales figures for cosmetics give an increase in NMVOC and thereby increased indirect CO₂ emissions of 72, 60 and 1 526 tonnes in 2008, 2009 and 2010 respectively. In 2010 revised sales figures for cosmetics give increased emissions, while a correction of error (missing industry code) results in emission reduction (due to the use of a smaller emission factor). In sum, this results in an increase in emissions of 1 526 tonnes CO₂- equivalents.

3 D 3 Other product use

A correction of error (missing industry code) resulted in a reduction of 81 tonnes in the emissions of NMVOC and thereby decreased indirect CO₂ of 243 tonnes for 2010. The amount was assigned to an industry code that is given a small emission factor.

5.2.9 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

5.3 Other product use -3D

5.3.1 Use of N₂O in anaesthesia – 3D1

5.3.1.1 Method

N₂O is used in anaesthesia procedures and will lead to emissions of N₂O. The figures are based on N₂O 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 N₂O is used for the year 2000. Number of births and bednights 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 N₂O.

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 N₂O 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 Recalculations

There has been no recalculation since NIR 2009.

5.3.1.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

5.3.2 Use of N₂O as propellant – 3D4

N₂O is used as a propellant in spray boxes and this use will lead to emissions of N₂O. 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 N₂O for these purposes in Norway.

5.3.2.1 Methodological issues

Information on sale volumes has been reported by the plants to Statistics Norway. Statistics Norway assumes that all propellant is released to air

5.3.2.2 Activity data

Information has been gathered from the plants indicating that there is no production or sale of N₂O for use as a propellant in Norway. The N₂O is already in the spray cans when imported. There was no import of these spray cans prior to 1993. Activity data for the year 2003 has been used for all years since.

For activity data on N₂O used in research work and in drag-racing, data on imported amounts in 2002 has been used for all years.

5.3.2.3 Uncertainty

The figures for one year are used for all years. It is believed that all figures from all major importers are included in the inventory.

5.3.2.4 Completeness

No major missing emission components are likely.

5.3.2.5 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.

5.3.2.6 Recalculations

There has been no recalculation since NIR 2009.

5.3.2.7 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2014.

6 Agriculture

6.1 Overview

About 8 per cent of the total Norwegian emissions of greenhouse gases (GHG) originated from agriculture in 2011¹¹. This corresponds to 4.5 million tonnes CO₂-eq. The emissions from agriculture are relatively stable with emissions in 2011 about 11 percent lower than in 1990¹², but about 0.6 percent higher than in 2010¹³.

The sectors clearly biggest sources of GHG's were "enteric fermentation" (CH₄) from domestic animals¹⁴, contributing with 45 per cent and "agricultural soils" (N₂O) contributing with 45 percent of the sectors emissions. "Manure management" contributed with about 10 percent¹⁵. Agriculture contributes particularly to CH₄, N₂O and NH₃ emissions. Domestic animals are the major source of CH₄ emissions from agriculture. Both enteric fermentation and manure management contribute to process emissions of CH₄. Manure management also generates emissions of N₂O.

Microbiological processes in soil lead to emissions of N₂O. Three sources of N₂O are distinguished in the IPCC methodology and are included in the Norwegian inventory:

1. direct emissions from agricultural soils (from use of synthetic fertilisers, animal excreta nitrogen used as fertiliser, biological nitrogen fixation, crop residues, industrial and urban wastes (sewage sludge) and cultivation of soils with a high organic content)
2. direct soil emissions from animal production (emissions from droppings on pastures)
3. N₂O emissions indirectly induced by agricultural activities (N losses by volatilisation, leaching and runoff).

There are also some emissions of the greenhouse gases N₂O and CH₄ arising from the burning of crop residues on the fields.

Animal manure and the use of fertiliser (manure, synthetic fertiliser and sewage sludge) also generate emissions of ammonia (NH₃). As indicated in Section 1.5, , the Tier 2 key category analysis performed in 2013 for the years 1990 and 2011 has revealed that in terms of total level and/or trend uncertainty the *key categories* in the Agricultural sector for 1990 and/or 2011 are the following:

- Enteric fermentation – CH₄ (4A)
- Direct soil emissions – N₂O (4D1)
- Animal production - N₂O (4D2)
- Indirect emissions - N₂O (4D3)
- Manure management – CH₄¹⁶ and N₂O (4B)

¹¹ 4484.53 ktonnes CO₂-eq

¹² 5012.63 ktonnes CO₂-eq

¹³ 4456.49 ktonnes CO₂-eq

¹⁴ 2023.10 ktonnes CO₂-eq

¹⁵ 460.31 ktonnes CO₂-eq

¹⁶ Key category only in Tier 1 key category analysis.

6.2 Emissions from enteric fermentation in domestic livestock 4A– CH₄ (Key Category)

6.2.1 Description

An important end product from the ruminal fermentation is methane (CH₄). The amount of CH₄ 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, 2000) the method for estimating CH₄ emission from enteric fermentation requires three basic items:

- The livestock population must be divided into animal subgroups, which describe animal type and production level.
- Estimate the emission factors for each subgroup in terms of kilograms of CH₄ per animal per year.
- 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 5.05 % to uncertainty in level and 2.62 % to uncertainty in trend.

Enteric fermentation contributed with 223.10 ktonnes CO₂ equivalents in 2011, which is 3.8 per cent of the national GHG emissions. Enteric fermentation constituted 87 per cent of the overall CH₄ emissions from agriculture and 45 percent of this sector GHG emission. Emissions have been rather stable with minor fluctuations. Emissions decreased by 130 percent in the period 1990-2011 and by 2 percent in 2010-2011.

6.2.2 Methodological issues

A Tier 2 methodology is used for calculating CH₄ from enteric fermentation for the main emission sources cattle and sheep. The Tier 2 methodology used is described more in detail in Annex X. The methodology for calculating CH₄ from enteric fermentation for the other animal categories is in accordance with IPCC's Good Practice Guidance Tier 1 method (IPCC 1997b, a). The numbers of animals of each kind and average emission factors of tonnes CH₄/animal/ year for each kind of animals are used to calculate the emissions.

6.2.3 Activity data

The main sources of the livestock statistics are the register of production subsidies (sheep, goats, pigs, poultry and beef cows), statistics of approved carcasses (bulls and finisher heifers) and the Cow Recording System at TINE BA¹⁷ (dairy cows). These sources cover 90-100 per cent of the animal populations. The registers are updated annually and the time series of data are consistent. In addition to the animals included in these registers, 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, pers. Comm., Expert Judgement by Department of Animal Science, Norwegian

¹⁷ TINE BA is the sales and marketing organisation for Norway's dairy cooperative and covers most of the milk production and the meat production induced by milk production).

University of Life Sciences, Ås 2001). The formula for calculating the average figure for lambs will then be:

$$(6.1) \quad \text{Lambs} * \frac{143}{365}$$

The Tier 2 method of calculation which is implemented for cattle and sheep 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.

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
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- Dec

For dairy cows, additional information from the Cow Recording System concerning annual milk production and proportion of concentrate in the diet is used (Tine BA *annually*). The Cow Recording System also supplies annual information about slaughter age for heifers and bulls (Moen, *pers. comm.*¹⁸). Average daily weight gain (ADG), which is utilized in the calculations for growing cattle, was in 2005 taken from the Cow Recording System when the Tier 2 model was developed.

For heifers and bulls for slaughter, animal numbers are based on data from statistics of approved carcasses which provide data on numbers slaughtered and slaughter weights. Combined with slaughter age from the Cow Recording System, this gives a precise estimation of animal life time for each animal slaughtered. One principal draw-back of this method for estimating animal population is that emissions in all stages of these animals' lives will be posted in the year of slaughter, even though the emissions of the early stages of the lives of these animals to a large extent took place in the previous year. In a steady population of animals, this error is automatically adjusted, and since animal populations are relatively stable, this error is considered much smaller compared to errors in connection with estimating animal year based on animal populations in the register of production subsidies which was

¹⁸ Moen, O. (*annually*): Personal information, email from Oddvar Moen Tine Rådgivning annually.

previously used (see table 6.2). The new data sources also ensure a better coherence between animal numbers, life time and weight.

The number of heifers bred for new milking cows is estimated correspondent to the method used for heifers and bulls for slaughter. The data source is the Cow Recording System, which provide data on the number, age and live weight of the young cows' at their first calving.

Table 6.2. Estimated animal years for cattle

	Heifer for replacement	Heifers for slaughter	Bulls for slaughter	Beef cows¹	Dairy cows
1990	290 958	47 020	289 945	8 193	325 896
1991	287 552	46 839	289 637	9 502	321 722
1992	286 972	48 711	300 402	11 949	320 442
1993	283 509	48 172	293 055	13 838	316 054
1994	278 963	48 701	292 839	17 331	310 034
1995	279 922	47 103	284 237	20 334	310 346
1996	283 987	47 520	286 633	23 186	314 199
1997	278 657	46 443	293 941	27 446	307 099
1998	274 848	49 325	301 152	30 889	301 923
1999	278 271	56 717	320 420	34 846	304 769
2000	262 327	63 512	285 349	42 324	284 880
2001	257 332	65 843	267 167	45 317	278 482
2002	259 904	63 919	273 243	45 831	272 296
2003	256 911	60 391	274 314	48 727	270 270
2004	254 146	58 846	270 546	50 605	263 422
2005	254 878	57 619	268 145	54 841	255 663
2006	245 758	58 446	264 751	55 706	250 903
2007	235 282	56 607	254 452	57 609	246 624
2008	229 847	54 831	244 243	60 401	238 550
2009	208 613	53 397	242 854	63 803	210 554
2010	208 634	53 410	237 354	67 110	209 094
2011	205 404	48 778	231 191	68 539	201 165

¹ Counted animals

Source: Cow Recording System at TINE BA (dairy cows) and estimations by Statistics Norway

There are some differences between these numbers and the FAO statistics. The explanation is that the figures reported 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 is used to calculate the CH₄ emission factor for the subgroups (Tier 2):

$$(6.2) \quad EF = (GE \cdot Y_m \cdot 365 \text{ days/yr}) / 55.65 \text{ MJ/kg CH}_4$$

Where:

EF = emission factor, kg CH₄/head/yr

GE = gross energy intake, MJ/head/day

Y_m = CH₄ conversion rate, which is the fraction of gross energy in feed converted to CH₄.

M = animal category

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 around 540 days, varying from year to year). Further description of the determination of the variables GE and Y_m for the different animal categories and the values used in the calculations are given in Annex X.

The emissions from domestic reindeer, deer, ostrich and fur-bearing animals are also included in the Norwegian calculations. For reindeer the emission factor 14.0 kg/animal/year is used and for deer 20.0 kg/animal/year. Both factors are expert judgments from the University of Life Sciences (Karlengen et al. 2012) and have been estimated based on the methodology described for cervidae in IPCC (2006). Danish emission factors are used for goat, and ostrich since they are considered to reflect Norwegian feed intake and circumstances (Karlengen 2012). Emission factor for fur-bearing animals has been developed by scaling emission factor for pigs that are assumed most similar with regard to digestive system and feeding. The scaling is done by comparing average weights for fur-bearing animals and pigs and the factor is set to 0.01 kg/animal/year.

For the other animal categories the Tier 1 default emission factors for each kind of animal (IPCC 1997b) is used. The factors used are shown in table 6.3.

Table 6.3 Emission factors for CH₄ from enteric fermentation and different animal types estimated with the Tier 1 method

Animal	Emission factor (Tonnes/animal/year)
Horses	0.018
Goats	0.013
Pigs	0.0015
Hens	0.00002
Turkeys	0.00002
Reindeer	0.014
Deer	0.02
Ostrich	0.00002
Fur-bearing animals	0.0001

Source: IPCC (1997b)), Karlengen et al. (2012).

6.2.5 Uncertainties

Activity data

The data are considered to be known within ± 5 per cent. There is also uncertainty connected to the fact that some categories of animals are only alive part of the year and the estimation of how long this part is.

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 ± 40 per cent, which is the estimate from (IPCC 2006). An uncertainty estimate of ± 25 per cent is used for the emission factors for cattle and sheep in the Tier 2 methodology (Volden, pers. Comm.) Email from Harald Volden 27.1.06, the Norwegian University of Life Sciences).

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 improve the estimate of the exact number of animal populations. This was completed in 2002. In 2012, a further revision of the numbers of bulls and heifers was implemented (see section 6.2.3). The revised data on animal populations form the basis for the emission calculations for all years. In 2005-2006, Statistics Norway and the Climate and Pollution Agency 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.

In a project in 2012 at the Norwegian University of Life Sciences (UMB) comparisons was made of the emission factors used for calculating enteric methane for the different animal species in Norway with the corresponding factors used in Sweden, Denmark and Finland and with IPCC default factors (Karlengen et al. 2012).

6.2.8 Recalculations

Revision and harmonization of animal statistics used has increased the estimated annual CH₄ emissions from young cattle between 75 and 93 per cent in the period 1990-2010. Emissions from all cattle have increased between 16 and 29 per cent in the period. There has been an expert review of the emission factors used. The review was performed by the University of Life Sciences (Karlengen et al. 2012) and has resulted in updated emission factors for ostrich, deer, reindeer and goat.

CH₄ emissions from source 4A increased 8 400 tons (9.3 per cent) in total for the year 2010 due to the new calculations. The emissions from young cattle increased 13 600 tons. This was partly due to the use of a new data source for this group of animals and partly due to changes in how these data were combined with the emission factors. Changes in the number of beef cows caused a decrease of 4 000 tons. Changes in the emission factors for ostrich, deer, reindeer and goats (tier 1 estimations) together brought about a decrease of 1 200 tons CH₄. For the previous years in the time series 1990-2010, the total changes were bigger. The calculations for 1999 gave an increase of 18.6 per cent, which was the highest increase for

any year in the time series. More details of the revision of the animal numbers for cattle and the rationales behind the updated emission factors are given in Chapter 9.

6.2.9 Planned improvements

The IEF differs from the actual emission factors used in the Norwegian emission inventory because the number of animals used in the inventory and the number of animals reported in the CRF differs for some emissions and groups of animals. The reason for this is the following: Parts of the inventory (estimations of N₂O from manure (4B) and CH₄ from enteric fermentation from cattle (4A1 and 4A2) was improved and this required a new set of activity data (animal numbers). In the parts of the inventory that was not improved, the old set of animal data was maintained. This has resulted in different sets of animal data in the various estimations. In the CRF, only one set of animal numbers is reported. This inconsistency in animal numbers will be resolved in the next submission.

No other improvements are planned before next NIR.

6.3 Emissions from manure management – 4B – CH₄, N₂O (Key categories)

6.3.1 Description

The relevant pollutants emitted from this source category are CH₄ (IPCC 4B (a)), N₂O (IPCC 4B (b)) and NH₃ (NFR 4B). Emissions from cattle are most important in Norway for all three components.

N₂O is key category according to Tier 2 key category analysis because of its contributions to level uncertainty. CH₄ is key category only in the Tier 1 key category analysis.

CH₄-emissions due to manure management amounted to 311 ktonnes CO₂ equivalents in 2011 whilst N₂O-emissions amounted to 149 ktonnes CO₂ equivalents.

Manure management emitted 460 ktonnes of CO₂ equivalents in 2011, which are approximately 10 per cent of the GHG emissions from agriculture and 0.9 per cent of the Norwegian emissions of GHGs.

Emissions of GHGs from manure management increased by 2.1 % in the period 1990-2011 and decreased by 1.1 % from 2010 to 2011.

Organic material in manure is transformed to CH₄ 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 N₂O. 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 NH₃ from manure depend on several factors, e.g. type of animal, nitrogen content in fodder, manure management, climate and time of spreading of manure, cultivation practices and characteristics of the soil. In the IPCC default method a NH₃ volatilisation fraction of 20 per cent is used for the total N excretion by animals in the country. But in the Norwegian emission inventory, yearly updated ammonia volatilisation values from Statistics Norway's ammonia model are used, which are expected to give more correct values for

Norway. The estimated national volatilization fractions have differed between 18-21 per cent since 1990.

6.3.2 Methodological issues

CH₄

Emissions of methane from manure are estimated using the following equation, in accordance with the IPCC Tier 2 method (IPCC 1997b, a):

$$(6.3) \quad E_i = \frac{N_i \cdot M_i \cdot VS_i \cdot B_{0_i} \cdot MCF_i}{1000} * \rho_{CH_4}$$

E: Emissions of methane

N: Population of animals

M: Production of manure (kg/animal/year)

VS: Volatile solids (per cent)¹⁹

B₀: Maximum methane-producing capacity (m³/kg-VS)

MCF: Methane conversion factor

i: Species

ρ_{CH₄}: Density methane (0.662 kg/m³)

¹⁹ Volatile solids (VS) are the degradable organic material in livestock manure (IPCC 1997b, a).

Table 6.4 Norwegian factors used to estimate CH_4 from manure management with 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
Dairy 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, B₀ and MCF are average factors meant to represent the whole country. The factor B₀ represents the maximum potential production of methane under optimum conditions. MCF is a correction of B₀ 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). The values used for B₀ have been reviewed by UMB in 2012 (Hanssen 2012, *pers. comm*²⁰) and are expected to still be representative values for methane production during manure storage in common

²⁰ Hanssen, J. F. (2012): Personal information, email from Jon Fredrik Hanssen, researcher, 20/9-2013, Ås: UMB

Norwegian manure management systems, where the temperature in the manure is about 10-15 °C.

N₂O

In Norway, all animal excreta that are not deposited during grazing are managed as manure. N₂O emissions from manure are estimated in a N₂O-side model. The estimations are made in accordance with the IPCC default method (IPCC 1997b), but with Norwegian values for N in excreta from different animals according to Table 6.5. The rationale for the Norwegian values for N in excreta is given in Karlengen (2012). The N-excretion factors for *cattle*, *poultry* and *pigs* have been scientifically investigated, while the remaining categories have been given expert judgements (Karlengen et al. 2012). Based on typical Norwegian feedstock ratios, the excretion of nitrogen (N) were calculated by subtracting N in growth and products from assimilated N. Comparisons have also been made with emission factors used in other Nordic countries and IPCC default factors..

The factors for cattle are based on equations where animal weight, production (milking cows), life time (young cattle) and protein content in the fodder are activity data used in the equations.

The Nordic feed evaluation system (NorFor) was used to develop the nitrogen factors for cattle. The excretion of N in the manure were calculated as the difference between their intake, and the sum of that excreted in milk, fetus and deposited in the animal itself. The procedure used for calculating the excretion of feces and N consisted of two steps:

1. Simulations in "NorFor" were conducted to gain values for the feces/manure characteristics covering a wide variation of feed characteristics (N content) and production intensities (milk yield/meat production)
2. The results from the simulations were used to develop regression equations between feces/manure characteristics and parameters related to the diet (N content) and animal characteristics (milk yield, weight, age etc).

Calculations of N-factors based on these equations have been made back to 1990 for cattle. For poultry and pigs, N-factors have been estimated for 2011 in Karlengen (2012). The factors used until this update were estimated in 1988 (Sundstøl and Mroz (1988), and are regarded as still valid for 1990. A linear interpolation has been used for the years between 1990 and 2011. For the remaining animal categories the N in excreta are considered constant throughout the time series.

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 6.6.

This distribution of manure is estimated in Statistics Norway's NH₃ model. In addition, NH₃ emissions from each management system and animal category are calculated. Hence, the NH₃ model gives the input on manure distribution and how much of the nitrogen in the manure which is lost as NH₃ during storage. This is necessary information so that the N₂O emissions are corrected for the nitrogen in NH₃ that volatilises during storage. Consequently, the distributions between the usage of different storage systems and pasture used in the estimations of both N₂O and NH₃ emissions are consistent.

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Table 6.5 N in excreta from different animals. 2011. kg/animal/year unless otherwise informed in footnote

	kg/animal/year ¹
Dairy cattle	123.2
Beef cattle	64.4
Replacement heifer ³	84.1
Bull for slaughter ³	67.3
Finishing heifer ³	63.5
Horses	50.0
Sheep < 1 year	7.7
Sheep > 1 year	11.6
Goats	13.3
Pigs for breeding	23.5
Pigs for slaughtering ³	3.2
Hens	0.670
Chicks bred for laying hens ³	0.046
Chicks for slaughtering ³	0.030
Ducks, turkeys/ goose for breeding ³	2.0
Ducks, turkeys/ goose for slaughtering ³	0.4
Mink	4.3
Foxes	9.0
Reindeer	6.0
Deer	12.0
Ostrich	15.6

¹ Includes pasture

² Factors for excreted nitrogen apply for the whole life time of animals, but nitrogen is calculated only when animals are slaughtered/replaced. This is described in section 6.2.3.

³ Per animal. For these categories, life time is less than a year. This means that the number of animals bred in a year is higher than the number of stalls (pens).

Source: Karlengen et al. (2012) and estimations by Statistics Norway.

Table 6.6 Fraction of total excretion per specie for each management system and for pasture. 2011

	Anaerobic Lagoon	Liquid system	Solid storage and drylot	Pasture range and paddock	Other manure management systems
Dairy cattle	0	0.75	0.06	0.19	0
Non-dairy cattle	0	0.64	0.05	0.31	0
Poultry	0	0.27	0.73	0	0
Sheep	0	0.25	0.30	0.45	0
Swine	0	0.88	0.12	0	0
Other animals	0	0.30	0.33	0.37	0

Source: Data for storage systems from Statistics Norway (Statistics Norway 2004) and (Statistics Norway 2001b) (poultry) and data for pasture times from (Tine BA annually) (Dairy cattle, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002b) (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 1997b, a):

$$(6.4) \quad E = \sum_s \left\{ \sum_i (N_i \cdot Nex_i \cdot MS_{i,s}) \right\} \cdot EF_s$$

E: Emissions of N₂O-N (kg N₂O-N/year, N₂O-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: N₂O emission factor (kg N₂O-N/kg N)

s: Manure management system

i: Species

For liquid system and solid storage and dry lot a correction is made for the NH₃ volatilisation from manure storage.

NH₃

Statistics Norway's NH₃ model is used for calculating the emissions of ammonia from manure management. The principle of the model is illustrated in figure 6.1.

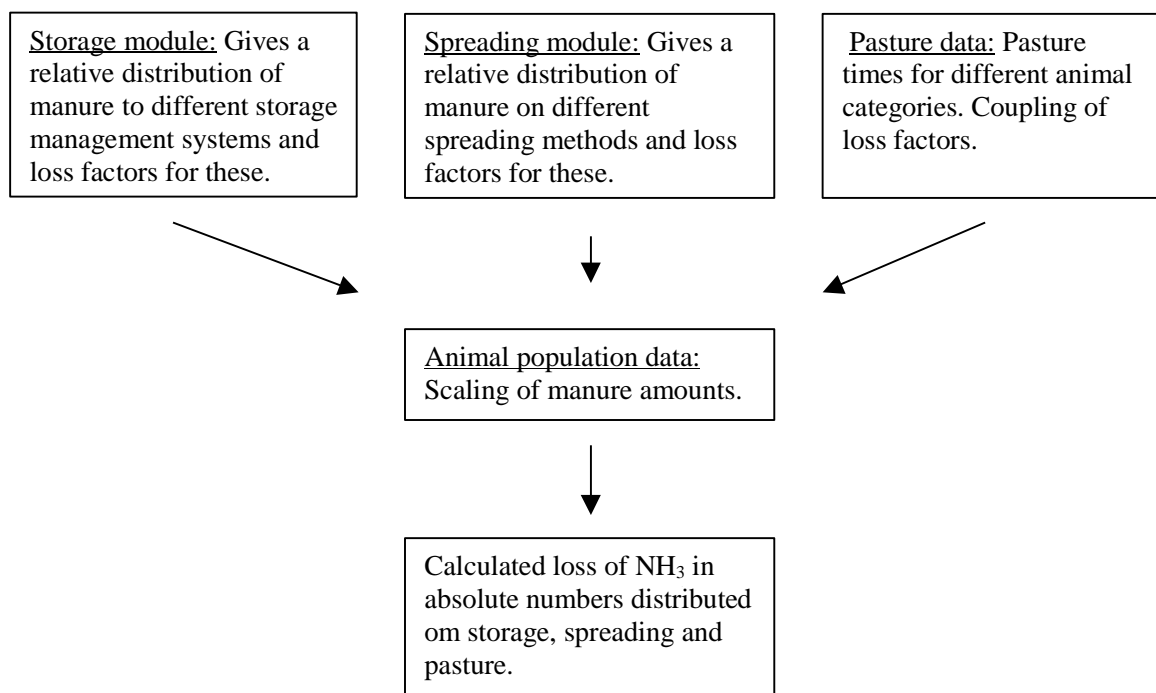


Figure 6.1 The principle of the NH_3 model

The storage module in the NH_3 model gives the relative distribution of manure nitrogen 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 nitrogen for each storage system and summarizing the results. The amount of manure nitrogen is estimated by the number of animals and nitrogen excretion factors for each type of animal (see table 6.5).

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 6.3.2 and Annex X.

NH_3

Activity data on storage systems are few, 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 (Statistics Norway 2001b). Data on 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 is 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
- Pigs
- Sheep and goat
- Poultry
- Horses, farm raised fur-bearing animals

6.3.4 Emission factors

CH₄

The calculated average emission factors for different animal types are shown in table 6.7. They are country specific factors which may deviate from the IPCC default values.

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Table 6.7 Average CH₄ emission factors for manure management in the Norwegian method. Tier 2

	Emission factor (kg/animal/year)
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.

N₂O

The IPCC default values for N₂O emission factors from manure management are used. These are consistent with the good practice guidance (IPCC 2000).

Table 6.8 N₂O emission factors for manure management per manure management system

Manure management system	Emission factor, kg N₂O-N/kg N
Liquid system	0.001
Solid storage and dry lot	0.02
Pasture range and paddock	0.02

Source: IPCC (1997b).

NH₃

Emission factors vary with production and storage system; in the model there is no variation between regions. The factors used are shown in Table 6.9.

The factors in Table 6.9 are based on data from Denmark, Germany and Netherlands, since measurements of NH₃-losses in storage rooms have so far not been carried out in Norway.

The factors are combined with the activity data in the Statistics Norway survey of different storage systems (Statistics Norway 2001b) and the Sample survey of agriculture and forestry 2003 (Statistics Norway 2004) and emission factors for NH₃ emissions from storage of manure and stalled animals, calculated for production and region (Table 6.10). To estimate losses, these emission factors are in turn multiplied with the amount of manure nitrogen (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.

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Table 6.9 NH_3 emissions factors for various storage systems and productions. Per cent $\text{NH}_3\text{-N}$ 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			
<i>Cattle, milking cow:</i>							
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
<i>Pigs:</i>							
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
<i>Sheep and goats:</i>							
Loss from animal room	5	5	5	5	8	8	5
Loss from storage room	2	6	2	2	10	10	10
Total loss	7	11	7	7	18	18	15
<i>Poultry:</i>							
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
<i>Other animals:</i>							
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 (pers. Comm.) Morken, J. (2003): Personal information, Ås: Department of Agricultural Engineering, Norwegian University of Life Sciences.

Table 6.10 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	8.0	8.0	7.7	7.9
Pigs	26.2	22.1	19.8	20.3	21.0	21.2
Sheep and goats	13.3	12.6	9.2	11.4	11.9	11.5
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.

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 kinds of treatment of manure (which will determine the emission factor), which have been assessed by expert judgments. This will contribute to the uncertainty.

N_2O and NH_3

The data for the number of animals are considered to be known within ± 5 per cent.

For the emissions 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/Statistics Norway 1999). The uncertainty has not yet been estimated for the revised nitrogen excretion factors used in the 2013 reporting, and in the key category analysis is the uncertainty estimate for the country specific nitrogen excretion factors from 1999 still used as the best available estimate. This can be considered as a conservative estimate of the uncertainty since it is expected that the new nitrogen excretion factors have a lower uncertainty. 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.

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 (Statistics Norway 2000).

N_2O

For the emission of N₂O from different storage systems, IPCC default emission factors are used. They have an uncertainty range of -50 to +100 per cent (IPCC 2000) except for the storage category "daily spread" where it is not applicable.

NH₃

Ammonia emissions from agriculture are estimated based on national conditions. There are uncertainties in several parameters (fraction of manure left on pastures, amount of manure, conditions of storage, conditions of spreading and climate conditions). There is not made any uncertainty analysis for the revised NH₃ model, which has been in use since 2003. The revision of the model is however supposed to have reduced the uncertainty. Also the new estimations of nitrogen excretion from animals (Karlengen et al. 2012) is believed to have reduced uncertainty further.

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 CH₄ and N₂O 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, in cooperation with the Norwegian University of Life Sciences (UMB), made improvements in 2003 in the calculation model for ammonia emissions from the agricultural sector. Data sources used for the recalculations in the revised NH₃ model are coefficients from the Norwegian University of Life Sciences, and two surveys from Statistics Norway; a manure survey (Statistics Norway 2001b) and the sample survey of agriculture and forestry (Statistics Norway 2002b).

In 2011, the Norwegian University of Life Sciences (UMB) published a comparison of the methodologies used for calculating CH₄ emissions from manure management in Sweden, Finland, Denmark and Norway (Morken 2011).

In a project in 2012 at the Norwegian University of Life Sciences (UMB) that updated the Norwegian nitrogen excretion factors and the values for manure excreted for the different animal species, comparisons was made with the corresponding factors used in Sweden, Denmark and Finland and with IPCC default factors as a verification of the Norwegian factors (Karlengen et al. 2012).

6.3.8 Recalculations

Revision and harmonization of animal statistics used has been made due to revised methods for estimating young cattle and animals for slaughter.

The N-excretion factors have been changed to better reflect the actual nitrogen excretion from the different animal groups. The N-excretion factors for *cattle*, *poultry* and *pigs* have been scientifically investigated in 2012, while the remaining categories have been given expert judgements (Karlengen et al. 2012).

The factors for cattle are based on equations where animal weight, production (milking cows), life time (young cattle) and protein content in the fodder are activity data used in the

equations. Calculations based on these equations have been made back to 1990 and have replaced the old N-excretion factors for the whole time series. For poultry and pigs, new N-factors have been estimated for 2011. The factors used until this update were estimated in 1989, and are regarded as still valid for 1990. A linear interpolation has been used for the years between 1990 and 2011. For the remaining animal categories, only a few changes have been made, based on expert judgement (Karlengen 2012). These changes have been applied for the whole time series.

More information about these recalculations is given in Chapter 9.

6.3.9 Planned improvements

A project with the aim to revise the Norwegian CH₄ conversion factors (MCF) for the manure storage systems in use is ongoing at the Norwegian University of Life Sciences (UMB). The maximum CH₄ producing capacity (B₀) is also planned to be revised for cattle manure. The results from the project are planned to be implemented in the 2014 submission.

An update of the manure distribution between different manure management systems will be made when the results of a survey conducted by Statistics Norway in 2013-2014 are available.

The IEF differs from the actual emission factors used in the Norwegian emission inventory because the number of animals used in the inventory and the number of animals reported in the CRF differs for some emissions and groups of animals. The reason for this is the following: Parts of the inventory (estimations of N₂O from manure (4B) and CH₄ from enteric fermentation from cattle (4A1 and 4A2) was improved and this required a new set of activity data (animal numbers). In the parts of the inventory that was not improved, the old set of animal data was maintained. This has resulted in different sets of animal data in the various estimations. In the CRF, only one set of animal numbers is reported. This inconsistency in animal numbers will be resolved in the next submission.

6.4 Direct and indirect emissions from agricultural soils – 4D – N₂O (Key Category)

6.4.1 Description

The greenhouse gases N₂O and CO₂ are emitted from agricultural soils in Norway. Emissions of CO₂ are discussed section 7.

The emissions of N₂O from agricultural soils in Norway amounted to 2.00 Mtonnes calculated in CO₂-equivalents. They accounted for about 65 per cent of the total Norwegian N₂O emissions in 2011 or about 3.7 per cent of the total Norwegian GHG emissions that year.

The emissions had minor fluctuations in the period 1990-2011. During the period 1990-2011 emissions decreased by 10.9 %. From 2010 to 2011 the emissions increased by 4.1 %.

Three sources of N₂O 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 volatilization, leaching and runoff).

The use of synthetic fertilisers, animal excreta nitrogen and sewage sludge used as fertiliser, and droppings on pastures also results in emissions of NH_3 . For the first three sources, the calculated amount of nitrogen that is emitted directly as N_2O has been corrected for the nitrogen emitted as NH_3 .

Emissions of N_2O from agricultural soils are key categories because of uncertainty, both in level and trend. Their contribution to uncertainty of the national inventory was:

- 4D1 Direct soil emissions: 22.70 % for level in 2011 and 11.15 % for trend (1990-2011).
- 4D2 Animal production: 1.59 % for level in 2011 and 0.76 % for trend (1990-2011).
- 4D3 Indirect emissions: 6.13 % for level in 2011 and 1.56 % for trend (1990-2011).

6.4.2 Methodological issues

6.4.2.1 Synthetic fertiliser

N_2O

The direct emissions of N_2O from use of synthetic fertilisers are calculated from data on total annual amount of fertiliser sold in Norway and its nitrogen content, corrected for the amount of synthetic fertiliser 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 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 N₂O from biological nitrogen fixation

Another source of N₂O 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 N₂O emissions derived from nitrogen fixation (IPCC 1997b, a). The amount of nitrogen fixed is multiplied with the IPCC default emission factor.

6.4.2.4 N₂O from crop residues

Concerning re-utilisation of nitrogen from crop residues, there is only limited information. N₂O emissions associated with crop residue decomposition are calculated by using the Tier 1b method, as described in the IPCC (IPCC 2000). 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. The fraction of crop residue burned on field was updated in 2012 by the Norwegian Agricultural Authorities²¹. This reduced the fraction for 2011 from 7.5 to 4 per cent.

$$(6.5) F_{CR} = \sum_i [Crop_i * (Res / Crop)_i * Frac_{DMi} * Frac_{Ni} * (1 - Frac_{BURNi} - Frac_{REMOVEDi})]$$

F_{CR} = N in crop residue returned to soils (tonnes)

Crop_i = Annual crop production of crop (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

Frac_{REMOVED} = Fraction of crop residue removed used as fodder and straw in animal rooms

²¹ Johan Kollerud, Norwegian Agricultural Authorities, unpublished material 2012.

Table 6.11 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
Rye wheat	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 (2000), Swedish Environmental Protection Agency (2005), Umweltbundesamt (2005), Statistics Norway.

6.4.2.5 N₂O from industrial and urban wastes

N₂O

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 N₂O 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 (2001f), and the same value of 2.82 per cent is used for all years.

The amount of N in the sludge lost as NH₃ is deducted before estimating the loss of N₂O.

NH₃

To calculate NH₃ emissions from sewage sludge, the fraction of N in manure lost as NH₃ is used (frac_{gasm}). The loss equals to total N in sewage sludge multiplied by frac_{gasm}.

6.4.2.6 N₂O from cultivation of soils with a high organic content

Large N₂O emissions occur as a result of cultivation of organic soils (histosols) due to enhanced mineralisation of old, N-rich organic matter. The emissions are calculated using the IPCC default emission factor of 8 kg N₂O-N/ha per year, and an estimation of the area of cultivated organic soil in Norway. The area estimate of organic soils is based on measurements of C in the soil. National figures for the carbon content in agricultural soils are estimated on the basis of carbon and area data from a soil database by the Norwegian Forest and Landscape Institute, which covers about 50 per cent of the agricultural area in Norway.

The figures are scaled up to a national level by using an area resource database by the Norwegian Forest and Landscape Institute and a soil database by Bioforsk (Norwegian Institute for Agricultural and Environmental Research). The soil database by Bioforsk contains results from about 600 000 soil samples. The soil samples represent about 65 per cent of the farms in Norway (Grønlund *et al.* 2008b).

The soil mapping was mainly carried out in 1994, which gives a relatively accurate figure for the area estimate this year, ca. 830 km². After 1995 the area has decreased both due to the transition to mineral soil after the peat layer has decomposed and because cultivated moors are taken out of production. This decrease has to some extent been counteracted by cultivation of new moors. Figures for the development of cultivated area after 1994 have been estimated by Bioforsk (Grønlund 2012, *pers. Comm.*²²) based on assumptions of an annual area decline of about 1 per cent due to transition of peat and abandonment of cultivated moors, and an annual cultivation of new moor of 2 km².

6.4.2.7 Direct soil emissions from animal production (emissions from droppings on pastures)

N₂O

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 6.6). The amount of N deposited during grazing is multiplied with the IPCC default emission factor.

NH₃

Statistics Norway's NH₃ 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 N₂O formation. Climate and fertiliser type influence the ammonia volatilisation. Deposition of ammonia is assumed to correspond to the amount of NH₃ that volatilises during the spreading of synthetic fertilisers, storage and spreading of manure and sewage sludge, and volatilisation from pastures. This amount is obtained from Statistics Norway's ammonia model. The N₂O emissions are calculated by multiplying the amount of N from deposition with the IPCC default emission factor.

6.4.2.9 N₂O 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 N₂O as the nitrogen undergoes nitrification and denitrification. The fraction of the fertiliser and manure nitrogen lost to leaching and surface runoff may range depending on several factors. The IPCC (IPCC 1997b, a) proposes a default value of 30 per cent, but in the Norwegian inventory a national factor of 22 per cent is used that is believed to give better results under Norwegian conditions. This country specific factor given by is an estimate of the amount of nitrate leaching in Bechmann *et al.* (2012). The estimation was based on data from the Agricultural Environmental monitoring program (JOVA). The overall $Frac_{leach}$

²² Grønlund, A. (2012): Personal information, email from Arne Grønlund 7/6-2012, Ås: Bioforsk.

estimated in this study was 22 % of the N applied. This value is a median of $\text{Frac}_{\text{leach}}$ for every year during the monitoring period and for each of eight catchments with different production systems. The JOVA-program includes catchment and field study sites representing typical situations in Norwegian agriculture with regard to production system, management, intensity, soil, landscape, region and climate. Data from plot-scale study sites confirmed the level of N leaching from the agricultural areas within the JOVA catchments. 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 6.12.

Table 6.12 Activity data for process emissions of N_2O in the agriculture.

	Sources
Consumption of synthetic fertiliser	Norwegian Food Safety Authority annually; total sale of synthetic fertiliser), Statistics Norway annually ; Fertilising of forest, Silvicultural statistics
Number of animals	Statistics Norway (applications for productions subsidies), no. and weight of approved carcasses), The Cow Recording System at TINE BA)
Distribution between manure storage systems	Sample Survey of agriculture and forestry 2003 (Statistics Norway 2004) (Statistics Norway 2001b)
Pasture times for different animal categories	Tine BA (annually) (Dairy cattle, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002b) (non-dairy cattle, sheep), expert judgements.
Biological N-fixation	Aakra and Bleken (1997)
Crop yield	Statistics Norway annually , agriculture statistics
Amount of sewage sludge	Statistics Norway annually, waste water statistics
Fraction sewage sludge applied on fields	Statistics Norway annually, waste water statistics
Area of cultivated organic soils	Grønlund <i>et. Al.</i> (2012) and pers. Comm., email from Arne Grønlund 16/8-2010, Ås: Bioforsk

The calculation of emissions from use of nitrogen fertiliser is based on sales figures for each year. A strong price increase for nitrogen fertiliser caused a stock building in 2008 and corresponding lower sales in 2009. In addition, new fertilisation standards may have brought about a reduction of the use of fertilisers. To correct for this a transfer of fertiliser use has been made from 2008 to 2009.

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 fertiliser used in forests which is given by silviculture statistics from Statistics Norway.

The silviculture statistics gives annually the weight of the fertiliser used on wet forest land (moor) and on dry forest land. An expert judgement has been made that almost only NPK with a nitrogen content of 15 per cent is used on wet forest land. On dry forest land it is assumed that half of the used synthetic fertiliser is NPK and the other half is fertiliser with a nitrogen content of 30 per cent (NIJOS 2005).

For the calculation of the emission of NH_3 we need a specification of the use of different types of synthetic fertiliser. This is given by the Norwegian Food Safety Authority for the years from 2000. Due to lack of data for the years before 2000, we have to assume that the percentual distribution between the usage of different fertiliser types is the same as in 1994 for these years.

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 (Statistics Norway 2001b), 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 2001 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 2001. The parameters used in the calculations and their sources are shown in Table 6.13.

Table 6.13 Parameters included in the estimation of NH_3 emissions from manure

Parameters (input)	Sources
Number of animals	Statistics Norway (applications for productions subsidies), no. and weight of approved carcasses), The Cow Recording System at TINE BA)
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, various years), (Statistics Norway 2001b)
Area and amount where manure is spread, split on spring and autumn	Statistics Norway (Sample Surveys of Agriculture, various years)
Addition of water to manure	(Statistics Norway 2001b), expert judgements, Statistics Norway's Sample Survey 2007 (Statistics Norway 2007a)
Spreading techniques	(Statistics Norway 2001b), expert judgements
Usage and time of harrowing and ploughing	(Statistics Norway 2001b), expert judgements, Statistics Norway's Sample Surveys of Agriculture
Pasture times for different animal categories	Tine BA annually (Dairy cattle, goats), Statistics Norway's Sample Survey 2001 (Statistic Norway 2002b) (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 2000).

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 volatilized NH_3 . 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 is based on sale statistics are annually given by the Norwegian Food Safety Authority for the years from 2000. For earlier years the distribution are based on data from 1994. The NH_3 emission factors (per cent loss of N) for the different types of fertilisers are shown in table 6.14.

Table 6.14 Emission factors for NH_3 -N for different fertilisers

Fertiliser	Emission factor (per cent of applied N)
Urea	15
Ammonium sulphate and Ammonium nitrate	5
Calcium nitrate	0
Calcium ammonium nitrate	1
NPK (Nitrogen, phosphorus, potassium)	1
Other	1

Source: ECETOC (1994) and Norsk Hydro, pers. Comm.²³

Animal manure applied to soil and pasture

Emission factors for spreading of stored manure vary with spreading method (Statistics Norway 2001b), water contents (Statistics Norway 2007a), type and time of treatment of soil (Statistics Norway 2001b), time of year of spreading (Statistics Norway 2001b)(Statistics Norway 2007a), cultivation and region. The basic factors used are shown in table 6.15

²³ Norsk Hydro (1995): Personal information, Kaarstad, Norsk Hydro.

National Inventory Report 2013 - Norway

Table 6.15 Emissions factors for $\text{NH}_3\text{-N}$ 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
<i>Meadow</i>								
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
<i>Open fields</i>								
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 6.15 are combined with data from the Sample survey of agriculture and forestry 2007 (Statistics Norway 2007a) and a time series on mixture of water in manure. 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 6.16). These factors are in turn connected to activity data that are updated for the whole time series when new information is available, i.e. number of animals (amount of manure), time of spreading and type of cultivation of the areas where the manure is spread.

Table 6.16 Average NH_3 emission factors for cultivated fields and meadows after time of spreading and region. 2011. Per cent

	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	28.6	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 6.17. These are the same as the emission factors used in Germany (Dämmgen *et. al.* 2002) and Denmark (Hutchings *et. al.* 2001).

Table 6.17 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

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 (Statistics Norway 2000). In addition come a possible error due to the fact that sale does not necessarily equal consumption in a particular year due to storage. The share of the various types of nitrogen fertiliser is assumed to be the same as in an investigation in 1994, and the error connected to this approach has probably increased over the years. The effect on the uncertainty in activity data due to these two factors has not been quantified, but it is assumed that it can be more important than the uncertainty in the sales figures.

Ammonia losses from fertiliser containing ammonium are related to soil pH. This could probably also lead to uncertainty, 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 monitoring of nitrogen leakage in parts of Norway, the certainty has been improved over time. The range is considered to be within ± 15 per cent (SFT/Statistics Norway 1999). The uncertainty is connected to differences in excreted N

between farms in different parts of the country, that the surveyed farms may have not been representative, general measurement uncertainty and the fact that fodder and feeding practices have changed since the factors were determined. The uncertainty has not yet been estimated for the revised nitrogen excretion factors used in the 2013 reporting, and in the key category analysis is the uncertainty estimate for the country specific nitrogen excretion factors from 1999 still used as the best available estimate. This can be considered as a conservative estimate of the uncertainty since it is expected that the new nitrogen excretion factors have a lower uncertainty.

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.

Atmospheric deposition of agricultural NH_3 emissions: The data are based on national NH_3 emission figures. These are within ± 30 per cent (SFT/Statistics Norway 1999).

Leakage of nitrogen: The upper limit for the leakage is the applied nitrogen. The uncertainty is roughly about ± 70 per cent (SFT/Statistics Norway 1999).

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 (Statistics Norway 2001c). This uncertainty could be lower if better data on fertiliser composition were obtained. The uncertainty is higher for animal manure, ± 30 per cent (Statistics Norway 2001c). 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 (Statistics Norway 2001c). Other factors that could lead to uncertainty 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).

Statistics Norway, in cooperation with the Norwegian University of Life Sciences (UMB), made in 2003 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 (Statistics Norway 2001b) and the sample survey of agriculture and forestry (2001).

In 2006, the methodology used for estimating N₂O from crop residues has been changed to the method Tier 1b (IPCC 2000). The new method is more detailed and is supposed to better reflect the real emissions than the earlier used national method.

In 2009, the earlier used constant estimate for the area of cultivated organic soils was replaced with new estimates for the whole time series. The recalculations give a decrease in N₂O emissions for the whole period. The time series for the area of cultivated organic soils was revised by Bioforsk in 2012 based on more information about the yearly decline of moor. There was a strong price increase for nitrogen fertiliser, which caused a stock building in 2008 and corresponding lower purchases in 2009. The calculation of N₂O emissions from use of nitrogen fertiliser is based on sales figures for each year. To correct for this a transfer of fertiliser from 2008 to 2009 was made in the calculations.

In a project in 2012 at the Norwegian University of Life Sciences (UMB) that updated the Norwegian nitrogen excretion factors for the different animal species, comparisons was made with the corresponding factors used in Sweden, Denmark and Finland and with IPCC default factors as a verification of the Norwegian factors (Karlengen et al. 2012).

A new Frac_{leach} factor was estimated in a study by Bioforsk (Norwegian Institute for Agricultural and Environmental Research) in 2012 (Bechmann et al. 2012). The updated factor is based on the data from the Agricultural Environmental monitoring program (JOVA).

6.4.8 Recalculations

Revision and harmonization of animal statistics used has been made due to revised methods for estimating young cattle and animals for slaughter.

The N-excretion factors have been changed to better reflect the actual nitrogen excretion from the different animal groups. The N-excretion factors for *cattle*, *poultry* and *pigs* have been scientifically investigated in 2012, while the remaining categories have been given expert judgements (Karlengen et al. 2012). The changes in nitrogen excretion factors and population data have resulted in recalculations for the emissions from animal manure applied to soils, atmospheric deposition and nitrogen leaching and run-off.

Nitrogen lost as NH₃ from the application of sewage sludge as fertilizer have been included in the N₂O calculation as recommended in a Saturday Paper from the ERT 2012. This has led to recalculations of the direct N₂O emissions from sewage sludge applied, and the following indirect emissions of N₂O from atmospheric deposition and from nitrogen leaching and run-off.

The amount of synthetic fertilizers used has been revised for 2009-2010, due to revised sales figures.

The Frac_{leach} factor has been updated from 0.18 to 0.22. The new factor was estimated in a new study by Bioforsk (Norwegian Institute for Agricultural and Environmental Research) (Bechmann et al. 2012).

Mean area figures for the development in cultivated area after 1994 have been estimated by Bioforsk. The time series has been updated in 2012 (Grønlund, *pers. comm*²⁴) based on

²⁴ Grønlund, A. (2012): Personal information, email from Arne Grønlund June 7 2012, Ås: Bioforsk.

assumptions of a yearly area decline of about 1 per cent due to transition of peat and abandonment of cultivated moors, and a yearly cultivation of new moor of 2 km².

More information about these recalculations is given in Chapter 9.

6.4.9 Planned improvements

A project with the aim to revise the Norwegian CH₄ conversion factors (MCF) for the manure storage systems in use is ongoing at the Norwegian University of Life Sciences (UMB). The maximum CH₄ producing capacity (B_o) is also planned to be revised for cattle manure. The results from the project are planned to be implemented in the 2014 submission.

An update of the manure distribution between different manure management systems will be made when the results of a survey conducted by Statistics Norway in 2013-2014 are available.

6.5 Emissions from agricultural residue burning (agricultural wastes) – 4F – CH₄, N₂O

Burning of agricultural residues gives emissions of standard non-fossil combustion products.

6.5.1 Methodological issues

CH₄, N₂O

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 the following equation:

$$CR = CRB * F_{dm} * F_o * F_c$$

CR: Amount of carbon released (tonnes C/yr)

CRB: Amount of crop residue burned (tonnes/yr)

F_{dm}: Dry matter fraction

F_o: Fraction oxidised

F_c: Carbon fraction

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).

$$E_i = CR * ER * MW_i * N/C$$

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

Table 6.18. Factors used for agricultural residue burning in Norway

Factor	Value		Source
F _{dm}	0.85		IPCC (1997b)
F _o	0.9		IPCC (1997b)
F _c	0.4643		IPCC (1997b), FAO (2002)
	CH ₄	N ₂ O	
ER	0.005	0.007	IPCC (1997b)
MW	16/12	44/28	IPCC (1997b)
N/C	-	0.012	IPCC (1997b)

To calculate the emissions of CH₄ the amount of carbon released is multiplied with an emission ratio. The emission ratio gives the mass of the actual chemical substance emitted (in C-units) related to the mass of the total carbon emissions by residual burning. To get total amount of emissions of the actual emission component, a molecular weight conversion factor must also be multiplied. For N₂O the emission ratio gives the ratio of emissions of N₂O 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.

6.5.2 Activity data

The calculation of the annual amount of crop residue burned on the fields is based on crop production data for cereals and rapeseed from Statistics Norway, and estimates of the fraction burned made by the Norwegian Crop Research Institute and Statistics Norway (chapter 6.4.2.4). For cereals a water content of 15 per cent is used (IPCC 1997b) and the water content for rapeseed is set to 9 per cent (Swedish environmental protection agency 2005). The activity data is consistent with the data used in the estimations of N₂O from crop residues.

6.5.3 Emission factors

Table 6.19. Emission factors for agricultural residue burning.

Components	Emission factors	Unit	Source
CH ₄	2.4	kg/ tonnes crop residue (d.m.) burned	(IPCC 1997b)
N ₂ O	0.0469	kg/ tonnes crop residue (d.m.) burned	(IPCC 1997b)

6.5.4 Uncertainties

Uncertainty estimates are given in Annex II.

6.5.5 Completeness

The main emission components from burning of agricultural residues are considered to be covered in the emission calculations.

6.5.6 Source specific QA/QC and verification

In 2002, the emissions of CH₄ and N₂O, from agricultural residual burning were included in the Norwegian inventory. 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. The amount of crop residues burned in Norway has been investigated by questionnaires in 2004 and 2012.

6.5.7 Recalculations

The amounts of crop residues burned in the fields have been changed for the years 2005-2010. It was earlier assumed that 7.5 per cent of the crop residues were burnt (based on a questioner in 2004). A questioner in 2012 showed that about 4 per cent of the crop residues were burned in 2012. Linear interpolation has now been used for the intervening years. Emission factors for CH₄ and N₂O have been changed from 2.7 to 2.4 kg/tonnes crop residue burned and from 0.07 to 0.0469 kg/tonnes crop residue burned respectively as recommended by the ERT in the 2012 in-country review. The new factors are according to the Revised 1996 IPCC Guidelines.

6.5.8 Planned improvements

No further improvements are planned before next NIR.

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). All C stock change estimates have been recalculated due to the updating of the activity data provided by the National Forest Inventory (NFI) for the entire country. The work has been carried out by the Norwegian Forest and Landscape Institute (NFLI).

7.1 Sector Overview

7.1.1 Emissions and removals

In 2011, the LULUCF sector contributed with a net sequestration of 27 573 Gg CO₂-equivalents. These removals are substantial and equal to approximately half of the total emissions from the Norwegian GHG accounting. The average annual net sequestration from the LULUCF sector was about 20 419 Gg CO₂-equivalents per year for the period 1990–2011.

Forest land was responsible for the vast majority of the CO₂ removals in 2011, with 32 367 Gg CO₂-equivalents per year (Figure 7.1). However, wetlands also accounted for a small part, with about 83 Gg CO₂-equivalents per year (invisible in Figure 7.1), due to biomass sequestration in trees. Cropland was the most significant source of emissions in the beginning of the inventory period, with 2 343 Gg CO₂-equivalents in 1990, but emissions reduced to 1 934 Gg CO₂-equivalents in 2011 because of the decrease in the area of cultivated organic soils. The total emissions from cropland in 2011, including the sequestration in living biomass, dead organic matter and soils, was 1 862 Gg CO₂. In 2011, grassland contributed with emissions of almost 176 Gg CO₂. Emissions from settlements have become more than five times greater from 1990 to 2011, and are now responsible for the largest emissions from the LULUCF sector, with 2 704 Gg CO₂ in 2011. Emissions from other land were 47 Gg CO₂-equivalents. Emissions reported under *5G other* includes C emissions from liming of lands and lakes and non-CO₂ emissions from fertilization, drainage, disturbance from conversion to cropland, and biomass burning. In 2011, C emissions from liming of lands and lakes were 61 Gg CO₂ and 17 Gg CO₂, respectively.

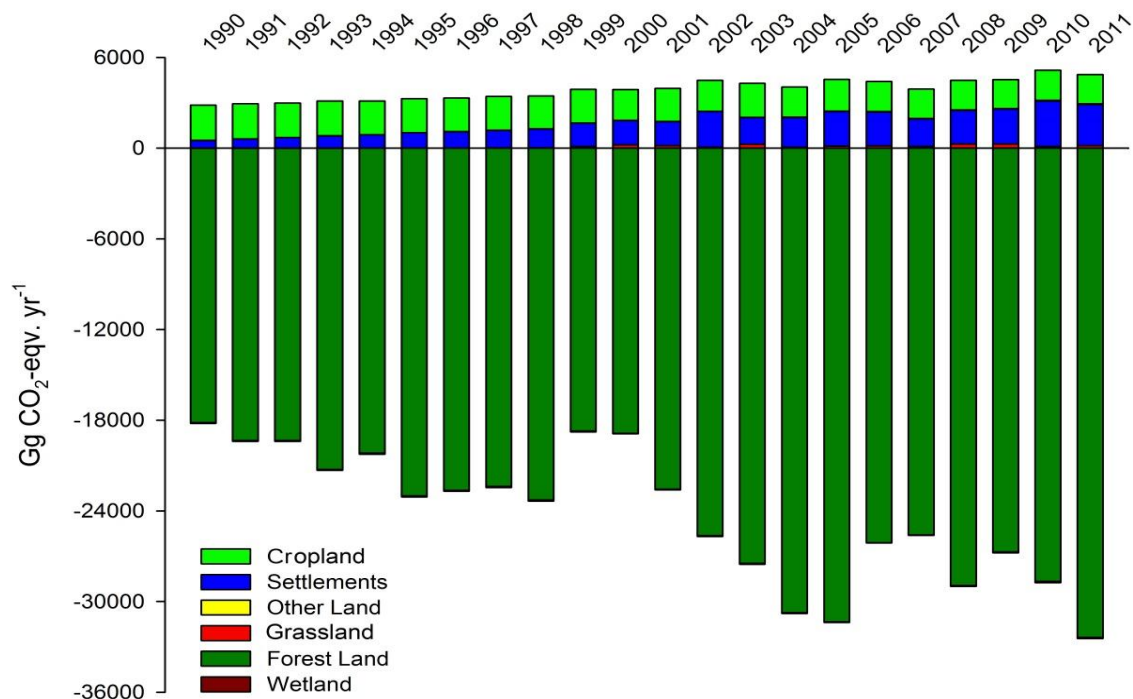


Figure 7.1 Emissions and removals of CO₂ (Gg CO₂-equivalents per year) from the LULUCF sector by land-use categories (forest land, cropland, grassland, wetlands, settlement and other land), 1990–2011. Source: The Norwegian Forest and Landscape Institute

Forest land was the major contributor to the net sequestration. For 2011, the total net removals were 32 367 Gg CO₂-equivalents including non-CO₂ emissions (Figure 7.1) The C stock changes on forest land excluding non-CO₂ emissions amounted to a net sequestration of 32 380 Gg CO₂ for 2011 (Figure 7.2). This includes emissions of 1 709 Gg CO₂ from organic soils on forest land remaining forest land and land converted to forest land. Living biomass was the primary contributor of sequestration, with 86 % of the total removals. Dead organic matter contributed with 13 % and mineral soils with 1 %. Land converted to forest land contributed with removals of 683 Gg CO₂-equivalents, primarily caused by sequestration in living biomass and mineral soil. Carbon removals by forest land have generally increased since 1990, and have been fluctuating over the last 8 years (Figure 7.2).

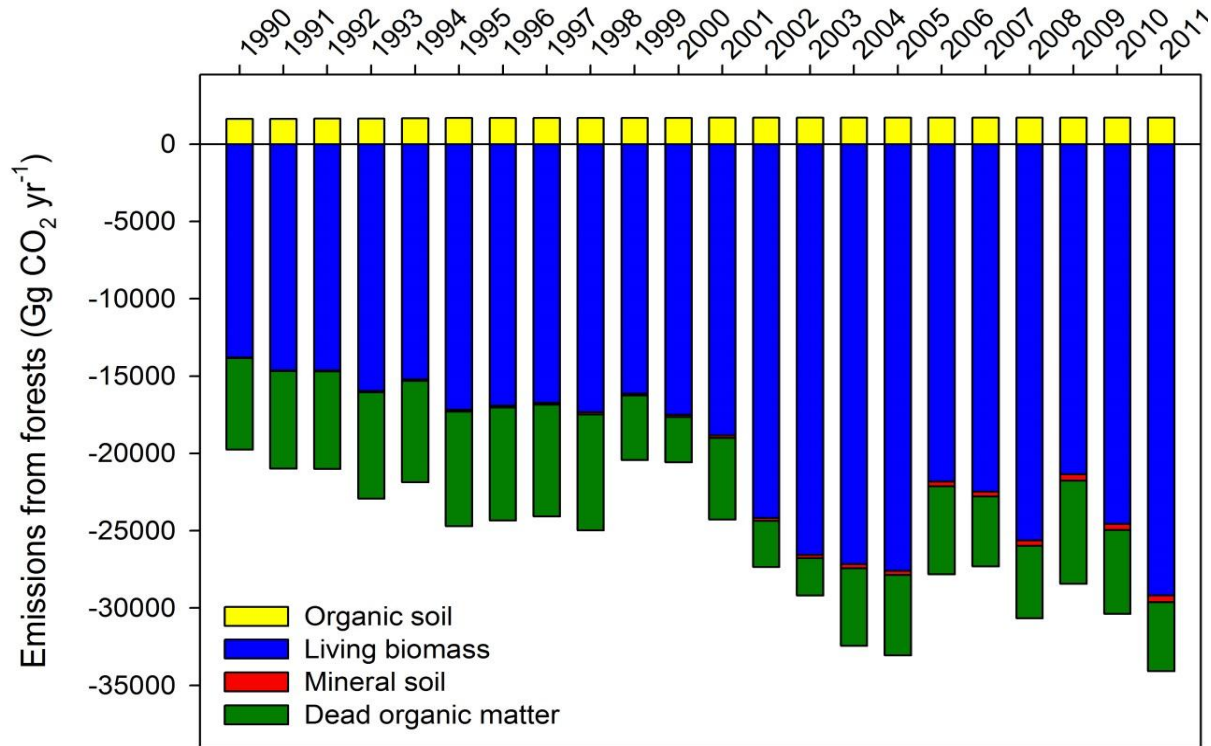


Figure 7.2 Emissions and removals of CO₂ (Gg CO₂ per year) on forest land from organic and mineral soil, dead organic matter (DOM), and living biomass, 1990–2011.

Source: The Norwegian Forest and Landscape Institute

Since 1990, the carbon stocks in living biomass in the LULUCF sector have increased significantly, by around 30 % (Table 7.1). This increase is mainly due to the increases in the growing stock within forest (Figure 7.3).

Table 7.1 Carbon stocks in 1990, 2009, 2010, and 2011, as well as differences in carbon stocks compared to 1990 over all land-use categories including associated uncertainties. Uncertainties from back-casting necessary for the mountain forest and Finnmark strata were ignored in the estimates for 1990. (SE = standard error, CI = confidence interval)

Year	C stock (Gg)	C stock difference to 1990 (Gg)	C stock difference to 1990 (% of 1990)	C stock difference to 1990, 2 SE (Gg)	C stock difference to 1990, 2 SE (%)	Lower limit of the 95 % CI of the C stock difference
1990	335 942	0	0	-	-	-
2009	427 712	91771	27.32	23209	25.29	68 562
2010	434 295	98353	29.28	23392	23.78	74 962
2011	442 209	106267	31.63	23638	22.24	82 629

Explanation of the annual variation of CO₂ removals on forest land

Forest land covers around one third of the mainland area of Norway and is the most important land-use category considered managed. The carbon stock has increased for living biomass throughout the time-series (Figure 7.3).

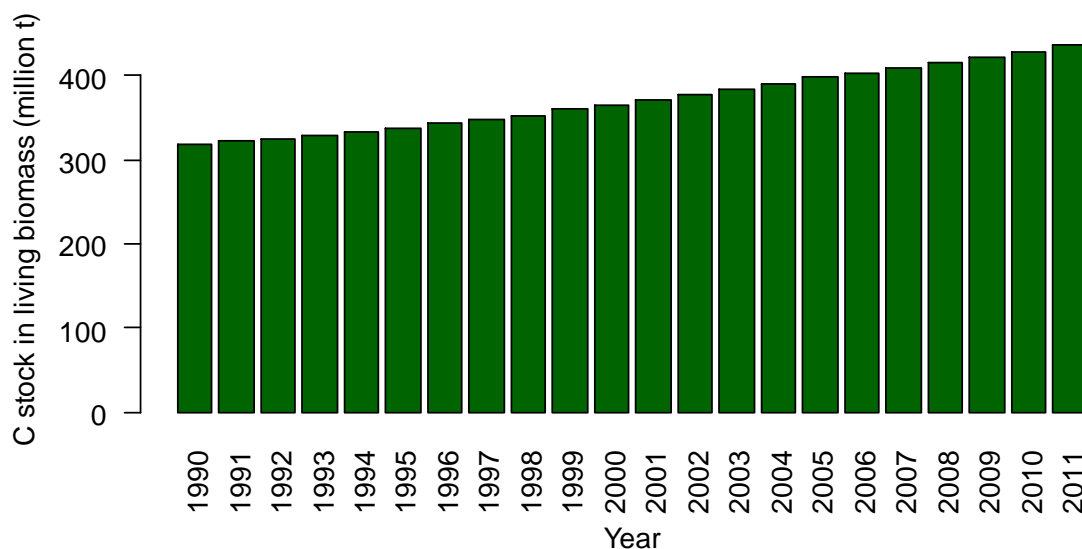


Figure 7.3 Development of the carbon stock in living biomass on forest land remaining forest land, 1990–2011. Source: The Norwegian Forest and Landscape Institute

The steady increase in living carbon stock is the result of an active forest management policy over the last 60–70 years. The combination of the policy to re-build the country after World War II and the demand for timber led to a great effort to invest in forest tree planting in new areas, mainly on the west coast of the country, and replanting after harvest on existing forest land. In the period 1955–1992 more than 60 million trees were planted annually with apex of more than 100 million annually in the 1960s. These trees are now in their most productive age and contribute to the increase in living biomass, and hence the carbon stock. Currently about 20 million trees are planted every year. The lower number may result in a relative decrease in biomass accumulation and hence the future net carbon sequestration. At the same time, annual drain levels are much lower than the annual increments, causing an accumulation of tree biomass (Figure 7.4).

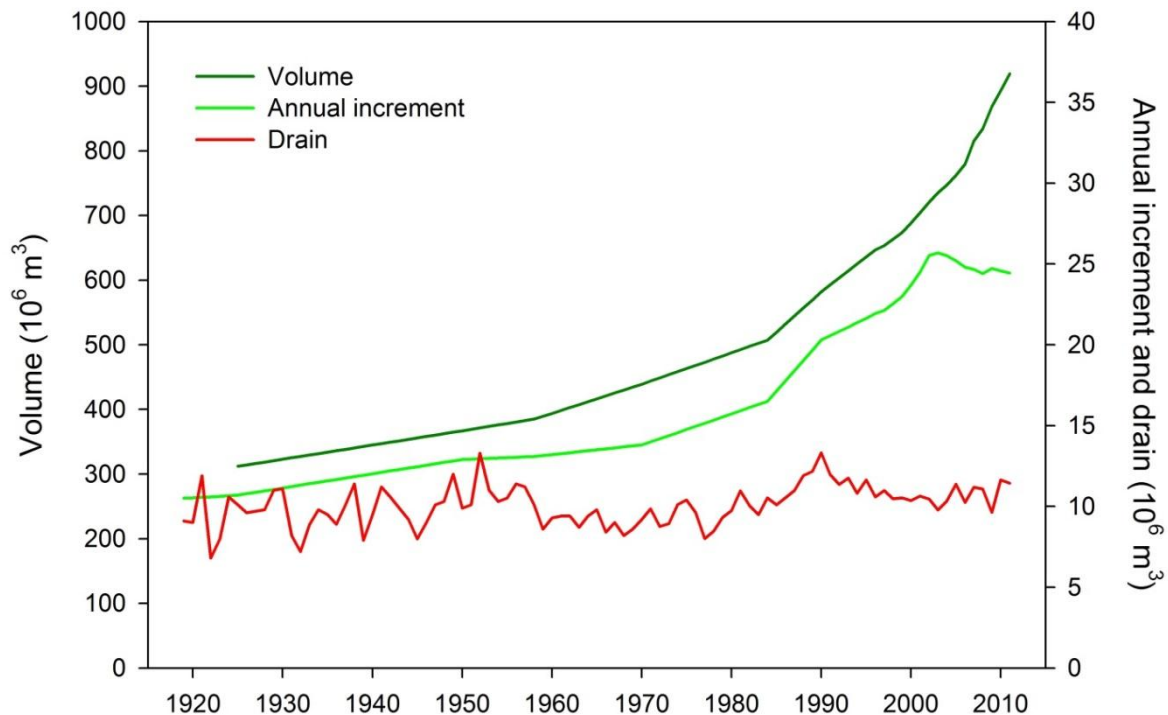


Figure 7.4 Forest drain, annual increment and volume, 1919–2011. The two last years are extrapolated for volume and annual increment. Source: The Norwegian and Landscape Institute and Statistics Norway

The calculations of carbon stock changes in living biomass are conducted according to the stock change method and are based on data obtained by the National Forestry 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 distributed across the country in order to reduce the periodic variation between years. The same plots are inventoried again after five years, and all plots are assessed during a 5 year period. The current system with permanent plots was put in place between 1986 and 1993, and made fully operational for the cycle covering the years 1994 through 1998. Because the re-sampling method was not fully implemented before 1994, the method used to calculate annual emissions and removals is not the same throughout the time-period, and the methods have been bridged. See section 7.4.1.2 for a detailed description of the method.

The annual changes in the C stock depend upon several factors such as site quality, variation of growing conditions such as temperature and precipitation at the location during the growing season, age and species distribution of the assessed forests, harvest levels and the amount of land-use changes in the area. All these factors influence indirectly the reported annual net change of CO₂ removals from the atmosphere.

The annual fluctuation seen in CO₂ sequestered for dead organic matter and soil are influenced by annual variation in the input data to the Yasso07 model; litter from standing biomass, natural mortality, harvest residues and, stumps and roots from harvested trees. All these factors are influenced by the same natural and man-made factors as stated for living biomass.

7.1.2 Activity data

The main data source used for the LULUCF sector is the National Forest Inventory (NFI), which was used to estimate the total areas of forest land, cropland, wetlands, settlements and other land, as well as the land-use transitions between these categories. Land area accounting for all areas has been done according to an Approach 2, as described in chapter 3 of the IPCC Guidelines (IPCC, 2006). Data from the NFI is also used to calculate net changes of carbon stocks in living biomass and as input values for modeling changes of carbon stock in dead organic matter and mineral soil for forest land remaining forest land.

In addition, the NFI data are complemented with auxiliary data for several other sink/source categories, e.g. horticulture, arable crop types, grassland management, artificial N fertilization, liming of agricultural land and lakes, drainage of forest soil, and forest fires. These data were acquired from Statistics Norway, Norwegian Agricultural Authority, Food Safety Authority, the Norwegian Directorate for Nature Management, and The Directorate for Civil Protection and Emergency Planning. Detailed descriptions of these data are given under their relevant emission sources.

7.1.2.1 Land-use changes 1990–2011

Land-use changes in Norway from 1990 to 2011 have been very small; only the area of settlements has increased slightly, while the other land-use categories have decreased (Figure 7.5). This year, the planned improvements and quality assurance on the NFI database (areas and C stocks in living biomass) were completed and implemented for the LULUCF reporting.

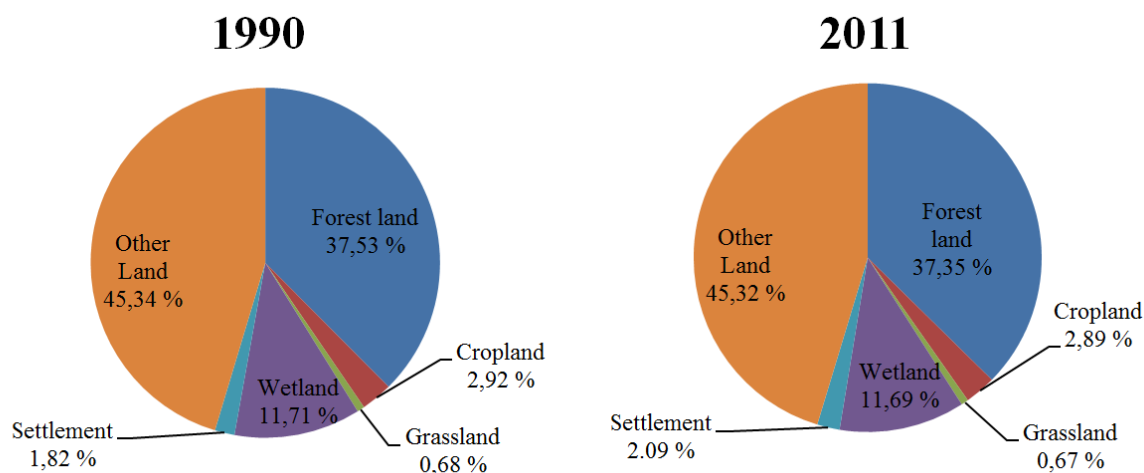


Figure 7.5 Area distribution (%) of the IPCC land-use categories for 1990 and 2011.

Source: The Norwegian Forest and Landscape Institute

The small land-use changes are also illustrated by the land-use conversion matrix for the whole inventory period from 1990 to 2011 (Table 7.2). A key finding from these data is that the changes in land-use from 1990 to 2011 are quite small; with approximately 0.6 % of the total land in a "land-conversion" category and the rest in a "remaining" category. The largest changes were in forest land and settlements. There have been land-use conversions from all categories to forest land and to settlements. The classification of land-use change is directly transferable to the activities reported under the Kyoto Protocol, which is illustrated by the land-use matrix in Table 7.3.

Table 7.2 Land-use change matrix for the IPCC land-use categories from 1990 to 2011 based on the NFI data (ha).

2011								
Land-use (ha)								
Year	Land-use	Forest land	Cropland	Grassland	Wetland	Settlements	Other land	Total
1990	Forest land	12 047 160	11 666	19 046	1 802	80 981	0	12 160 656
	Cropland	9 884	919 242	0	0	15 001	0	944 126
	Grassland	15 551	1 702	196 770	0	4 406	2 604	221 033
	Wetland	3 355	3 064	541	3 780 440	831	0	3 788 230
	Settlements	14 360	801	0	0	573 786	0	588 947
	Other land	1 802	0	0	901	1 973	14 670 530	14 675 206
	Total	12 092 112	936 476	216 357	3 783 143	676 978	14 673 134	32 378 200

Table 7.3 Land-use change matrix with classification of the KP activities and the corresponding land-use classes. The following notation is used for classification of land-use changes. AR: Article 3.3 Afforestation/Reforestation, D: Article 3.3 Deforestation, FM: Article 3.4 forest management.

	Forest	Cropland	Grassland	Wetlands	Settlements	Other
Forest	Forest Management	Human induced D	Human induced D	Human induced D ¹	Human induced D	Human induced D
Cropland	Human induced AR ³		Human induced	Human induced	Human induced	Human induced
Grassland	Human induced AR ³	Human induced		Human induced	Human induced	Human induced
Wetlands	Not human induced ²	Human induced	Human induced		Human induced	Human induced
Settlements	Human induced AR	Human induced	Human induced	Human induced		Human induced
Other	Not human induced ²	Human induced	Human induced	Human induced	Human induced	

¹ Forest land flooded because of constructed reservoirs.

² Conversion from wetland and other land to forest land is considered human-induced only when actual evidence of management is present.

³ Includes agricultural areas which have been abandoned. The abandonment is considered to be an active change in management of those areas.

7.1.3 Uncertainties

Uncertainties of area estimates are based on standard sampling methodology (see section 7.2.3). The areas of the largest land-use categories, other lands remaining other lands and forest land remaining forest land can be estimated with precisions < 2 % (Table 7.4). Land-use changes are generally small in Norway. The largest change categories are lands converted to settlements and lands converted to forest land. Due to the small number of NFI sample plots in the categories lands converted to wetlands and lands converted to other lands, uncertainty estimates would be extremely unreliable. These two categories were therefore considered as one group.

Table 7.4 Uncertainties of area estimates by land-use category in 2011 based on sample plots observed between 2007 and 2011. 2 SE means two times the standard error.

Land-use category	Area (kha)	Area, 2 SE (%)
Forest land remaining forest land	12 047	1.8
Cropland remaining cropland	919	6.7
Grassland remaining grassland	197	13.5
Settlement remaining settlements	574	8.0
Wetland remaining wetland	3 780	4.8
Other land remaining other land	14 671	1.7
Land converted to cropland	18	42.4
Land converted to forest land	47	26.2
Land converted to grassland	20	40.4
Land converted to other land & wetland	5	81.6
Land converted to settlement	107	16.2

The uncertainties of carbon estimates in living biomass in forests, grasslands, wetlands and other lands were estimated using the methods described in section 7.2.4. The net stock changes, gains, losses and the associated uncertainties by using the Tier 3 method are shown in Table 7.5.

Table 7.5 Carbon stock change estimates for living biomass based on the Tier 3 method (except for cropland remaining cropland) from 2010 to 2011 and associated uncertainties for land-use categories.

Land-use category	Gains (Gg)	Losses (Gg)	Gains, 2 SE (%)	Losses, 2 SE (%)
Forest land remaining forest land	11 425	-3 500	6.1	26.0
Cropland remaining cropland ^a	-4	-12	75.0	-
Grassland remaining grassland	20	NO	162.5	NO
Settlement remaining settlements	NE	-	-	-
Wetland remaining wetland	26	-2	34.4	82.2
Other land remaining other land	56	-4	26.5	123.4
Land converted to cropland	NO	-	-	-
Land converted to forest land	38	NO	79.0	NO
Land converted to grassland	9	-30	200.0	109.7
Land converted to other land & wetland	-	-	-	-
Land converted to settlement ^b	0.1	-121	200.0	91.2

^a Tier 1 method and default uncertainty.

^b Uncertainties are based on the category forest converted to settlements. A tier 2 method was used for remaining categories converted to settlements. Contribution of remaining categories to emissions is negligible due to low carbon stocks on these categories.

As shown in Figure 7.3, the carbon stocks in living biomass increased significantly from 1990 to 2011. The development of the annual change estimates and their uncertainty for all LULUCF land-use categories (except for cropland remaining cropland) is shown in Figure 7.6.

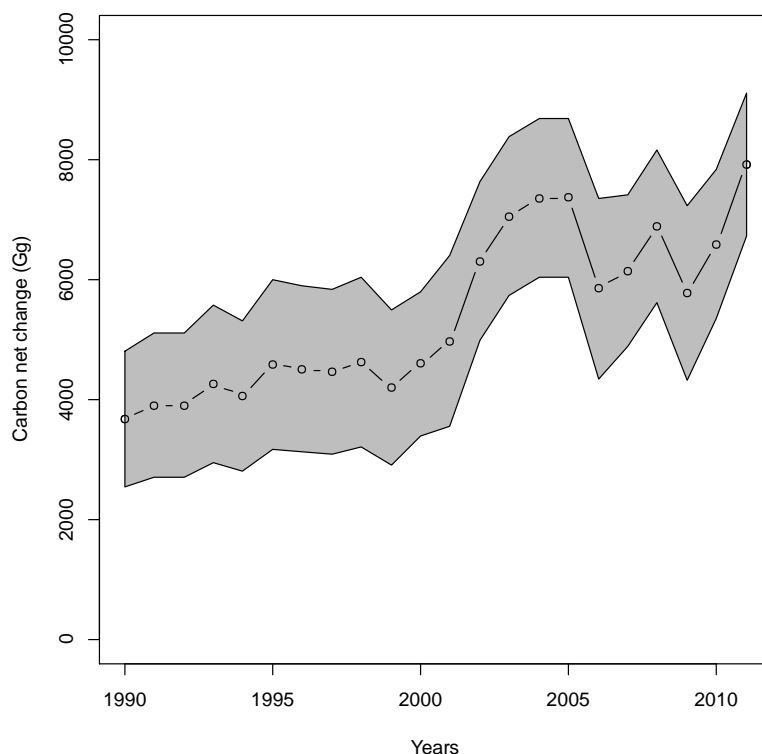


Figure 7.6 Annual carbon net changes (removals indicated by circles) and 95 % point-wise confidence interval (grey area). Estimates are based on 1/5th of the sample plots that were observed in the reference year. Uncertainties resulting from bridging the methods between 1990 and 1998 were ignored. Source: The Norwegian Forest and Landscape Institute

Uncertainties for soil organic carbon on forest land remaining forest land and non-CO₂ estimates are based on expert judgment (NIJOS, 2005). For soil C estimates using the Tier 1 method (grassland remaining grassland, and all land-use conversions), default uncertainty estimates from IPCC have been used.

7.1.4 Key categories

Statistics Norway carried out the standard key category analysis at Tier 1 and Tier 2 levels for the whole greenhouse gas inventory, including sink and source categories from LULUCF (IPCC, 2001). See chapter 1.5 for details on the key category analysis for the whole inventory. Table 7.6 lists the identified LULUCF key categories based on the results from the Tier 2 level analysis. There were no key categories identified in the Tier 1 analysis that were not identified in the Tier 2 analysis. Of highest importance in the LULUCF sector was forest land remaining forest land, with all three source categories (living biomass, dead organic matter, and soils (organic)) identified as large key categories. Land converted to forest is also identified as key category for living biomass, dead organic matter, and soils (mineral). The two latter sinks/sources were new key categories this year due to the change in method (Tier 1 and 2), which caused larger uncertainties in addition to the uncertainty quantified for the areas (see Table 7.4). Cropland remaining cropland is also an important key category due to the emissions from cultivated organic soils.

Table 7.6 Tier 2 key category results for the LULUCF sector showing level assessments for 1990 and 2010, the trend assessment for 1990–2010, and indicator of 1 if sink/source is a key category at both Tier 1 and Tier2 analyses. Key categories are indicated by bold values and the larger the value the more important is the key category.

Code	Sink/source category	Gas	Level assess 1990	Level assess 2011	Trend assess 1990–2011	Key category at any tier
5A1	Forest land remaining forest land, living biomass	CO ₂	12.13	20.38	28.56	1
5A1	Forest land remaining forest land, dead organic matter	CO ₂	13.05	7.57	0.15	1
5A1	Forest land remaining forest land, organic soils	CO ₂	19.9	16.66	10.78	1
5A2	Land converted to forest land, living biomass	CO ₂	0.35	0.86	1.41	1
5A2	Land converted to forest Land, dead organic matter	CO ₂	0.01	0.28	0.6	1
5A2	Land converted to forest land, mineral soils	CO ₂	0.05	1.44	3.05	1
5B1	Cropland remaining cropland, soils (organic)	CO ₂	9.13	6.02	1.45	1
5B2	Land converted to cropland, mineral soils	CO ₂	0.01	0.36	0.75	1
5C1	Grassland remaining grassland, living biomass	CO ₂	0.37	0.58	0.79	1
5C2	Forest converted to grassland, living biomass	CO ₂	0.16	0.5	0.88	1
5E2	Land converted to settlements, living biomass	CO ₂	0.94	0.78	0.48	1
5E2	Land converted to settlements, dead organic matter	CO ₂	0.03	0.58	1.23	1
5F2	Land converted to other land, soils	CO ₂	0.02	0.36	0.76	1
5E2	Land converted to settlements, soils	CO ₂	0.29	6.58	13.79	1

7.1.5 Completeness

All mandatory sources and sinks have been reported for the LULUCF sector under the Convention. The area of organic soils of the following land-use change categories have not been recorded in the NFI and have therefore been reported as NE (not estimated): grasslands, wetlands, and settlements converted to croplands; and forest land and wetlands converted to grassland. Emissions related to hydroelectric power production (in the sub-category flooded lands under wetlands) are not reported due to the lack of data. This category is expected to be included in the next submission.

Additionally, the following sources were not estimated because they are not mandatory and methods or data are currently lacking: living biomass and dead organic matter for wetlands with peat extraction; dead organic matter and soils for unmanaged wetlands; living biomass for settlements remaining settlements; CH₄ emissions for organic soils in forest land and wetlands; N₂O emissions from disturbance associated with land converted to cropland on organic soils. It generally applies that in the cases where NE was reported, emissions are likely to be negligible.

The use of notation keys has been consistently applied throughout this report in the following manner: NE for a sink/source that could not be estimated due to a lack of methods, activity data or when not mandatory according to the guidelines; NO for a sink/source with emissions approximately close to zero or when estimated emissions, areas, or quantities (e.g., lime or fertilizer) were actually zero; NA for sink/sources that do not exist.

7.2 National Forest Inventory

The Norwegian National Forest Inventory (NFI) can shortly be characterized as being a single-phase, permanent, rotating, systematic, and stratified survey. The Norwegian Forest and Landscape Institute is responsible for the NFI. Inventory work was started in 1919 with regular inventory cycles. The 10th inventory cycle started in 2010 and will be completed in 2014.

7.2.1 Current NFI design

For the NFI, Norway is divided in 3 large strata depending on the forests typically found in the area: Lowlands (typically below 800 m above sea level (ASL)), mountain areas (typically above 800 m ASL), and Finnmark county. The lowland stratum contains the most productive forests, while the forests in the other strata consist mainly of very low productive birch forests. The NFI sample plots are placed on the intersections of grid lines to ensure a systematic distribution of the plots (Figure 7.7).

The distance between neighboring plots is different in the three strata. A 3x3 km (Easting x Northing) grid is used in the lowlands, a 3x9 km grid is used in the mountains and a 9x9 km grid is used in Finnmark county (Figure 7.8).

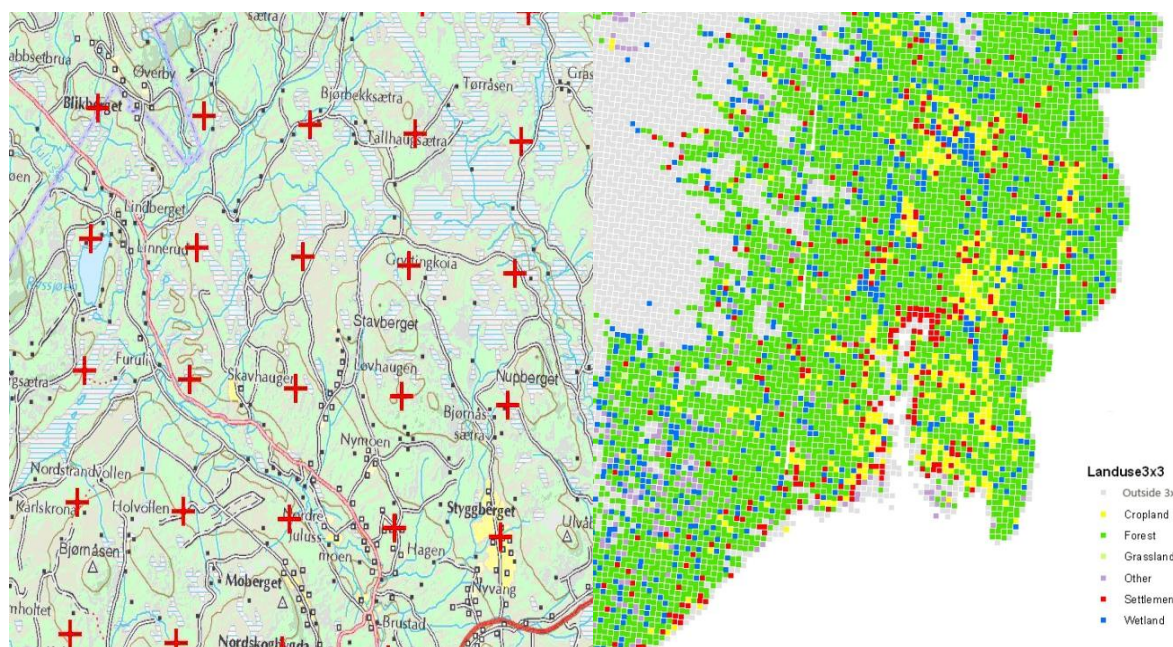


Figure 7.7 The sample plots are covering all land-use categories. In the example map to the left, plots are placed in the systematic 3x3 km grid. On the right-hand side, we see the distribution of land use-categories in the south eastern part of Norway below the coniferous tree line (only 3x3 grid).

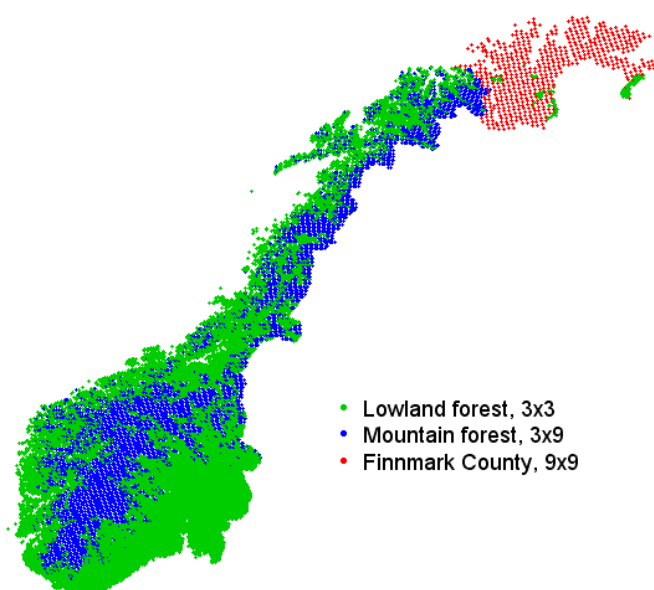


Figure 7.8 Spatial distribution (approximate locations) of the NFI sample plots in the three strata lowlands (green), mountain forests (blue), and Finnmark county (red).

As can be seen from the estimate over all land-use categories for the year 2011, almost 95 % of the living biomass stock is allocated in the lowland forests (Table 7.7). The mountain forest and Finnmark county account for 3.7 % and 1.6 % of the carbon in living biomass, respectively.

Table 7.7 Area and estimates of carbon stocks in living biomass in 2011 (based on observations from 2007-2011) by stratum and associated uncertainties (SE = standard error).

Stratum	Area (kha)	C stock (Gg)	C stock, 2 SE (%)	Percentage of total C stock (%)
Lowlands	15 124	418 888	2.9	94.8
Mountain forest	12 528	16 255	12.5	3.7
Finnmark	4727	7 065	24.8	1.6
All	32 378	442 209	2.0	100

The NFI utilizes a 5-year inventory cycle with re-measurement of permanent sample plots. Each year 1/5th of the plots are inventoried following a Latin square design that ensures all annual re-measurements to have sample plots distributed across the country. The same plots are inventoried again after five years, and all plots are assessed during a 5-year period. A plot that has measured trees in the current inventory is always revisited in the next inventory except if the plot has been converted to croplands or settlements. Plots that were not visited in the field in the most recent inventory are monitored using aerial images, which are acquired every five years over the entire country. From the aerial images, the plot is assessed for land-use changes and the occurrence of trees. If it is not possible to determine the land-use category with certainty, or if there is an indication that the sample plot may have trees with a Diameter at Breast Height (DBH²⁵) >5cm, the sample plot is visited in the field. Exceptions

²⁵ Diameter measured at 1.3 m above the ground.

are croplands and settlements, which are not visited in the field in order to measure tree parameters.

Among other attributes, the positions, DBH and tree species of all trees with DBH >5 cm are recorded on circular sample plots with a 8.92 m radius (250 m²). On plots with 10 trees or less, all tree heights are measured using hypsometers. On plots with more than 10 trees, a relascope-selected subsample with a target sample size of 10 trees per plot is measured (NFLI, 2008). The heights of the unmeasured trees are estimated using tariffs (models) calibrated at the plot-level with data from measured trees (Breidenbach et al., 2013).

7.2.2 Changes in the NFI design

The current system with permanent plots in the lowland stratum was put in place between 1986 and 1993, and made fully operational for the cycle covering the years 1994 through 1998. Because the re-sampling method was not fully implemented before 1994, the method used to calculate annual emissions and removals is not the same throughout the time-period, and the methods have been bridged.

The sample plots in the mountain stratum were established between 2005 and 2009. The first re-measurements of plots were consequently started in 2010. The sample plots in the Finnmark stratum were established between 2005 and 2011. First re-measurements of plots were consequently started in 2012. This made special methods for estimating changes necessary, as described below. Almost 95% of the carbon stock in living biomass is, however, found in the lowland stratum. The decision on which stratum a sample plot belongs to was made between 2000 and 2004. In this inventory cycle, all potential sample plots on the 3x3 km grid were assessed to decide to which stratum they belong.

The area of a stratum A_h was estimated by multiplying the proportion of points on the 3x3 km grid that belong to the stratum h with Norway's land area. The representation factor, also known as the design weight or the inverse of the sampling probability, determines how much area of Norway one sample plot represents. The representation factor of a sample plot is given by A_h/n_h where n_h is the number of sample plots on the grid that is specific to the stratum.

7.2.3 Estimates of areas

The area of a land-use class is given by the sum of representation factors of the sample plots of a full NFI cycle (observed over a 5 year period) that belong to a specific land-use class. The estimate is attributed to the last year of the cycle by definition (end-year reporting). More formally, the estimates of land-use class areas are stratified estimates of land-use class proportions multiplied with Norway's land area (including lakes). Random sampling is assumed in all estimates. The variances are therefore conservative estimates.

The estimated proportion of a land-use class within a stratum is given by

$$p_h = 1/n_h \sum_i y_{hi}$$

where $h = (1, 2, 3)$ is the stratum identifier, n is the number of sample plots, y is an indicator variable for a land -use class which is 1 if the sample plot belongs to the class and 0 otherwise, and $i = 1, \dots, n_h$.

The estimated variance of the proportion is given by

$$\text{var}(p_h) = \frac{p_h(1 - p_h)}{n_h - 1}$$

The area estimate of a land-use class (A_{LUC}) over all strata is then given by the stratified estimator

$$A_{LUC} = A \frac{1}{N} \sum_h N_h p_h$$

where A is Norway's land area, N is the land area divided by the NFI plot size, N_h is the stratum area divided by the plot size and p_h is the proportion of the respective land-use class. The estimated variance of the area estimate is given by

$$\text{var}(A_{LUC}) = A \sum_h \left(\frac{N_h}{N} \right)^2 \text{var}(p_h)$$

7.2.4 Estimates of biomass stock changes

As opposed to the area estimates, changes in the biomass stock are estimated using the 1/5th of the plots that are measured in a reference year. The estimate is attributed to the reference year by definition (end-year reporting). Instead of adjusting the sample plot representation factors²⁶, the 5-year gain or loss observed on a sample plot (compared to the last measurement) is the variable of interest. Gains and losses are the net changes observed on a sample plot.

The estimate of the total biomass gain or loss within a stratum is given by the ratio estimator

$$T_h = \frac{N_h}{n_h} \sum_{i=1}^{m_h} y_{hi}$$

where $m_h = n_h/5$ is the number of sample plots observed in one year and y is either the gain or loss that occurred during the last five years on a sample plot. An estimate of the variance is given by

$$\text{var}(T_h) = N_h^2 \frac{s_h^2}{m_h}$$

with $s_h^2 = \frac{1}{m_h - 1} \sum_i (y_{hi} - \bar{y}_{hi})^2$. The total biomass gain or loss estimate (T) over all strata and its variance ($\text{var}(T)$) is the sum over T_h and $\text{var}(T_h)$, respectively.

Post-stratification did not improve the precision of biomass gain and loss estimates. We tested climatic zones, counties and forest districts as possible post-strata.

The estimation of biomass or carbon stocks is not required in the CRF. In this report, stocks were calculated in analogy to the biomass change estimates, however, based on a full NFI cycle consisting of 5 years.

7.2.5 Estimates of carbon and uncertainties

The C stock within a land-use class was estimated by multiplying the biomass estimate by 0.5. The uncertainty of the carbon estimates results from the sampling error as detailed above but also the variability within the biomass models that are used to estimate single tree biomass. We found that the influence of the biomass models is negligible compared to the

²⁶ The difference to estimates with adjusted representation factors was found to be negligible compared to the sampling error.

sampling error for Norway spruce (Breidenbach *et al.*, 2013). Biomass model errors are therefore ignored. The uncertainties of carbon estimates are consequently given by

$$U(C) = \sqrt{U(T)^2 + U(CF)^2}$$

where $U(T)$ is the uncertainty of the total biomass gain or loss estimate in percent of the estimate

$U(T) = \frac{2\sqrt{\text{var}(T)}}{T} 100$ and $U(CF)=2\%$ is the relative uncertainty in the carbon fraction (IPCC, 2003b; p. 5.18).

For the key category analyses, also the area was calculated based on $1/5^{\text{th}}$ of the sample plots. The variance of the area was the mean of these area estimates of the last 5 years. The area itself was, however, estimated as described for the area estimate above. In addition, the mean gain or loss was estimated in analogy to the description above.

7.2.6 Possible improvements

It is planned to change the way biomass gain or loss are estimated (see section 7.2.4) to

$$T_h = \frac{N_h}{m_h} \sum_{i=1}^{m_h} y_{hi}$$

where y_{hi} = average biomass change in one year. This is equivalent to adjusting the sample plot representation factor such that $1/5^{\text{th}}$ of the plots represent Norway's land area. This method was tested already this year and only minor differences to the current estimates were observed.

7.3 Source categories

7.3.1 Land-use category definitions – 5A, 5B, 5C, 5D, 5E and 5F

The National Forest Inventory data are used to estimate total area of forest land, cropland, grassland, wetlands, settlements and other land and the land-use transitions between these. The rationale of using the NFI as activity data for all land-use categories is that covers the whole country by sample plots. Additionally, the data from the NFI is the only available data that can be used to determine transitions between different land-use categories. The land-use categories are defined in accordance with the IPCC Good practice Guidance (IPCC, 2003). They are described below, using the national terminology. The Norwegian land cover and land-use categories are illustrated in Table 7.8.

Table 7.8 National land cover and land-use categories and their correspondence to the UNFCCC land-use categories.

Land cover	Land use								
	Forestry (no other use or restrictions)	City urban area Settlements of different kinds	Cabin area	Recreation area	Military training field	Protected Area, Nature Reserve	Roads/Railroad Airport	Power line	Other
Productive forest land (1)	Forest	Settlements	Forest	Forest	Forest	Forest	Settlements	Settlements	Settlements
Non-productive forest land (2)	Forest	Settlements	Forest	Forest	Forest	Forest		Settlements	Settlements
Other wooded land, Crown cover 5-10% (3)	Other		Other	Other	Other	Other		Other	
Wooded mire, Crown cover 5-10%	Wetland		Wetland		Wetland	Wetland		Wetland	Wetland
Calluna heath	Other								
Bare rocks, shallow soil	Other		Other	Other	Other	Other		Other	Other
Mire without tree cover	Wetland					Wetland		Wetland	Wetland
Lakes and rivers (not sea)	Wetland				Wetland	Wetland			Wetland
Grazing land, not regularly cultivated									Grassland
Arable land, regularly cultivated					Cropland	Cropland			Cropland
Other areas, gravel pits, mines, gardens, halting places, skiing slopes, 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.*
- (2) 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 than one cubic meter, inclusive bark, per hectare and year.*
- (3) Other wooded land is defined as land with sparse tree cover with crown cover larger than 5 percent but less than 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.*

Forest land (5A) is defined according to the Global Forest Resources Assessment (FRA) 2005. Forest land is land with tree crown cover of more than 10 %. The trees should be able to reach a minimum height of 5 m at maturity in situ. Minimum area and width for forest land considered in the Norwegian inventory is 0.1 ha and 4 m, respectively, causing a small discrepancy from the definition in FRA 2005 (0.5 ha and 20 m). Young natural stands and all plantations established for forestry purposes, as well as forest land, which are temporarily unstocked as a result of e.g. harvest or natural disturbance, are included under forest land. All forest in Norway is managed either for wood harvesting, protecting and protective purposes, recreation, and/or to a greater or smaller extent for hunting and picking berries. On more marginal and less productive forest land the intensity of the various management practices will decrease, but will still be present. Hence, all forest in Norway is defined as managed.

Cropland (5B) is defined as lands that are annually cropped and regularly cultivated and plowed. Both annual and perennial crops are grown. It also encompasses, grass leys that are in rotations with annual crops, which may include temporarily grazed fields that are regularly being cultivated.

Grassland (5C) is identified as areas utilized for grazing on an annual basis. More than 50 % of the area should be covered with grass. The grass may be mechanically harvested but the soil is not plowed and can be partly covered with trees, bushes, stumps, rocks etc. Land with tree cover may be classified as grassland if grazing is considered more important than forestry. According to the agricultural statistics that are used for determining grassland management practices, grasslands include the two categories grazing lands and surface-cultivated grass. All grasslands are considered managed according to these categories.

Wetlands (5D) are defined as mires and areas regularly covered or saturated by water for at least some time of the year. Most wetlands are assumed to be unmanaged. A wetland area of about 338 ha is used for peat extraction and assumed managed. Land used for reservoirs (dams) used to hydroelectric power production are also considered managed wetlands, but is not reported due to lack of data. Emissions will be incorporated as soon as they are available (reporting of these emissions is not mandatory (IPCC, 2003)).

Settlements (5E) 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 land (5F) is defined as waste land, areas with bare rocks, shallow soil or particularly unfavorable 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 land.

An overview of the management status of the reported land-use categories are summarized in Table 7.9.

Table 7.9 Management status of different land-use categories. An area is only classified as belonging to one land-use category. The predominant national land cover and land use decides to which category.

Land-use category	Management status
Forest land	Managed
Cropland	Managed
Grassland	Managed
Wetlands	Unmanaged and managed (small area)
Settlements	Managed
Other land	Unmanaged

7.3.2 Consistency in reporting Land use categories – 5A, 5B, 5C, 5D, 5E

7.3.2.1 Area consistency

Up to the 2010 submission, the area of the different land-use categories were based sample plots below the coniferous limit. In order to determine the land use at higher altitudes and in Finnmark county, the NFI included the first complete set of sample plots for these areas in the period 2005–2010. This allows for assessment of the extent of forest area, other wooded land and other land uses in these areas. The plots are incorporated in the management plan for the future forest inventories. Back-casting has been used on plots without previous measurements, using data from the NFI for “forest” and “other” areas, maps and aerial photographs for “settlements”, “grassland” and “cropland”, to improve the area estimates back to 1990 for all new plots included in the system.

All areas of different land-use categories are reported for the entire country in this inventory submission. The land use reported for 2011 is derived from approximately 22 000 sample plots. The land-use change matrix has been recalculated.

Table 7.2 gives the land-use change from 1990 to 2011 and Table 7.10 gives the land-use change from 2010 to 2011. The values are based on data from the NFI and Norwegian Mapping Authority that provided the values for the total land area for Norway.

The definitions of land cover and land-use categories have been consistent for most categories since the permanent plots were established in the period 1986-1993. There have however been some changes in definitions throughout this period that have affected the land-use change matrix. The most important one is the forest definition. In 2005, the NFI adapted the UNFCCC definition for forest, replacing a similar but not identical definition. Also the category “grassland” had not been defined in the land-use classification in the first cycle of the NFI (6th NFI, 1983 - 1993). The land-use classes assessed in the 7th NFI has been utilized for the corresponding plots in the 6th NFI. Consequently, no land-use transfers from “grassland” were assumed.

There were also changes in the definitions for when to divide a sample plot into two subplots. As a result of this, we have conducted an inspection of all sample plots with a change in land cover or land use within the NFI. In order to separate real changes from changes in definitions and practices, the changed plots were inspected on recent and historical maps, recent and historical aerial photos and in some cases by checking with local authorities. For areas moving from other land or wetlands to forest land, we have only reported this as land conversions (and as afforestation under the Kyoto Protocol) if the conversion is documented to be directly human induced (planting and/or ditching).

Table 7.10 Land-use change matrix for 2010 to 2011 (ha).

		2011						
		Land-use (ha)						
Year	Land-use	Forest land	Cropland	Grassland	Wetland	Settlements	Other land	Total
2010	Forest land	12 090 039	0	3 064	0	5 678	0	12 098 781
	Cropland	0	935 575	0	0	0	0	935 575
	Grassland	0	901	212 752	0	901	0	214 554
	Wetland	631	0	541	3 783 143	270	0	3 784 585
	Settlements	1 442	0	0	0	670 129	0	671 571
	Other land	0	0	0	0	0	14 673 134	14 673 134
	Total	12 092 112	936 476	216 357	3 783 143	676 978	14 673 134	32 378 200

7.3.2.2 Land use changes prior to 1990

According to the Good Practice Guidance (IPCC, 2003), 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. Land should be reported in a conversion category for 20 years, and then be moved to a remaining category, unless a further change occurs. Tier 3 modeling approaches may utilize different assumptions, but still with a conversion category of 20 years, i.e. 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 7.11. 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 have 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 land converted to forest may be underestimated, but the potential changes in living biomass are included in forest land remaining forest land.

Table 7.11 Estimates of productive forest land 1967–1989 (kha).

Region	1967	1979	1989
Eastern and Southern Norway	3 903,1	4 085,1	4 288,8
Western Norway	689,4	770,3	894,7
Trøndelag	974,0	975,6	996,8
Northern Norway	915,9	828,6	1 438,7
Total	6 482,4	6 659,6	7 619,0

Source: Statistics Norway 1969, 1983, 1992.

7.3.3 Sink/source categories

Changes in C stocks are reported for three main pools under the UNFCCC convention: living biomass (gains and losses), dead organic matter (DOM), soils (mineral and organic). The pools are defined as follows.

Living biomass: The tree biomass is defined as the sum of the biomass estimates of the tree fractions stem wood, stem bark, living branches, dead branches, needles or leaves as well as stump and roots down to a root diameter of 2 mm (see section 7.4.1.1).

Dead organic matter: The changes in the dead organic matter pool are the changes in all soil organic C output from the decomposition model except the humus pool originating from the decomposition of below ground litter (i.e. roots). Estimates are modeled. Conceptually the changes in the dead organic matter pool may be viewed as the changes resulting from the input and decomposition of all dead organic material (woody and non-woody, above ground and below ground) regardless of size and in all stages of decomposition. Only the most recalcitrant material (humus) originating from root decomposition is allocated to the soil reporting pool.

Soils: See the description of dead organic matter above for the definition of soil vs. dead organic matter on mineral forest soils. The separation of organic and mineral soils differs somewhat between forest land and cropland. On forest land organic soils are defined as having an organic layer deeper than 0.4 m. On cropland, organic soils are defined as soils with more than 10 % C in the topsoil (plow layer). Furthermore, the distinction is made between mixed-mineral organic soils that have between 10 % C and 20 % C and highly organic soils with > 20 % C.

7.4 Forest land 5.A

7.4.1 Forest land remaining forest land – 5A1 (Key Category)

Forest land remaining forest land covers slightly above 12 million ha. Forest ownership in Norway is dominated by private ownership, with many small properties. There were 131 800 forest holdings in Norway with more than 2.5 hectares of productive forest land in 2011 (Statistics Norway, 2012). Due to the ownership structure and specific terrain conditions, Norwegian forestry is diversified and characterized by small-scale activity. The average size of clear-cuttings was estimated to be 1.9 ha in 2003 (Statistics Norway 2004). Approximately 90 % of harvesting is fully mechanized.

Forest is the most important land-use category with respect to biomass sequestration in Norway. According to the Tier 2 key category analysis (Section 7.1.4) forest land is a key category for sequestration in living biomass, and emissions from organic soils, because of the uncertainty in both the level and trend. Sequestration in DOM is also a key category with respect to the level assessment for 1990 and 2011.

7.4.1.1 Methodological issues

Living biomass

The IPCCs (2003) stock change method is used. The method implemented corresponds to Tier 3; a combination of NFI data and models to estimate changes in biomass.

The reported carbon refers to the biomass of all living trees observed on an NFI sample plot with a stem diameter at breast height (DBH) larger than 50 mm. Thus, shrubs and non-woody vegetation are not included in the estimates. Since tree coordinates are measured on NFI plots, each tree can be assigned to a land use category. The Swedish single tree allometric regression models developed by Marklund (1988) and Petersson and Ståhl (2006) are applied to DBH and height measurements from the NFI for estimating the tree biomass. The tree biomass is defined as the sum of the biomass estimates for the tree fractions stem wood, stem bark, living branches, dead branches, needles or leaves as well as stump and roots down to a root diameter of 2 mm. The biomass models are defined for Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and birch (*Betula pendula* and *Betula pubescens*). These species

constitute approximately 92 % of the standing volume in Norway (Larsson and Hylen, 2007). Other broad-leaved species constitute most of the remaining 8 %. The birch biomass models are applied to all broad-leaved species. Table 7.12 lists the biomass model used per tree fraction. The living biomass is estimated consistently based on the same biomass models with data from the base year of 1990 onwards.

Table 7.12 Biomass models for estimating living biomass. In Marklund's (1988) models, the notation "G" indicates Norway spruce, "T" Scots pine and "B" deciduous (birch).

Component	Reference and specific model
Dead branches	Marklund (1988), G20, T22, B16
Living branches	Marklund (1988), G12, T12, B11
Needles and leaves	Marklund (1988), G16, T18 For deciduous: stem biomass x (0.011/0.52) (de Wit <i>et al.</i> , 2006)
Bark	Marklund (1988), G8, T10, B8
Stem	Marklund (1988), G5, T6, B5
Stump and roots (>2 mm)	Pettersen and Ståhl (2006), B i (for Norway spruce, Scots pine and deciduous)

Dead organic matter

The model used to estimate C stock changes in soils provides a change estimate for total soil organic carbon (SOC), which includes both the dead organic matter and soil pools. This methodology is used for mineral soil only. The estimate of total SOC entails all stages of decomposition and all litter elements regardless of size and origin (above ground or below ground). The total SOC change estimate was allocated to the dead organic matter and soil pools, respectively. This was done by allocating specific chemical model pools to the reporting pools and by using the information about the size of the litter input as well as its origin as either above ground or below ground litter. Only the changes in the H pool (humus) (0.4 %) originating from the below ground litter of all sizes were allocated to the changes in the UNFCCC soil sink/source category. The remaining changes in SOC were allocated to the changes in the DOM sink/source category. The same allocation percentages were used for all years since 1990. See section 7.4.1.1 for a description of the Yasso07 model used for the simulations on mineral soils.

Mineral soils

Choice of method

A Tier 3 method was chosen. The emissions and removals of soil organic C (dead organic matter and soil organic matter) from forest land on mineral soil are estimated using the decomposition model Yasso07 (Tuomi *et al.*, 2011; Tuomi *et al.*, 2009). Yasso07 represents processes for mineral soils down to a depth of 1 m and operates using five chemical soil C pools (Figure 7.9). Decomposition (CO₂ release) and fluxes among the chemical C pools are regulated by climatic input data and parameters governing decomposition, transformation and fractionation of large litter. The model is applied to the time series for each individual NFI plot. It is run on an annual time step but only estimates for the NFI registration years are used. The term "entry" below refers to any combination of an NFI plot and registration year.

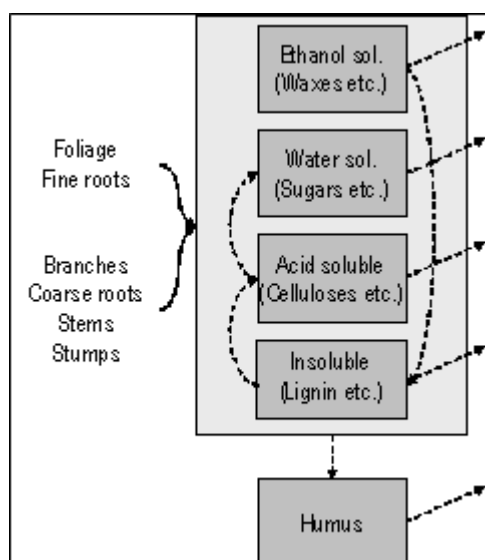


Figure 7.9 Flow diagram for Yasso07. Fluxes significantly different from 0 are indicated by the arrows (Liski et al. 2009: www.environment.fi/syke/yasso).

For each entry (ca. 11 200 NFI plots) annual living tree litter input to the model is estimated from tree registrations. On plots where the time series was not complete, back-casting was applied (see section 7.4.1.1). Tree biomass models were used to estimate biomass components (Table 7.13) and annual turnover rates for roots and branches were applied to estimate the annual litter production (Table 7.14 and Table 7.15).

Tree litter generated annually from natural mortality and residues from diffuse harvest (i.e. harvest not including commercial thinning and final harvest) was estimated on all entries as a percentage of the standing biomass. Data from the 8th NFI (2000-2004) and the 9th NFI (2005-2009) were used to establish look-up tables for this purpose (Anton-Fernandez and Astrup, 2012). Registrations of mortality and harvest on NFI plots started in 1994. The look-up tables list percentages of tree species (broadleaved or conifer), site-index (up to six classes) and age (up to nine classes) for each NFI plot. Harvest residues from commercial thinning and final harvest were estimated from plot specific registrations (since 1994) of harvested volume. This litter input was relevant on a total of 1311 entries.

Table 7.13 Biomass models used in Yasso07 simulations. When models from Marklund 1988 are used, the notation “G” is used for Norway spruce, “T” for Scots pine and “B” for deciduous (birch).

Component	Reference and specific model
Dead branches	Marklund 1988, G20, T22, B16
Living branches	Marklund 1988, G12 and G16, T12 and T18, B11
Foliage	Marklund 1988, G16, T18 For deciduous: stem biomass x (0.011/0.52), (de Wit <i>et al.</i> , 2006)
Bark	Marklund 1988, G8, T10, B8
Stem	Marklund 1988, G5, T6, B5
Stump	Marklund 1988, G26, T28 (for Scots pine and for deciduous)
Roots (> 5 cm)	Marklund 1988, G28, T31 For deciduous ^a : Petterson and Ståhl 2006, (Bi - T28) x 0.5
Roots (2 mm – 5 cm)	Petterson and Ståhl 2006, Bi (for Norway spruce, Scots pine and deciduous) Marklund 1988, G28, G26, T31, T28 For deciduous: as above
Roots (< 2 mm)	0.3 x foliage biomass; (Kjønaas <i>et al.</i> , in prep)

^a Thus, a distinct diameter limit for deciduous coarse roots is not inferred.

Table 7.14 Annual turnover rates applied for tree litter estimation. Compiled in (Peltoniemi et al., 2004) and (de Wit et al., 2006).

Component	Norway spruce	Scots pine	Broadleaved	Reference
Foliage	0.143	0.33	1	(Tierney and Fahey, 2002)
Live and dead branches, roots > 2 mm	0.0125	0.027	0.025	(Muukkonen and Lehtonen, 2004) (DeAngelis D.L, 1981) (Lehtonen <i>et al.</i> , 2004)
Roots < 2 mm	0.6	0.6	0.6	(Matamala <i>et al.</i> , 2003)

The litter generated from the ground vegetation is estimated using models based on plot tree species and age (Muukkonen et al., 2006; Muukkonen and Mäkipää, 2006). Distinction is made among Norway spruce, Scots pine and deciduous (birch spp.), with an age span of 0-200 years (Norway spruce and Scots pine) or 0-100 years (deciduous). Output of above ground biomass is generated for four layers of ground vegetation: moss, lichens, herbs and grasses, shrubs. It is assumed that below ground biomass is twice the above ground biomass. A compilation of studies documenting the above-to-below ground ratio for biomass and the annual turnover rates for ground vegetation litter (Table 7.15) can be found in Peltoniemi et al. (2004).

Table 7.15 Annual turnover rates for litter from ground vegetation.

Component	Moss	Lichens	Herbs and grasses	Dwarf shrubs
Above ground	0.33	0.1	1	0.25
Below ground	-	-	0.33	0.33

The chemical composition of tree litter was based on data used in the development of the model <http://www.ymparisto.fi>. For ground vegetation litter the values in Peltoniemi et al. 2004 were used (Table 7.16).

Table 7.16 The fraction of litter made up of acid soluble (A), water soluble (W), ethanol soluble (E) and insoluble (N). See also Figure 7.9. If more than one value was available these were averaged by species and by chemical fraction and normalized to a sum of 1 across all four fractions.

Component	A	W	E	N
<u>Stem</u>				
Norway spruce	0.63, 0.7	0.03, 0.005	0, 0.005	0.33, 0.28
Scots pine	0.66, 0.68	0.03, 0.015	0, 0.015	0.29, 0.28
Deciduous	0.65, 0.78	0.03, 0	0	0.32, 0.22
<u>Roots (<2mm)</u>				
Norway spruce	0.5508	0.1331	0.0665	0.2496
Scots pine	0.5791	0.1286	0.0643	0.228
Deciduous	as foliage	as foliage	as foliage	as foliage
<u>Foliage</u>				
Norway spruce	0.4826	0.1317	0.0658	0.3199
Scots pine	0.5180	0.1773	0.0887	0.2160
Deciduous	0.4079, 0.46	0.198, 0.1929	0.099, 0.0964	0.2951, 0.2507
<u>Living and dead branches</u>				
Norway spruce	as stem	as stem	as stem	as stem
Scots pine ^a	0.3997-	0.0105-	0.0382-	0.411- 0.4608
Deciduous	0.5307	0.0295	0.1309	as stem
	as stem	as stem	as stem	
Roots > 2 mm	as branches	as branches	as branches	as branches
Stumps	as stem	as stem	as stem	as stem
Bark	as foliage	as foliage	as foliage	as foliage
<u>Ground vegetation^b</u>				
Moss	0.74	0.0867	0.0433	0.13
Lichens	0.836	0.0747	0.0373	0.052
Herbs and grasses	0.27	0.4667	0.2333	0.03
Shrubs	0.56	0.2067	0.1033	0.13

^a 25 observations were available. The range is given. ^b From Peltoniemi et al. 2004: W is 2/3 of "extractable"; E is 1/3 of "extractable".

Litter was either non-woody (foliage, fine roots, all ground vegetation litter), fine-woody (living and dead branches, coarse roots and bark) or coarse-woody (stems and stumps). The dimensions entering Yasso07 for each of the three size-groups are 0, 2 and 10 cm respectively. Mean litter for all entries are found in Table 7.17.

Table 7.17 Mean values for input litter and predicted soil C.

	Non-woody	Fine-woody	Coarse woody mortality	Coarse woody harvest	Total
Litter (kg C m ⁻² yr ⁻¹)	0.134	0.051	0.008	0.004	0.197
Predicted spin-up stock (kg C m ⁻²)	1.76	0.65	0.17	0.02	2.59
Predicted stock* (kg C m ⁻²)	1.78	0.73	0.17	0.05	2.72

* across all entries in the time series.

For each NFI plot, start values for the five chemical C pools (Figure 7.9) were found by a pre-simulation or spin-up. Litter input for the spin-up was the mean litter estimated for the first entry on all relevant NFI plots per tree species and site-index (all first entries were found in the period 1986-1993). In the spin-up, Yasso07 was run in a loop with 5000 annual time steps. For the inventory period, SOC was estimated for each entry i.e. each time where an NFI registration was available. Plot specific SOC was found as follows: individual plot litter for each entry in the time series was used as input. Stock from the previous entry was used as the start value. A loop was applied to drive the model in as many years as is found between the

entries (mostly five years but in some cases more). For the first entry (first NFI registration) a loop of five years was applied following the spin-up stock.

Litter input as well as the simulated soil organic C stocks are kept in units of kg C m⁻². The global parameter set for Yasso07 (Rantakari *et al.*, 2011) was applied. The estimated soil organic C stock changes (and stocks) for each entry were merged with data on living biomass (see section 7.4.1.1) and up-scaling to total forest area and arrival at the annual total values for the different parts of the NFI time series was done as for living biomass.

For spin-up as well as for the time series, the applied weather data for Norway (Engen-Skaugen *et al.*, 2008) was specifically produced for the NFI grid. Weather data for spin-up was the plot-specific climatic normal for the time period 1961-1990. For the simulations for the inventory period from 1990 to 2011, plot specific weather data using the mean for 1991-2008²⁷ was applied.

The estimate of SOC changes between entries in the time series have been distributed to the dead organic matter and soil sink/source categories described above under the section on dead organic matter.

Activity data

For mineral soils a variety of input data were used. This includes area representation for plots (as described for the NFI), basic NFI registrations (as described for the living biomass) as well as site-index and stand age, complementary models and parameters including biomass models, turnover rates, chemical litter composition and litter dimensions. Climate data were available from the Norwegian Meteorological Institute. The usage and values of input data are described under *Method choice* above.

The input data from the NFI used for the Yasso07 simulations did not account for the fact that certain plots of land converted to forest were exiting the 20 year conversion period in 2011 and where therefore considered forest land remaining forest land. Instead the NFI input data correspond to the KP activity forest management (and for emission estimates under KP plot-specific estimation was made). But for forest land remaining forest land it was necessary to make a separate emission estimate for those plots that entered the remaining land-use category in 2011. To account for this an apparent sequestration rate of 0.104 Gg C kha⁻¹ was simulated for the year 2011 and multiplied with the area of land converted to forest land (mineral soil) in 1990 which was 1.35 kha.

Assumptions/justification

The NFI definition of mineral soil is based on the depth of the organic layer (< 0.4 m). We assume that the decomposition processes on these areas are represented by the model structure and the parameters of the Yasso07 model found from data on mineral soils throughout the world. A more detailed delineation between mineral and organic soils (based on soil taxonomical classification) is currently not possible.

The allocation to dead organic matter and soil organic matter assumes that there was no transportation of humus (H) from the above ground pools to the mineral soil since 1990. Thus, changes in soil organic C originating from above-ground litter in all stages of decomposition are assumed to be found in the organic layer above the mineral soil. While this is not strictly to be expected in reality, all soil organic C is accounted for and assumptions

²⁷ For technical reasons climate data is currently not available for 2009-2011.

related to the distribution to dead organic matter and soil organic matter do not affect the total emissions/removals. The assumptions result in a very small part of the total change to be allocated to the soil organic matter in mineral soil. According to field studies, changes in the mineral soil are very slow and often not significantly different from 0 (Emmett *et al.*, 2007; Peltoniemi *et al.*, 2004).

Organic soils

A Tier 2 method is chosen. 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. For organic soils the area drained was obtained from the Statistics Norway (SSB, 2000; SSB, 2013).

The area of organic soil drained on forest land increased in the 1950's to a peak of approximately 13000 ha annually in the early 1960's. Since then it has been drastically reduced and for the period 2000-2010 this amounted to approximately 200 ha year⁻¹ (Figure 7.13 in section 7.10.2.1). This is due to changes in the economic conditions and an increased focus on the preservation of mires. From 2007 establishment of drainage ditches on organic soils with the aim of forest production has been prohibited by law. There are no national data on the CO₂ losses due to drainage. An emission factor of 1.9 Mg C ha⁻¹ year⁻¹, was used (Von Arnold *et al.*, 2005). The emissions are calculated for the drained area accumulated since 1950 and assuming a low level of maintenance of the drainage ditches. Thus, the emission factor for poorly drained forest was used.

Organic soils on forest land not subject to drainage were assumed to be in equilibrium. No methods are available for the estimation of the C emissions or removals on these areas. During the in-country review, it was discussed with the ERT how much forestry activity actually takes place on undrained organic soils. Based on NFI registrations since 1990, final harvest or thinning was registered on about 8 % of the forest area (NFI definition of forest, i.e. including areas in conversion in UNFCCC terminology) on organic soil not subject to drainage and 22 % on mineral soils, thus the forestry activity on undrained organic forest soils is relatively low.

7.4.1.2 Uncertainties and time-series consistency

Living biomass

The estimation of uncertainties for C stock changes in living biomass on forest land is described in section 7.2.4 and estimated uncertainties are presented in Table 7.5.

The calculations of carbon stock changes in living biomass are conducted according to the stock change method and are based on data obtained from the 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 distributed across the country. The same plots are inventoried again after 5 years, and all plots are assessed during a 5-year period. The current system with permanent plots was put in place between 1986 and 1993, and made fully operational for the cycle covering the years 1994 through 1998. Because the re-sampling method was not fully implemented before 1994, the method used to calculate annual emissions and removals is not the same throughout the time-period, and the methods have been bridged.

The data obtained between 1986 and 1993 form the basis for the estimated carbon stock in living biomass per 31.12.1989. There are no annual biomass data available in the NFI for the years between 1989 and 1998. The annual estimates of carbon stock in living biomass for the years from 1990 to 1997, inclusive, are therefore based on the values for 1989 and 1998 using linear interpolation between these years. Because of the linear interpolation, the calculated annual change in carbon stock is the same for all years in this period. To make the estimates for the annual carbon stock change more realistic, taking into account the relationship between annual increment and annual drain, we have constructed an adjustment factor which has been used for every year in this period. This adjustment is basically a model-based interpolation. The equation for the adjusted estimate is

$$Z_t^* = [(X_t - Y_t) / (\sum_{t=1990}^{1998} X_t - \sum_{t=1990}^{1998} Y_t)] \sum_{t=1994}^{1998} \frac{3}{2} Z_t$$

where

Z_t^* = adjusted yearly carbon change estimate

Z_t = yearly carbon change estimate

$t = 1990, \dots, 1998$

X_t = annual increment of timber volume in year t

Y_t = drain in year t as given by harvest statistics

The factor $3/2$ is necessary to change the estimates from mid-year reporting until 31.12.1989 to end-year reporting beginning with 1990. It results from the fact that the mid-years of observed carbon changes (1990 and 1996) are 6 years apart and the estimate is distributed over 9 years ($9/6=3/2$).

The alternative to the model-based interpolation would be linear interpolation. This would have resulted in the same yearly carbon change estimates from 1990 to 1998 which is hard to communicate.

Values for subsequent years (after 1998) are calculated based on data obtained during the corresponding 5-year cycle.

Dead organic matter and soils

The uncertainties for dead organic matter and soil organic matter used in the key category analyses are based on expert judgment. These have not been changed since the NIR submitted in 2012. It is planned to establish uncertainty estimates based on the new methodology on dead organic matter and on soil organic matter on forest on mineral soil (Yasso07 and plot specific litter estimation) using the Monte-Carlo simulation methodology. These will be reported in the NIR in 2014. A preliminary study showed that the sampling related uncertainty (for each year since 1990) in the soil organic C estimates is between 22 % and 42 %.

7.4.1.3 QA/QC and verification

The Tier 1 QC procedures were followed for all source categories. Since the method to estimate C stock changes in living biomass was not generally changed, external QA was not necessary. The area estimates were carried out by two independent experts using two different statistical software systems based on the same data base. Similarly, the carbon change estimates were compared on a sample basis.

The NFI database has QA/QC procedures as explained in section 7.12. For estimation of mineral soils, all input was kept strictly to one unit (kg C m^{-2}). An area based unit makes it easier to compare estimates with those from other studies and regions. Specific attention was given to units conversions particularly when data were moved from one platform to another. The input data was screened for inconsistencies i.e. occurrence of null-data/missing data, length of input objects etc. Plot specific input litter scaled in the expected manner with total plot standing biomass and plot specific soil organic C changes had the expected dynamics (i.e. large positive changes starting in 1994 when harvest input is first registered, large negative changes beginning in the following NFI rotation when decomposition of harvest residues start). The area based annual changes were in the range observed in Liski et al. (2005). The programming methodology (programming software “R”) was characterized by i) step-by-step development of functions, ii) checking the reproducibility of new functions (new code), and close cooperation among programmers/developers; often code development and code control was done by different people.

The estimated C stocks were low compared to field measurements (deWit and Kvindesland 1999). However, this was expected based on earlier studies with Yasso (old version of the model; de Wit et al. 2006), which showed that the model estimated about 40 % of the measured forest soil C stock in southeast Norway. In deWit et al. (2006) this was suggested to be due in part to an overestimation of decomposition rates for recalcitrant organic matter.

A validation project on soil C changes is currently being finalized. Results will be included in the NIR in 2014. A group of external experts have been contracted to i) comment on the validation project and ii) comment on the overall estimation methodology. The estimates of changes in dead organic matter (specifically dead wood) relative to soil organic matter is planned to be validated using NFI dead wood registrations. The results will be included in the NIR in 2014.

7.4.1.4 Recalculations

Living biomass

Differences in the annual carbon change estimates from 1999 onwards are mainly due to the improved consistency of the time series. The differences in the years 1990 to 1998 mainly result from the changes in the adjustment factor that was used to bridge the change in the survey design. The method for considering Finnmark and the mountain forest stratum has slightly contributed to the difference compared to the previous reporting.

Dead organic matter and soils

A new decomposition model has been applied (Yasso07) resulting in changes from the previous NIR to the current NIR. Individual tree biomass models have been applied where previously biomass expansion factors on a stand level were applied. Litter from ground vegetation is now included and plot specific climate is applied where previously climate data was not incorporated other than assuming the same overall decomposition rates as in a climate exemplified by Finland. There is now a direct link between the living biomass data from the NFI as applied in the inventory for *Living biomass* and the amount of litter entering the soil/dead organic matter pools. This was not the case in earlier NIR's. The basic structure of output data for soil organic C (sum of dead organic matter and soil organic matter) is now

identical to that of the living biomass data which means that the up-scaling and the methodology to deal with the regional set-up of the early NFI is the same.

Recalculations were done in order to have estimates specifically for forest land remaining forest land on mineral soil (and avoid the notation key IE previously used in other categories when estimates were included in the Forest land remaining Forest land estimate), apply state of the art models and make maximum use of available country specific data. Thus, the litter inputs on mineral soil areas are generated purely from the biomass on these areas. The sinks and sources related to the production and decomposition of litter on organic soil is assumed to be incorporated into the emission factors applied.

7.4.1.5 Planned improvements

Living biomass

It is planned to slightly change the estimator for annual changes in living biomass. The way biomass gains or losses are estimated (see section 7.2.4 for notations) could be changed in the next reporting period by using the following equation:

$$T_h = \frac{N_h}{m_h} \sum_{i=1}^{m_h} y_{hi}$$

This method was tested already this year and only minor differences to the current estimates were observed. Additionally, alternatives to the adjustment factor used to bridge the estimates from 1990 to 1998 will be considered.

Dead organic matter

Estimates for dead organic matter are closely related to those of soil organic matter as both pools are estimated together using the Yasso07 model. Efforts will be made to evaluate the current method used to split the total soil organic C change into the two pools. See below.

Soils

It is known that the initial soil organic C pools (start values) influence the following estimates of annual changes (de Wit et al. 2006). This influence diminishes over time. Thus, to minimize errors due to an unrealistic start value, an equilibration period of at least 15 years will be implemented in the NIR in 2014. The amount of standing biomass in the forest has steadily increased since the beginning of the 19th century. Thus, it is expected that a model spin-up with relatively low litter input (resulting from less than current standing biomass) will result in a relatively low initial C stock and higher annual C stock changes. Further, the output from the plot specific methodology (Yasso07, plot litter estimation) will be investigated to identify strengths and weaknesses in the predictability of the model. Also the sensitivity of the model to the choice of climate data and parameter set will be studied. Efforts mentioned in section 7.4.1.3 are likely to result in modifications of the methods. An evaluation of the methods used on organic soils is planned.

7.4.2 Land converted to forest land – 5A2 (Key Category)

Land converted to forest land primarily occurs from grassland, settlements and cropland. Estimates of C stock changes are provided for living biomass, dead organic matter (DOM)

and mineral soils for all conversions possible. Emissions from organic soils are assumed to take place on drained areas which implies only wetland converted to forest land. Although the areas of organic soils are estimated for all lands converted to forest, emissions are not reported for the other land-use categories (except for wetland) due to the lack of method.

Land converted to forest land is identified as key category for living biomass and mineral soils, because of the uncertainty in both level (2011) and trend. Dead organic matter is also a key category (although small) in the trend analysis (Table 7.6).

7.4.2.1 Methodological issues

Living biomass

When a stand of trees reaches the predetermined minimum size and crown cover, the stand is measured by the NFI. Estimates of the carbon stock change in this category are carried out as for the category forest land remaining forest land (see section 7.4.1.1).

Dead organic matter

Choice of method and carbon stock

To estimate C changes in dead organic matter (DOM) for land converted to forest land, a Tier 2 method was chosen. Stock changes in DOM were estimated using the IPCC equation 3.3.4 (IPCC, 2003a) where changes in soil organic carbon (SOC) is defined as $\Delta SOC = (SOC_0 - SOC_{0-T}) / D$, and D by default is 20 years. SOC_0 is an estimate of the mean national SOC stock in DOM before the conversion and SOC_{0-T} is the estimated SOC stock in DOM under forest land. The national mean stock estimate was $22.47 \text{ Mg C ha}^{-1}$. For all other land-use classes, the mean dead organic matter stocks were assumed to be zero. The areas of land converted to forest land were estimated by NFI data.

The mean national C stock in DOM for forest land was estimated based on the Yasso07 simulation for forest land remaining forest land. Carbon stocks of the litter and dead wood model pools were added and the mean C stock was estimated as the mean of the simulated C stocks for all the NFI plots of forest remaining forest from 1990 to 2011. This estimate depends on the assumptions used when allocating C to the litter and dead wood pools (see Figure 11.2).

Mineral soils

Choice of method

For soil organic matter, a Tier 1 method was chosen. In the default methodology, changes in SOC is estimated by $\Delta SOC = (SOC_0 - SOC_{0-T}) / D$, where D is the time-dependency of the stock change factors and is by default 20 years. The SOC stock at any time can be estimated by the product of the soil C reference stock (SOC_{REF}), the stock change factors (F) and the area (A) according to: $SOC = SOC_{REF} \times F \times A$.

Activity data

For mineral soil, the areas of land converted to forest land were obtained from the NFI. In addition a distribution of IPCC soil types for forest in Norway was based on national registrations (de Wit and Kvindesland, 1999; Grønlund and Solbakken, 1987) and assuming that brunisols (according to the Norwegian classification) with low pH were categorized as spodic in WRB.

Soil C reference stock and stock change factors

A reference C stock for forest was estimated to $109.4 \text{ Mg C ha}^{-1}$ based on the C stock of the soil types provided by the IPCC in Table 2.3; (IPCC, 2006a) for the cold temperate moist climate. The distribution of IPCC soil types for Norwegian forest was 12 % as wetland soils, 77 % as spodic soils, and 11 % as high-activity clay (HAC) soils. Stock change factors (land-use, management and input factors) under forest land are by default equal to one. Thus, the mean national SOC stock for forest was $0.12 \times 87 + 0.77 \times 115 + 0.11 \times 95 = 109.4 \text{ Mg C ha}^{-1}$. For the other land-use classes, reference C stocks were 0 Mg C ha^{-1} for settlements and other lands, $76.9 \text{ Mg C ha}^{-1}$ for croplands, $98.4 \text{ Mg C ha}^{-1}$ for grasslands and 87 Mg C ha^{-1} for wetlands. See description of how these were derived under their individual chapters (i.e. section 7.5.2.1 for cropland, section 7.6.2.1 for grassland etc.).

The assumption of 0 Mg C ha^{-1} for settlements may not be entirely true. In reality, some areas under “settlements” are vegetated (parks, gardens, road sites etc.), thus soils will contain C and therefore have C accumulation rates close to those of natural ecosystems. Conversion of settlements to forest is not a negligible category and C sequestration may be overestimated for the land-use conversion.

Organic soils

For conversions to forest land on organic soils (wetland to forest land) subject to drainage, a Tier 2 methodology was used. A country specific emission factor of 1.9 Mg C ha^{-1} was applied (Von Arnold *et al.*, 2005). The emissions were calculated for the accumulated drained area since 1990 and assuming a low level of maintenance of the drainage ditches. Thus, the emission factor for poorly drained forest was used (Von Arnold *et al.*, 2005).

The activity data of the areas of wetlands converted to forests land on drained organic soil was available from the Statistics Norway (SSB, 2000).

7.4.2.2 Uncertainties and time-series consistency

Generally, the uncertainties related to emission estimates are large. For net C change in living biomass the uncertainty was $\pm 79 \%$ (Table 7.5) and for mineral soils the default values is 90%. Estimated uncertainty for the area of land converted to forest land was 26% (table 7.4). The time-series was consistent.

7.4.2.3 QA/QC and verification

The internal QA/QC plan was completed as relevant for all source categories under land converted to forest.

7.4.2.4 Recalculations

Carbon stock changes in living biomass on land converted to forest land were recalculated for the whole time-series, due to the revision of the NFI database. The estimate for 2010 was reduced from a C gain of 130 Gg C to a C loss of 22 Gg for land converted to forest land in total. The areas of especially other land, wetlands and settlements converted to forest land were significantly reduced with the revision of the NFI database. The changes in area estimates were likely the major cause of the change in the estimate.

The previous methodology for DOM and mineral soils (Yasso07, Tier 3) was replaced by Tier 1 and Tier 2 methodologies in the current NIR because it was not possible (within the available time) to establish the full Tier 3 methodology for both forest land remaining forest land and land converted to forest land. Priority was given to the development of the

methodology for forest land remaining forest land and transparent lower Tier methods were chosen as an alternative for the land-use conversions. Emissions from organic soils were also separated from mineral soils in this submission, as recommended by ERT. Changes in C stock of DOM were previously included in the estimate for soils, but in the current submission the category was reported separately using a Tier 2 method. SOC stock changes for mineral soils are reported by using a Tier 1 method, which substantially increased the C sequestration from -13 Gg SOC to 103 Gg SOC for 2010.

7.4.2.5 Planned improvements

The planned improvements described for living biomass under forest land remaining forest land will also apply for land converted to forest land as the same methodology is applied. For dead organic matter and soils, methodological improvements are planned. To the extent possible, the conversions to forest land will be estimated using the same geographically disaggregated Yasso07 application as for forest land remaining forest land. Attention will be given to the shortcomings of the previous Tier 3 method including initial C stock for areas converted from settlements, cropland and grassland. Thus, the current method is not considered final and is expected to undergo evaluation in the NIR in 2014.

7.4.3 Completeness

The reporting of emissions and removals from forest land is complete, except for estimation of C emissions from cropland, grassland, and settlements converted to forest land on organic soils.

7.5 Cropland 5B

Agricultural cropland in Norway includes annual crops, temporary grass leys and horticulture. Most of the area for agriculture is used for annual crops; primarily cereals and leys used as forage or green manure, and a smaller area with root crops where potatoes and swedes are the most important crops. Consequently, carbon is not stored over very long time in aboveground biomass. An exception is horticultural crops, where fruit trees can store large amounts of C. However, the area of perennial woody crops is a small fraction of the cropland area (approximately 0.2 %). Changes in C stock in living biomass for horticulture is reported as a sub-category.

Substantial amounts of C reside in the soil, which is affected by agricultural management practices such as tillage, crop residues input, and organic manure application (Paustian *et al.*, 2000). Dead organic matter is not a relevant source category for cropland in Norway since agroforestry systems are uncommon, and the notation key NO has been used in the CRF-tables. This is with the exception of forest land converted to cropland, where emissions are reported. Liming of agricultural land (5 IV) is described in section 7.10.4.

The cropland area has been decreasing on a national scale, but land conversion to cropland also occurs, mostly from forest land and grassland.

7.5.1 Cropland remaining cropland – 5B1 (Key Category)

The following emission sources were reported under cropland remaining cropland: C stock changes in living biomass of perennial horticultural crops (fruit trees); C emission from mineral soils due to agricultural management (crop rotations, C inputs and tillage); and C emission caused by cultivation of organic soils (histosols). By far, the vast majority of

emissions are caused by cultivation of organic soils ($\sim 1750 \text{ Gg CO}_2 \text{ yr}^{-1}$) and this is a key category because of uncertainty in the level and trend (see section 7.1.1.4). Small net losses and gains are reported for living biomass and mineral soils, respectively.

7.5.1.1 Methodological issues

Annual changes in C stocks on cropland remaining cropland can be estimated as the sum of changes in living biomass and soils: $\Delta C_{CC} = \Delta C_{LB} + \Delta C_{SO}$. Norway applies the Tier 1 steady state assumptions for dead organic matter because agroforestry is generally not practiced. Thus, the agricultural systems have small amounts of dead organic matter. Living biomass is reported for fruit trees and emissions from soils are reported for mineral soils and organic soils (histosols).

Living biomass

Changes in C in living biomass are only considered for perennial woody crops, i.e. fruit trees. Perennial berry bushes are not considered due to the small area of approximately 300 ha (Borgen and Hylen, 2013). Orchards may be felled but are considered to remain cropland. It is likely that orchards are converted to annual crops, leys, or vegetables or are replanted with fruit trees. Previously in the NIR, it was assumed that orchards were converted to grassland, however no statistics were available to support this. As the C stock changes in horticultural land are now reported under cropland remaining cropland, the subcategory horticulture under cropland converted to grassland is no longer in the CRF. Annual changes in the area of fruit trees fluctuate, leading to both net emissions and removals during the inventory period. However, C stock changes are relatively small as seen in Table 7.18.

Table 7.18 Horticultural area with fruit trees, annual area change, annual C losses, annual C gains, annual C changes (ΔC) and CO₂ emissions/removals due to changes in living biomass of fruit trees on cropland remaining cropland.

Year	Area (kha)	Area change (ha)	C losses (Gg C)	C gains (Gg C)	Annual ΔC (Gg C)	CO ₂ emissions (Gg CO ₂)
1990	3.23	-39	2.48	6.78	4.30	-15.76
1991	3.19	-39	2.48	6.70	4.22	-15.46
1992	3.15	-39	2.48	6.61	4.13	-15.16
1993	3.11	-39	2.48	6.53	4.05	-14.85
1994	3.07	-39	2.48	6.45	3.97	-14.55
1995	3.03	-39	2.48	6.37	3.89	-14.25
1996	2.99	-39	2.48	6.28	3.80	-13.95
1997	2.76	-231	14.57	5.80	-8.77	32.15
1998	2.69	-68	4.25	5.66	1.40	-5.14
1999	2.65	-46	2.90	5.56	2.65	-9.73
2000	2.65	3	0	5.56	5.56	-20.40
2001	2.65	3	0	5.57	5.57	-20.42
2002	2.61	-39	2.48	5.49	3.01	-11.04
2003	2.56	-50	3.12	5.38	2.26	-8.28
2004	2.54	-26	1.63	5.33	3.70	-13.58
2005	2.48	-58	3.66	5.21	1.55	-5.67
2006	2.40	-83	5.25	5.03	-0.22	0.79
2007	2.41	19	0	5.07	5.07	-18.59
2008	2.49	76	0	5.23	5.23	-19.18
2009	2.52	32	0	5.30	5.30	-19.43
2010	2.18	-347	21.86	4.57	-17.29	63.40
2011	1.99	-188	11.81	4.17	-7.63	28.00

Choice of method and emission factors

Due to lack of national data on biomass and carbon content in Norwegian fruit trees, we apply the Tier 1 gain-loss method. In the default method the change in C stock in living biomass (ΔC_{LB}) is equal to the C gain (ΔC_G) minus the C loss (C_L): $\Delta C_{LB} = \Delta C_G - \Delta C_L$.

Activity data

Statistics Norway collects data on the areas of fruit trees (apples, plums, cherries, sweet cherries and pears). The data were collected as a questionnaire survey with the objective to provide information about yields and production area. We use the data as collected for the whole time series 1990-2011. The area of fruit trees has generally been reduced since 1990 (Table 7.18).

Emission/removal factors

The IPCC default value for biomass accumulation in the temperate climate is $2.1 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$ and the corresponding value for C loss when plantations are terminated is $63 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$. The default age for fruit trees to reach maturity and cease accumulating C is 30 years.

Assumptions/justification

Given the default method, we assume that 1) all orchard trees are less than 30 years old and growth accumulates at the default growth rate and 2) all felled orchards are plantations with mature trees around 30 years of age. These assumptions may not be representative for Norway, as Norwegian fruit trees may mature in 20-25 years. However, the activity data does not provide information on the age of the plantations when felled. Hence, this has not been considered in our calculations.

Mineral soils

The methodology for CO₂ emissions from mineral soils has been changed in the 2013 submission because a review of recent literature did not support using an erosion-based method (Borgen and Hysten, 2013). We also adopted the advice of the 2006 Guidelines that the net effect of soil erosion from changes in land management is highly uncertain (IPCC, 2006a) and, thus, changes in soil erosion rates should not be used as an indicator for soil respiration and CO₂ emissions. Literature illustrating the lack of uniform support for erosional events as a net source of CO₂ is given in NFLI report (Borgen and Hysten, 2013). Previously, reported emissions and removals were estimated based on erosion as well as tillage practices. Emission estimates caused by different tillage practices were based on studies of soil erosion differences on spring and fall plowed fields, which was assumed indicative of reduced and traditional tillage, respectively. For those reasons, we considered it necessary to abandon the previous Tier 2 method. This decision was supported by the ERT in discussions during the in-country review in 2012.

Choice of method

The new Tier 2 method estimates annual changes in soil organic C (SOC) according to Equation 2.25 (IPCC, 2006a), where the annual change in SOC is: $\Delta \text{SOC} = (\text{SOC}_0 - \text{SOC}_{0-T})/D$, where D is the time dependency of the stock change factors. SOC_0 is the stock the last year of the inventory period and SOC_{0-T} is the C stock at the beginning. We adjusted the default value for D to 30 years given the slower decomposition rates under the cool temperate climate in Norway. The SOC stock is calculated as the product of the soil C reference stock (SOC_{REF}), the stock change factor for a given management and climate regime (F), and the associated area (A): $\text{SOC} = \text{SOC}_{\text{REF}} \times F \times A$. We used the reference stock and stock change

factors estimated by the Introductory Carbon Balance Model (ICBM) in a study where CO₂ emissions were estimated for Norwegian cropland for 1999-2009 (Borgen *et al.*, 2012). The ICBM is an ecosystem model from Sweden developed by Andrén *et al.* (2004). Soil C reference stocks were estimated for 31 different climatic zones (agrozones) assuming that continuous grass ley cropping was the reference condition. Stock change factors were calculated for eight rotations with and without manure application. The rotations were 1:2 ley-grain, 1:1 ley-grain, 2:1 ley-grain, continuous grain (with and without straw removal), continuous ley, 1:2 roots-grain, and 1:2 roots-ley. Further details of the model application and the stratification are given in Borgen *et al.* (2012). We calculated annual SOC changes per agrozone and summed the emissions for the whole country.

Activity data

A recent study illustrated how the agricultural area statistics per crop type collected by the Norwegian Agricultural Authority (NAA) could be compiled (given certain assumptions) to create crop rotations, manure application and C input level (Borgen *et al.*, 2012). In brief, Norway was divided into 31 agrozones based on a combination of counties (*fylke*) and climate-based production zones (defined by NAA for subsidy applications). Within each agrozone, the relation between the major crops of small grains (cereal and oilseeds), root crops (potato and rutabaga), and grass ley were used to allocate the areas under each of eight crop rotations. In addition, activity data of manure production applied to fields were received from Statistics Norway and correspond to the data used for estimating non-CO₂ emissions related to animal manure for the Agricultural sector. Estimated manure availability was translated into areas receiving animal manure per crop rotation.

Stock change factors and soil C reference stocks

The stock change factors represent the annual response of SOC to a change in management from a reference condition and can be calculated as $F = \text{SOC}_{\text{REF}}/\text{SOC}$. The soil C reference stocks were estimated by solving the ICBM model for steady state conditions. Both stock change factors and soil C reference stocks are listed in Borgen *et al.* (2012).

Assumptions/justification

The Tier 1 and 2 methods assume that the SOC change resulting from a change in management is linear between two steady states. Soil C changes are likely to be more dynamic and it has been argued that the lower tier methods overestimate net C sequestration, particularly where the soil was not a steady state at the beginning of the inventory (Sanderman and Baldock, 2010). However, at the present time, this method provides a decent approximation. Furthermore, the sink/source category mineral soil on cropland remaining cropland is not a key category.

Organic soils

Organic soils make the largest contribution of CO₂ emissions within the source categories for cropland. It is a key category with a large uncertainty in the estimates. The Norwegian definition of histosols (organic soils) for cropland is soils with a topsoil layer (0-30 cm) with >10 % C.

Choice of method

A Tier 2 method is used for estimation of CO₂ emissions from organic soils on cropland. The IPCC Tier 2 method necessitates a country-specific emission factor (EF) to be multiplied by the area (A) of organic cultivated soil according to Equation 2.26 (IPCC, 2006a): $C_{\text{LOSS}} = \sum (A \times \text{EF})$, where the summation is applicable if stratified emission factors are applied e.g. by

climate or crop type. Norway has applied national emission factors in two different strata that depend on the % of C in the soil: highly organic soils have >20 % C and mixed organic soils have between 10 and 20 % C in the topsoil. The mean national emission factors were the same regardless of climate region or management system.

Activity data

The area of cultivated organic soils was estimated using soil maps from the Norwegian Forest and Landscape Institute (*DMK* and *AR5*) and a soil sample database from Bioforsk (Grønlund *et al.*, 2008). At the time of the analysis, approximately 50 % of the cultivated area had been mapped and the total area estimate of cultivated organic soils was between 75 kha and 90 kha, with a final corrected value of 83 170 ha. This value was considered realistic in 1994 and used to initiate a time series (extrapolated back to 1990). In 1994 subsidies were no longer provided for cultivation of new organic soils and from then on we may assume a smaller increase in the area of cultivated histosols (200 ha yr⁻¹, expert judgment). Also, we assume that 1.4 % yr⁻¹ of the area becomes mineral soil or is taken out of production. This time series entails substantial assumptions; however, it is currently the best available activity data. In previous submissions, 90 % of the area of cultivated organic soils was considered to be grassland because grass was the main vegetation. However, given the redefinition of grasslands, the entire area is now reported as cropland.

Emission/removal factors

Few data are available on measured CO₂ emission from cultivated histosols in Norway. Thus, the emission factor is based on expert judgment. Given the range of plausible emission factors (2-10 Mg C ha⁻¹ yr⁻¹), we assume emissions from highly organic soils at the upper value of 10 Mg C ha⁻¹ yr⁻¹ and emissions from mixed organic-mineral soils at the lower value of 5 Mg C ha⁻¹ yr⁻¹. The ratio of the areas of highly organic and mixed organic-mineral soil is 1:2, which makes the mean emission factor for cropland equal to 6.67 Mg C ha⁻¹ yr⁻¹.

Assumptions/justification

Currently, there are substantial assumptions related to both the estimated area of organic soils and the time-series produced, as well as to the emission factor. Experiments aiming to quantify emissions from organic soils are producing a wide range of results due to differences in location, climate, soil, and management practices. It is therefore not possible at this time to improve the estimate of the emission factor.

7.5.1.2 Uncertainties and time-series consistency

Estimation of uncertainty is related to the tier level of the methodology used for each sink/source category and land-use category. For cropland remaining cropland, Tier 1 and 2 methods were applied. The IPCC guidelines include uncertainty estimates for default emission/removal factors.

For cropland remaining cropland the total uncertainty is equal to the propagation of the uncertainty related to the living biomass (U_{CC_LB}), mineral soils (U_{CC_MS}), and organic soils (U_{CC_OS}):

$$U_{CC} = \sqrt{U_{CC_LB}^2 + U_{CC_MS}^2 + U_{CC_OS}^2}$$

For each source category, the uncertainty is a combination of the uncertainties related to the emission factors U_{EF} and the activity data U_A , which can be calculated by:

$$U = \sqrt{U_A^2 + U_{EF}^2}$$

The uncertainty of the activity data may include errors in census returns as well as differences in definition between agencies, sampling design and interpretation of samples. The activity data used under cropland, i.e. areas per crop types and manure production, were collected through the subsidy application scheme administrated by NAA and compiled by SSB. The data is based on a total national census. The NAA performs quality control on 5 % of farms to determine if areas are provided correctly. These sample checks show very few errors. The area reported is based on a factor value multiplied by the last year's area, thus errors in previous years may accumulate. However, according to expert judgment given by SSB, the uncertainty of the activity data is approximated to 0 %.

In the case where the NFI areas are used for cropland (mineral soils), the uncertainties were, as for all the LULUCF land-use and land-use change classes, calculated as described in section 7.1.2.5.

Living biomass

Sources of uncertainty for the Tier 1 method for living biomass includes the degree of accuracy in the C accumulation and loss rates and the land-use activity data. The IPCC default uncertainty error ranges for above-ground woody biomass accumulation in the temperate climate is ± 75 % based on expert judgment. Uncertainty of the activity data was estimated by SSB as approximately 0 %. The areas of orchards are used directly from the NAA/SSB data and are not related to the NFI database. The uncertainty of the C biomass accumulation per unit area is therefore equal to the total uncertainty of the C changes in living biomass on cropland remaining cropland.

Mineral and organic soils

Uncertainty related to emission estimates from mineral soils on cropland can currently only be quantified for the area uncertainty based on the NFI data. For the total area of cropland remaining cropland the uncertainty estimate was 6.7 %. The areas per crop type that are used to determine the areas under individual crop rotations were collected and compiled by the Norwegian Agricultural Authority (NAA) and Statistics Norway (SSB). The uncertainty in the crop type areas was approximated to 0 % by a SSB expert. In addition, there are uncertainties related to both, the stock change factors estimated by ICBM for the mineral soil emissions, and the emission factor applied to organic soils. Furthermore, the area estimate of cultivated organic soils is also uncertain. At present time, we cannot quantify the uncertainties. However, for organic soils, it is assumed to be 100 %, although it could be higher.

To insure area consistency of other land-use categories and the cropland area defined in the NFI, proportions of the cropping systems were derived from the SSB data and multiplied with the cropland remaining cropland area estimated by the NFI.

Making a quantitative uncertainty assessment combining emission factor and activity data uncertainties is not possible for estimates from cultivated organic soils because expert judgment is the foundation of both the emission factor and the time-series of the area. At the present time, it may suffice to state that the uncertainty is substantial and ± 100 % is assumed

in the key category analysis. Efforts should be placed to make a proper assessment in the future, possibly as suggested below under improvements.

7.5.1.3 QA/QC and verification

Living biomass

The standard Tier 1 QC procedures described in section 7.12 were performed. No external QA was performed on the Tier 1 method for estimating C changes in living biomass stocks in orchard trees. The reason for this is that we are evaluating a Tier 2 method for the next inventory submission. If it is decided to stay with the Tier 1 method, external QA will be performed before the 2014 submission.

Soils

The standard Tier 1 QC procedures described in section 7.12 were performed for calculations related to mineral and organic soils. In addition, QA of the new Tier 2 method for estimation of CO₂ emission from mineral soils on cropland was done through the standardized peer-review process.

In 2012, QA was performed on the emission factor applied for organic soils by solicitation of an externally performed literature review with the purpose to consult recent literature and potentially improve the EF. The conclusion of the report was that the previously applied EF based on expert judgment was still the best option as measured data of sufficient quality and quantity is not yet available (Borgen and Hylen, 2013).

7.5.1.4 Recalculations

Living biomass

In this submission, we used the unadjusted area of horticultural crops, whereas in previous submissions areas were adjusted back to the 2004 estimate. This was done to improve the transparency of the activity data. In addition, the differences between the two time-series were small (Figure 7.10). Due to the updated activity data the whole time series has been recalculated. Emissions and removals only changed slightly when summed for the inventory period. With the previously used adjusted area data, net CO₂ removals were 116 Gg CO₂ compared to 159 Gg CO₂ for the whole inventory period, when the unadjusted activity data was used (this submission).

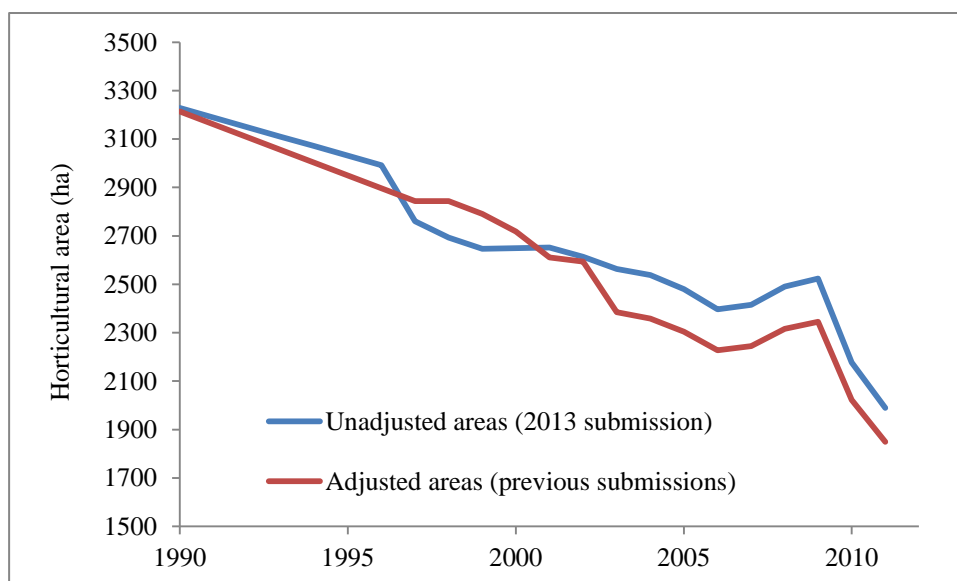


Figure 7.10 Unadjusted and adjusted areas of horticultural crops.

Soils

The entire time-series was recalculated due to the change in methods and applicable activity data. The new Tier 2 method resulted in a slight increase in SOC stocks on cropland, which was caused by the larger area receiving animal manure. In fact, total manure production did decrease slightly over the past 20 years, but even more so did the area of cropland. Consequently, we observe a net SOC sequestration.

Emissions from cultivated histosols increased drastically due to the redefinition of grassland and the inclusion of the grass area under cropland. Consequently, the emissions reported previously under grassland for organic soils are now reported under cropland.

7.5.1.5 Planned improvements

Living biomass

Given the large uncertainties of the default C gain and loss factors and the current lack of tree biomass data on fruit trees in Norway, a Tier 2 method similar to the one used in Denmark could be used. This would imply using the stock-difference instead of the gain-loss method and apply the Danish biomass C stocks per ha specifically to apples, pears, plums, and cherries (Gyldenkerne *et al.*, 2005). The method has been tested and tentative results indicate a total net CO₂ loss of ~ 60 Gg with the stock-difference method. The currently used loss-gain method gives a total CO₂ uptake of ~ 160 Gg in the period from 1990 to 2010. Given the opposed results of two methods, it would be necessary to evaluate the method and possible future implementation further. However, areas and emissions are relatively small.

Mineral soils

The Tier 2 method we are using has its limitations and further improvements are possible. Given the groundwork already done using the model to estimate stock change factor for the Tier 2 method, it seems possible to make a dynamic model implementation using the ICBM and elevate to a Tier 3.

Organic soils

As recommended during the in-country review in 2012, efforts to improve the estimated area and emission factor related to organic soils have been made. In the spring of 2012, the emission factor was evaluated with the conclusion that more research and field work is necessary to improve the emission factor value. We plan to continuously evaluate the emission factor by staying updated on research advances in Norway and Scandinavia. The area of organic soils and the estimation of the time-series will be further evaluated. In the future, it is planned to improve the area estimates of cultivated organic soils by overlays of updated soil maps and information collection in order to reduce the reliance on the expert judgments.

7.5.2 Land converted to cropland – 5B2 (Key Category)

Emissions on land converted to cropland are reported from the C stock changes in living biomass and mineral soils. Changes in dead organic matter were only estimated for forest land converted to cropland. Carbon stock changes in dead organic matter on other land-use conversions than those to and from forest land can be considered negligible and are reported with the notation key NO in the CRF-reporter.

Land conversion to cropland primarily occurs from forest land and grassland and less so from wetlands and settlements. There were no conversions from other land to cropland during the inventory period. Conversion of land to cropland usually results in a net loss of carbon from living biomass and soils to the atmosphere (IPCC, 2003). However, the SOC stock on settlements converted to cropland will increase due to the larger SOC stock on cropland compared to settlements.

Land converted to cropland is identified as a key category with respect to mineral soils, due to uncertainty in trend.

7.5.2.1 Methodological issues

Living biomass

We used the Tier 3 method to estimate C stock changes in living biomass, described in section 7.4.1.1. Changes in living biomass were miniscule and reported as NO during the inventory period for all land-use classes converted to cropland, except for forest land converted to cropland. Net C stock changes were smaller than 60 Gg C for any year in the inventory period.

Dead organic matter

Emissions caused by changes in dead organic matter (DOM) increased during the inventory period (as a consequence of the Tier 2 method) but were not larger than 50 Gg CO₂ yr⁻¹ in 2011.

Choice of method

A Tier 2 method was used to estimate C stock changes in DOM from forest land converted to cropland. Stock changes in DOM were estimated using the IPCC equation 3.3.4 (IPCC, 2003a) where $\Delta\text{SOC} = (\text{SOC}_0 - \text{SOC}_{0-T}) / D$, where D by default is 20 years. SOC₀ is the mean national SOC stock under forest land and SOC_{0-T} is the estimated SOC stock in DOM under cropland.

Activity data

Areas of land converted to cropland were estimated using the NFI data.

Soil C reference stocks

The soil C reference stocks for DOM on forest land is estimated as described under *Land converted to forest – dead organic matter*. The mean national SOC stock for forest land was 22.47 Mg C ha⁻¹. For cropland and all other land-use categories the mean national SOC stocks for DOM were assumed to be zero.

Soils

Choice of method

We used a Tier 1 method for estimating C stock changes on land converted to cropland. This method was used for all land-use conversions and described in detail in section 7.4.2.1 under mineral soil.

Activity data

Areas of land converted to cropland were estimated using the NFI data.

Soil C reference stock and stock change factors

The mean national SOC stock estimate for cropland was 76.9 Mg C ha⁻¹. The estimate was derived considering both the soil type and management practice. Specifically, cropland was considered on soils with high-activity clays and the default soil C reference stock of 95 Mg C ha⁻¹ (Table 3.3.3; IPCC, 2003a) was multiplied by a mean stock change factor, which was the product of the tillage, management and land-use factors listed in Table 5.5 (IPCC, 2006c). The mean stock change factor was determined for each of the 16 crop rotations used in the Tier 2 for cropland remaining cropland and these were weighted by the national mean area under each crop rotation.

Mean national SOC stocks estimates were 109.4 Mg C ha⁻¹ for forest land, 98.4 Mg C ha⁻¹ for grasslands, 87 Mg C ha⁻¹ for wetlands (the IPCC default reference stock), and 0 Mg C ha⁻¹ for settlements and other lands. More details on methods to estimate these stocks are given under the respective chapters (e.g. for the grassland stock see the land converted to grassland chapter and so on).

7.5.2.2 Uncertainties and times-series consistency

For living biomass, the associated uncertainty is only available for the area and not for the C stock change. The area uncertainty for land converted to cropland is ±42 % (Table 7.4). For mineral soils, the estimated uncertainty related to the stock change factors and SOC stocks that are based on the IPCC default soil C references is approximately ±92 %. Generally, the uncertainty is rather large for these emission estimates.

7.5.2.3 QA/QC and verification

The Tier 1 QC procedures were performed during the estimation of C stock changes for land converted to cropland. No additional QA was performed.

7.5.2.4 Recalculations

Emissions were not recalculated for living biomass on land converted to cropland but the notation key was changed from NE to NO. Although we have a consistent time-series of C stock changes in trees, no living biomass changes were recorded on the NFI plots converted to cropland.

Emissions were recalculated for DOM on forest land converted to cropland, which was previously included in the soils estimate produced by Yasso07. With the change of methods to Tier 2, we have produced separate emission estimates for this category.

Estimated C losses in mineral soils related to land conversion to cropland increased by 66 %. This was due to the implementation of the Tier 1 method. The revision of the NFI database did not result in large differences in the area estimates.

7.5.2.5 Planned improvements

We plan to improve the estimation method for mineral soils. The current Tier 1 method can be replaced by a higher tier level, particularly for forest land converted to cropland. This could be done by bridging the estimates derived from the Yasso07 simulations (forest land remaining forest land) with estimates from the planned ICBM simulations for cropland. Currently, no area estimates are reported for organic soils on lands converted to cropland. In the next submission we plan to include estimates of areas of organic soils for forest land converted to cropland.

7.5.3 Completeness

The reporting of emissions from cropland is complete with the exception of the areas of organic soils on land converted to cropland. The NFI database does not register organic soils on land that are converted to cropland, except for forest land converted to cropland, but no emission factors are available for this land-use change category.

7.6 Grassland 5C

Grasslands cover a very small (approximately 0.7 %) part of Norway. According to the IPCC guidelines, grasslands are defined as grass areas that have insufficient woody biomass to be classified as forest and that are not considered cropland (IPCC, 2006b). These lands include ranging lands and pastures where some mechanical surface harvesting for fodder may take place. The Norwegian interpretation of the IPCC land-use category grassland, which is based on available data, is that grasslands are generally mechanically harvested or grazed, but are never plowed. They may be cultivated more or less intensively by the use of fertilization, mechanical harvesting and utilization of improved species.

In the national agricultural statistics collected through the subsidy application scheme, two types of grassland areas can be identified. These are surface-cultivated grass pastures (*overflatedyrka eng*) and unimproved grazing land (*innmarksbeite*). Surface-cultivated pastures tend to have shallow topsoil layers, often with surface rocks. They can be mechanically harvested but not plowed. Unimproved grazing lands are never mechanically harvested (or plowed) and can be considered semi-natural landscapes. Furthermore, unimproved grazing land is defined as areas covered by a minimum of 50 % grasses or grazable herbs and enclosed by a fence or a natural barrier. An additional requirement for both grassland types is that the area must be grazed or harvested at least once a year to be eligible for subsidy support.

7.6.1 Grassland remaining grassland – 5C1 (Key Category)

For grassland remaining grassland, emissions are estimated from C stock changes in living biomass and in mineral soils.

Grassland remaining grassland is identified as a key category with respect to living biomass, due to uncertainty in both level and trend.

7.6.1.1 Methodological issues

Emissions due to changes in dead organic matter are assumed negligible for this category because the mass of aboveground biomass is small and is likely to be in a steady state condition. This is in accordance with IPCC (2003) and the notation key NO is used in the CRF tables.

Living biomass

The Tier 3 method described under *Forest land remaining forest land - living biomass* is used to estimate C stock changes in living biomass on grassland remaining grassland. Carbon removals are very small. The activity data are taken from the NFI.

Soils

All cultivated organic soils are considered under cropland, thus soils in the category grassland remaining grasslands are mineral. Since the beginning of the inventory period in 1990, the total area of permanent grasslands in Norway appears to have been losing soil C, due to the extensification of management practices. The area of extensively-managed grassland (unimproved) has increased while more intensively managed (improved) grazing lands have decreased. The associated CO₂ emissions are small, and not larger than 61 Gg CO₂ yr⁻¹ for any year during the inventory period.

Choice of method

The default Tier 1 approach was used for estimating CO₂ emissions from grassland on mineral soils. The default IPCC methodology estimates soil C changes based on default stock change factors specific to management and climate regimes and soil C reference stocks specific to climate and soil type. Associated uncertainties may also be estimated. The annual changes in SOC can be calculated as the difference between the SOC stock at the beginning (SOC₀) and at the end (SOC_{0-T}) of the inventory period divided by D; the time dependency of the stock change factors, which by default is 20 years:

$$\Delta SOC = (SOC_0 - SOC_{0-T})/D \quad \text{Equation 2.25 (IPCC, 2006a)}$$

If T is larger than D, then T replaces D and T is equal to the length of the inventory period. This is relevant for the emission estimated for 2011 where the inventory period is 21 years. SOC stocks for any year of the inventory can be calculated as the product of the soil C reference stock (SOC_{REF}), the stock change factors (F) and the area under a given management practice (A) according to:

$$SOC = SOC_{REF} \times F \times A. \quad \text{Equation 2.25 (IPCC, 2006a)}$$

The C reference stock is the soil C stock under the reference condition, which in the default method is native uncultivated soil. The reference stock is specific to climate zone (boreal, temperate moist, temperate dry, etc.) and soil type (high-activity clay, low-activity clay, spodic, sandy, wetland, or volcanic soils). Exposed bedrock should be assigned a reference stock of zero. However, this is not specifically accounted for in the current emission estimate for grassland.

Activity data

Area data of the two grassland management types were collected by NAA and SSB. These data were collected in form of a questionnaire available to farmers interested in applying for subsidies. Areas of unimproved and improved grasslands are given per farm unit. The total area of grassland remaining grassland was derived from the NFI database and the percentages under each management type were taken from the SSB data. The area estimated by NFI is larger than the area from the SSB data. The difference is larger in the beginning of the inventory period than later (Table 7.19). From 1990 to 1997 the area of unimproved grassland only accounted for fertilized pasture, whereas all unimproved pastures were included in the later years. Furthermore, the degree of farmers applying for subsidies is likely to have increased over the years, thus making the difference between the two area estimates smaller.

Table 7.19 Areas (ha) of unimproved, improved and total grasslands in Norway from 1990 to 2011.

Year	Area (ha) from Statistics Norway (SSB)			Area (ha) from the NFI database
	Unimproved grassland	Improved grassland	Total grassland	Grassland remaining grassland
1990	81 357	27 180	108 537	220 883
1991	85 453	26 973	112 426	220 182
1992	89 735	27 153	116 888	219 481
1993	94 215	25 975	120 190	218 780
1994	98 422	26 050	124 471	218 079
1995	100 719	26 447	127 166	217 378
1996	103 008	26 672	129 681	216 677
1997	107 900	25 478	133 378	215 976
1998	111 474	29 179	140 653	215 276
1999	121 607	29 517	151 123	213 473
2000	129 133	28 997	158 129	213 473
2001	132 293	28 244	160 536	212 392
2002	135 408	28 067	163 474	209 688
2003	137 061	27 382	164 443	208 246
2004	139 083	26 951	166 033	208 246
2005	142 407	26 770	169 177	206 894
2006	145 588	26 110	171 698	206 894
2007	149 207	25 375	174 582	205 993
2008	150 810	24 327	175 137	204 731
2009	152 352	22 455	174 806	201 126
2010	155 136	20 704	175 839	198 422
2011	156 452	20 119	176 571	196 770

The grassland areas per management type were stratified to eight regions (Figure 7.11). The area data from SSB are available on a municipality level facilitating the stratification. Soil maps were collected to stratify the areas according to soil types and to assign specific C reference stocks based on the distribution of soil type within each region.

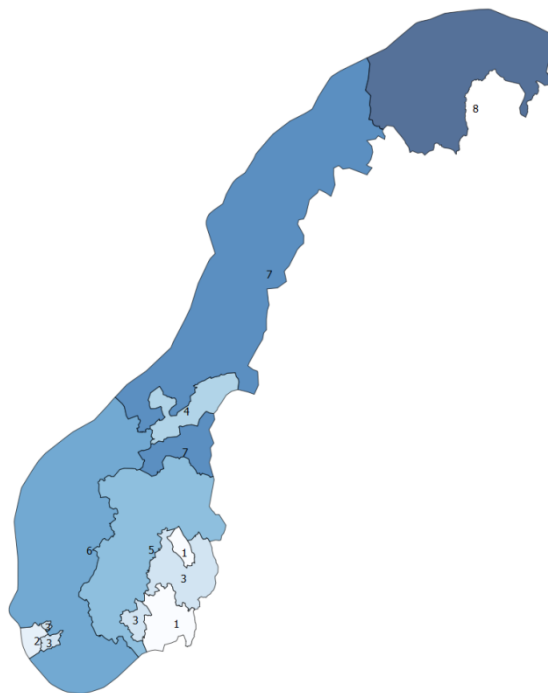


Figure 7.11 Eight regions of Norway used to stratify grassland activity data for the Tier 1 application.

Stock change factors and soil C reference stocks

The default stock change factors developed by Ogle *et al.* (2004) were used; see Table 6.2 (IPCC, 2006d). The land-use factor for grassland is one ($F_{LU} = 1$). There are four management factors (F_{MG}): unimproved/nominal (non-degraded), moderately degraded, severely degraded, and improved grasslands, and two input factors (F_I): nominal and high input level. For the two types of grassland management identified (unimproved and improved) we assigned the following management factors: $F_{MG} = 1$ as per nominally managed (non-degraded) grassland for permanent unimproved grass, i.e. *innmarksbeite*, and $F_{MG} = 1.14$ as per improved grassland for surface cultivated grassland, i.e. *overflatedryka eng*. The latter factor is assigned to grassland that is sustainably managed with moderate grazing pressure and that receives one improvement of fertilization, species improvement or irrigation. The input factor is not modified due to a lack of activity data. Under Norwegian conditions, it is a reasonable assumption that most grassland receives only one improvement in form of fertilizers, as grazing areas are seldom reseeded (except in cases of severe frost damage) and also irrigation is generally not practiced.

To assign the soil C reference stock, an analysis was made of the national soil classification (World Reference Base, WRB, soil taxonomy) database developed by the Norwegian Forest and Landscape Institute. The percent of the total grassland area that has been sampled until now varies between the eight strata defined. High-activity clays soils predominate in all climate zones but spodic soils make up almost one third in region 2 (Figure 7.12).

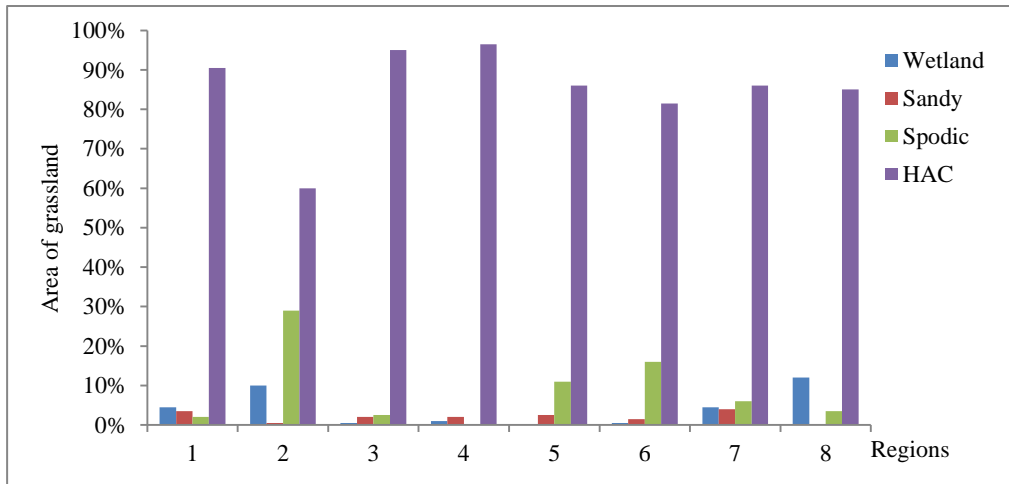


Figure 7.12 Distribution of soil types on grassland areas for the eight strata. The IPCC soil types are high-activity clay soils (HAC): leptosols, fluvisol, phaeosem, albeluvisol, luvisol, umbrisol, cambisol, regosol; wetland soils: gleysols; sandy soils: arenosols; and spodic soils: podzol.

The soil C reference stock (SOC_{REF}) for the cold temperate moist climate zone in 0-30 cm depth are 95 Mg C ha^{-1} , 71 Mg C ha^{-1} , 115 Mg C ha^{-1} , and 87 Mg C ha^{-1} for HAC, sandy, spodic, and wetland soils, respectively; Table 2.3 (IPCC, 2006a). Soil C stock changes were first calculated per stratum and soil type. The final stock changes were given by multiplying the C stocks per stratum and soil type with the fractions under each soil type.

7.6.1.2 Uncertainties and time-series consistency

A Tier 1 uncertainty assessment was made considering both the uncertainty related to the C stock estimate (the stock change factors) and the activity data. First, we estimated the uncertainty of the SOC stock estimate (U_C) by propagating the uncertainty of the stock change factors and SOC reference stock. The errors of the stock change factors are provided in Table 6.2 (IPCC, 2006d). For the improved grassland management stock change factor, the uncertainty is $\pm 11\%$. The stock change factor for nominally managed grassland has no associated uncertainty as it is the reference condition. The SOC reference has an uncertainty of $\pm 90\%$ according to Table 2.3 (IPCC, 2006a). Secondly, the uncertainty of the activity data was combined with that of the C stocks.

The uncertainty in the activity data (U_A) covers both uncertainty in the estimates of the grassland management type (SSB data) and uncertainty in the areas of grassland remaining grassland determined in the NFI. The first source of uncertainty, which is related to the determination of the type of grassland management system, was estimated to be close to zero by SSB. According to the sample check-ups routinely performed by the collection agency (NAA), farmers are unlikely to make errors (or false reporting) and very few of these errors exist. The second source of uncertainty in the activity data, i.e. of the area estimate of grassland remaining grassland, was determined by the sample error and equal to 14% . Uncertainties of the area estimates are quantified as described in section 7.2.5.

The total uncertainty for grassland remaining grassland was propagated using equation 5.2.1 of the Good Practice Guidance (IPCC, 2003b):

$$U_{GG} = \sqrt{U_F + U_A} = \sqrt{11^2 + 90^2 + 14^2} = 90.8\%$$

7.6.1.3 QA/QC and verification

The Tier 1 QC procedures were performed both for living biomass and mineral soil emission estimates. In addition, an external QA was elicited for the new Tier 1 method applied for mineral soils. All necessary documentation was supplied to an international expert for an evaluation of the method application and description. The expert emphasized the need to keep the area of grassland remaining grassland constant at the beginning and end of each inventory period when recalculating the entire time-series. Furthermore, quality checks were implemented to ensure that the total land area per stratum remains constant over the time series.

7.6.1.4 Recalculations

The whole time-series was recalculated both for living biomass and mineral soils due to a change in methods and activity data. Previously, C stock changes in living biomass on grassland remaining grassland were reported as NO, whereas the NFI database revision resulted in a small C gain. Emissions from changes in SOC due to grassland management changes were reported as NO in preceding submissions but was this year estimated by a Tier 1 method resulting in a small C loss. The C gain for living biomass and the C loss for mineral soils offset one another and yielded very small net emissions and removals for the land-use category over the whole time-series.

7.6.1.5 Planned improvements

The method for estimating emissions from mineral soils on grassland has potential for improvement, by for example using a model to estimate country-specific emission factors, turning it into a Tier 2 method. The Swiss-developed Oensingen Grassland Model (OGM) has been especially calibrated for differentiating extensive and intensive grassland management (De Bruijn et al., 2012), which may be particularly relevant for Norway partly due to the similar grassland and climatic systems and also due to the changes observed in the activity data since 1990. However, efforts are necessary to compile more information about the grassland management practices in Norway, and especially the application of manure, which significantly influences soil C loss or uptake (De Bruijn et al., 2012).

7.6.2 Land converted to grassland – 5C2 (Key Category)

Emissions from land converted to grassland were primarily caused by SOC changes on forest land converted to grassland. For forest land converted to grassland, C emissions were estimated from changes in living biomass, DOM, and mineral soils. No methodology is available for emissions estimates for organic soils. Hence, NE was reported.

Forest land converted to grassland is identified as a key category with respect to living biomass, due to uncertainty in both level and trend.

7.6.2.1 Methodological issues

Living biomass

The choice of method, activity data and assumptions related to the estimation of C stock changes in living biomass on land converted to grassland are identical to those described under section 7.4.1.1.

Dead organic matter

Carbon stock changes in DOM are only reported for forest land converted to grassland. For all other land conversions to grassland we assume no net change in carbon of dead organic matter, thus the notation key NO in the CRF-tables. In addition, according to the IPCC (2003) the carbon stock change in DOM is considered negligible when land is converted to grassland.

A Tier 2 method was used; see section 7.4.2.1 for details. The areas of land converted to grassland were estimated using the NFI data

Soil C reference stocks

The soil C reference stocks for DOM on forest land is estimated as described under *Land converted to forest land – dead organic matter*. The mean national SOC stock for forest land was 22.47 Mg C ha⁻¹. For grassland, the mean national SOC stock for DOM was assumed to be zero.

Soils

A Tier 1 method was used for estimating C stock changes on land converted to grassland. This method was used for all land-use conversions and described in detail in section 7.4.2.1 under land converted to forest – soils. The activity data for land converted to grassland were estimated using the NFI data.

Soil C reference stocks and stock change factors

The mean national SOC stock estimate for grassland of 98.4 Mg C ha⁻¹ was derived by multiplying the mean stock change factor with the mean SOC reference stock. This estimate is based on the national ratio of improved and unimproved grassland management practices and the national distribution of IPCC defined soil types for the grassland area. More specially, a mean stock change factor was calculated as $F = 0.82 \times 1 + 0.18 \times 1.14 = 1.03$, because the long-term mean distribution of unimproved and improved grassland was 82 % and 18 %, respectively. A mean SOC reference stock was estimated assuming the following distribution: 85 % HAC, 2 % sandy soils, 9 % spodic soil, and 4 % wetland soils (i.e. gleysols), resulting in an estimate of $SOC_{REF} = (0.85 \times 95 + 0.02 \times 71 + 0.09 \times 115 + 0.04 \times 87) \text{ Mg SOC ha}^{-1} = 95.9 \text{ Mg SOC ha}^{-1}$.

The mean national SOC stock estimate was 109.4 Mg C ha⁻¹ for forest land, 76.9 Mg C ha⁻¹ for cropland, 87 Mg C ha⁻¹ for wetlands (the IPCC default reference stock), and 0 Mg C ha⁻¹ for settlements and other land. See details regarding the stock estimates under their respective chapters.

7.6.2.2 Uncertainties and time-series consistency

The uncertainties in the estimate of the area of land converted to grassland is rather large (± 40 %) due to the small area of this conversion category. For living biomass, the uncertainty in the C stock and change estimate is shown in Table 7.5. For SOC changes in mineral soils, the estimated uncertainty is assumed to be ± 95 % based on the default uncertainties for the SOC reference stocks. The time-series is consistent.

7.6.2.3 QA/QC and verification

The standard Tier 1 QC procedures were performed during the estimation of C stock changes for land converted to grassland. No additional QA was performed.

7.6.2.4 Recalculations

The estimated area of forest land converted to grassland for 2010 was reduced from 22 kha in last year's submission to 16 kha in the current submission, which was caused by the revision of the NFI database. The area of cropland converted to grassland was reduced to zero for the whole inventory period. Carbon stock changes in living biomass on forest land converted to grassland increased slightly. The main changes due to the recalculation occurred from the new methods implemented for C stock changes in DOM and mineral soils.

7.6.2.5 Planned improvements

We plan to evaluate possible improvements for estimation of SOC changes on mineral soils. However, few studies have been made in Norway on the effects of grassland management on soil C dynamics. It may be possible to apply a model to estimate stock change factors or determine a country-representative emission factor from a country with similar soil and climate conditions.

Currently, no area estimates are reported for organic soils on lands converted to grassland. In the next submission, estimates of forest land on organic soils converted to grassland may be included; however, a country-specific emission factor is not readily available.

7.6.3 Completeness

The reporting for grassland is complete, with the exception of estimates of the areas of organic soils on land converted to grassland. All related emissions are reported as NE in the CRF.

7.7 Wetlands 5D

Wetlands in Norway cover almost 12 % of the total land area. Areas of land converted to wetlands are very small (2.7 kha in 2011). Most of the wetlands in Norway are unmanaged mires, bogs and fens, as well as lakes and rivers. Carbon stock changes in living biomass on wetlands/wooded mires are reported. Managed wetlands include peat extraction and reservoirs (dams). Emissions caused by soils undergoing peat extraction are also reported. On lands converted to wetlands emission and removals are reported for living biomass, DOM, and soils. Liming of lakes is practiced in Norway with the purpose of stabilizing the pH value and associated emissions are described under section 7.10.4.

7.7.1 Wetlands remaining wetlands – 5D1

Wetlands remaining wetlands is only covered in appendix 3a.3 in the Good Practice Guidance (IPCC, 2003) and reporting of C stock changes from this land-use category is therefore not mandatory. However, since the NFI contains data on C stock changes in living biomass, the associated emissions and removals for wooded mires have been reported this year. Carbon stock changes in other sources (DOM and soils) in unmanaged wetlands have not been estimated. Emissions caused by soil C changes during peat extraction have been accounted for according to the GPG 2003.

Emissions related to dams or reservoirs are not reported this year. 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. Preliminary results from a project managed by SINTEF-Statkraft have been classified information according to the Norwegian Water Resources and Energy Directorate. However,

finalized (public) reports and /or publications is expected to be available before the next reporting and qualified information in terms of a potential emission factor could hence be available for the 2014 submission.

7.7.1.1 Methodological issues

Living biomass – wooded mires

Wooded mire would according to Norway's national definition be classified as forest, if the requirements of the international forest definition are met. When this is not the case, wooded mire is considered under wetlands remaining wetlands as the subgroup "wooded mire". Carbon stock changes in living biomass are modest and correspond to a net C sequestration of 87 Gg CO₂ yr⁻¹ for 2011.

To estimate C stock changes in living biomass, we applied the Tier 3 method, which was used for all reported biomass estimates, except for cropland remaining cropland and especially for land converted to settlements. The stock difference method based on the NFI is used, which is described in detail under section 7.4.1.1. The areas of wetland remaining wetlands and C stocks on wooded mires that are used to estimate living biomass were taken from the NFI database.

Soils – peat extraction

Emissions caused by peat extraction are constant over the inventory period and quite small. Soil C stock changes are estimated to be 0.9 Gg C yr⁻¹, which is equal to emissions of 3.4 Gg CO₂ yr⁻¹.

Choice of method

For wetlands subject to peat extraction, changes in soil C stocks are estimated with a country-representative emission factor, thus we apply a Tier 2 method. However, similar to the IPCC default method, we consider only changes in soil carbon during peat extraction. Thus, changes in living biomass and DOM due to other processes associated with extraction (drainage, stockpiling, etc.) are assumed to be zero. Extraction could enhance oxidation and soil may continue to lose carbon.

Activity data

The area of peat extraction is based on research projects at Bioforsk. Peat extraction in Norway is between 220 000 and 300 000 m³ yr⁻¹ (we assume no change in extraction). The extraction is around 5–10 cm yr⁻¹. This corresponds to 13 m² m⁻³. The total area harvested is consequently around 338 ha.

Emission/removal factors

We propose to use an emission factors based on a Swedish study (Uppenberg *et al.*, 2001). Prior to drainage and extraction, peatland acts as a small carbon sink (62-96 g m⁻¹ yr⁻¹). During extraction emissions will be around 10 Mg CO₂ ha⁻¹ yr⁻¹ (2.7 Mg C ha⁻¹ yr⁻¹). This emission factor is somewhat higher than the default value given by IPCC for boreal areas (0.2 Mg C ha⁻¹ yr⁻¹).

7.7.1.2 Uncertainties and time-series consistency

The estimation of the uncertainty of the area and the C stock of wooded mire is described in section 7.3.4. Uncertainties for all areas per land-use category are shown in Table 7.4. The

time-series consistency for the NFI areas is explained in section 7.3.2. The uncertainty of the emissions from soil C changes under peat extraction can be assumed relatively small due to the small emissions.

7.7.1.3 QA/QC and verification

In addition to the QA/QC performed on the NFI area estimates and the general QC procedures, no specific QA/QC was performed for this category.

7.7.1.4 Recalculations

No recalculations were made for wetland remaining wetland. However, the estimates of C stock changes in living biomass on wooded mires for the whole time-series are new in the 2013 submission.

7.7.1.5 Planned improvements

We plan to develop estimates for emissions related to hydropower production reservoirs in the 2014 submission.

7.7.2 Land converted to wetlands – 5D2

Conversion of land to wetlands can be expected to be a slow process. Only very small areas of forest land and other land are converted to wetlands. Forest land converted to wetlands involves re-growth of ditches and a steady increase in water level, which takes time. Additionally, a conversion to the land-use category 'wetlands' requires a reduction in tree cover; otherwise the land would still be considered forest land.

We report C stock changes in living biomass, dead organic matter and soils for land converted to wetlands. Carbon stock changes in living biomass were estimated not to occur by using the Tier 3 method, and hence were given the notation key NO in the CRF tables.

7.7.2.1 Methodological issues

Emissions from forest land converted to wetlands from DOM and soils together were approximately equal to the removals by soils estimated for other land converted to wetlands. Thus net emissions were very small ($<1 \text{ Gg CO}_2 \text{ yr}^{-1}$) for land converted to wetland.

Dead organic matter

A Tier 2 method was used to estimate C stock changes in DOM on forest land converted to wetlands. The method is described in section 7.4.2.1. The C stock in DOM on wetlands was assumed to be zero.

Soils

Changes in SOC were estimated by using a Tier 1 method, described in section 7.4.2.1. The default SOC stock on wetlands of 87 Mg C ha^{-1} , was taken from Table 2.3 (IPCC, 2006a). The mean SOC stock for forest land was $109.4 \text{ Mg C ha}^{-1}$ and 0 Mg C ha^{-1} for other land.

7.7.3 Completeness

All mandatory emissions and removals were estimated from the wetland land-use class.

7.8 Settlements 5E

7.8.1 Settlements remaining settlements – 5E1

Reporting emissions and removals from this category is not mandatory, thus the notation key NE has been used in the CRF-tables. For C stock changes in DOM and soils, we assume that no changes occur, and hence the notation key NO is reported.

7.8.2 Land converted to settlements – 5E2 (Key Category)

The conversion of land to settlements is a significant source of emissions, primarily due to the C losses in soils and dead organic matter (when land is converted from forest land).

Land converted to settlements is identified as a key category with respect to living biomass and soils, due to uncertainty in both level and trend. In addition, dead organic matter is identified as key according to the trend assessment.

7.8.2.1 Methodological issues

Living biomass

For forest land converted to settlements, the Tier 3 method described in section 7.4.1.1 was used. For conversion of all other land-use classes to settlements, a new Tier 2 method was introduced this year. Living biomass is usually not estimated on the NFI sample plots on settlements, cropland, grassland, wetland and other land. Therefore, it was assumed that the mean biomass for the land-use category on the converted plot was changed to the mean biomass on settlement plots. Since biomass on cropland and settlement are not measured in the NFI, mean biomass for these categories was estimated in a separate survey (Løken, 2012). The mean biomass on the categories wetland, grassland and other land was estimated using NFI data. The resulting mean change was multiplied with the area of the respective land-use class to obtain an estimate of the total change.

Dead organic matter

A Tier 2 method was used to estimate C stock changes in DOM on forest land converted to settlements, which is described in detail in section 7.4.2.1. The C stock in DOM on settlements was assumed to be zero.

Soils

Changes in SOC were estimated by using the Tier 1 method, described in section 7.4.2.1. The SOC stock on settlements was considered to be zero. The mean national SOC stock estimates were 109.4 Mg C ha⁻¹ for forest land, 98.4 Mg C ha⁻¹ for grasslands, 87 Mg C ha⁻¹ for wetlands (the IPCC default reference stock), and 0 Mg C ha⁻¹ for other lands. See details for estimation of these stocks in their respective chapters.

The assumption that all soil C is lost when land is converted to settlements may overestimate C emissions. However, it is not unlikely to assume that substantial amounts of carbon are lost in the process of making the surface suitable for building purposes, e.g., by leveling the surface and by removing the top soil. Furthermore, most of the SOC is in the top soil, which makes it reasonable to assume that the majority of SOC is lost in a short time.

7.8.2.2 Uncertainties and time-series consistency

The uncertainties estimates of the area of land converted to settlements was ± 16 % (Table 7.4). Uncertainties of the C stock change in living biomass and soils estimates were much larger and estimated at ± 91 % (see Table 7.5) and ± 95 % for soils. The uncertainty for living biomass was only quantified for forest land converted to settlements. This is justified because the very small biomass changes estimated for the other land-use class conversion. The time series was consistent.

7.8.2.3 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure.

7.8.2.4 Recalculations

The whole time-series was recalculated for living biomass, dead organic matter and soils for land converted to settlements, due to the revised area estimates and the Tier 2 and 1 methods implemented for DOM and soils, respectively. The recalculation led to a 62 % increase in estimated emissions. Due to recalculations, net C changes in living biomass for 2010 changed from -242 Gg C to -228 Gg C, and thus losses were reduced by 6 %. The Tier 2 method for conversion of forest land to settlements produced net C gain of 0.09 Gg C for 2010. Carbon losses from DOM and soils combined increased from 72 Gg SOC to 596 Gg SOC with the new methods. Emissions from soils were responsible for most of the changes in the estimates.

7.8.2.5 Planned improvements

In the next submission, we plan to include Tier 3 estimates for living biomass on grassland, wetlands and other land converted to settlements. Also, the Tier 1 method used for soils will be evaluated during 2013. The large uncertainties associated with these fairly large estimates, especially for forest land and cropland converted to settlements, demand further method development. As recommended in the review of the 2012 submission, the assumption that all SOC is lost upon conversion to settlements will also be evaluated.

7.8.3 Completeness

All mandatory emission sources and sinks were reported for settlements. Carbon stock changes in living biomass on settlements remaining settlements were not reported because the NFI does not register trees on residential areas. However, this is not mandatory.

7.9 Other land 5F

Other land is approximately 45 % of the total land area in Norway. Land-use changes to other land only occurred from grassland throughout the inventory period. Emissions are reported for C stock changes in soils and for living biomass.

7.9.1 Other land remaining other land – 5F1

Reporting of emissions from other land remaining other land is not mandatory.

7.9.2 Land converted to other land – 5F2 (Key Category)

Only small areas of grassland were recorded as land converted to other land during the inventory period.

Land converted to other land is identified as a key category with respect to soils, because of uncertainty in the trend.

7.9.2.1 Methodological issues

The Tier 3 method described in section 7.4.1.1 was used for estimating C stock changes in living biomass. During the time-series, no changes in living biomass were estimated on this area except for in 2010, where a small C gain was reported 0.15 Gg C.

The Tier 1 method was used to estimate SOC changes on grassland converted to other land. See details in section 7.4.2.1. We assumed that the SOC stock on other land was equal to zero.

7.9.2.2 Uncertainties and time-series consistency

Due to the small area of land converted to other land, the uncertainties of the area and the living biomass are not quantified. The SOC stock changes estimate is assumed to have a ± 91 % uncertainty due to the IPCC default value for grassland soil C reference stock and stock change factors (see section 7.6.1.2).

7.9.2.3 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure.

7.9.2.4 Recalculations

The time-series for C changes for living biomass and soils was recalculated, which increased emissions from zero (NO, NE, IE) to 48 Gg CO₂ yr⁻¹ in 2010.

7.9.2.5 Planned improvements

No methodological improvements are planned for other land or land converted to other land. However, due to the large area of other land, further improvements in classifying these areas more specifically and possibly developing sub-categories is considered.

7.9.3 Completeness

The reporting for emissions and removals occurring on other land is complete.

7.10 Other and non-CO₂ emissions 5G

The category *Other 5G* includes the estimation of non-CO₂ emissions, i.e. nitrous oxide (N₂O) and methane (CH₄) from forest fertilization, drainage of forest and wetlands, disturbance associated with new agricultural land, and biomass burning, CO₂ emissions resulting from liming of agricultural lands and lakes, and harvested wood products. Emissions of non-CO₂ gases are small (not key category). Emissions from liming are of some importance but have been decreasing since 1990 (from approximately 200 Gg CO₂ yr⁻¹ to 80 Gg CO₂ yr⁻¹). Default parameters and methods have been applied in most circumstances. Norway is not reporting emissions from harvested wood products in the CRF but an annex is provided. Conversion to forest land from cropland, grassland and settlements does, according to IPCC (2003), not alter emissions of non-CO₂ greenhouse gases.

7.10.1 Direct N₂O emissions from forest fertilization – 5(I)

N₂O is produced in soils as a by-product of nitrification and denitrification. According to IPCC (2003) fertilizer input is particularly important for this process. However, fertilization of forest land is of little importance in Norway. The area fertilized is very small, and has

decreased during the period (1990 – 2011). In 1990 24 km² was N-fertilized, while in 2011 only 6 km² was N-fertilized (Statistics Norway, Forestry Statistics). N₂O emission decreased from 4.6 Mg N₂O to 1.6 Mg N₂O during the inventory period.

Table 7.20 Estimated emissions from fertilization of forest land, 1990–2011.

Year	Fertilizer input (Mg N)		Net amount N applied (Mg N)	N ₂ O emissions (Mg N ₂ O)
	Dry land	Wetland		
1990	177	59	234	4.6
1991	326	67	388	7.6
1992	253	102	352	6.9
1993	181	67	245	4.8
1994	169	67	233	4.6
1995	160	60	218	4.3
1996	199	36	233	4.6
1997	232	19	249	4.9
1998	243	23	263	5.2
1999	218	44	259	5.1
2000	135	22	155	3.0
2001	154	19	171	3.4
2002	178	8	185	3.6
2003	85	1	86	1.7
2004	76	2	77	1.5
2005	53	31	83	1.6
2006	34	4	37	0.7
2007	81	1	81	1.6
2008	106	1	106	2.1
2009	113	1	113	2.2
2010	73	0	72	1.4
2011	85	0	84	1.6

7.10.1.1 Methodological issues

Choice of method

Because national emission factors for fertilization of forest soil are unavailable, the estimate is based on a Tier 1 method with a default emission factor. Emissions are calculated according to:

$$N_2O \text{ direct-}N_{fertilizer} = (F_{SN} + F_{ON}) \times EF \times 44/28,$$

where F_{SN} is the amount of synthetic fertilizer nitrogen applied (Gg N) to forest soil adjusted for volatilization as NH_3 and NO_x . F_{ON} is the amount of organic fertilizer applied (Gg N) to forest soil adjusted for volatilization as NH_3 and NO_x , and EF is the emission factor for emissions from N inputs, kg N₂O-N/kg N input. Organic fertilizer is assumed not to be applied to forests in Norway.

Activity data

Statistics Norway has supplied unpublished data on the application of synthetic fertilizer for the period 1995-2005. The statistics include the area applied with fertilizer, the amount of different fertilizer types applied and whether it is applied on mineral soil or organic soil. For the period 1990 – 1994, only data for the total fertilized area is available. Data from the period 1995 – 2004 were used to estimate the amount of N-fertilizer applied for the period 1990 – 1994.

The amount of fertilizer applied is given as total weight. The nitrogen content depends on the type of fertilizer. Yara supplied sales numbers for forest fertilization. From 1993 to 1994 and onwards, calcium ammonium nitrate based fertilizer has dominated the market for fertilization of forest on mineral soils (sales name Opti-KAS Skog, http://www.yara.no/fertilizer/Fertilizer_range/forest/opti_kas_skog.aspx). The N-content of calcium ammonium nitrate is 27 % (weight percent). According to Statistics Norway, 92 % NPK-fertilizer is used on wetlands. For this fertilizer N-content of 15 % is applied.

Emission/removal factors

The default emission factor is 1.25 per cent of applied N. 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. However, there are no national data to improve this. One percent of the N-applied is volatilized as NH_3 (the ammonia model of Statistics Norway).

7.10.1.2 Recalculations

Statistics Norway provided new activity data, with information on the amount of different fertilizer types in use and whether it is applied on mineral soil or organic soil for the period 1995 – 2011. This made it possible to update the time series. Yara provided statistics on fertilization types sold for forest fertilization. These data have been used to update the estimate of N-content in fertilizer applied on mineral soil. Emission estimates for the whole time-series were recalculated and resulted in a 16 % increase in emissions for 2010.

7.10.2 N_2O and CH_4 from drainage of soils and wetlands – 5(II)

Non- CO_2 emissions caused by drainage of forest soils and wetlands (peatlands) are reported. Drainage can produce N_2O emissions but may reduce methane (CH_4) emissions and even generate a sink (IPCC, 2003). There is no default methodology available for estimation of CH_4 emissions or removals and Norway has no national data available, either of the area or an emission factor. Methane emissions are therefore reported as NE for forest land and wetlands.

7.10.2.1 Drainage of forest soil (N_2O)

Drainage of forest soil can occur both on forest land remaining forest land and on wetland converted to forest land. For non- CO_2 emissions these areas are reported together under forest land. After a peak in the 1960's the activity has decreased. And from 2007 establishment of drainage ditches on organic soils with the aim of increasing the forest production has been prohibited by law. Emissions have been around 40 Mg N_2O yr^{-1} for the inventory period (Table 7.21).

Table 7.21 Accumulated area drained and N₂O emissions from drainage of forest soil, 1990–2011.

Year	Area drained (kha)	Estimated N ₂ O emissions (Gg)
1990	231.8	0.04
1991	234.8	0.04
1992	237.1	0.04
1993	238.7	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	243.3	0.04
2000	243.7	0.04
2001	244.1	0.04
2002	244.5	0.04
2003	244.6	0.04
2004	244.9	0.04
2005	245.1	0.04
2006	245.3	0.04
2007	245.3	0.04
2008	245.3	0.04
2009	245.3	0.04
2010	245.3	0.04
2011	245.3	0.04

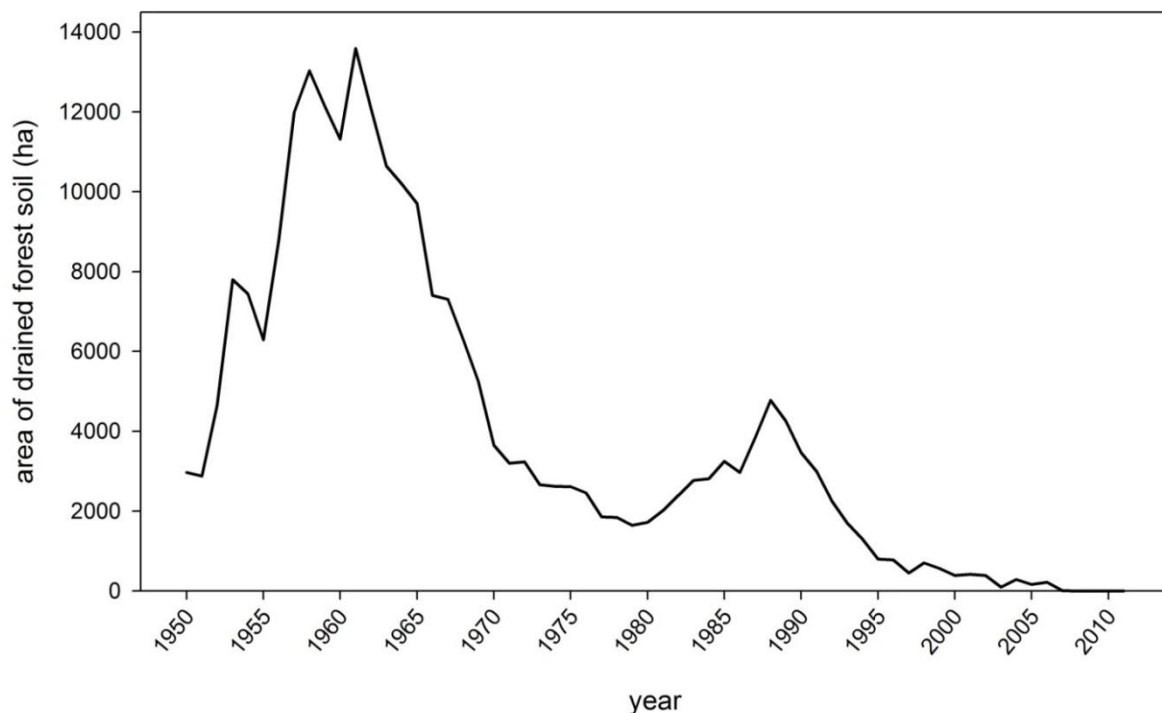
Choice of method

The method used is a Tier 1, because no national data are available. The estimation methodology for N₂O is based on IPCC (2003).

$N_2O \text{ emissions} = \text{area of drained forest soil} \times \text{emission factor}$

Activity data

Activity data of the area of drained forest soil was provided by Statistic Norway, including both forest remaining forest and wetland converted to forest (Figure 7.13). About 245 000 ha have been drained accumulated since 1950. It is assumed that there is no rewetting of drained forest soils. We assume that drainage only occurs on organic soils.



Source: Statistics Norway

Figure 7.13 The area drained and N_2O emissions from drainage of forest soil from 1950 to 2011.

Emission/removal factors

The emission factor is taken from IPCC (2003). It is assumed that all soil is nutrient poor; the corresponding emission factor is $0.1 \text{ kg } N_2O\text{-N ha}^{-1}\text{yr}^{-1}$ (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.

Recalculations

Updated activity data from Statistics Norway provided a small reduction in the accumulated area (from 245.42 to 245.30 kha in 2010).

7.10.2.2 Drainage of wetlands

Emissions of N_2O are estimated from drainage of wetlands due to peat extraction.. According to a peat extraction study, drainage reduces CH_4 emissions ($2\text{--}40 \text{ g m}^{-2}$ before drainage and $0.2\text{--}4 \text{ g m}^{-2}$ after) (Uppenberg *et al.*, 2001). In line with IPCC 2003 this reduction is not accounted for in the calculations, hence the notation key NE is used in the CRF.

Methodological issues

N_2O emissions from organic soils managed for peat extraction are estimated using a Tier 2 method with a country-representative emission factor from a Swedish study (Uppenberg *et al.*, 2001). Emission factors after drainage and before extraction range from $0.02\text{--}0.1 \text{ g m}^{-2}$. The first years after extraction has started (6–7 years) the range is $0.2\text{--}1 \text{ g m}^{-2}$, later on reduced to $0.01\text{--}0.05 \text{ g m}^{-2}$. Because the age of the land is not known we propose using an emission factor of 0.05 g m^{-2} for all years. Activity data of the area under peat extraction is provided by Bioforsk. See details in section 7.7.1.1. No recalculations were made for the estimation of N_2O emissions from drainage related to peat extraction.

7.10.2.3 Emissions from flooded land

Norway has considerable areas of reservoirs for hydroelectric power generation and has noted their potential relevance for emissions of N_2O and CH_4 . An ongoing national project (SINTEF and Statkraft) is expected to provide estimates of emissions, and information concerning emissions will be incorporated as soon as they are available.

7.10.3 N_2O from new agricultural land – 5(III)

N_2O emission resulting from disturbance associated with land-use conversion of forest, grassland, wetlands, or other land to cropland is reported under category 5(III). According to the GPG (IPCC, 2003a), conversion of settlements to cropland is not included. During the inventory period no land was converted from other land to cropland and most of the area converted to cropland came from forest land. Emissions occur as a consequence of the induced N mineralization of soil organic matter, which is expected to occur upon soil cultivation. Emissions are relatively small; equal to less than 10 Gg CO_2 -equivalents (Figure 7.14).

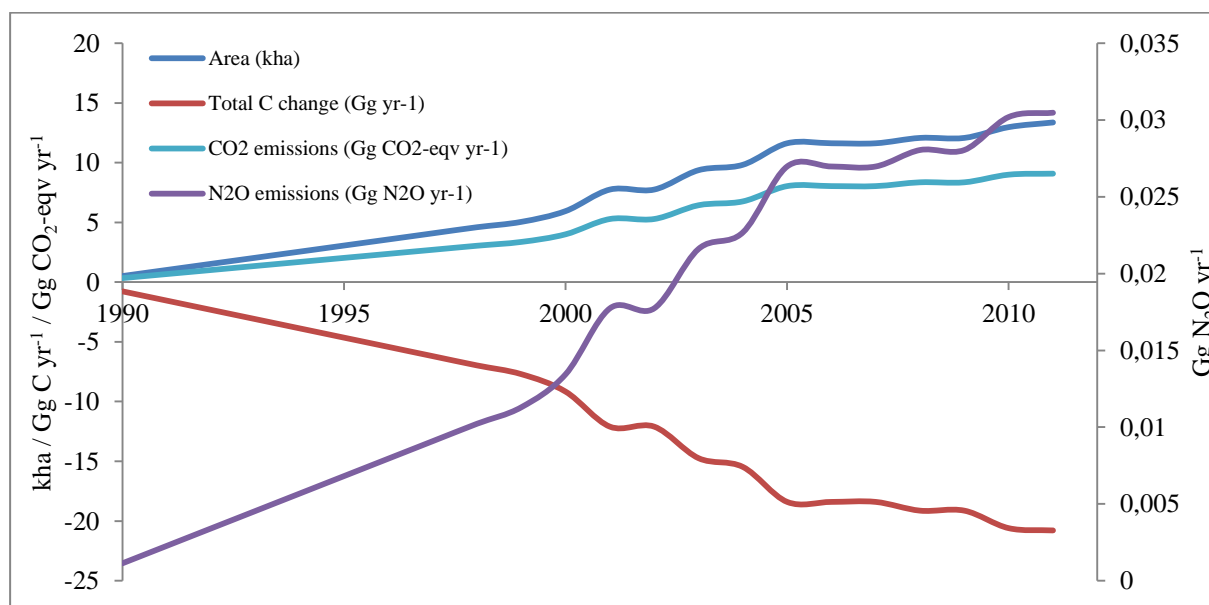


Figure 7.14 Area (kha), soil C change ($Gg\ C\ yr^{-1}$), N_2O emissions ($Gg\ N_2O\ yr^{-1}$, right side axis) and CO_2 emissions ($Gg\ CO_2\ equivalents\ yr^{-1}$) from disturbance associated with land converted to cropland.

7.10.3.1 Methodological issues

The default methodology based on IPCC (2003) was used to estimate N_2O emission by using the following equation:

$$N_2O-N = \text{area converted to cropland} \times N \text{ mineralized} \times \text{emission factor}$$

We applied the default emission factor but a country specific value was used for the C/N ratio used to derive N mineralization according to the equation 3.3.14 in the Good Practice Guidelines (IPCC, 2003a):

$$N_{\text{mineralized}} = \Delta C_{LC} \times 1/C:N,$$

where ΔC_{LC} is equal to the estimated change in soil C stocks on land converted to cropland (with the exception of settlements), and C:N is the C/N ratio of cropland soils. Thus, a Tier 2 method was applied.

Activity data

The areas of land converted to cropland were derived from the NFI database and were equal to those reported under the category *5.B.2 Land converted to cropland (LC)*, except for the exclusion of settlements converted to cropland.

Emission factors

To calculate the N released by mineralization, the estimate of C mineralization were taken from the Tier 1 method used for land converted to cropland, which is described in section 7.5.2.1. We used a country-specific C/N ratio for soil organic matter of 13.4 (instead of the default value of 15). This value was provided by Bioforsk as the national average for Norway. The default emission factor implies that 1.25 % of N mineralized is emitted as N₂O.

7.10.3.2 Recalculations

The entire time-series was recalculated since the last submission because of 1) the updated areas due to the NFI database revision and 2) new estimates of soil C changes due to the Tier 1 method used in the current submission. For the 2010 estimates, the recalculations resulted in a 99 % increase in the estimated emissions, which was primarily caused by the larger C stock changes estimated by the Tier 1 method for mineral soils.

7.10.3.3 Planned improvements

The improvements planned for the estimation of C stock changes in mineral soils on land converted to cropland will also affect the estimates of N₂O emissions due to the disturbance.

7.10.4 Liming of agricultural land and lakes – 5(IV)

It is common to lime Norwegian soils because of the low buffer capacity of most soils. The use of limestone is more popular than dolomite. Also, for several years many lakes in the southern parts of Norway have been limed to reduce the damages from acidification. Estimated emissions from liming on agricultural lands have reduced since 1990 (Figure 7.15).

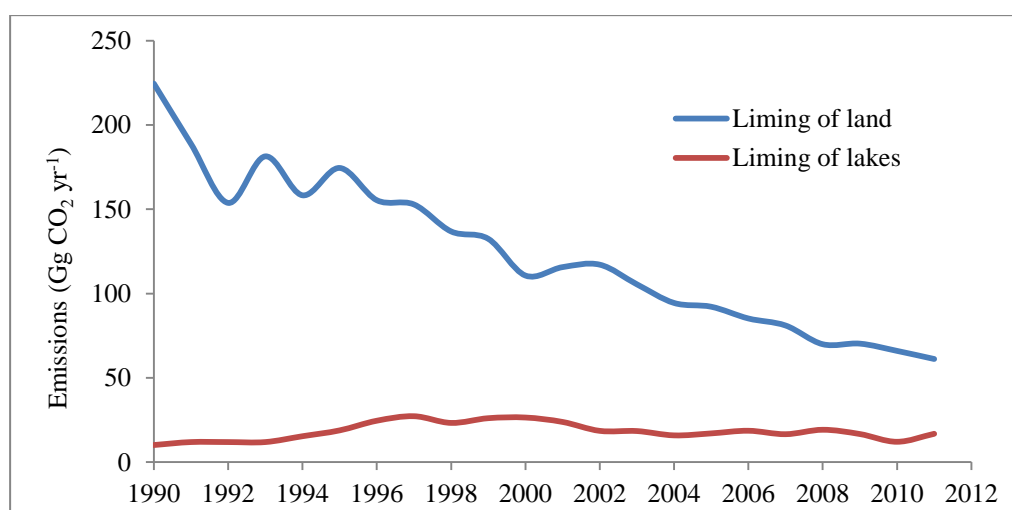


Figure 7.15 Emissions (Gg CO₂ yr⁻¹) from liming of agricultural lands and lakes, 1990–2011.

7.10.4.1 Methodological issues

Choice of method and emission factors

A Tier 2 method was used with specific emission factors for limestone and dolomite. The default emission factor values provided by IPCC are $EF_{\text{limestone}} = 0.12 \text{ Mg CO}_2\text{-C Mg}^{-1}$ for lime and $EF_{\text{dolomite}} = 0.13 \text{ Mg CO}_2\text{-C Mg}^{-1}$ for dolomite. For limestone this is equal to emissions of 0.44 Mg CO₂ per Mg CaCO₃ applied. The emission factors are based on the stoichiometry of the lime types.

For emissions estimates for liming on lakes, the emissions factor for limestone is used (0.12 Mg CO₂-C Mg⁻¹) as only the total amount of lime was available.

Activity data

Statistics on consumption of liming applied to agricultural soils are derived from the Norwegian Food Safety Authority. The statistics are based on reports from commercial suppliers of lime. The amount of lime applied to lakes was collected from the Directorate for Nature Management. It was not possible to separate the amount of lime originating as limestone or dolomite for lakes for the whole time-series.

7.10.4.2 Recalculations

In this submission we have fulfilled the recommendation of the ERT from earlier reviews and used emissions factors specific to the two types of lime, limestone and dolomite for liming of agricultural land. The result was hardly noticeable; an increase in emissions for 2010 from 65.11 Gg CO₂ to 65.96 Gg CO₂ from dolomite and limestone together.

7.10.4.3 Planned improvements

The ERT noted for the 2005 submission that Norway uses the same emission factor for liming of lakes as the one applied to cropland and it was 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 CO₂ than lime in soil. These annual emissions are minor, thus Norway has used the agriculture emission factor for the application of lime to water in the 2013 submission. It is not mandatory to estimate emissions from liming of lakes and emission factors are not well-established.

7.10.5 Biomass burning – 5(V)

The area burned varies considerably from year to year due to natural factors (for example variations in precipitation). No prescribed burning of forest takes place in Norway and all forest fires are due to accidents in dry periods (wildfires)²⁸. According to IPCC (2003) the emissions of CO₂ 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 CO₂ will be included in the estimate of C change in living biomass that is derived from the stock-change method and estimates of CO₂ emissions from wildfires are hence reported as IE.

7.10.5.1 N₂O and CH₄ from forest wildfires

Emissions of N₂O and CH₄ from forest wildfires are relatively small (Table 7.22).

²⁸ There may be some trials of burning as part of forest management, but this is only performed in small scale and is ignored here.

Table 7.22 Estimates of CH₄ and N₂O emissions (Gg) from forest fire from 1990 to 2011.

Year	CH ₄ (Gg)	N ₂ O (Gg)	CO ₂ -eqv. (Gg)
1990	0.053	0.000	1.228
1991	0.089	0.001	2.065
1992	0.082	0.001	1.895
1993	0.015	0.000	0.347
1994	0.017	0.000	0.393
1995	0.007	0.000	0.157
1996	0.047	0.000	1.077
1997	0.051	0.000	1.183
1998	0.019	0.000	0.430
1999	0.004	0.000	0.091
2000	0.008	0.000	0.190
2001	0.003	0.000	0.079
2002	0.016	0.000	0.360
2003	0.034	0.000	0.796
2004	0.007	0.000	0.154
2005	0.019	0.000	0.450
2006	0.179	0.001	4.144
2007	0.013	0.000	0.309
2008	0.274	0.002	6.339
2009	0.050	0.000	1.160
2010	0.077	0.001	1.788
2011	0.010	0.000	0.239

Choice of method

There are no national data on emission factors for non-CO₂ gases from forest fires. N₂O and CH₄ emissions from forest wildfires are estimated based on a Tier 1 method with a default emission factor and are based on the C released as described in IPCC (2003). The following equations are used:

$$\text{N}_2\text{O emissions} = (\text{carbon released}) \times (\text{N/C ratio}) \times (\text{emission ratio}) \times 44/28$$

$$\text{CH}_4 \text{ emissions} = (\text{carbon released}) \times (\text{emission ratio}) \times 16/12$$

Activity data (area of forest burned) is based on country level estimates. The quantification of national estimates for biomass burned and carbon released is based on expert judgments.

Activity data

Data on the burned area in forest fires are available from the Directorate for Civil Protection and Emergency Planning for 1993–2011 (Table 7.23). Data are available for the number of fires and the area of productive and unproductive forests that burned. There were only data available for the number of fires for 1990–1992 and these data were therefore used to estimate the area burned for subsequent years based on the ratio of fires in productive and unproductive forests. 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.

Standing volume for productive and unproductive forest were based on average numbers, and accounted for 23 and 109 m³ ha⁻¹, respectively (Granhus et al. 2012). In biomass this is equal to 12 and 55 Mg ha⁻¹, respectively. IPCC (2003) estimates that 50 % of the carbon is released during fires, because this is assumed to be the C content of woody biomass.

In addition to data on the tree biomass, 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 would burn. The mass of trees burned constitute 25 % of the biomass, which is consistent with IPCC (2003). It is also likely that about 1 m³ dead-wood per ha 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 and we assume that 10 % of this is burned. This percentage, however, is very dependent on the vegetation type. The estimates provided in Table 7.23 are for comparison only and to enable estimation of other pollutants, and are not used in the reported CO₂ emission estimates.

Table 7.23 Forest fires in Norway 1990–2011.

Year	Number of fires	Unproductive forest (ha)	Productive forest (ha)	Area burned (ha)	CO ₂ emissions (Gg)
1990	578	679.6*	256.4*	936.0*	12.2
1991	972	1 142.8*	431.2*	1 574.0*	20.5
1992	892	1 048.8*	395.7*	1 444.5*	18.8
1993	253	135.5	88.3	223.8	3.4
1994	471	123.6	108.1	231.7	3.9
1995	181	77.6	35.5	113.1	1.6
1996	246	169.7	343.8	513.5	10.7
1997	533	605.8	260.6	866.4	11.7
1998	99	164.7	110.3	275	4.3
1999	148	73.4	12.7	86.1	0.9
2000	99	142.6	29.3	171.9	1.9
2001	117	84.3	5.2	89.5	0.8
2002	213	124.7	95.8	220.5	3.6
2003	198	905.6	36.8	942.4	7.9
2004	119	84.6	32.3	116.9	1.5
2005	122	252.4	93.2	345.6	4.5
2006	205	3 222.20	606.7	3 828.90	41.1
2007	65	22.2	106.1	128.3	3.1
2008	174	1 210.20	1 963.60	3 173.80	62.8
2009	109	1 257.90	70.8	1 328.70	11.5
2010	62	165.9	602.8	768.7	17.7
2011	49	47.8	73.4	121.2	2.4

Source: Norwegian Directorate for Civil Protection (DSB) *Area estimated in NIJOS (2005).

Emission factors

IPCC (2003) suggests a default N/C ratio of 0.01. The methane emission ratio is 0.012 and for nitrous oxide 0.007.

7.10.5.2 Recalculations

We have derived separate values for the volume for productive and unproductive forest, in order to increase the accuracy of the estimated emissions, and have used these values in the calculations. This improvement was recommended by the ERT in the draft review report of the 2012 submission. As a result, the estimated non-CO₂ emissions increased by 10 % for 2010. But this year was an exception due to the large area of productive forest that burned this year (Table 7.23). The general trend was, however, a reduction in emissions.

7.10.6 Harvested wood products

Stock changes in HWP are only provided in Annex VII, and are not reported in the CRF tables under the category *Other– 5G*.

If more wood is stored than oxidized in a given year, the harvested wood products (HWP) will act as a sink, and a removal of CO₂ is recorded. However, if the consumption of wood decreases to a level below what is oxidized, HWP will act as a source, and emissions of CO₂ are recorded. In Norway, as in many other countries, the stock of HWP has been increasing for many years, and is likely to increase further in the future.

Harvested wood products (HWP) are accounted for in the year of harvest and for the country where the harvest occurred. The currently valid IPCC default approach is based on the perception that HWP stocks are not changing. That is, the annual carbon inflow and outflow for the HWP reservoir is assumed to be equal and the oxidation from pre-existing wood products stocks could be replaced (and hence omitted) by an implied oxidation directly after harvesting. More precisely the IPCC default assumption was that the inputs to the HWP reservoir are equal to the outputs. In the 2009 and 2010 submissions, Norway estimated the net removals from HWP following the stock change approach (SCA) and the revised method. In the 2011 submission Norway changed to the production approach (PA) and the IPCC HWP method for the reporting of HWP to the UNFCCC due to Decision 2/CMP.7 in Durban. Hence, in the 2012 submission we continued to use PA. The results are preliminary and will be recalculated in future submissions.

7.11 Uncertainties for LULUCF

For all land-use class area estimates, the uncertainties were estimated based on standard sampling theory. For all land-use classes except for croplands and settlements, also uncertainties of the annual carbon stock changes in living biomass were estimated. Croplands and settlements are excluded since the NFI does not usually measure tree attributes on these land-use classes. (The uncertainty of the living biomass estimate on cropland remaining cropland was provided by default values). The uncertainties are given by the sampling-related variability since the model-related variability was found to be negligible (Breidenbach *et al.*, 2013). An overview of the estimated uncertainties is given in Table 7.4 and Table 7.5.

The estimated uncertainties were generally larger than those previously assumed (NIJOS, 2005). Estimates for other sources were based on expert judgment as reported by NIJOS (2005) and default values provided by the IPCC. Uncertainties resulting from the missing

time series in Finnmark County and the mountain forest stratum were ignored. They were, however, assumed negligible since the carbon stock in living biomass in these two strata comprises only approximately 5 % of the total carbon stock because changes in these strata are less common compared with the lowland forests (Table 7.7).

The NIJOS (2005) report identified particularly large uncertainties for emissions of non-CO₂ gases and for CO₂ from cultivated histosols. For these categories, also the activity data are usually uncertain but the emissions are very small.

7.12 Quality assurance and quality control (QA/QC) for LULUCF

The Norwegian Forest and Landscape Institute (NFLI) completes the QA/QC plan described for the National Inventory System in Annex V. In addition, a LULUCF-specific plan for QA/QC was developed internally at the NFLI. The plan had two objectives 1) to ensure that emission estimates and data contributing to the inventory are of high quality and 2) to facilitate an assessment of the inventory, in terms of quality and completeness. These objectives are in accordance with chapter 8 of the 2000 GPG guidelines for quality assurance and quality control.

The QA/QC plan for LULUCF is based on the general Tier 1 QC procedures and includes two check lists (one for the source-category compiler and one for the LULUCF inventory compiler), an annual timeframe of the outlined QC activities, and a tentative time schedule for QA reviews. Specifically, QC is performed on the following 12 points:

1. Documentation of assumptions and selection criteria
2. Transcription errors
3. Emission calculations
4. Labeling of parameter units, conversion factors and unit transfer
5. Database integrity
6. Consistency within sectors and source categories
7. Transfer of estimated emissions between inventory staff
8. Uncertainty estimation and calculations
9. Review of internal documentation
10. Time-series consistency
11. Completeness
12. Comparison to previous estimates

In addition, two external quality-assurance actions have been undertaken since the last submission in 2012. First, elicitation by the NFLI of a qualified researcher to evaluate and improve the methodologies applied for emission estimates from cropland and grassland. This work resulted in substantial method revisions for most source categories due to the lack of methods evaluation since their development, which was in 2005 (NIJOS, 2005). Moreover, a detailed documentation and justification of the new methods are provided in the report *Emissions and methodologies for cropland and grassland used in the Norwegian national greenhouse gas inventory* (Borgen and Hysten, 2013). The second external QA was a smaller task performed on the final emission estimates for mineral soil on grassland remaining grassland, which was elicited to an expert at Colorado State University. This task provided a review of the emission calculations (the application of the new Tier 1 method) and of the method and activity data documentation.

Internal structures for the work on LULUCF reporting have been changed. One important aim of this change was to improve the QC procedures and to ensure that methods and calculations are put through an internal QC before reporting. This is an ongoing process that will be further improved towards the 2014 submission.

7.12.1 QA/QC for the NFI data

Fieldwork is conducted by National Forest Inventory field staff. Qualification requirements are forestry or natural management education at the college level or higher. Before a new employee can work independently, a training period of at least 3 weeks is conducted. All field staff undergoes a week long course prior to each field season. There are currently about 25 people who perform fieldwork in the period from May to October. It has been a stable situation with few changes in the field personnel, and in average the field workers have more than 10 years' experience.

All data collection is done on handheld computers with software developed particularly for the purpose. The field computer program has a number of features built in for quality assurance:

- The program ensures that everything that must be recorded is recorded.
- A series of tests on the logical values of measurements.
- Categorical variables recorded with the help of menus.

For plots that have been previously registered, the program is loaded with data from the previous record. Depending on the character of the variable, quality checks are handled in three different ways:

- The old value is displayed and can be confirmed or amended.
- The old value is hidden, but a warning is given if the new value is not logical compared to the old value.
- The old value is displayed as information before a new registration is done.

Data is sent by e-mail to the data reception center at the main office once a week. The data reception center keeps track of which sample plots that are registered and which ones remain, thereby ensuring that no plots are omitted. The data is then read into a database and further quality checks made. Incorrect data or questions are returned to the field worker for clarification.

During the season, each field worker normally has a visit by a supervisor from the office for one day in the field. Control registrations are carried out by an experienced field worker who makes a second registration for selected sample plots. The control data is then analyzed with the view partly to document the quality of field recordings, and partly to clear up misunderstandings and to correct any systematic errors. Results of control entries are published in a separate report.

During the winter months, there is a systematic review of the data with additional error testing and inspection of all codes and mutually logic. This happens before the data is read into the final table structure.

The database is a relational database that is designed to ensure data quality. Primary keys and foreign keys prevent double accounting and ensure coherence in the data.

7.13 Recalculations for LULUCF

Substantial improvements of the NFI data base implemented in the 2013 submission caused changes in the land area estimations compared to the 2012 submission. The improvements included consistency checks of the land use classification, an updated time series by back-casting data on plots without previous measurements and a general quality control of the data for the whole time-series. Also, several improvements were made in methods.

Due to design changes in the Norwegian National Forest Inventory (NFI) between 1990 and 1998, the area estimates of land-use classes and the estimates for C stocks in living biomass for forest, grassland, wetland and other land have been bridged for the years 1990-1998. An adjustment factor was used to bridge the estimates in these years in the reporting last year. The adjustment factor was slightly changed this year in order to better accommodate the change from mid-year reporting in 1990 to end-year-reporting in 1998.

The whole time-series was recalculated for all C sources and sinks due to the updates and improvements of activity data and methods. Total changes in emissions (including non-CO₂ emissions) caused by recalculations for the LULUCF sector are shown in Figure 7.16. Effects of recalculations on the land-use category and sink/source category level are described in more detail in previous sections.

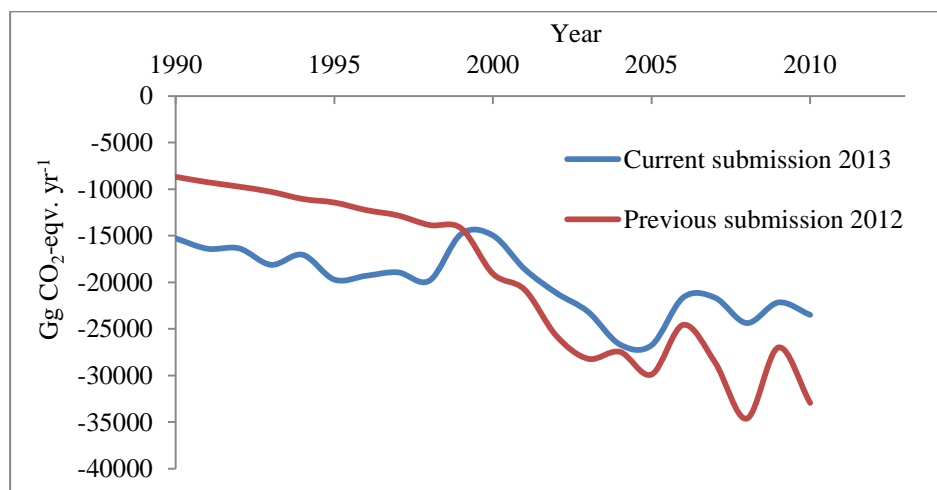


Figure 7.16 Recalculations illustrated for the total net emissions (Gg CO₂-equivalents per year) estimated for the LULUCF sector in the 2013 submission compared to the 2012 submission.

The following effects of recalculations are described for the emissions and removals reported for the year 2010.

5A Forest Land

5A1 Forest land remaining forest land

The whole time-series was recalculated due to the implementation of the revised NFI database, which affected estimates from all sources and sinks.

- The change in the adjustment factor implemented for the years 1990-1998 had a major influence on the area estimates and for C stocks in living biomass. Compared to the last year's reporting, C uptake in living biomass for 2010 was reduced by 10 % from 7384 Gg C to 6721 Gg C.

- Sequestration by dead organic matter (DOM) increased by 34 % and C uptake in mineral soils reduced by 23 709 %. Considering the DOM and soil pools together, the total C sequestration was reduced by 61 %. Although, a part of this reduction can be contributed to the revised data base (approximately 10 % as for living biomass), the majority was caused by the implementation of the Yasso07 model.
- A significant change occurred for organic soils, where emissions for 2010 increased by 92 % due to the use of a country-representative emission factor from Sweden.

5A2 Land converted to forest land

The definition of this land-use change category was changed. Areas are now considered belonging to this class, if the conversion to forest land is actively human induced.

- Total C stock change for land converted to forest dropped by 51 % for 2010. Carbon uptake in living biomass decreased by 704 % solely due to a drop in the areas converted to forest land due to the changed definition. The areas of cropland converted to forest land decreased from 44 to 10 kha, wetland converted to forest decreased from 117 to 3 kha, settlement converted to forest decreased from 46 to 14 kha, and other land converted to forest decreased from 296 to 2 kha. Consequently, the C stock changes in living biomass for wetland converted to forest and other land converted to forest were very high (roughly 2 400 % and 22 000 %, respectively).
- Carbon changes in DOM were 100 % because of the implementation of a Tier 2 method.
- For organic soils C changes also increased by a 100 % as previous submission did not report specifically for this category.
- Another methodological change occurred for mineral soils with the application of a Tier 1 method, which resulted in 112 % increase in C uptake.

5B Cropland

5B1 Cropland remaining cropland

- Total emissions for cropland remaining cropland increased by 97 %, primarily due to the inclusion of all cultivated histosols under cropland (previously 90 % of this area was considered grassland). The emission factor was not changed; the increase was solely caused by the re-allocation of the cultivated organic soils.
- For mineral soils, the Tier 2 method was completely revised replacing the previous erosion-based emission factors with an IPCC method using soil C reference stocks and stock change factors. The result was a 400 % reduction in soil C sequestration from 51 Gg SOC to 10 Gg SOC for 2010.
- Changes in living biomass were also affected because the C losses on felled horticultural plantations are now included under cropland instead of, as previously reported, under cropland converted to grassland. In addition, updating the activity data resulted in a modest increase in the C gains of 7 %.

5B2 Land converted to cropland

- Recalculations for 2010 increased C losses by 80 %; annual C losses increased from 6.33 Gg SOC to 32.55 Gg SOC.
- The revised NFI database resulted in minor area changes.
- The implementation of a Tier 1 method applied to all lands converted to cropland was responsible for increasing SOC losses from 6 to 19 Gg SOC, as previously only conversion of forest land to cropland was reported.

5C Grassland

5C1 Grassland remaining grassland

- Emissions from grassland remaining grassland were reduced by 1 575 %, due to the allocation of all cultivated histosols to cropland.
- The effects of the implementation of a Tier 1 for mineral soils and the Tier 3 for living biomass counter balanced one another by a soil C loss of 16 Gg SOC and an uptake in living biomass of 14 Gg C.

5C2 Land converted to grassland

- Total emissions for land converted to grasslands increased by 25 Gg (19 %) for 2010 due to the implementation of three new methods: 1) Tier 3 for living biomass, 2) Tier 2 for dead organic matter, and 3) a Tier 1 for mineral soils.
- Additionally, previously felled fruit trees were considered to be converted to grassland, and these C losses are now reported under cropland remaining cropland.

5D Wetlands

5D1 Wetlands remaining wetlands

- Living biomass was reported for wetland remaining wetlands in this submission, resulting in net C gains of 23 Gg for 2010.
- No changes were made in the reporting of peat extraction.

5D2 Land converted to wetlands

- Two new Tier 1 and 2 methods implemented for dead organic matter (forest-related conversion only) and mineral soils resulted in small net emissions from land converted to wetland. The soil C loss of 4.04 Gg from forest land converted to wetland was practically offset by the C sequestration of 3.92 Gg from other land converted to wetlands. The total areas of land converted to wetlands were reduced from 7.2 kha to 2.7 kha. The changes had little effect on the estimated emissions.

5E Settlements

5E1 Settlements remaining settlements

- No emissions were recalculated for settlements remaining settlements as these are not reported due to a lack of methods.
- However, the area was recalculated and estimated as 572 kha by the revised NFI database compared to 494 kha in the 2012 submission.

5E2 Land converted to settlements

- The area of land converted to settlements was reduced from 156 kha to the current estimate of 100 kha as a consequence of the revised NFI data base.
- Carbon stock changes decreased by 57 % mostly due to the Tier 1 method applied for mineral soils. Especially, forest land converted to settlements had increased soil C losses, from 72 Gg to 428 Gg, and cropland converted to settlements contributed with a net C release of 60 Gg. The latter was not estimated in the 2012 submission.
- The revised NFI data base resulted in a small increase in the area of forest land converted to settlements (from 70 to 78 kha), a noticeable decrease in cropland converted to settlements (from 59 to 16 kha), and a decrease in other land converted to settlements (from 17 to 2 kha).

5F Other Land

5F2 Land converted to other land

- In the revised NFI database, only a small area (2.7 kha) of grassland was identified as being converted to other land throughout the whole times series. Total soil C losses (13 Gg SOC) constituted the majority of the increased emissions, whereas C gains in living biomass were very small (0.14 Gg).
- Carbon stock changes were not reported for this land-use change in the previous submission.

5G Other and non-CO₂ emissions

5(I) N₂O emissions from fertilization of forest and other

- Improvements in the activity data resulted in an increase of 16 % in the N₂O emissions caused by fertilization of forests. The improvements consisted in adjusting the N content of the fertilizer and updating the quantity of fertilizer applied.

5(II) Non-CO₂ from drainage of soils and wetlands

- N₂O emissions from drained forest soils reduced by 0.05 % due to updated activity data.

5(III) N₂O emissions from disturbance associated with land-use conversion to cropland

- Nitrous oxide emissions associated with conversion to cropland increased by 99 %, which was primarily caused by the change to the Tier 1 method for estimating soil C changes. The soil C changes are utilized for estimating N mineralization, the precursor of N₂O emissions.

5(IV) CO₂ emissions from agricultural lime application

- Previously, emission from agricultural lime application was estimated with the assumption that all lime applied occurred in the form of limestone. Recalculation of the whole time-series was done using activity data for limestone and dolomite and the default emission factors. Total emissions estimated for 2010 increased by 1.3 % as a result of this.

5(V) Biomass burning

- The emissions of methane and nitrous oxide caused by biomass burning during wildfires increased by 10 % and 11 %, respectively for 2010. This was due to an improvement in the activity data by separating fires occurring on unproductive and productive forests and using specific biomass-volume estimates for each forest type. However, in 2010 there were a large number of wildfires on productive forest, which caused the increase in emissions compared to the previous method. For all other years in the inventory, the improvement in the activity data generally resulted in smaller emissions.

Table 7.24 gives an overview of the changes in emission/removal estimates for 2010 due to the recalculations.

Table 7.24 Recalculations for 2010 in the LULUCF sector per reporting category for CO₂, N₂O and CH₄.

Land-use categories	Emissions for 2010 (Gg CO ₂ yr ⁻¹)	
	2013 submission	2012 submission
5A. Forest land	-28681	-35876
5B. Cropland	1978	67
5C. Grassland	100	1680
5C. Wetland	-82	3
5E. Settlement	3022	1155
5F. Other land	48	IE,NE,NO
5G. Non-CO ₂ (Gg CH ₄ yr ⁻¹)	0.0773	0.0692
5G. Non-CO ₂ (Gg N ₂ O yr ⁻¹)	0.0731	0.0407

7.14 Planned improvements for LULUCF

An overview of planned improvements according to recommendations from the ERT is given in Table 9.11 and more details are provided under the individual sink/source category. Currently, the following improvements are planned.

Estimation of SOC changes on lands converted to forest land will be subject to plot-specific estimation using Yasso07 as for forest land remaining forest land. Such a Tier 3 method is aimed to be in place by the 2014 submission. For other land-use transitions we plan to evaluate the potential for a Tier 2 method.

For forest land remaining forest land (and forest management), the estimation of the dead organic matter (dead wood and litter) and the soil pools provides a challenge with the current use of the Yasso07 model. A project has been initiated with the objective to improve the separation of these pools by the use of both field measurements and published literature. The results are planned to be incorporated in the next submission in 2014. Furthermore, the estimator for annual C stock changes in living biomass estimates will be slightly changed, the adjustment factor for the years 1990-1998 will be reconsidered, and methods for reducing the sampling variability will be analyzed.

The estimation of SOC changes on cropland remaining cropland contain a great number of assumptions and restrictions regarding possible crop rotations implied, which would be avoided with the implementation of a Tier 3 method, for example using ICBM as done in Sweden.

Emissions from cultivated organic soils are a key category with a large uncertainty. During 2013, it is planned to evaluate how to improve the area estimate of cultivated histosols. Soil maps generated by the Norwegian Forest and Landscape Institute have been updated since the last area estimate was made and further analyses can be performed. An evaluation of the emission factor was done in 2012 by literature review. However, no better estimate is available at the present time (Borgen and Hylen, 2013). Thus, we will continue to evaluate and remain updated on the research activities within this field especially from the Nordic countries.

8 Waste

8.1 Overview

This sector includes emissions from landfills (6A), wastewater handling (6B), small scale waste incineration (6C) and other waste (6D). 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 CO₂ from methane flared at landfills and combustion of hospital waste in hospital incinerators until 2005 and cremations. The source sector 6D (waste other) covers emissions from accidental car fires, building fires, and emissions from recovering processes in the waste trade.

The emissions of greenhouse gases from the waste sector decreased by 34,3 per cent (0.639 million ton CO₂ eq.) from 1990 to 2011. The reductions were due to decreased CH₄ emissions from landfills 37.8 per cent (0.651 million ton CO₂ eq.) while the source category Domestic and Commercial Wastewater increased their emissions by 0.013 ton million ton CO₂ eq.

Solid waste disposal on land (i.e. in landfills) is the main emission category within the waste sector, accounting for in 2011 about 88 per cent of the sector's total emissions. Wastewater handling in domestic and commercial sector accounts for approximately 12 per cent of the sectors emission in 2011. From the other sectors there are only minor emissions. The waste sector accounted for 2.3 per cent of the total GHG emissions in Norway in 2011.

8.2 Managed Waste Disposal on Land – CH₄ – 6A1 (Key Category)

8.2.1 Description

CH₄ and non-fossil CO₂ 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 CO₂. When there is no more oxygen left, the decomposition becomes anaerobic, and methane emissions start to increase. After a year or so, CH₄ emissions reach a peak, after that the emissions will decrease over some decades (SFT (1999b) and Barlaz (2004)).

The emissions of methane from landfills have decreased since 1990 and specifically after 1998 due to reduction of the amount of degradable waste disposed at disposal sites. This reduction in emissions is the result of several policy and measures which were introduced in the waste sector particularly in the 1990s. With some few exceptions, notably the mixed waste from households in municipalities with a source separation of food waste, it was then prohibited to dispose easy degradable organic waste, sewage sludge included, at landfills in Norway.

From July 1 2009 it was banned to deposit biodegradable waste to landfills and due to that this will result in further reduction of methane emissions. In 1999 a tax was introduced on waste delivered to final disposal sites, and in 2013 this tax was 289 NOK per tonne waste. There is a possibility of exemption from the prohibition of depositing biodegradable waste at landfills – in such cases the tax is 479 NOK per tonne waste.

In addition to the above described policy and measures, landfills receiving biodegradable waste (waste containing degradable organic carbon (DOC)) are required to collect and treat landfill gas. In 2011 80 landfills who had installed a landfill gas extraction system reported extraction of gas. 16.3 kilo tonnes of methane were recovered. This is 16 per cent lower than in 2010. The extraction of methane has fluctuated between 18.8 and 23.1 kilo tonnes since 1999. And the fluctuation is due to instability in the pipeline system e.g. due to setting in the landfill area and therefore there is a need for maintaining the pipeline system and hence the extraction of methane is reduced. In addition, the amounts of waste recycled have increased significantly since 1990. The total amount of waste generated has increased by about 39 per cent from 1995 to 2011 but due to the increase in material recycling and energy utilization in the period the amount disposed at landfills has dropped substantially since 2007, and is at its lowest since 1995. As a consequence of the prohibition against depositing of biodegradable waste of July 1st 2009 there has been a strong decrease in waste depositing. Since building the necessary treatment capacity would take time, temporary exemptions was granted in certain cases in a transitional period. There are given many permits for disposal of biodegradable waste for one year extra, some extended out 2010, and a few within 2011. The transitional period ended on December 31st 2012. The amount of waste generated in 2011 was 5 per cent higher than in 2010. Figure 8.1 shows the relative change (1995=1) in methane emissions from landfills, extraction of methane, solid waste disposed at landfills and total amount of waste generated in Norway.

Emissions of CH₄ from solid waste disposal are key category in level in 1990 and 2011 and trend due to uncertainty in AD and EF. Note that the IEF for CH₄ varies due to variation in the amount of extracted CH₄ from the landfills.

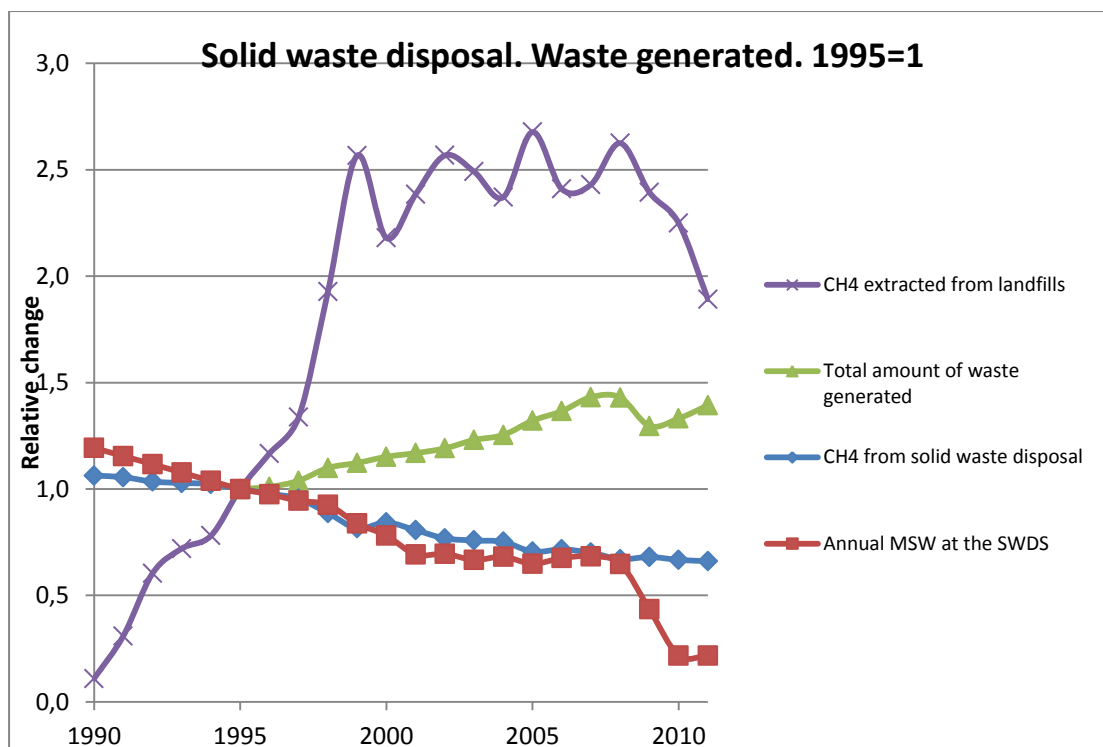


Figure 8.1. Relative change in emissions of methane from solid waste disposal, annual MSW at the SWDS, methane extracted from landfills and total amount of waste generated in Norway.

Source: Statistics Norway/Climate and Pollution Agency.

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 2005b). The model is the same as described in IPCC 2006.

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:

$$(8.1) \quad DDOC_{mdiss} = (DDOC_{ma(ly)} + DDOC_{md}) * (1 - e^{-k})$$

$$(8.2) \quad DDOC_{ma} = (DDOC_{ma(ly)} + DDOC_{md}) * e^{-k}$$

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

$$(8.4) \quad DDOC_{ml} = DDOC_{md} * e^{-k * ((13-M)/12)}$$

$$(8.5) \quad DDOC_{ma} = DDOC_{ma(ly)} * e^{-k} + DDOC_{ml}$$

To calculate $DDOC_m$ dissimilated

$$(8.6) \quad DDOC_{mdi} = DDOC_{md} * (1 - e^{-k * ((13-M)/12)})$$

$$(8.7) \quad DDOC_{mdiss} = DDOC_{ma(ly)} * (1 - e^{-k}) + DDOC_{mdi}$$

To calculate methane produced from DDOC dissimilated

$$(8.8) \quad CH_4_{prod} = DDOC_{mdiss} * F * 16/12$$

To calculate methane emitted

$$(8.9) \quad CH_4 \text{ emitted in year } T = (\sum CH_{4 \text{ prod}}(T)) - R(T) * (1-OX)$$

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 DDOC _m 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 DDOC _m 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 methane is formed by decomposition of biological waste in landfills. The decomposition time varies from material to material. Easy degradable waste (food, etc.) has shortest decomposition time, while wood waste has the longest decomposition time. Other materials do not emit methane at all, either because they are inorganic (metal, glass, etc.) or because they break down extremely slowly (plastic). It is therefore of vital importance for the calculations that the waste

quantities used as input to the model are correct, both total quantity and the distribution by material.

Data over the amount of different waste materials is taken from Statistics Norway's waste accounts. Statistics Norway's waste accounts consist of data from several sources, such as special surveys, register data and statistics, indirect data sources as production statistics, foreign trade statistics and different factors combined with activity data. Data from all these sources are put together and used in the waste accounts, which give an overview of waste quantities in Norway, divided into type of product, material, industry and method of treatment.

Historic data have been recalculated from the former waste category basis, to a waste material basis. The amount of each material type deposited is estimated based on surveys and sorting analyses. The model is based on types of waste materials for instance food waste (incl. garden waste), paper, wood and textiles. All sources of waste, MSW, industrial, commercial, construction and demolition waste are accounted for in these annual surveys.

Municipal landfills

Historical data for years before 1973 on municipal solid waste deposited are based upon:

1. New statistics on municipal waste, divided into household waste and industrial waste (1974 to 1997)
2. Estimates based on population
3. 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 and 1985. The amount of waste going to landfills is allocated to material based on sorting analyses. For the period 1995-2008 the amounts of waste is taken from the waste accounts, with three adaptations:

- 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 materials" is assumed to contain degradable organic matter with an average half-life. This degradable share is added to the amount of paper. The amount is estimated by $0.2 * \text{landfilled 'other materials' from manufacturing} + 0.5 * \text{'other combustible' in landfilled mixed waste from all sectors}$. See chapter 8.1.5 for details.

Contaminated soils are assumed not to develop methane in landfills. The same applies to waste used as cover material, due to excess oxygen availability
No bio-degradable hazardous waste is landfilled in Norway.

No organic waste is imported for landfilling, as it is prohibited. Waste incineration in the waste accounts includes export, and is thus not comparable with the emission inventory as a substantial amount is exported to Sweden for incineration.

Linear interpolation of the amount of waste deposited has been applied for the period 1985 to 1995.

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, 1999 and 2003 have been used. Linear interpolation is used for the years where data are missing.

Data from each landfill site with methane recovery units are reported by the landfills via an electronic web portal and the Norwegian Climate and Pollution Agency assembles these data in their own database. Further 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.

Variables	Type of waste				
	Food waste	Paper	Wood	Textiles	Sewage sludge
$t_{1/2}$ (half life time)	3,7 years	11,6 years	23,1 years	11,6 years	3.7 years
DOC	0.150 Mg/Mg	0.400 Mg/Mg	0.400 Mg/Mg	0.24 Mg/Mg	0.05 Mg/Mg
DOC _f (Part of DOC dissimilating)	0.5	0.5	0.5	0.5	0.5
Ox. Methane oxidized in top layer	0.1	0.1	0.1	0.1	0.1
F. Part of methane in generated landfill gas	0.5	0.5	0.5	0.5	0.5

Source: IPCC 2006 based on The Climate and Pollution Agency (Norwegian pollution control authority 2005b) and Skullerud (2006).

8.2.5 Uncertainties

The amount of different waste materials is considered to be known within ± 20 per cent. The emission factors used are considered to have the uncertainty range ± 30 per cent. More information about the uncertainty estimates for this source is given 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.

The methodology Statistics Norway/the Climate and Pollution Agency use to calculate methane emissions from landfills is identical for the whole time series. The quality of the activity data used in the model has been improved in the last years. This is also the case regarding the data for recovered methane.

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

6 A Solid waste disposal on land

- **Changes of DOC factors:** The DOC factor is changed for wood from 0.40 to 0.43 and for textiles from 0.40 to 0.24, in line with the IPCC default values.
- **Inclusion of landfilled sewage sludge:** Emissions of CH₄ from deposited sewage sludge have been included in the inventory for all years since 1990 as recommended by the ERT. This has improved the completeness of the inventory. The amount of landfilled sewage sludge is based on Statistics Norway's waste water statistics and linear interpolations in missing years.
- **Changed method for estimating the amount of organic biodegradables in 'other materials' going to landfills:** The share of organic materials in the category 'other materials' except incineration residues is changed from 13 per cent to a varying share based on statistical sources. The fraction of 13 per cent has been difficult to document properly, and furthermore a fixed share leads to unwanted side-effects if for instance new and strictly mineral substances are being put on the landfill.

The new method applies the following relation:

Amount of biodegradable organic materials in landfilled 'other' = 0.2 * landfilled 'other materials' from manufacturing (other sectors not relevant) + 0.5 * 'other combustible' in landfilled mixed waste from all sectors.

Landfilled 'other materials' from manufacturing is the dominant of the two fractions, comprising 70 to 95 per cent of the total biodegradable organics in landfilled 'other materials' during the time series from 1995 to 2010. The factor of 0.2 is derived from studying the data from the manufacturing waste surveys in 1993, 1996, 1999, 2003 and 2008, which show that in 2008 40 per cent of the landfilled 'other materials' from manufacturing came from industries with mainly biodegradable organic production waste. Of this, (at least) half was assumed to be non-organic in order to get

permission for landfilling the waste. Earlier reference years showed lower shares coming from industries with biodegradable organic production waste. Thus, the fraction of 0.2 is judged to be conservative. Since the data on waste from manufacturing are uncertain at this detailed level, a trend adjustment is performed to fit the trend in landfilled biodegradable 'other material' from manufacturing with the overall trend in landfilled biodegradable waste in Norway.

The factor 0.5 applied on 'other combustible' in landfilled mixed waste is chosen as a medium value, due to absence of information.

Emission of CH₄ from landfills increased by 2.4 per cent in 1990 due to these method improvements. For the Kyoto-years 2008-2010 the overall changes were minor ($\pm 0,1$ per cent). The positive change in 1990 was due to the new DOC factors and inclusion of sewage sludge, but the effect reduced gradually until 2010. New method for 'other materials' gave an insignificant negative change in 1990, but rising until 2010 to give an estimated total that is almost unchanged.

8.2.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2013.

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 unmanaged waste disposal sites are not occurring and hence Norway does not separately report emissions from unauthorized/unmanaged SWDSs.

8.4 Wastewater handling – N₂O – 6B (Key category)

8.4.1 Description

Emissions of CH₄ and N₂O from Wastewater handling has been relative stable during the 1990 to 2006, with a small increase for CH₄. The emission trend for this period is described in Section 2.3.

According to the Tier 2 key category analysis emissions of N₂O from wastewater handling are key category in level in 1990 and 2011.

The Norwegian wastewater treatment system is characterised by few big and advanced wastewater treatment plants (WWTPs) and many smaller WWTPs. In 2011, 61 per cent of Norway's population was connected to high-grade treatment plants – biological and/or chemical treatment. Furthermore, 19 per cent of the population was connected to mechanical or other types of treatment, 14 per cent of the population was connected to small wastewater facilities (less than 50 pe) and the remaining 5 per cent had direct discharges. The wastewater facilities in Norway with a capacity of more than 50 population equivalents (pe) treated wastewater from 80 per cent of the population.

The source category 6B includes estimation of the emission of CH₄ and N₂O from wastewater handling; i.e. wastewater collection and treatment. CH₄ is produced during anaerobic conditions and treatment processes, while N₂O may be emitted as a bi-product from nitrification and denitrification processes under anaerobic as well as aerobic conditions.

No distinction between emissions from industrial and municipal WWTPs is made, as Norwegian industries to a great extent are coupled to the municipal sewer system. Wastewater streams from households and industries are therefore mixed in the sewer system prior to further treatment at centralised WWTPs.

It should be mentioned that no activity data are available for industrial WWTPs. Therefore, the emissions from industries having separate wastewater treatment is unknown and i.e. not included in the Norwegian inventory for category 6.B. Wastewater handling.

Wastewater treatment facilities in the Norwegian industry:

- Oil refining: there are two oil refineries both with facilities cleaning wastewater for total organic carbon (TOC). Aerob treatment of wastewater.
- The pharmaceutical industry: two companies connect their wastewater to the municipal treatment facilities. Another company burns the gas for energy production (recovery), this amount of methane is not included in the energy statistics. Hence the emissions are not included in the emission inventory (NE).
- Pulp and paper industry; two companies treat wastewater anaerobically. These plants recover methane for energy production. The amount of gas from one of the plants is not included in the energy statistics. Hence the emissions are not included in the emission inventory (NE). Methane recovered from the other plant is included in the energy statistics (since 2010), emissions are estimated. These emissions are included in energy combustion for Manufacturing Industries and construction (sector 1A2d) pulp, paper and print. Hence the emissions are included elsewhere. (IE).
- Chemical industry: Norway will investigate whether emissions from this industry occur in the NIR 2014.

8.4.2 Methodological issue

CH₄

Emissions of methane from domestic waste water and from water consumption in food processing industries (breweries, dairies and slaughterhouses) are included in the inventory. No activity data are available for industrial WWTPs. Emissions of methane from other industries are not calculated CH₄ 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)

B₀: Maximum methane-producing capacity (kg CH₄/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)

B₀: Maximum methane-producing capacity (kg CH₄/kg DC)

MCF: Methane conversion factor

i: Industry

N₂O

For this source emissions of nitrous oxide from domestic and commercial wastewater have been calculated. Until this year only N₂O emissions from the part of the population and the part of the industry that is connected to large waste water treatment plants (>50 pe) have been estimated. As recommended by the review team Norway now estimates N₂O emissions from human sewage, which is not treated in sewage treatment plants. Emissions of N₂O from industries with their own waste water treatment plants are not estimated.

N₂O emissions from the part of the population and the part of the industry connected to large treatment plants (>50 pe) are calculated from nitrification/denitrification that occurs in the pipelines and the N₂O emissions that occur as a by-product in biological nitrogen-removal plants. This is assumed to be a more precise method than the recommended IPCC method that is based on the annual per capita protein intake. The N₂O from sewage sludge applied on fields is included under Agriculture in chapter 6.

For the part of the population connected to treatment plants (> 50 pe), the N₂O emissions are estimated like this:

N₂O emissions from pipelines

$$N_2O_{(S)} = N_{\text{supplied to pipelines}} \times 0,01 \times 1.57$$

For the part of the population that is connected to large treatment plants the N₂O emissions are calculated by multiplying the total amount of nitrate supplied to the pipelines by the IPCC default emission factor of 0.01 kg N₂O-N/kg sewage-N produced. Conversion factor of N₂O-N to N₂O is 1.57.

N₂O emissions in biological nitrogen removal-plants:

$$N_2O_{(S)} = N_{\text{removed}} \times 0.02 \times 1.57$$

It is assumed that 2 per cent of the nitrogen removed from plants will form N₂O. 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 is multiplied with 0.02 and then multiplied with the factor of 1.57 for conversion of N-removed to N₂O-N.

For the part of the population that is not connected to large treatment plants, the N₂O emissions are estimated as recommended by the IPCC review team. The IPCC method based on the annual per capita protein intake is being used.

Emissions of N₂O from the 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:

$$(8.12) N_2O_{(S)} = Protein \times Frac_{NPR} \times NR_{PEOPLE} \times EF_6$$

N ₂ O _(s) :	N ₂ O emissions from human sewage (kg N ₂ O –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 N ₂ O –N/kg sewage- N produced)
Frac _{NPR} :	Fraction of nitrogen in protein (default = 0.16 kg N/kg protein).

The N₂O from sewage sludge applied on fields is included under Chapter 6, Agriculture.

8.4.3 Activity data

CH₄

Data for the number of residents in Norway are given from Statistics Norway's population statistics. Population for a year is calculated by the average of the population at the beginning of the year and the end of the same year. 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 to a great extent coupled to the municipal sewer system. Emissions of methane from industries with their own wastewater treatment plants are not calculated due to lack of activity data. The emissions are assumed to be small, because the plants are mainly aerobic..

As recommended by the review team Norway has estimated emissions of CH₄ 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 2008.

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).

N₂O

A yearly estimate for the amount of nitrate supplied to the pipelines is obtained from Statistics Norway's waste water statistics (http://www.ssb.no/avlut_en/about.html). These figures are used for estimating N₂O emissions from the part of the population and the part of industry connected to large waste water treatment plants.

Data for the amount of nitrogen that is removed in the biological step in the actual waste water plants is obtained from Statistics Norway's waste water statistics (http://www.ssb.no/avlut_en/about.html). An oversight of which plants that removes nitrogen is given by the Climate and Pollution Agency.

Data for the number of people in Norway connected to waste water treatment plants are obtained from the waste water statistics at Statistics Norway:

<https://www.ssb.no/statistikkbanken/selecttable/hovedtabellHjem.asp?KortNavnWeb=avlut&CMSSubjectArea=natur-og-miljo&PLanguage=1&checked=true>

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 after 2002. 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. The number of people connected to different treatment systems one year is calculated by the average of the number of people connected at the beginning of the year and the end of the same year.

8.4.4 Emission factor

CH₄

The IPCC emission factor for B₀ of 0.6 kg CH₄/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 after 2000, 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", these are the treatment methods assumed to be anaerobic and hence emit CH₄. 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 was 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 the years after 2000. The number of people connected to "Sealed tank" and "Separate toilet system" each year is calculated by the average of the number of people connected at the beginning of the year and the end of the same year.

Table 8.2. The methane conversion factor (MCF) for the period 1990-2011

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
MCF	0.02	0.019	0.018	0.017	0.016	0.015	0.014	0.013	0.012	0.011	0.010	0.009
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2002	2003
MCF	0.008	0.007	0.009	0.009	0.009	0.009	0.009	0.008	0.008	0.009	0.008	0.007
	2004	2005	2006	2007	2008	2009	2010	2011				
MCF	0.009	0.009	0.009	0.009	0.009	0.008	0.008	0.009				

Emissions from water consumption in food processing industries are calculated using the average MCF-factor (0.01) for wastewater. The IPCC emission factor for B₀ of 0.6 kg CH₄/kg DC is used. The COD factors for the different groups are taken from IPCC 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 8.3. The table also shows 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 8.3. 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: IPCC (2006) and Statistics Norway.

N_2O

For the part of the population and the part of the industry that are connected to large 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. N_2O emissions also 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 (country-specific EF). Based on measurements at an early stage of the development of the process at one large waste water treatment plant it was hypothesized that the performance of this plant is much better than this (i.e. a lower percentage of processed N emitted as N_2O). During 2011 the emissions were tested by measuring N_2O emissions at various spots within the treatment plant, as well as the concentrations of N_2O in the liquid phase throughout, including the exit water. The results verified that the performance of this process with respect to N_2O emission is much better than the emission factor used for this treatment plant. On the average, the emission of N_2O -N to air from the entire plant (through the chimney) amounts to 0.2% of the processed N. If the N_2O lost as dissolved N_2O in the exit water is included, the percentage increase to 0.3 (Bakken 2012). For this treatment plant it is assumed that 0.3 per cent of the nitrogen removed from plants will form N_2O . This emission factor has been used for all years since 1996. The year the nitrification and denitrification reactors were fully operational. The amount of N removed at the plant is multiplied with 0.02 (0,003 for one plant) and then multiplied with the factor of 1.57 for conversion of N-removed to N_2O -N.

For the part of the population that is not connected to large 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 kilos per year. For the years 1990, 1995, 2000, 2003, 2004, 2005, 2006, 2007, 2009 and 2010 the Directorate for Health and Social Affairs has estimated the potential protein intake for the population (Directorate for Health and Social Affairs 2012).

This is estimated based on the equation:

$$(8.13) \text{ Potential protein intake} = \text{production} + \text{import} - \text{export}$$

This estimation does not reflect that the actual consumption is lower because not everything is eaten. Parts of the food end up as waste. Norway uses an estimated protein intake of 31.39 kilos per person for 1997 and the trend in potential protein intake when making the time series. Statistics Norway has estimated the intermediate years by interpolation. This is based on recommendations from the Directorate for Health and Social Affairs (Johansson, pers. Comm.²⁹). This is shown in the Table 8.4.

Table 8.4. Potential protein intake, and estimated protein intake, in g/person/day, kg/person/year, for the years 1990-2011.

Year	Potencial protein intake g/person/day	kg/person/year	Index 1997 =100	Estimated protein intake kg/person/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	108,07	33.9
2005	100	36.5	107.0	33.6
2006	102	37.2	109.1	34.2

²⁹ Johansson, L. (2005): Personal information by telephone, Directorate for Health and Social Affairs.

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2007	112	40.9	119.8	37.6
2008	111	40.5	118.7	37.3
2009	110	40.2	117.6	36.9
2010	106	38,7	113.4	35.6
2011	106	38,7	113,4	35,6

Numbers in bold in column 2 are from the Directorate for Health and Social Affairs, 2006 (2006)

¹Estimates for 2007 are also used for 2008 and 2009, due to lack of newer data.

8.4.5 Uncertainties

Uncertainty estimates for greenhouse gases are presented and discussed in Annex II.

8.4.6 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.

8.4.7 Recalculations

6 B1 Industrial wastewater

- Revised activity data. Adjustments and revision in the National account has led to small changes in the gross values from the food processing industries. Minor decrease in CH₄ emission for all years.

6 B2 Domestic and commercial wastewater

- Updated emission factor. N₂O –emissions have been measured at one waste water treatment plant in 2011. Based on the measurements a new emission factor has been provided. This EF has been used for this plant since 1996. This has led to a decrease in N₂O – emissions between 23 and 58 tonnes or 0.2 and 0.6 per cent.
- Changes in estimated figures, protein intake kg/person/year. The estimation of emissions of N₂O has been updated with new estimates of the daily per capita protein intake for 2009-2010. Earlier the emissions reported for 2007 has been used for the following years. Small decrease in emission for all years.
- Updated emission factor. MCF for waste water handling. The number of people connected to "Sealed tank" and "Separate toilet system" each year is now calculated by the average of the number of people connected at the beginning of the year and the end of the same year for all years. In last year submission the number of people connected to "Sealed tank" and "Separate toilet system" for the years 2006 -2009 were the number of people connected at the beginning of the year. The CH₄ emissions for 2006 and 2007 decreased by 9 and 27 tonnes respectively, while the CH₄ emissions for 2007 and 2010 increased by 20 and 4 tonnes respectively.

8.4.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2013.

8.5 Waste incineration – CO₂ – 6C

8.5.1 Description

Emissions from waste incineration in district heating plants are reported under energy (IPCC 1A1a), as the energy is utilized, and therefore described in Chapter 3. In 2010, there were 15 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. These emissions are reported and described in the relevant subsectors under 1A2. Flaring off-shore and in refines are included under sector 1B2c, Flaring in chemical industry are included under sector 2B5. 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 until 2005.

CO₂ emissions from cremations of human bodies are biogenic.

8.5.2 Methodological issues

Emissions from flaring of landfill gas by landfills are estimated. However, CO₂ 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 8.6.

Emissions from cremation are estimated by emission factors multiplied with activity data that is the number of cremated bodies. Emissions from combustion of hospital waste were until 2006 calculated based on an emission factor multiplied by the amount hospital waste incinerated. After that hospital waste is incinerated in municipal waste incineration plants and emissions are reported under energy.

8.5.3 Activity data

Landfill gas

The total amount of landfill gas extracted each year is reported by landfill owners to the Climate and Pollution Agency. The data are based on measurements both of the amount of gas and of the CH₄ content. Most landfill owners are required to measure continuously, and as a minimum report on: Hours of operation, amount of gas extracted, volume percentage of CH₄, and amount of CH₄ for flaring, heat, and electricity. The landfill operator reports the percentage of methane, along with the total amount of landfill gas (volume) to the Climate and pollution agency. The amount of recovered methane is than calculated.

Statistics Norway subtracts the amount utilized for district heating and thermal power, which is given by the energy statistics in Statistics Norway. Information on the amount flared is given by the Climate and Pollution Agency.

Emissions from the amount of landfill gas flared is included under 6c Emissions from landfill gas used for district heating and used in other sectors are reported in the relevant subsectors under 1A1 and 1A4.

Table 8.5 Amount of landfill gas flared and used for energy purposes. Tonnes. 1990-2011

Year	6c. Flared	1A1a district heating	1A4a, Other sectors, commercial /institutional
1990	879	0	67
1991	2 483	0	189
1992	4 103	0	1 109
1993	4 893	0	1 322
1994	5 304	0	1 433
1995	5 951	208	2 472
1996	6 869	350	2 853
1997	9 309	224	2 016
1998	13 505	201	2 925
1999	16 222	2 420	3 513
2000	12 459	3 654	2 698
2001	11 674	3 235	5 672
2002	11 769	121	10 270
2003	11 183	121	10 199
2004	10 550	174	9 739
2005	8 995	187	13 925
2006	8 093	177	12 528
2007	10 419	1 767	10 558
2008	10 351	3 061	8 483
2009	9 870	4 752	6 041
2010	8 280	4 076	7 053
2011*	6 965	3 428	5 933

Natural gas

The amount of natural gas flared by the production of methanol is, as recommended by the ERT, reported under 2B5.

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 2006 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 incineration of human bodies is a common practice that is performed on an increasing share of the annually deceased. The number of cremated bodies is gathered by the Ministry of Culture and published in Statistics Norway's Statistical Yearbook. The average body weight is assumed to be 60 kg.

8.5.4 Emission factors

Table 8.6. 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 ¹	0.00001176	0.00023
N ₂ O	0.0015 ¹	0.0000147	0.000035

Source: ¹⁾ SFT 1996

8.5.5 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 2005 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. See Annex II.

8.5.6 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.

8.5.7 Recalculations

There were performed no specific recalculations for this sector.

8.5.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2012.

9 Recalculations

9.1 Overall description of recalculations

The Norwegian greenhouse gas emission inventory has in 2013 been recalculated for the entire time series 1990-2010 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 continuous 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 performed by UNFCCC. The figures in this inventory are therefore, to the extent 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.8. 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.

The most important recalculations for greenhouse gases in the 2013 submission are:

Agriculture:

- New factors for nitrogen excretion from animals and revision of animal statistics used have increased annual direct and indirect N₂O emissions from manure between 3 and 12 per cent in the period 1990-2010.
- Revision and harmonization of animal statistics used has increased the estimated annual CH₄ emissions from young cattle between 75 and 93 per cent in the period 1990-2010. Emissions from all cattle have increased between 16 and 29 per cent in the period.

Waste:

- Inclusion of landfilled sewage sludge: Emissions of CH₄ from deposited sewage sludge have been included in the inventory for all years since 1990 as recommended by the ERT in the in-country review in autumn 2012.
- The DOC factor is changed for wood from 0.40 to 0.43 and for textiles from 0.40 to 0.24, in line with the IPCC default values.
- The method for estimating the amount of organic biodegradables in 'other materials' going to landfills is changed.

The emission of CH₄ from landfills increased by 2.4 per cent in 1990 due to these method improvements. For the Kyoto-years 2008-2010 the changes were minor (\pm 0.1 per cent).

Industrial processes and product use:

The emission estimates of HFCs and PFCs from product use have undergone a major revision. Most importantly, the activity data has been updated to improve accuracy: Old projections of imports of chemicals in products have been replaced by annual

data collected from the Norwegian Directorate of Customs and Excise. Some of the emission factors have also been updated in order to be better in line with the recommendations in the IPCC 1996 Guidelines. In addition, the calculation model set up in 1998 has been upgraded in several ways: In order to improve transparency and provide the UNFCCC with adequate data, changes have been made to the application categories used in the calculations, and activity data and emissions from disposal are now available for reporting. Disposal data used to be reported as a part of operating stocks and was therefore not in line with reporting requirements. A slight overestimation of emissions has been removed by the incorporation of data on destruction of used gas and by removing the requirement set by the model that a gas has to be imported every subsequent year after it was first imported. The production process, i.e. the data flow from input to output has been streamlined, both for the dissemination of statistics and for reporting to the UNFCCC.

9.2 Specific description of the recalculations

In the following description of recalculations that have been performed since 2012 submission, *reported emissions* are emissions calculated by the plants and reported to the Climate and Pollution Agency, whereas *calculated emissions* are emissions calculated by Statistics Norway, based on figures on energy use reported to Statistics Norway. There are three different types of reports that *reported emissions* are based upon. First, it is the reports from the mandatory reporting obligation that is a part of the plants permits given by the authorities, secondly, the authority receive as part of voluntary agreements between industry and authorities reports and last but not least from 2005 emission data is collected from all plants that is a part of the emission trading system (ETS). All reports with different activity and emissions data are submitted annually to the Climate and Pollution Agency.

9.2.1 Energy

Most of the recalculations in the Energy sector have been performed for 2010, because the energy figures for 2010 used in the 2012 submission were preliminary. There will always be some changes in the energy figures, e.g. some figures on energy use in manufacturing industries will be adjusted, which will lead to adjustments in other sectors, as total use of oil products must sum up to national sales. Now the final figures for energy use are available and are used in the emission calculations. 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

- Improved completeness. Use of bio-oil has been included for 2010. Increased emissions for all components, except CO₂.
- Correction of error. N₂O from district heating plants were previously double counted for 1996-2010. Removal of this double counting has reduced the emissions somewhat.
- Correction of error. CH₄ figures for 2010 for a thermal power plant located at the same place as an oil refinery, are included in reported figures for the latter and registered under 1A1b Petroleum refining. An additional factor estimation of emissions from the thermal power plant, registered under 1A1a, caused a double counting in the previous submission, and this has now been removed.

Hopefully, the plants will report separate emission figures for CH₄ in the future.

- Correction of error. A small amount of natural gas previously erroneously registered as used for production of electricity in 2006 has been removed. This causes minor reductions in emissions of CH₄ and N₂O.
- Consistency. As the ERT has pointed out, previous IEFs for CO₂ from gaseous fuels fluctuated remarkably for the latest years in the time series. A thorough examination of the energy figures used has led to revisions for five gas-fired power plants in 2007-2010. In addition to a minor revision of emission figures for another plant in 2004 and 2005, this has given far more reasonable IEFs.

1A 2 a Iron and steel

- Correction of error. Previously, combustion emissions from coal at one plant in 2010 were estimated, although the amount in question actually was used as a reducing agent. The removal of this coal amount has resulted in a reduction in emissions of CH₄ and N₂O, which are factor estimated. As reported emission figures (in this case CO₂) are distributed between different energy goods relatively to the use of the goods, the removal of coal has caused larger emissions for other energy goods, i.e. light fuel oil, LPG and blast furnace gas.
- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³.

1A 2 b Non-ferrous metals

- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³.

1A 2 c Chemicals

- Correction of error. A previous double counting of CO₂ from one plant in 2007 has been removed.
- Correction of error/reallocation/revised data. The figure on use of natural gas in 2002 at one plant has been corrected and this has led to an increase in factor estimated emissions, i.e. CH₄ and N₂O. At the same time, there has for the same plant been both a revision of total emission figures for CO₂ and a reallocation between combustion with energy utilisation (1A2c) and flaring, registered as process emissions (2B5.5 Methanol), all years 1997-2010. The revised figures are based on data from the emission trading system (ETS). There are decreases all years in 1A2c, ranging between 22 and 44 ktonnes CO₂.
- Correction of error. For one plant, reported CH₄ emissions 2005-2010 were previously erroneously registered both as combustion emissions in 1A2c Chemicals and process emissions in 2B5 Plastic, and thus causing a double counting. The figures have now been split between the two groups, and this has led to minor reductions in both (less than 1 tonne CH₄).
- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³.

- Revised data/reallocation. For one plant, there has been a reallocation between 1A2c Chemicals and 2B5 Plastic for CO₂ emissions in 1990-2005. Previously, all emissions prior to 2006 were registered as emissions from combustion in boilers, whereas flaring, which is registered under 2B5, now has been separated for all years, as previously was the case only from 2006. There have also been many revisions for total emission figures, causing changes also for the years from 2006. This has caused a decline for CO₂ in 1Ac. Factor estimated emissions (CH₄ and N₂O) have also been influenced by these changes
- Reallocation. For one plant there, has been a reallocation between 1A2c Chemicals and 2B5 Plastic for CO₂ 2001-2005. Previously all emissions were registered in 1A2c.

1A 2 d Pulp and paper

- Correction of error. Marginal change in reported CH₄ from one plant in 2010. Assumed typing error.
- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³.

1A 2 f Other

- Correction of error. Somewhat higher emissions from natural gas for all factor estimated emissions in 2008, due to the correction of previous use of a too low conversion factor for all use of LNG in tonnes to natural gas in Sm³
- Revised data. For 2002-2010, figures for combustion of wood waste, waste and special waste at two plants have been changed. Reported consumption figures in tonnes from the plants are used in factor estimations. Previously, reported figures in GWh were converted to tonnes via another conversion to toe. This results in minor emission changes for CH₄ and N₂O.

1A 3 b i-iii Road transport

There have been two significant corrections to activity data within road transport, and one minor adjustment. In total, these three adjustments have had no effect on totals for CO₂ because the total fuel consumption figures have not been changed, only the allocation between different vehicle categories. The time series of CH₄ has been adjusted upwards by 0- 6.9 per cent annually, while N₂O emissions are reduced by 0.8- 0 per cent annually in the 1993-2004 time period, and increased by approximately 1.4 per cent in 1990-1992 and 5.8 to 7.6 per cent annually in 2005-2010.

- Correction of activity data 1990-1992: Traffic activity for a segment of heavy duty vehicles has previously been omitted in the calculations in HBEFA. This traffic activity has now been included, leading to a reallocation of traffic activity within road transport. This reallocation has led to an increase in N₂O emissions of approximately 1.5 per cent each year, and a negligible reduction in CH₄ emissions.
- Corrections of coupling between activity data sets in HBEFA 2005-2010: Previously, there has been a direct coupling between statistics on number of vehicles, which have the vehicle population per December 31 of the inventory year, and statistics on driving lengths, which has had data on mean driving lengths for the average vehicle for each inventory year. This has led to an

underestimation of total traffic activity data. This error has been addressed by adjusting mean annual driving lengths in such a way that the totals now represent annual traffic activity. For CO₂, this has only led to a reallocation of emissions between vehicle categories, while it has led to an increase in both CH₄ emissions (4-6 per cent) and N₂O emissions (5-7 per cent).

- New coupling of age distributions and introduction schemes of new technologies has led to different traffic activities being coupled to different sub segments (with different emission factors). N₂O emissions are reduced by less than one per cent annually. The reduction is due to that a larger proportion of driving is calculated to having been performed by older vehicles without a catalyst. CH₄ emissions have increased in the same order of magnitude.

Additional recalculations for road transport:

- Correction of error: Emission factors for CNG vehicles are adjusted to 74% of the previous values. The previous factors were by mistake calculated as emissions per kg fuel, whereas the activity data are given in Sm³. The correction only affects emissions originally calculated in the road traffic emission model from activity data in vehicle kilometres (N₂O and CH₄). Emissions calculated from the fuel composition (CO₂) are not affected.
- Reallocation: Energy consumption and emissions for biofuels in 1A3b Road Transportation are now reported under *Biomass*. *Liquid Fuels\Gasoline* og *Liquid Fuels\Diesel* now has only the fossil fuel fraction.

The reallocation has no effect on total emissions. Emissions of CO₂ from *Liquid Fuels* are unchanged. Emissions of CO₂ from *Biomass* are now included, but do not enter the totals. Emissions of CH₄, N₂O, and precursors from biofuels use the same emission factors as for regular fuels.

The reallocation currently does not include all consumption of biofuels. Ethanol in gasoline used for non-road purposes in 1A3e, 1A4, etc. is still included with *Liquid fuels* in these sectors. Approximately 700 tonnes of ethanol was used for non-road purposes in 2011.

1 A 3 c Railways

- Completeness. Emissions from coal used in museum railways have previously not been estimated. The inclusion of these emissions causes a minor rise in all emissions from this source. Due to lack of exact data on consumption, the same amount is used for all years in the period from 1990. This gives 353 tonnes CO₂ annually.

1A 3d National navigation

- Reallocation. In 2009, 26 ktonnes marine gas oils have been transferred from 1A4c Agriculture/forestry/fishing to 1A3d Navigation. This results in corresponding changes in emissions (83 700 tonnes CO₂).

1 A 4 a Commercial / Institutional: Stationary

- Revised activity data. For one plant, previously not registered with use of coal coke in 2005 and 2006 and petrol coke in 2009 and 2010 has been included. This results in higher emissions of CO₂, CH₄ and N₂O. For CO₂ the emissions amount to 383, 3088, 4272 and 6843 tonnes in, 2005, 2006, 2009 and 2010, respectively.

1A 4 b Residential

- Revised activity data. For 2009 the amount of wood burned in holiday houses have been revised due consistency in the routine of imputation of data. Minor decrease for all components apart from CO₂.

1A 4 c Agriculture/Forestry/Fishing

- Reallocation. In 2009, 26 ktonnes marine gas oils have been transferred from 1A4c Agriculture/forestry/fishing to 1A3d Navigation. This results in corresponding changes in emissions (83 700 tonnes CO₂).

1A 5 Other

- Reallocation. Due to new information, military use of natural gas in 2010 has been reallocated from stationary to mobile use (ships). As the emission factor for CH₄ from natural gas in ships is considerably higher than the factor for boilers which previously was used, CH₄ emissions in 1A5b Mobile in 2010 are ten times higher (increased by 90 tonnes CH₄) in the 2013 submission than in the 2012 submission. In addition to this reallocation, which is less remarkable for other emissions, emission changes in 1A5 are mainly caused by revised emission factors for CH₄ and N₂O from vehicles, in addition to revised consumption figures from the energy statistics for 2010.

1B 2a v Distribution of oil products

- Improved consistency. Previously, a lower emission factor for NMVOC from refuelling of petrol at stations belonging to one petroleum company was used in the period 1993-2010, due to supposed emission reducing measures at these stations. Uncertainties regarding this lower emission factor has caused that the same factor now is used for all refuelling. This has given somewhat higher indirect CO₂ emissions for all years 1993-2010, ranging from 32 to 267 tonnes annually.

1B 2b Natural gas - gas distribution

- Revised activity data. Revised figures of use of natural gas 2008-2010 causes marginal changes in emissions of CH₄ from gas distribution.

1B 2c2ii Flaring of gas

- Correction of error. Reported emissions of CO₂ from one plant onshore in 2010 were previously erroneously registered as 2, instead of 24 446 tonnes.

1B 2c Venting and flaring

- Correction of error: The activity data for well testing of oil and gas for 2010 were erroneous and have been corrected. CO₂ emissions were increased by 89 000 tonnes.

9.2.2 Industrial processes

2 A 3 Limestone and dolomite use

Revised data. The reported 2009 figure for CO₂ from one plant has been altered from 23 300 to 21 000 tonnes. This is due to revised data from the plant.

2 A 4 b Soda Ash Production and Use – Other use of soda ash

Emissions from the use of soda ash other than glassworks and nickel production have been calculated and included for the first time. Figures on import of soda ash were taken from statistics on foreign trade from Statistics Norway. There were no data on soda ash in Norway in production statistics from Statistics Norway (PRODCOM 2008-2010). Reported use of soda ash in glassworks and nickel production was subtracted from the import figures. In addition, some consumption in chemical industry assumed to be non-emissive, based on table 2.7 “Emissive and non-emissive uses of carbonates” in the 2006 IPCC Guidelines. These amounts were excluded from the calculations. It is assumed that the remaining consumption is emissive and that 100 per cent calcination is achieved. Thus, the time series was multiplied by the emission factor for soda ash use given in Table 2.1 in the 2006 IPCC Guidelines: 0.41492 tonnes CO₂/tonne soda ash. All soda ash consumption was assumed to be emissive. Table 9.1 presents the additional emissions that are now reported under 2A4.

Table 9.1 Emissions from other use of soda ash in 2A4.

Year	Tonnes CO₂	Year	Tonnes CO₂
1990	15,233	2001	6,386
1991	16,440	2002	7,281
1992	5,604	2003	6,878
1993	2,614	2004	5,700
1994	5,949	2005	8,094
1995	8,816	2006	5,965
1996	10,465	2007	6,030
1997	6,558	2008	8,409
1998	2,422	2009	570
1999	3,509	2010	-
2000	5,931		

2 A 7 3 Glassworks

Additional emissions from the use of soda ash and limestone/dolomite at two point sources included for the first time. Table 9.2 gives the resulting increase in emissions of CO₂ now reported in 2A7.

Table 9.2 Additional emissions (tonnes CO₂) from use of soda ash and limestone/dolomite in 2A7.

Year	Tonnes CO₂	Year	Tonnes CO₂
1990	5 576	2001	6 010
1991	5 576	2002	5 259
1992	5 831	2003	5 149
1993	5 231	2004	5 643
1994	5 682	2005	5 001
1995	5 589	2006	4 301
1996	5 839	2007	3 940
1997	6 019	2008	4 456
1998	5 815	2009	4 090
1999	5 010	2010	4 152
2000	5 390		

2 B 1 Ammonia production

Revised data. The reported CO₂ figure for 2010 has been reduced by 25 200 tonnes due to new information provided by the plant. Previously used 2009 figures are replaced by actual 2010 figures.

2 B 5.5 Methanol

Reallocation. There has been both a revision of total emission figures for CO₂ and a reallocation between combustion with energy utilisation (1A2c) and flaring, registered as process emissions (2B5.5 Methanol), all years 1997-2010. The revised figures are based on data from the emission trading system (ETS). There has been an increase in figures in 2B5.5 all years, varying between 69 100 (1998) and 22 800 (2004) tonnes CO₂.

2 B 5 Plastic

Correction of error. For one plant, the reported CH₄ emissions 2005-2010 were previously erroneously registered both as combustion emissions in 1A2c Chemicals and process emissions in 2B5 Plastic. The figures have now been split between the two groups, and this has led to minor reductions in both groups (less than 1 tonne CH₄).

Revised data/reallocation. For one plant, there has been a reallocation between 1A2c Chemicals and 2B5 Plastic for CO₂ 1990-2005. Previously, all emissions prior to 2006 were registered as emissions from combustion in boilers, whereas flaring, which is registered under 2B5, now has been separated for all years, as previously was the case only from 2006. This has caused a rise for CO₂ in 2B5 ranging between 42 and 73 ktonnes CO₂. There have also been many revisions for total emission figures, causing changes also for the years from 2006. The only noticeable changes for these years are declines in 2007 and 2008, 25 and 18 ktonnes CO₂, respectively. The reallocation has also given minor emissions of CH₄ and N₂O from flaring.

2 B 5 Titanium dioxide production

Revised data. The reported CO₂ figures has been revised for 1990, 1991, 1998-2001 and 2005 due to new information from the plant. The changes vary between a 7 400 tonnes rise in 1998 and a 15 100 tonnes reduction in 2005.

2 C 2 Ferroalloys production

Revised data. There are minor reductions in the reported CH₄ and N₂O figures for 2005 from one plant due to new information from the plant.

2 C 5 Other metal production

Improved completeness/Correction of error/Revised activity data. For one plant, the reported CO₂ emissions for 1990 were previously erroneously omitted. This reported figure of 7 600 tonnes CO₂ has now been included in the inventory. The reported figures for the period 1991-1997 have been updated based on new reported figures to Klif. The changes vary between a 2 600 tonnes increase in 1994 and a 600 tonnes reduction in 1991.

2 D 2 Food and drink

Revised data. The activity data for calculation of CO₂ from carbonic acid in 2010 has been altered. Previously used 2009 figures are replaced by actual 2010 figures and results in 25 200 more CO₂ in 2010.

2 F Consumption of HFCs and PFCs

The emission estimates of HFCs and PFCs from product use has undergone a major revision. Most importantly, the activity data has been updated to improve accuracy. Old projections of imports of chemicals in products have been replaced by new calculations based on annual data collected from the Norwegian Directorate of Customs and Excise. Some of the emission factors have also been updated in order to be better in line with the recommendations in the IPCC 1996 Guidelines.

In addition, the calculation model set up in 1998 has been upgraded in several ways. In order to improve transparency and provide adequate data, changes have been made to the application categories used in the calculations, and activity data and data on emissions from disposal are now available. Disposal data used to be reported as a part of operating stocks and was therefore not in line with reporting requirements. A slight overestimation of emissions has been removed by the incorporation of data on destruction of used gas and by removing the requirement set by the model that a gas has to be imported every subsequent year after it was first imported. The production process, i.e. the data flow from input to output has been streamlined, both for the dissemination of statistics and for reporting under the UNFCCC.

As a consequence of updated activity data, emission factors (including life times), and the application of a new calculation model, the estimated emissions increased by nearly 168 000 tonnes CO₂ equivalents (up 22 per cent) in 2010. Table 9.3 gives an overview of the changes in emissions for all years, both in tonnes and per cent. The table shows that HFC-134a, HFC-125 and HFC-143a are the chemicals primarily affected.

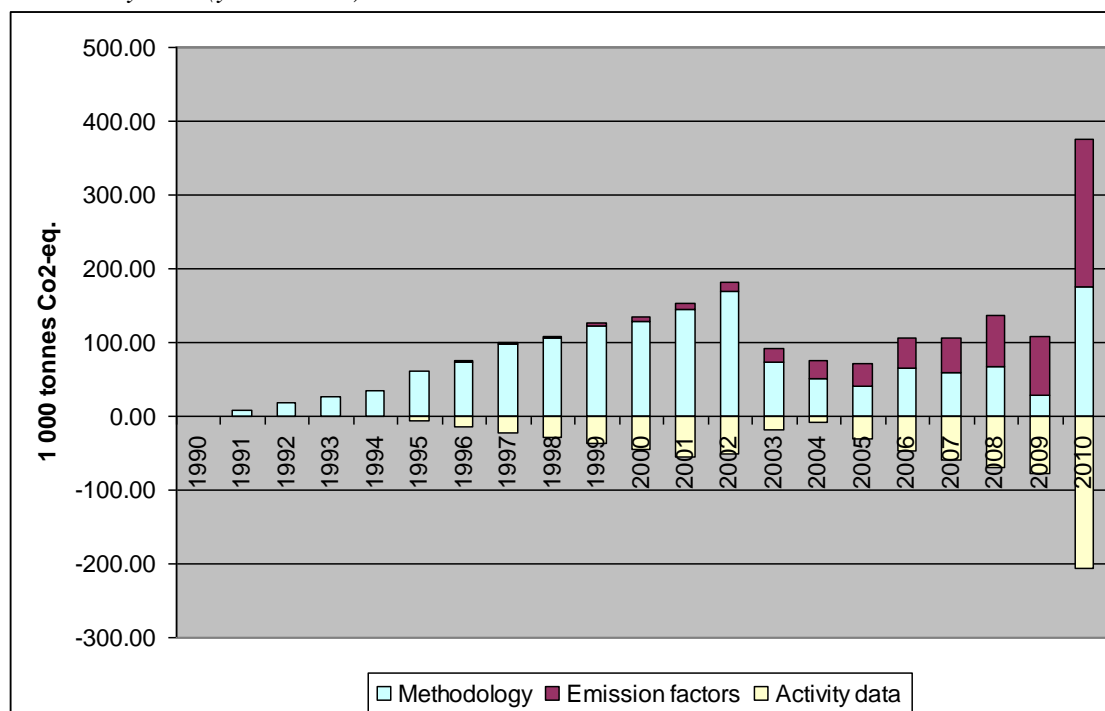
According to the new calculations, the total emissions have been underestimated for all years in the previous calculations. This is mainly due to changes made in the calculation methodology and emission factors (i.e. reduced life time for some products) resulting in emissions occurring earlier in time. New activity data have pulled in the opposite direction, as the imports of chemicals in general are lower in the current estimate.

Table 9.3 Difference in emissions after recalculations (current minus previous estimate)

	Total (ktonnes CO ₂ - eq)	HFC- 23 (tonnes)	HFC- 32 (tonnes)	HFC- 125 (tonnes)	HFC- 134 (tonnes)	HFC- 134a (tonnes)	HFC- 143 (tonnes)	HFC- 143a (tonnes)	HFC- 152a (tonnes)	HFC- 227ea (tonnes)	PFC- 218 (tonnes)
1990	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00
1991	9.01	0.00	0.03	0.04	0.00	6.72	0.00	0.00	0.21	0.00	0.00
1992	18.12	0.00	0.10	0.10	0.00	13.39	0.00	0.00	0.19	0.00	0.00
1993	26.45	0.00	0.18	0.19	0.00	19.51	0.00	0.00	0.03	0.00	0.00
1994	35.19	0.00	0.29	0.96	0.00	23.44	0.00	0.43	0.04	0.00	0.00
1995	54.35	0.00	0.42	2.82	0.00	28.18	0.00	2.54	0.29	0.00	0.03
1996	60.24	0.01	0.57	3.54	0.00	29.54	0.00	2.91	-0.03	0.06	0.05
1997	77.86	0.03	0.62	5.80	0.00	32.75	0.00	4.85	1.02	0.05	0.04
1998	79.86	0.00	0.74	5.81	0.00	34.40	0.00	4.88	0.51	0.01	0.04
1999	89.89	0.00	0.83	7.20	0.00	31.97	0.00	7.48	-2.10	0.00	0.03
2000	89.45	0.00	0.96	8.64	0.00	25.93	0.00	8.21	-4.17	0.00	0.03
2001	99.21	0.00	1.11	10.68	0.00	20.82	0.00	11.11	-5.79	0.15	0.03
2002	128.94	0.00	1.08	15.60	0.00	20.75	0.00	14.86	-8.69	0.92	0.02
2003	72.31	-0.03	1.16	9.21	0.00	10.38	0.00	8.89	-12.06	0.23	0.02
2004	68.73	-0.05	1.22	9.75	1.03	1.17	0.00	10.09	-3.95	0.15	0.02
2005	42.23	0.03	1.50	9.20	0.75	-9.86	0.70	7.27	-1.12	-0.09	0.01
2006	59.64	0.00	2.53	12.97	0.67	-9.93	0.65	9.22	-4.58	-0.32	0.00
2007	47.29	-0.02	3.54	11.55	0.59	-8.49	-0.14	6.22	0.85	-0.13	0.00
2008	68.13	-0.05	4.79	13.60	2.66	-8.51	-0.29	9.94	-3.12	-0.44	0.00
2009	28.65	-0.06	7.22	16.59	2.07	-36.49	-0.45	6.77	-4.14	-0.40	-0.01
2010	167.62	-0.04	10.33	34.07	1.85	-20.30	-0.60	24.67	-3.31	-0.76	-0.01

Figure 9.1 shows the influence on total emissions for each year, by the changes made in methodology (blue bars), emission factors (red bars) and activity data (yellow bars). The figure illustrates that in the beginning of the time series, changes in methodology was responsible for almost 100 per cent of the emission changes in the recalculations. Towards the end of the time series, the three groups of changes are equally important – each causing a change in emissions of about 1/3 of the total change. This means that if only activity data was updated in 2010, the emissions would have been about 207 000 tonnes CO₂ equivalents lower than the previous estimate of 747 000 tonnes. If only emission factors were updated, the emissions would have been about 199 000 tonnes CO₂ equivalents higher than the previous estimates. And equally, if only the methodology had been changed, the emissions would have been about 176 000 tonnes CO₂ equivalents higher than the previous estimates. The net increase in the emissions after performing all three changes was therefore 168 000 tonnes CO₂ equivalents.

Figure 9.1. The influence of change in methodology (blue bars), emission factors (red bars) and activity data (yellow bars) on the recalculations/emission estimates



Methodological changes

Accumulated over time, it is the change in methodology that is responsible for the largest share of changes in the recalculation of emissions. An important methodological change is that the *new* model bases the emission estimates on the original amount of chemical filled in to a product. The emission factors are applied to the amount of chemical a product initially contained, even if some of the chemical have leaked out over time. This is in line with the recommendations of the IPCC 1996 Guidelines. The old model applied the emission factors to the amount stored in the products at any given time. For products not being refilled, like household refrigeration and foam products, this will cause the chemicals to be released at a higher pace. It is important to note that this will not lead to a change in the accumulated amount of chemicals emitted over time, but it leads to the emissions occurring earlier in time.

For one product group, i.e. mobile air conditioning, the emissions are no longer calculated based on emission factors. A mass balance approach is used, as the emissions are equal to imports of chemicals for refilling. This has also caused the emissions to increase.

Of less importance is the fact that the new model takes amounts of destructed chemicals into account. This has slightly lowered the emissions.

Changes in emission factors, including life time

The changes in emission factors have also contributed to higher emissions, but this has mainly had an effect on later years. A reduction in life time for some products has lead emissions to occur earlier in time than what was estimated in the previous model. For some products the emission factors are higher, for some they are lower. These changes will have opposed effects on the emissions. See table 9.4 with new and old

emission factors and life times. The effects are accounted for in the red bars in figure 9.1.

Table 9.4 Emission factors used before and after recalculations. Old values shown in bold

Application category	Leakage rates for production of new equipment. Per cent of initial charge		Leakage rates for operating equipment. Per cent of initial charge/year		Lifetime (years)	
	New	Old	New	Old	New	Old
Refrigeration						
Domestic Refrigeration	Not occurring		0,5	1	15	
Commercial Refrigeration						
Stand-alone Commercial Applications	Not occurring		3,5		10	15
Medium and Large Commercial Refrigeration	2		10		15	
Transport Refrigeration	1	2	20		9	15
Industrial Refrigeration	2		10		15	
Residential and Commercial A/C, including heat pumps	1	2	4		15	
Mobile Air-Conditioning	Not occurring		Not applicable ²	10	12	
Foam	5		4,5	1 and 3	20	30/40
Fire protection	2 ¹		5		15	
Aerosols						
Metered Dose Inhalers	Not occurring		50		2	
Other aerosols	Not occurring		50		2	
Solvents	Not occurring		50		2	

¹Country specific SFT 99:03

²A mass balance approach is used to estimate emissions from mobile air conditioning

Activity data

The yellow bars in figure 9.1 show the effect of updating the activity data. This has overall lead to a decrease in emission figures. The updating of activity data results in a decrease in net consumption caused by lower total imports for the whole period 1990-2010 for HFC-134a and HFC-152a, and less importantly of HFC-143a and HFC-125. Net consumption increased for the other chemicals. As projections based on data collected in mid 90ties were replaced by annual import statistics, the current activity data is believed to be of much higher quality. Projections seem to have been too high especially for imports of chemicals in hard foam products and too low for imports in stationary air conditioning.

2 F Consumption of SF₆

Based on new reporting from a company, the emissions for 2010 were slightly changed (increased by 0.3 per cent).

2G Other

Revised method. The CO₂ emissions from use of paraffin wax in 2008-2010 were previously calculated by using the standard method (import, export, sold amounts). Due to confidentiality problems, these figures have now been replaced by interpolated figures. This has caused a decrease in CO₂ emissions from this source by 151, 426 and 528 tonnes for 2008, 2009 and 2010, respectively.

9.2.3 Solvents and other product use

3 A 1 and 3 A 3

- A correction of error (missing industry code) resulted in 1 tonne NMVOC being reallocated from 3A3 to 3A1 in 2010. This has increased the emissions of indirect CO₂ emissions in 3A1 and a corresponding decrease in 3A3.

3 D 2 Domestic solvent use

- Revised sales figures for cosmetics give an increase in NMVOC and thereby increased indirect CO₂ emissions of 72, 60 and 1 526 tonnes in 2008, 2009 and 2010 respectively. In 2010 revised sales figures for cosmetics give increased emissions, while a correction of error (missing industry code) results in emission reduction (due to the use of a smaller emission factor). In sum, this results in an increase in emissions of 1 526 tonnes CO₂- equivalents.

3 D 3 Other product use

- A correction of error (missing industry code) resulted in a reduction of 81 tonnes in the emissions of NMVOC and thereby decreased indirect CO₂ of 243 tonnes for 2010. The amount was assigned to an industry code that is given a small emission factor.

9.2.4 Agriculture

4A Enteric fermentation

CH₄ Heifer<1 (for slaughter), CH₄ Young bull<1year, CH₄ Heifer>1year (for slaughter), CH₄ Bull>1year

- Changes in activity data. Animal numbers, lifetimes and slaughter weights are collected from the slaughter statistics, and these variables are internally coherent. These variables are the bases for the emissions estimates. Previously, animal numbers were collected from animal census, and the corrections were made for animal years. The new method implies that emissions in the early stages of most of the animals' lives will be posted in the current year, while it took place in the previous year. In a steady population of animals, this error is automatically corrected for, and since animal populations are relatively stable, this error is considered much smaller compared to errors in connection with correcting for animal year in the previous method.

CH₄ Heifer (for breeding)

- Changes in activity data. The change of data and how the estimates are done corresponds to the changes that were made for cattle for slaughter, see above. The data source is the Cow Recording System at TINE BA³⁰, which provides data on the number, age and live weight of the young cows' at their first calving.
- The revision and harmonization of animal statistics used has increased the annual CH₄ emissions from young cattle between 75 and 93 per cent in the period 1990-2010, compared to previous published figures.

³⁰ TINE BA is the sales and marketing organisation for Norway's dairy cooperative and covers most of the milk production and the meat production induced by milk production)

CH₄ Beef cow

- Changes in activity data. The number was previously estimated. The number is now collected from official animal statistics. This has given a reduction in emissions between 6 and 60 per cent in the period 1990-2010, compared to previous published figures.

CH₄ Ostrich

- Change in emission factor. Emission factor is changed from 4.97 kg/animal/year to 0.02 kg/animal/year based on expert judgement at the University of Life Sciences (Karlengen et al. 2012). The earlier used factor is considered to be too high by a concentrates diet, and the Danish factor that now is used is expected to better reflect Norwegian circumstances.

CH₄ Deer

- Change in emission factor. Emission factor is changed from 52.6 kg/animal/year to 20.0 kg/animal/year. The new factor is an expert judgement at the University of Life Sciences (Karlengen et al. 2012) and has been estimated based on the methodology described for cervidae in IPCC (2006).

CH₄ Reindeer

- Change in emission factor. Emission factor is changed from 19.9 kg/animal/year to 14.0 kg/animal/year. The new factor is an expert judgement at the University of Life Sciences (Karlengen et al. 2012) and has been estimated based on the methodology described for cervidae in IPCC (2006).

CH₄ Goat

- Change in emission factor. Emission factor is changed from 5 kg/animal/year to 13.0 kg/animal/year based on expert judgement at the University of Life Sciences (Karlengen et al. 2012). The earlier used factor is considered to be too low since the Norwegian goats are expected to have a higher feed intake than the assumptions that was basis for the default factor, and the Danish factor that now is used is expected to better reflect Norwegian circumstances.

CH₄ emissions from source 4A increased 8 400 tons (9.3 per cent) in total for the year 2010 due to the new calculations. The emissions from young cattle increased 13 600 tons. This was partly due to the use of a new data source for this group of animals and partly due to changes in how these data were combined with the emission factors. Changes in the number of beef cows caused a decrease of 4 000 tons. Changes in the emission factors for ostrich, deer, reindeer and goats (tier 1 estimations) together brought about a decrease of 1 200 tons CH₄. For the previous years in the time series 1990-2010, the total changes were bigger. The calculations for 1999 gave an increase of 18.6 per cent, which was the highest increase for any year in the time series.

4B Liquid systems, 4B Solid storage and dry lot and 4D2 Pasture range and paddock

- Changes in activity data, number of animals.
Young cattle for slaughter: Previously, animal numbers were based on counted live animals registered for production subsidies, and then corrections were made for animal years. Animal numbers are now based on data from slaughter statistics which provide data on numbers slaughtered, lifetimes and slaughter

weights. The changes in activity data are made to better match the categories of the new N-excretion factors. All these three variables are inputs in the equations that are used to calculate the new N-excretion factors (see below). These variables are also internally coherent.

One principal draw-back of this method is that emissions in all stages of these animals' lives will be posted in the year of slaughter, while the emissions of the early stages of the lives of these animals to a large extent took place in the previous year. In a steady population of animals, this error is automatically corrected for, and since animal populations are relatively stable, this error is considered much smaller compared to errors in connection with correcting for animal year in the previous method that used information on weight and age. Better estimations of N-factors are possible when they are connected to the full lifetime of cattle with short lifetime, and the numbers are counted at the time of slaughter or first calving.

Heifers bred for new milking cows: The number of heifers bred for new milking cows are estimated correspondingly to the method used for young cattle for slaughter, see above. The data source is the Cow Recording System at TINE BA³⁰, which provides data on the number, age and live weight of the young cows' at their first calving.

Dairy cows: Previously, animal numbers were based on counted live animals registered for production subsidies. This is changed to estimated number of "year cows" (one year cow = one cow alive through a whole year), which is provided by Cow Recording System at TINE BA³⁰. The reason for this change is that N-excretions factors are estimated according to "year cows". Empirically, the number of "year cows" are 10-15 per cent lower than the number of counted cows.

- **Changes in N-excretion factors.**
The N-excretion factors have been changed to better reflect the actual nitrogen excretion from the different animal groups. The N-excretion factors for *cattle*, *poultry* and *pigs* have been scientifically investigated in 2012, while the remaining categories have been given expert judgements (Karlengen et al. 2012).

The factors for cattle are based on equations where animal weight, production (milking cows), life time (young cattle) and protein content in the fodder are activity data used in the equations. Calculations based on these equations have been made back to 1990 and have replaced the old N-excretion factors for the whole time series. The equations used are as follows:

Milking cow and beef cow:

$$N_{\text{total}} = -120,827 + (0.00798 * Y) + (0.0433 * V) + (0.605 * PG) + (0.355 * PK)$$

$$N_{\text{faeces}} = 13,956 + (0.00452 * Y) + (0.00920 * V)$$

$$N_{\text{urine}} = N_{\text{total}} - N_{\text{faeces}}$$

where

N_{total} = total nitrogen excretion, kg/animal/year

N_{faeces} = nitrogen excretion in the faeces, kg/animal/year

N_{urine} = nitrogen excretion in the urine, kg/animal/year

Y = milk yield, kg per year

V = live weight of animal, kg

PG = protein content in coarse fodder, per cent of dry weight

PK = protein content in grain fodder, per cent of dry weight

Young bull for slaughter:

$$N_{\text{gj}} = -130,554 + (0,319 * SV) + (1,283 * SA) + (0,342 * PG) + (0,168 * PK)$$

$$N_{\text{faeces}} = -13,845 + (0,115 * SV) + (0,355 * SA)$$

$$N_{\text{urine}} = N_{\text{total}} - N_{\text{faeces}}$$

where

N_{gj} = total nitrogen excretion, kg/animal/animal through whole lifetime

N_{faeces} = nitrogen excretion in the faeces, kg/animal/animal through whole lifetime

N_{urine} = nitrogen excretion in the urine, kg/animal/animal through whole lifetime

SV = slaughter weight, kg

SA = slaughter age, months

PG = protein content in coarse fodder, per cent of dry weight

PK = protein content in grain fodder, per cent of dry weight

Young cows for slaughter

Total N:

$$Y = 9.7675 \times 10^{-8} a^4 - 0.000209333 a^3 + 0.242937 a^2 + 8.77947 a - 9.7675 \times 10^{-8} b^4 + 0.000209333 b^3 - 0.242937 b^2 - 8.77947 b$$

- Urine N:

$$Y = -0.0000363333 a^3 + 0.112968 a^2 + 5.82073 a + 0.0000363333 b^3 - 0.112968 b^2 - 5.82073 b$$

where

Y = total nitrogen excretion, kg/animal through time span $a - b$

a = age of slaughter, days

b = age first day of estimated period, days (birth = 0)

These equations are based on a live weight of 520 kg at 24 months and a protein content in fodder of 185 and 140 g/kg dry matter in grain and coarse fodder respectively.

Young cows bred for new milking cows:

$$N_{\text{total}} = -166,680 + (0,221 * V) + (1,689 * FT) + (0,513 * PG) + (0,119 * PK)$$

$$N_{\text{faeces}} = -14,850 + (0,0737 * V) + (0,485 * FT) - (0,0220 * PG)$$

$$N_{\text{urine}} = N_{\text{total}} - N_{\text{faeces}}$$

where

N_{gj} = total nitrogen excretion, kg/animal from birth to 1. calving

V = live weight at first calving, kg

FT = age at first calving, months

PG = protein content in coarse fodder, per cent of dry weight

PK = protein content in grain fodder, per cent of dry weight

Poultry and pigs

For poultry and pigs, new N-factors have been estimated for 2011, but equations are not provided, so it is not possible to estimate backwards in time based on other activity data. The factors used until this update were estimated in 1989, and are regarded as still valid for 1990. A linear interpolation has been used for the years between 1990 and 2011.

Remaining animal categories

For the remaining animal categories, only a few changes have been made, based on expert judgement (Karlengen 2012). These changes have been applied for the whole time series.

Table 9.5. N-excretion factors for animal categories in Norwegian agriculture. Average estimates when categories consist of sub-categories. kg N/animal/year unless otherwise informed in the table.

	Total nitrogen	
	Old factor 1990-2010	New factor 2010
Reindeer	6.0	6.0
Horse	50.0	50.0
Milking cow	82.0	124.0
Beef cow	40.0	64.6
Young cattle (average) (per animal, whole life time)	31.8	44.4
Sheep	11.6	11.6
Lamb (per year, not corrected for lifetime)	7.7	7.7
Goats (average)	15.5	13.3
Breeding pigs (average)	18.3	23.5
Pigs for slaughter (per animal, whole life time)	4.4	3.2
Laying hens	0.671	0.70
Chickens bred for laying hens (per animal, whole life time)	0.051	0.147
Chickens bred for slaughter (per animal, whole life time)	0.031	0.053
Ducks and turkey for breeding (average)	2.0	2.0
Ducks and turkeys for slaughter (average) (per animal, whole life time)	0.34	0.403
Foxes incl. males	9.0	9.0
Minks incl. males	4.3	4.3
Deer, ostrich (average)	12.0	12.0

The total change in estimated N-excretion due to the new nitrogen factors and revised methods for estimating young cattle and animals for slaughter has for 2010 been an increase of 14.2 per cent in total nitrogen.

4D1.2 Animal Manure Applied to Soils

- Changes in estimated amounts applied due to changes in N-factors and activity data (no. of animals), see above.

4D1.1 Synthetic fertilizers

- Corrections of amount of total consumption of nitrogen fertilizers 2009-2010. Nitrogen contents in 2009 reduced from 99 441 to 93 823 and in 2010 reduced from 100 661 to 85 131 tonnes. This was due to revised sales figures.

4D3.1 Atmospheric Deposition

- Changes in estimated amounts deposited due to changes in N-factors and activity data (no. of animals), see above.
- Changes in estimated amounts deposited due to ammonia emissions from sewage sludge included as source as recommended in a Saturday Paper from the ERT 2012.

The new factors for nitrogen excretion from animals and revision of animal statistics used have increased annual N₂O emissions from manure between 3 and 12 per cent in the period 1990-2010. This includes both direct and indirect emissions.

4D3.2 Nitrogen Leaching and Run-off

- $Frac_{leach}$ factor updated from 0.18 to 0.22. The new factor was estimated in a new study by Bioforsk (Norwegian Institute for Agricultural and Environmental Research) (Bechmann et al. 2012) and the updated factor is based on the data from the Agricultural Environmental monitoring program (JOVA), and is expected to better reflect Norwegian circumstances than the old factor from 1998.
- Changes in estimated amounts deposited due to changes in N-factors and activity data (no. of animals), see above
- Reduced application of N in sewage sludge due to inclusion of N lost in NH₃ emission from sewage sludge as recommended in a Saturday Paper from the ERT 2012.

4D1.5 Cultivation of Histosols

- Mean area figures for the development in cultivated area after 1994 have been estimated by Bioforsk. The time series has been updated in 2012 (Grønlund, pers. comm³¹) based on assumptions of a yearly area decline of about 1 per cent due to transition of peat and abandonment of cultivated moors, and a yearly cultivation of new moor of 2 km². This has induced an annual change in emissions between 0.15 and -1.05 in the years 1990-2010 compared to previous estimations. The reason for the change is that the expert estimates of yearly cultivation of new moor have been reduced, since it was overestimated before.

4F Burning of crop residues

- Changes in activity data. The amounts of crop residues burned in the fields have been changed for the years 2005-2010. It was earlier assumed that 7.5 per cent of the crop residues were burnt (based on a questioner in 2004). A questioner in 2012 showed that about 4 per cent of the crop residues were burned in 2012. Linear interpolation has now been used for the intervening years.
- Emission factors for CH₄ and N₂O have been changed from 2.7 to 2.4 kg/tonnes crop residue burned and from 0.07 to 0.0469 kg/tonnes crop residue burned respectively as recommended by the ERT in the 2012 in-country review. The new factors are according to the Revised 1996 IPCC Guidelines.

³¹ Grønlund, A. (2012): Personal information, email from Arne Grønlund June 7 2012, Ås: Bioforsk.

Emissions of CH₄ and N₂O have decreased by less than 0.1 per cent.

9.2.5 Waste

6 A Solid waste disposal on land

- **Changes of DOC factors:** The DOC factor is changed for wood from 0.40 to 0.43 and for textiles from 0.40 to 0.24, in line with the IPCC default values.
- **Inclusion of landfilled sewage sludge:** Emissions of CH₄ from deposited sewage sludge have been included in the inventory for all years since 1990 as recommended by the ERT. This has improved the completeness of the inventory. The amount of landfilled sewage sludge is based on Statistics Norway's waste water statistics and linear interpolations in missing years.
- **Changed method for estimating the amount of organic biodegradables in 'other materials' going to landfills:** The share of organic materials in the category 'other materials' except incineration residues is changed from 13 per cent to a varying share based on statistical sources. The fraction of 13 per cent has been difficult to document properly, and furthermore a fixed share leads to unwanted side-effects if for instance new and strictly mineral substances are being put on the landfill.

The new method applies the following relation:

Amount of biodegradable organic materials in landfilled 'other' = $0.2 * \text{landfilled 'other materials' from manufacturing (other sectors not relevant)} + 0.5 * \text{'other combustible' in landfilled mixed waste from all sectors}$.

Landfilled 'other materials' from manufacturing is the dominant of the two fractions, comprising 70 to 95 per cent of the total biodegradable organics in landfilled 'other materials' during the time series from 1995 to 2010. The factor of 0.2 is derived from studying the data from the manufacturing waste surveys in 1993, 1996, 1999, 2003 and 2008, which show that in 2008 40 per cent of the landfilled 'other materials' from manufacturing came from industries with mainly biodegradable organic production waste. Of this, (at least) half was assumed to be non-organic in order to get permission for landfilling the waste. Earlier reference years showed lower shares coming from industries with biodegradable organic production waste. Thus, the fraction of 0.2 is judged to be conservative. Since the data on waste from manufacturing are uncertain at this detailed level, a trend adjustment is performed to fit the trend in landfilled biodegradable 'other material' from manufacturing with the overall trend in landfilled biodegradable waste in Norway.

The factor 0.5 applied on 'other combustible' in landfilled mixed waste is chosen as a medium value, due to absence of information.

Emission of CH₄ from landfills increased by 2.4 per cent in 1990 due to these method improvements. For the Kyoto-years 2008-2010 the overall changes were minor (± 0.1 per cent). The positive change in 1990 was due to the new DOC factors and inclusion of sewage sludge, but the effect reduced gradually until 2010. New method for "other materials" gave an insignificant negative change in 1990, but rising until 2010 to give an estimated total that is almost unchanged.

6 B1 Industrial wastewater

- Revised activity data. Adjustments and revision in the National account has led to small changes in the gross values from the food processing industries. Minor decrease in CH₄ emission for all years.

6 B2 Domestic and commercial wastewater

- Updated emission factor. N₂O –emissions have been measured at one waste water treatment plant in 2011. Based on the measurements a new emission factor has been provided. This EF has been used for this plant since 1996. This has led to a decrease in N₂O – emissions between 23 and 58 tonnes or 0.2 and 0.6 per cent.
- Changes in estimated figures, protein intake kg/person/year. The estimation of emissions of N₂O has been updated with new estimates of the daily per capita protein intake for 2009-2010. Earlier the emissions reported for 2007 has been used for the following years. Small decrease in emission for all years.
- Updated emission factor. MCF for waste water handling. The number of people connected to "Sealed tank" and "Separate toilet system" each year is now calculated by the average of the number of people connected at the beginning of the year and the end of the same year for all years. In last year submission the number of people connected to "Sealed tank" and "Separate toilet system" for the years 2006 -2009 were the number of people connected at the beginning of the year. The CH₄ emissions for 2006 and 2007 decreased by 9 and 27 tonnes respectively, while the CH₄ emissions for 2007 and 2010 increased by 20 and 4 tonnes respectively.

9.2.6 Land Use, Land-Use Change and Forestry

Substantial improvements of the NFI data base implemented in the 2013 submission caused changes in the land area estimations compared to the 2012 submission. The improvements included consistency checks of the land use classification, an updated time series by back-casting data on plots without previous measurements and a general quality control of the data for the whole time-series. Also, several improvements were made in methods.

Due to design changes in the Norwegian National Forest Inventory (NFI) between 1990 and 1998, the area estimates of land-use classes and the estimates for C stocks in living biomass for forest, grassland, wetland and other land have been bridged for the years 1990-1998. An adjustment factor was used to bridge the estimates in these years in the reporting last year. The adjustment factor was slightly changed this year in order to better accommodate the change from mid-year reporting in 1990 to end-year-reporting in 1998.

The whole time-series was recalculated for all C sources and sinks due to the updates and improvements of activity data and methods. Total changes in emissions (including non-CO₂ emissions) caused by recalculations for the LULUCF sector are shown in Figure 9.2. Effects of recalculations on the land-use category and sink/source category level are described in more detail in previous sections.

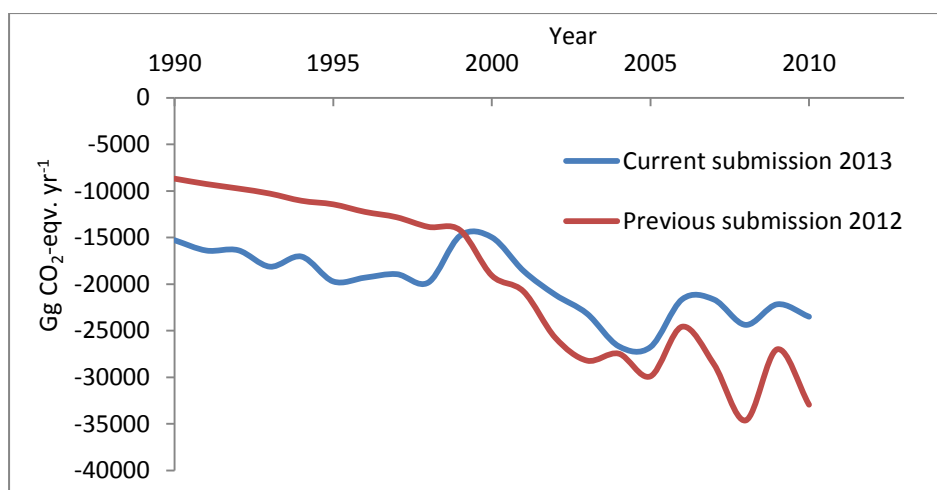


Figure 9.2 Recalculations illustrated for the total net emissions (Gg CO₂-equivalents per year) estimated for the LULUCF sector in the 2013 submission compared to the 2012 submission.

The following effects of recalculations are described for the emissions and removals reported for the year 2010.

5A Forest Land

5A1 Forest land remaining forest land

The whole time-series was recalculated due to the implementation of the revised NFI database, which affected estimates from all sources and sinks.

- The change in the adjustment factor implemented for the years 1990-1998 had a major influence on the area estimates and for C stocks in living biomass. Compared to the last year's reporting, C uptake in living biomass for 2010 was reduced by 10 % from 7384 Gg C to 6721 Gg C.
- Sequestration by dead organic matter (DOM) increased by 34 % and C uptake in mineral soils reduced by 23 709 %. Considering the DOM and soil pools together, the total C sequestration was reduced by 61 %. Although, a part of this reduction can be contributed to the revised data base (approximately 10 % as for living biomass), the majority was caused by the implementation of the Yasso07 model.
- A significant change occurred for organic soils, where emissions for 2010 increased by 92 % due to the use of a country-representative emission factor from Sweden.

5A2 Land converted to forest land

The definition of this land-use change category was changed. Areas are now considered belonging to this class, if the conversion to forest land is actively human induced.

- Total C stock change for land converted to forest dropped by 51 % for 2010. Carbon uptake in living biomass decreased by 704 % solely due to a drop in the areas converted to forest land due to the changed definition. The areas of cropland converted to forest land decreased from 44 to 10 kha, wetland converted to forest decreased from 117 to 3 kha, settlement converted to forest decreased from 46 to 14 kha, and other land converted to forest decreased from 296 to 2 kha. Consequently, the C stock changes in living biomass for

wetland converted to forest and other land converted to forest were very high (roughly 2 400 % and 22 000 %, respectively).

- Carbon changes in DOM were 100 % because of the implementation of a Tier 2 method.
- For organic soils C changes also increased by a 100 % as previous submission did not report specifically for this category.
- Another methodological change occurred for mineral soils with the application of a Tier 1 method, which resulted in 112 % increase in C uptake.

5B Cropland

5B1 Cropland remaining cropland

- Total emissions for cropland remaining cropland increased by 97 %, primarily due to the inclusion of all cultivated histosols under cropland (previously 90 % of this area was considered grassland). The emission factor was not changed; the increase was solely caused by the re-allocation of the cultivated organic soils.
- For mineral soils, the Tier 2 method was completely revised replacing the previous erosion-based emission factors with an IPCC method using soil C reference stocks and stock change factors. The result was a 400 % reduction in soil C sequestration from 51 Gg SOC to 10 Gg SOC for 2010.
- Changes in living biomass were also affected because the C losses on felled horticultural plantations are now included under cropland instead of, as previously reported, under cropland converted to grassland. In addition, updating the activity data resulted in a modest increase in the C gains of 7 %.

5B2 Land converted to cropland

- Recalculations for 2010 increased C losses by 80 %; annual C losses increased from 6.33 Gg SOC to 32.55 Gg SOC.
- The revised NFI database resulted in minor area changes.
- The implementation of a Tier 1 method applied to all lands converted to cropland was responsible for increasing SOC losses from 6 to 19 Gg SOC, as previously only conversion of forest land to cropland was reported.

5C Grassland

5C1 Grassland remaining grassland

- Emissions from grassland remaining grassland were reduced by 1 575 %, due to the allocation of all cultivated histosols to cropland.
- The effects of the implementation of a Tier 1 for mineral soils and the Tier 3 for living biomass counter balanced one another by a soil C loss of 16 Gg SOC and an uptake in living biomass of 14 Gg C.

5C2 Land converted to grassland

- Total emissions for land converted to grasslands increased by 25 Gg (19 %) for 2010 due to the implementation of three new methods: 1) Tier 3 for living biomass, 2) Tier 2 for dead organic matter, and 3) a Tier 1 for mineral soils.
- Additionally, previously felled fruit trees were considered to be converted to grassland, and these C losses are now reported under cropland remaining cropland.

5D Wetlands

5D1 Wetlands remaining wetlands

- Living biomass was reported for wetland remaining wetlands in this submission, resulting in net C gains of 23 Gg for 2010.
- No changes were made in the reporting of peat extraction.

5D2 Land converted to wetlands

- Two new Tier 1 and 2 methods implemented for dead organic matter (forest-related conversion only) and mineral soils resulted in small net emissions from land converted to wetland. The soil C loss of 4.04 Gg from forest land converted to wetland was practically offset by the C sequestration of 3.92 Gg from other land converted to wetlands. The total areas of land converted to wetlands were reduced from 7.2 kha to 2.7 kha. The changes had little effect on the estimated emissions.

5E Settlements

5E1 Settlements remaining settlements

- No emissions were recalculated for settlements remaining settlements as these are not reported due to a lack of methods.
- However, the area was recalculated and estimated as 572 kha by the revised NFI database compared to 494 kha in the 2012 submission.

5E2 Land converted to settlements

- The area of land converted to settlements was reduced from 156 kha to the current estimate of 100 kha as a consequence of the revised NFI data base.
- Carbon stock changes decreased by 57 % mostly due to the Tier 1 method applied for mineral soils. Especially, forest land converted to settlements had increased soil C losses, from 72 Gg to 428 Gg, and cropland converted to settlements contributed with a net C release of 60 Gg. The latter was not estimated in the 2012 submission.
- The revised NFI data base resulted in a small increase in the area of forest land converted to settlements (from 70 to 78 kha), a noticeable decreased in cropland converted to settlements (from 59 to 16 kha), and a decrease in other land converted to settlements (from 17 to 2 kha).

5F Other Land

5F2 Land converted to other land

- In the revised NFI database, only a small area (2.7 kha) of grassland was identified as being converted to other land throughout the whole times series. Total soil C losses (13 Gg SOC) constituted the majority of the increased emissions, whereas C gains in living biomass were very small (0.14 Gg).
- Carbon stock changes were not reported for this land-use change in the previous submission.

5G Other and non-CO₂ emissions

5(I) N₂O emissions from fertilization of forest and other

- Improvements in the activity data resulted in an increase of 16 % in the N₂O emissions caused by fertilization of forests. The improvements consisted in

adjusting the N content of the fertilizer and updating the quantity of fertilizer applied.

5(II) Non-CO₂ from drainage of soils and wetlands

- N₂O emissions from drained forest soils reduced by 0.05 % due to updated activity data.

5(III) N₂O emissions from disturbance associated with land-use conversion to cropland

- Nitrous oxide emissions associated with conversion to cropland increased by 99 %, which was primarily caused by the change to the Tier 1 method for estimating soil C changes. The soil C changes are utilized for estimating N mineralization, the precursor of N₂O emissions.

5(IV) CO₂ emissions from agricultural lime application

- Previously, emission from agricultural lime application was estimated with the assumption that all lime applied occurred in the form of limestone. Recalculation of the whole time-series was done using activity data for limestone and dolomite and the default emission factors. Total emissions estimated for 2010 increased by 1.3 % as a result of this.

5(V) Biomass burning

- The emissions of methane and nitrous oxide caused by biomass burning during wildfires increased by 10 % and 11 %, respectively for 2010. This was due to an improvement in the activity data by separating fires occurring on unproductive and productive forests and using specific biomass-volume estimates for each forest type. However, in 2010 there were a large number of wildfires on productive forest, which caused the increase in emissions compared to the previous method. For all other years in the inventory, the improvement in the activity data generally resulted in smaller emissions.

Table 9.6 gives an overview of the changes in emission/removal estimates for 2010 due to the recalculations.

Table 9.6 Recalculations for 2010 in the LULUCF sector per reporting category for CO₂, N₂O and CH₄.

Land-use categories	Emissions for 2010 (Gg CO ₂ yr ⁻¹)	
	2013 submission	2012 submission
5A. Forest land	-28681	-35876
5B. Cropland	1978	67
5C. Grassland	100	1680
5C. Wetland	-82	3
5E. Settlement	3022	1155
5F. Other land	48	IE,NE,NO
5G. Non-CO ₂ (Gg CH ₄ yr ⁻¹)	0.0773	0.0692
5G. Non-CO ₂ (Gg N ₂ O yr ⁻¹)	0.0731	0.0407

9.2.7 KP-LULUCF

The whole time series from 2008 to 2011 was recalculated for all estimated emissions and removals under the Kyoto protocol. This section describes recalculated changes occurring for the year 2010.

KP.A.3.3 Afforestation and Reforestation

Units of land not harvested since the beginning of the commitment period

C stock changes

Carbon uptake increased by 64 % in 2010 as the combined result of reduced C gains in below- and above-ground biomass (222 % and 203 %, respectively) and increased C sequestration in mineral soils (128 %), as well as in litter and dead wood (previously included in the soils estimate).

- In the revised database, conversions from wetland or other land to forest are considered as a natural expansion of the forest if there is no direct evidence of management. This is a change based on a recommendation from the ERT. For above- and below-ground biomass, this change reduced the afforested area from 379 kha to 43 kha.
- For all land-use change categories except “Other to Forest land” and “Wetland to Forest land” the changes in the areas were almost exclusively due to the updated time series and general quality control of the time series data.
- For soils, litter, and dead wood, the difference in C stock changes was due to methodological changes.

Non-CO₂ emissions from fertilization and biomass burning

- Previously, emissions from these sources were accounted for under Forest management due to the lack of precise activity data. In this submission, we used an area-weighted factor to allocate a portion of the emissions under Article 3.3.

Units of land harvested since the beginning of the commitment period

- Previously, this category was not separated from “Units of land not harvested since the beginning of the commitment period” due to the lack of data. The revised NFI database allowed separate estimates for all C stock changes.

KP.A.3.3 Deforestation

C stock changes

Total emissions reported for deforestation increased by 60 % in 2010.

- This was only marginally due to the revised NFI database, as the area of deforestation in 2010 was reduced from 113 kha to 101 kha.
- The methodological changes with the Tier 1 method used for mineral soils and the Tier 2 method for litter and dead wood were responsible for an increase in C losses.

Non-CO₂ emissions from disturbance and liming of agricultural land

- Both source categories were not reported last year. An inclusion of the categories this year resulted in increased emissions.

KP.A.3.4 Forest Management

C stock changes

Total C uptake was reduced by 29 % for 2010 estimates.

- Changes in biomass estimates were only minor, and were caused by a larger area under FM (12 050 kha) compared to the previous submission (11 734 kha).
- The implementation of the Yasso07 model resulted in reduced soil C sequestration of 82 % from 2 618 Gg SOC yr⁻¹ to 1 441 Gg SOC yr⁻¹ for mineral soil, litter and dead wood combined, which was the major cause of the changed estimate.

Non-CO₂ emissions from fertilization, biomass burning, and drainage

- Emissions from fertilization increased by 16 % due to the improvements mentioned above.
- The separation of productive and non-productive forest resulted in increased CH₄ and N₂O emissions of 10 %.
- Drainage-related N₂O emissions were just slightly affected due to the update of activity data.

Recalculations for source specific C stock changes for AR, D, and FM for are shown in table 9.7. In the 2012 submission, emissions for AR. KP.A.1.2 *Units of land harvested since the beginning of the commitment period* were not estimated, and this was done in the current submission. Therefore all estimates for this category were increased by 100 % (not shown in the table).

Table 9.7 Recalculation changes in C stocks per activity and source/sink category for 2010.

Activity	Source/sink	Current submission (ΔC Gg yr ⁻¹)	Previous submission (ΔC Gg yr ⁻¹)	Change %
Afforestation KP.A.1.1	Above-ground biomass	23.76	72.95	-207
Afforestation KP.A.1.1	Below-ground biomass	6.96	22.97	-230
Afforestation KP.A.1.1	Mineral soil + litter + dead wood	158.41	-30.13	119
Deforestation KP.A.1.3	Above-ground biomass	-182.28	-192.41	-6
Deforestation KP.A.1.3	Below-ground biomass	-44.66	-50.58	-14
Deforestation KP.A.1.3	Mineral soil + litter + dead wood	-458.16	-78.61	86
Forest Management KP.B.1	Above-ground biomass	5 356.86	5 859.46	-9
Forest Management KP.B.1	Below-ground biomass	1 364.04	1 524.28	-12
Forest Management KP.B.1	Mineral soil + litter + dead wood	1 441.4	2 618.96	-82

9.3 Implications of the recalculations for the greenhouse gases

9.3.1 Implications for emissions levels

Table 9.8 shows the effects of recalculations on the emission figures for CO₂, CH₄ and N₂O 1990-2010. Table 9.9 shows the effect on recalculations on the emission figures for HFCs, PFCs and SF₆ 1990-2010.

Table 9.8 Recalculations in 2013 submission to the UNFCCC compared to the 2012 submission. CO₂, CH₄ and N₂O. Tonnes CO₂-equivalents

	CO ₂			CH ₄			N ₂ O		
	2012 submission	2013 submission	Difference (%)	2012 submission	2013 submission	Difference (%)	2012 submission	2013 submission	Difference (%)
1990	34797.9	34833.3	0.1	4666.9	5030.1	7.8	4759.4	4928.7	3.6
1991	33342.3	33369.0	0.1	4708.7	5047.5	7.2	4613.3	4767.6	3.3
1992	34152.0	34167.3	0.0	4764.5	5128.8	7.6	4049.9	4211.3	4.0
1993	35797.9	35805.2	0.0	4827.5	5181.1	7.3	4266.4	4399.7	3.1
1994	37705.5	37718.8	0.0	4895.6	5254.1	7.3	4358.0	4482.3	2.9
1995	37777.3	37791.1	0.0	4868.8	5199.5	6.8	4414.8	4533.6	2.7
1996	41023.6	41040.5	0.0	4878.1	5228.9	7.2	4457.5	4567.4	2.5
1997	41130.6	41142.1	0.0	4893.4	5232.9	6.9	4457.1	4554.5	2.2
1998	41311.2	41369.9	0.1	4756.4	5086.4	6.9	4494.1	4593.8	2.2
1999	42145.0	42119.6	-0.1	4605.2	5006.4	8.7	4696.1	4825.8	2.8
2000	41742.9	41790.8	0.1	4733.4	5057.6	6.9	4475.3	4588.8	2.5
2001	43109.3	43159.6	0.1	4740.3	5068.5	6.9	4379.6	4506.1	2.9
2002	42245.0	42282.5	0.1	4571.3	4937.4	8.0	4566.8	4715.9	3.3
2003	43601.6	43647.3	0.1	4666.2	5015.0	7.5	4405.8	4568.4	3.7
2004	44041.0	44057.3	0.0	4646.4	4978.0	7.1	4566.4	4719.0	3.3
2005	43052.0	43059.5	0.0	4460.3	4762.7	6.8	4630.5	4788.8	3.4
2006	43505.3	43463.7	-0.1	4325.5	4650.6	7.5	4288.6	4452.3	3.8
2007	45472.4	45482.0	0.0	4470.3	4740.2	6.0	4116.4	4279.8	4.0
2008	44370.3	44411.0	0.1	4351.4	4601.4	5.7	3636.8	3801.3	4.5
2009	42893.7	42902.7	0.0	4324.3	4505.9	4.2	3106.6	3190.0	2.7
2010	45455.0	45547.8	0.2	4345.8	4522.0	4.1	3068.3	3052.6	-0.5

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Table 9.9 Recalculations in 2013 to the UNFCCC submission compared to the 2012 submission. HFCs, PFCs and SF₆. Ktonnes CO₂-equivalents

	HFCs			PFCs			SF ₆		
	2012 submission	2013 submission	Difference (%)	2012 submission	2013 submission	Difference (%)	2012 submission	2013 submission	Difference (%)
1990	0.02	0.05	172.81	3370.40	3370.40	0.00	2199.78	2199.78	0.00
1991	0.11	9.01	7841.31	2992.92	2992.92	0.00	2079.15	2079.15	0.00
1992	0.34	18.12	5303.08	2286.92	2286.92	0.00	705.03	705.03	0.00
1993	2.42	28.45	1075.03	2297.72	2297.72	0.00	737.71	737.72	0.00
1994	9.20	44.19	380.09	2032.47	2032.47	0.00	877.98	877.98	0.00
1995	25.82	80.35	211.14	2007.74	2007.96	0.01	607.79	607.79	0.00
1996	52.24	112.24	114.86	1829.08	1829.46	0.02	574.10	574.10	0.00
1997	86.52	164.86	90.55	1632.94	1633.25	0.02	579.86	579.86	0.00
1998	129.82	209.86	61.66	1485.53	1485.80	0.02	726.74	726.74	0.00
1999	180.56	270.89	50.02	1388.46	1388.70	0.02	873.96	873.96	0.00
2000	238.36	327.45	37.38	1317.90	1318.11	0.02	934.42	934.42	0.00
2001	303.71	403.21	32.76	1328.63	1328.81	0.01	791.20	791.20	0.00
2002	362.68	491.94	35.64	1437.60	1437.76	0.01	238.30	238.30	0.00
2003	402.84	475.31	17.99	909.10	909.25	0.02	227.86	227.86	0.00
2004	439.42	507.74	15.55	879.94	880.06	0.01	276.05	276.05	0.00
2005	481.80	524.23	8.81	828.65	828.71	0.01	312.03	312.03	0.00
2006	520.24	579.64	11.42	742.50	742.51	0.00	212.09	212.09	0.00
2007	565.00	612.29	8.37	820.91	820.94	0.00	76.24	76.24	0.00
2008	623.92	692.14	10.93	772.74	772.75	0.00	65.40	65.40	0.00
2009	707.70	736.65	4.09	376.76	376.72	-0.01	61.46	61.46	0.00
2010	746.66	914.62	22.49	205.12	205.08	-0.02	74.81	75.38	0.77

Table 9.10. Trends in emissions 1990-2010. 2013 submission compared to 2012 submission. GHG. Per cent change 1990-2010

	Total GHG	CO ₂	CH ₄	N ₂ O	PFCs	SF ₆	HFCs
2013 submission	7.85	30.76	-10.10	-38.07	-93.92	-96.57	1 829 142
2012 submission	8.24	30.63	-6.88	-35.53	-93.91	-96.60	4 073 797

9.3.2 Implications for emission trends

In the 2013 submission, there are no major changes in CO₂ emissions, compared to the 2012 submission. In 2010, the emissions have risen by 0.2 per cent, whereas the change for other years varies between +/-0.1 per cent. There is a considerable increase in emissions of CH₄ for all years, because of a revision of data used in the calculation of emissions from young cattle. In addition to some other minor changes, this has caused an overall rise in CH₄ emissions that varies between 4.1 and 8.7 per cent in the period 1990-2010. Also for N₂O there is a considerable rise in emissions for the whole time period, except 2010, where a strong reduction in emissions from synthetic fertilizers makes up for the increase. For all years 1990-2009 overall N₂O emissions have a rise that varies between 2.2 and 4.5 per cent, whereas the emissions decrease by 0.5 per cent in 2010. Whereas there are no significant changes for PFCs and SF₆, HFC emissions have risen substantially, due to both a major revision of the data used in the calculations and an upgrading of the calculation model. The increase is particularly strong in the early 1990s, with a peak in 1991, where there is a 7841 per cent rise. The emission trend for total greenhouse gas emissions from 1990 to 2010 shows a somewhat smaller increase in the 2013 submission compared with the 2012 submission, due to both larger decreases in emissions of CH₄ and N₂O and a smaller rise in emissions of HFCs.

9.4 Recalculations, including in response to the review process, and planned improvements to the inventory

The Climate and Pollution Agency co-ordinates the development of the inventory's different sectors. The recommendations from the review process are recorded in a spread sheet together with the needs recognised by the Norwegian inventory experts to form a yearly inventory improvement plan. The overall aim of inventory improvement is to improve the accuracy and reduce uncertainties associated with the national inventory estimates. Each issue is assigned to a sector/theme and the overview tracks where the issue has originated from and the organization/person responsible for following up the recommendations. The overview is discussed among the agencies and each issue is given a priority and a dead line. Each organization in the inventory preparation therefore have responsibility for the development of the inventory. The issues are prioritized on the basis of the recommendations from the ERT and available human and financial resources.

The national greenhouse gas inventory has undergone substantial improvements over the recent years, and the inventory is considered to be largely complete and transparent. Table 9.11 summarizes the improvements implemented since the 2012 submission and how these are related to the review process. Note that the final review report of the inventory submitted in 2012 has not yet been finalized. Despite this, the recommendations are to the extent possible, been included in tables 9.11 and 9.12. When references are made to specific paragraphs in the draft ARR12, these relate to the first draft received from the ERT.

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Table 9.11. Implemented improvements in response to the review process

Sector/issue	ERT recommendation/self-initiated	Source	Implementation
Cross-cutting (completeness of the inventory)	Provide estimates for some categories under the LULUCF sector, KP-LULUCF activities and remaining CO ₂ emissions from soda ash use under the industrial processes sector.	Draft AAR2012, §§10,80, 118 and 160	The inventory is considered as complete, see comments to §80, §118 and §160.
Cross-cutting (Key category analysis)	Clearly indicate which activities are identified as key categories under Article 3, paragraphs 3 and 4, of the Kyoto Protocol and provide the rationale for including them as key categories.	Draft ARR2012, §23 and ARR2011, §18	Results of key category analysis have been presented in the NIR and in table NIR-3 of the CRF.
Cross-cutting (Uncertainty analysis)	Provide the results of the uncertainty analysis for the latest inventory year in all future submissions.	Draft ARR2012, §24	A tier 1 uncertainty analysis has been performed. The uncertainties in the emission levels for 2011 are presented in NIR section 1.7.1.
Cross-cutting (Uncertainty analysis)	Provide the rationale for the low uncertainty estimates for the AD used to estimate the CO ₂ emissions from the energy sector.	Draft ARR2012, §25 and ARR2011, §19	Section 3.2.1.4 now contains information about this issue.
Cross-cutting (Recalculations)	Describe the reasons and provide justification for all recalculations.	Draft ARR2012, §29 and ARR2011, §22	This has been improved in the current NIR.
Cross-cutting (QA/QC and verification)	Enhance the implementation of the QA/QC plan, ensure that all experts understand the plan and its aims and document the measures implemented on an annual basis and the results of the measures.	Draft ARR2012, §31	Section 1.6 of the NIR on QA/QC procedures and the sections on category-specific QA/QC and verification approaches have been expanded to give a better oversight of the QA/QC measures performed each year.
Cross-cutting (verification and QA/QC approaches)	Ensure that additional checks are conducted in order to ensure the correctness of the data and the consistency between the data provided in the NIR and in the CRF tables.	Draft AAR2012, §32	Enhanced routines are implemented for quality control of the common reporting format data that includes more rounds with checks by the Climate and Pollution agency, the Forest and Landscape Institute and Statistics Norway to ensure the correctness of the data and the consistency between the data provided in the NIR and in the CRF tables.
Cross-cutting	Provide updated information	Draft	Chapter 1.6.2 in the NIR now

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(verification and QA/QC approaches)	on the verification measures	AAR2012, §33 and ARR2011, §24	provides updated information on the verification measures.
Cross-cutting (verification and QA/QC approaches)	Provide a summary of the comprehensive information on the QA/QC procedures applied to the plant-specific data.	Draft AAR2012, §34 and ARR2011, §25	See Annex IX and updated QA/QC sections in chapters 3 and 4.
Cross-cutting (Transparency)	Prioritize the improvement of the transparency of the NIR, taking into account the detailed comments under the cross-cutting and sectoral sections of the review report (strong recommendation)	Draft ARR2012, §39 and ARR2011, §27	Many of the implemented improvements listed here in table 9.11 has made the 2013 NIR is more transparent.
Cross-cutting (follow-up to previous reviews)	Provide a summary of how it has responded to or plans to respond to the recommendations of the ERT.	Draft AAR2012, §42 and ARR2011, §29, §31	Tables 1.17 and 1.18 in Norway's NIR for 2012 listed the implemented and planned improvements, but were not specific with regards to how these relate to the recommendations of the ERT. The tables have been expanded to be more specific and have been moved to chapter 9, see tables 9.11 and 9.12.
Cross-cutting (inventory planning)	Strengthen its monitoring to ensure that periodically planned QA/QC and other measures are implemented as planned, or provide information in the NIR when those planned activities have not been implemented	ARR2011, §14	Tables 9.11 and 9.12 will provide a good basis for monitoring this.
Sectoral versus reference approach	The ERT considered the action plan (to resolve and explain discrepancies between RA/SA) provided by Norway and concluded that it addressed all of the relevant issues identified in the list of potential problems and further questions. However, the ERT notes that without the full and effective implementation of the action plan, the underlying problems will not be resolved. The ERT strongly recommends that Norway, in its 2013 annual submission, transparently and comprehensively report on the outcomes of the action	Draft ARR2012 §§57 and 58 and previous ARR	Norway have taken action to answering issues about RA/SA as recommended by ERTs and described in action plan as an answer to potential problem raised by ERT in the Saturday Paper. Included in NIR2013 are issues that according to the action plan should be reported. Data have been updated but the main conclusion is, as been for many years, that the discrepancy between RA/SA is statistical differences. The production of crude oil and natural gas in Norway is very high compared to domestic consumption. Small errors in production and/or

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	plan, including the results of all the QC checks carried out for both the sectoral and the reference approaches and for all fuel groups (i.e. solid, liquid and gaseous).		export data will lead to a large statistical error, compared to domestic consumption figures, and we anticipated that main source(s) of the statistical difference was to be found at the supply side. The action plan has, however, focused on both sides of the equation, looking for discrepancies in activity data and methodologies both on the supply and use side.
Energy	ERT ask for more detailed EB e.g. by adding more significant digits and by disaggregating fuel groups such as “other gases”)	Draft AAR2012 §47	EB in Annex III NIR2013 is now with three digits. “Other gases” in EB; our aim is to perform a split as described in the annex about statistical differences. There are some confidential issues that have to be solved.
Energy	The ERT strongly recommends that Norway provide information on the methodologies used by the companies to estimate emissions and documentation to justify that those methods are in line with the IPCC good practice guidance	Draft AAR2012, §47	In Annex IX, URLs are provided to the guidelines for measuring within the emissions trading system, the voluntary agreement between the industry and the authority and the guidelines for reporting that all plants with a permit have to follow would be included in the 2013 annual submission. The guidelines are too long to be included in NIR in full text.
Energy	Provide a reference in the NIR and include a discussion on the applicability of the same conversion factor for all sources of NMVOCs	ARR2012, §63	Reference is given in the NIR.
Energy	CO ₂ IEF for gaseous fuels for public electricity and heat production varied significantly	Draft ARR2012 §65	Incorrect allocation of emissions and errors are corrected
Energy	ERT noted significant inter annual fluctuations in the CO ₂ IEFs for gaseous fuels for chemicals in CRF table 1.A(a) and very high values	Draft ARR2012 §68	Corrections are made and substantial improvements.
Energy	Emissions from paraffin wax use. ERT recommends reporting emissions and consumption in IP.	Draft ARR2012 §70	Emissions and consumption of paraffin waxes is now reported under 2G
Energy	Report the consumption of and emissions from biofuels	Draft ARR2012 §71	Consumption of biofuels is reported as biomass in CRF

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	separately under biomass in the CRF tables. Include information on the amount of bioethanol and biodiesel used and the applied EFs in the NIR		and EFs (IEF) are reported. Table 3.4 in NIR shows the consumptions of biofuels followed by a description of the use.
Energy	ERT ask for improved description of methodology and explanation of the rationality for reporting under current categories.	Draft ARR2012 §72	More description of methodologies and the rational for reporting is explained in NIR 2013.
Energy	The EB contains data on losses in addition to specific fuel consumption for flaring in oil and gas extraction. ERT ask for an explanation of losses.	Draft ARR2012 §73	Explanation included in NIR2013
Energy	Road transportation. ERT ask for an explanation to change in time series for N ₂ O IEF.	Draft ARR2012 §75	The information has been included in the 2013 submission.
Energy	ERT ask that emissions of CO ₂ from biomass in 1A5A I reported.	Draft ARR2012 §76	CO ₂ emissions is reported in CRF2013
Energy	The evaluation of the EF for coal mining based on measurements.	ARR2005	This issue has been addressed in several NIRs in the sector chapter and also in this NIR. However, we have not yet prioritized evaluate the EF.
Industrial processes	Document clearly the reasons for all recalculations.	ARR2011, §54	The justifications for recalculations have been improved. This improvement has been acknowledged by the ERT in the draft ARR12, §78.
Industrial processes, transparency	Include more information about the AD and EFs and a discussion on the inter-annual fluctuations in the IEFs.	Draft AAR2012, §81 and ARR2010, §48	Chapter 4 in the NIR includes more information on AD for several source categories. There is also some more information about the EFs and to a less extent, fluctuations in the IEFs.
Industrial processes	Explain in the NIR which data from the annual reports of the EU ETS are used in the IP sector, which QA/QC processes are used to ensure the data quality and how the data are incorporated to ensure time-series consistency.	ARR2011, §55 and draft ARR2012, §34	Chapter 4 of NIR better explains where data from the EU ETS have been used and the QA/QC sections have been updated. In Annex IX, URLs are provided to the guidelines for measuring within the emissions trading system, the voluntary agreement between the industry and the authority and the guidelines for reporting that all plants with a

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			permit have to follow would be included in the 2013 annual submission. The guidelines are too long to be included in NIR in full text.
Industrial processes, QA/QC and verification approaches.	Improve the sector-specific QC procedures in order to avoid errors.	Draft ARR2012 §82	More time has been given to check that the percentages given in the NIR match the figures in the CRF, see chapter 4 in the NIR.
Industrial processes, iron and steel	Investigate whether there are additional reasons for the increasing variation in the CO ₂ IEF for steel since 2005.	ARR2011, §57 and draft ARR2012, §84	The process emissions prior to 2005 have to a large extent been estimated based on the process emissions per ton steel produced in 1998 and 2005 whereas the emissions from 2005 and onwards are based on annual reported data from the EU ETS. See chapter 4.4.1.
Industrial processes, iron and steel	There is a lack of transparency in the NIR regarding the AD and a lack of sufficient detail in the description of the carbon inputs and outputs.	Draft ARR2012, §84	The NIR has lacked a description of AD, this is now included in chapter 4.4.1.3 in the NIR.
Industrial processes, aluminium production (PCFs)	Include a table in the NIR showing the shares of the two technologies and the PCF IEFs for each year of the time series.	ARR2011, §58	This is now included in the NIR, see table 4.17 in chapter 4.4.3.1.
Industrial processes, consumption of halocarbons and SF6	Provide a justification for the 3.5 per cent factor for imported refrigeration equipment.	ARR2011, §59	The justification is now given in chapter 4.6.1.4 of the NIR.
Industrial processes, consumption of halocarbons and SF6	Correct the misallocation of emissions within commercial and industrial refrigeration.	ARR2011, §60	This has been corrected through the recalculations, see chapter 4.6.1.4 in the NIR.
Industrial processes, consumption of halocarbons and SF6	Include the information provided during the review on the relative share of imported products for the refrigeration subcategories.	ARR2011, §60	The information on the relative share of imported products for the refrigeration sub categories is now included in the NIR, see table 4.20 in chapter 4.6.1.7.
Industrial processes, consumption of halocarbons and SF6	Correct the error in the EF used.	ARR2011, §61	This has been corrected through the recalculations, see chapter 4.6.1.7 in the NIR.
Industrial processes, lime production	Report final lime production values in the CRF sectoral background table and include	ARR2011, §63	The CRF table now includes final lime production values as AD instead of consumption.

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	the necessary explanations in the NIR.		The change of AD in the CRF results in IEFs closer to the default IPCC EF, see figure 4.4 and chapter 4.2.2.3 in the NIR.
Industrial processes, lime production	Complete the investigation of the large inter-annual changes in the CO ₂ IEF to obtain a consistent and accurate time series.	ARR2011, §65	The time series consistency for the IEF was improved already in the 2012 NIR due to the revised data. See chapter 4.2.2.3 in the NIR.
Industrial processes, limestone and dolomite use	Provide a balance of the limestone and dolomite use	Draft ARR2012, §86	The NIR now includes a balance of the limestone and dolomite use for 2010 and 2011. See table 4.5 in chapter 4.2.3.1 in the NIR.
Industrial processes, limestone and dolomite use	Investigate whether flue gas desulfurization is used in Norway in the environmental controls for SO ₂ emissions.	Draft ARR2012, §82	We do not have any information that FGD is used in Norway and have included this information in 4.2.3.1 in the NIR.
Industrial processes, soda ash use	Obtain data on soda ash use and include corresponding estimates.	ARR2011, §66 and draft ARR2012, §87	Some emissions from the use of soda ash has for many years been reported under 2C5, this is now clearer in the NIR, see chapter 4.4.6. In addition, we have reported emissions in 2A7 (glassworks), see chapter 4.2.5. The remaining uses of soda ash are now reported under 2A4, see chapter 4.2.4 in the NIR.
Industrial processes, soda ash use	Provide information on imports and on the different uses of soda ash in the NIR, as well as on the categories under which the emissions are reported.	Draft ARR2012, §87	The balance of the various uses of soda ash is presented in table 4.6. Chapter 4.2.4.1 in the NIR explains under which the emissions are reported.
Industrial processes, other (chemical industry).	Provide a justification for the constant value of the CH ₄ and NMVOC emissions from the methanol production.	Draft ARR2012, §88	The justification is given in chapter 4.3.5.2 in the NIR.
Industrial processes, other (chemical industry).	Explain the unstable and increasing trend for CO ₂ .	Question during centralized review 2011	For 2B5 (plastic), the emissions prior to 2006 for one plant were previously registered as emissions from combustion, although they stem from flaring. In chapter 4.3.6.7, we explain that the emissions from flaring now have been separated for all years and are reported under IP.

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Industrial processes, ferroalloys production	Use notation keys and notes in the CRF tables and the NIR to transparently explain that the CO ₂ emissions from limestone and dolomite used in ferroalloys production are reported in the ferroalloys production.	ARR2010, \$53	Chapter 4.2.3.1 in the NIR clearly explains that the CO ₂ emissions from limestone and dolomite used in ferroalloys production are reported in the ferroalloys production. This is also made clear in the CRF.
Industrial processes, ferroalloys production	Provide the information on consistent use of methods by the plants.	Draft ARR2012, \$85	Chapter 4.4.2.2 in the NIR states that each plant for consistency just have used one method for the entire time series,
Agriculture, QA/QC	The ERT recommends that the Party document the QA/QC activities conducted for the data incorporated into the most recent inventory in the “source-specific QA/QC and verification” sections in the next NIR.	Draft AAR12, §93	The sector specific QA/QC descriptions in NIR are updated.
Agriculture, animal population data	Norway reported the number of beef cattle under the mature dairy cattle subcategory in the CRF tables.	Draft AAR2012, §§95 and 98	Number of beef cattle is reported under “Mature non-dairy cattle” instead of incorrectly under “Mature dairy cattle” in CRF.
Agriculture, animal population data	The ERT recommends that the Party provide the definitions for the respective subcategories for each animal type and describe how the AD are obtained for the respective animals in the NIR of its next annual submission, in order to increase the transparency of its reporting.	Draft AAR2012, §100	Revision and harmonization of animal statistics used has been made due to revised methods for estimating young cattle and animals for slaughter.
Agriculture, enteric fermentation			There has been an expert review of the emission factors used. The review was performed by the University of Life Sciences (Karlengen et al. 2012) and has resulted in updated emission factors for ostrich, deer, reindeer and goat.
Agriculture, enteric fermentation	Improve the information on the tier 2 methodology used to estimate emissions from cattle and sheep.	Draft AAR2012, §94	Annex X describes in more detail the tier 2 methodology used. Tables are provided in NIR Table 6.2 and Annex X containing disaggregated data on the population numbers, GE and Ym on a subcategory level.

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Agriculture, enteric fermentation	The ERT recommends that Norway use the notation key “NE” (not estimated) instead of the notation key “NO” if there is a lack of population data for deer and ostrich.	Draft AAR2012, §96	Population data for deer and ostrich are reported as “NE” from 1990 until 1997 instead of “NO”. Population data are not available for these years but are probably insignificant.
Agriculture, manure management and emissions from agricultural soils	The ERT recommends that Norway document and archive the information on the updated N excretion factors and report the impact of the recalculations in its next annual submission.	Draft AAR2012, §93	The N-excretion factors have been changed to better reflect the actual nitrogen excretion from the different animal groups. The N-excretion factors for cattle, poultry and pigs have been scientifically investigated in 2012, while the remaining categories have been given expert judgements (Karlengen et al. 2012).
Agriculture, direct emissions from agricultural soils			The amount of synthetic fertilizers used has been revised for 2009-2010, due to revised sales figures.
Agriculture, direct emissions from agricultural soils			Mean area figures for the development in cultivated moor area after 1994 have been updated by Bioforsk (Norwegian Institute for Agricultural and Environmental Research) based on a revised expert estimate of the yearly cultivation of new moor.
Agriculture, direct emissions from agricultural soils	Reallocation of the direct emission from sewage sludge in the CRF.	Recommendation during in-country review 2012	Direct emissions from sewage sludge are reported under “4.D.1.6. Other direct emissions” instead of under “4.D.4. Other” in CRF.
Agriculture, indirect emissions from agricultural soils	Norway has reported direct N ₂ O emissions from sewage sludge application. However, the Party did not report the indirect N ₂ O emissions for the whole time series, even though the estimation methodologies for indirect emissions from sewage sludge are provided in the IPCC good practice guidance.	Draft AAR2012, §105. Saturday Paper from the ERT 2012	Nitrogen lost as NH ₃ from the application of sewage sludge as fertilizer have been included in the N ₂ O calculation. This has led to recalculations of the direct N ₂ O emissions from sewage sludge applied, and the following indirect emissions of N ₂ O from atmospheric deposition and from nitrogen leaching and run-off.
Agriculture, indirect emissions from agricultural soils	The ERT encourages Norway to use the new Frac _{LEACH} parameter, based on the results of measurements conducted in Norway for leaching, when	Draft AAR2012, §107	The Frac _{LEACH} factor has been updated from 0.18 to 0.22. The new factor was estimated in a study by Bioforsk (Norwegian Institute for Agricultural and Environmental Research)

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	the new data become available.		(Bechmann et al. 2012).
Agriculture, agricultural residue burning	Norway applied the methodology contained in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the 2006 IPCC Guidelines) to estimate CH ₄ and N ₂ O emissions in the 2011 and 2012 annual submissions without providing a justification for the change in the EFs.	Draft AAR2012, §108	Emission factors for CH ₄ and N ₂ O have been changed from the factors in 2006 IPCC Guidelines to factors according to the Revised 1996 IPCC Guidelines.
Agriculture, agricultural residue burning			The amounts of crop residues burned in the fields have been revised for the years 2005-2010 based on information from questionnaires in 2004 and 2012.
Waste	Provide references and explanations for all country-specific data in its next annual submission.	ARR2011 §89	References is included for half-life values, but not all CS EF is documented (see table 1.18)
Waste	Explain and provide information on key parameter values used to calculate CH ₄ from landfills	ARR2011 §90	More information on the calculation of waste generation is included in the NIR, section 7.2.1.3
Waste	include more information regarding the requirements for measurements and information on the determination of the methane content of the landfill gas at Norwegian landfills, including requery of data collection.	Draft ARR2012 §138	Information is included in the NIR section 7.5.3
Waste	Provide a time series for the AD and methane conversion factor used	ARR2011 §92 and draft ARR2012 §146	A link to data on the number of people in Norway connected to waste water treatment plants are included in the NIR, as well as table 7.2 showing the MCF time series
Waste	Include a description of the method used to derive the MCF value supported by all the relevant data in order to allow the ERT to reproduce the MCF calculation	Draft ARR2012 §147	A description of the method is included in the NIR, as well as a link to the waste water statistics at Statistics Norway, showing data on the number of people in Norway connected to waste water treatment plants.
Waste	explore whether CH ₄ emissions from industrial wastewater facilities occur from other than food	ARR2011 §92 and draft ARR2012	Information on emissions and treatments facilities is included in the NIR, save Chemical Industry which will

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	processing industry and report in the inventory of the next annual submission. including information on the processes used	§145	be included in the next NIR (see table 1.18)
Waste	Correct error that no methane recovery takes place in connectin with wastewater handling, and investigate to what extent the recovery is used for energyt purposes and weather this is included in the energy balance	Draft ARR2012 §145	Corrections are made and information saying that some, but not all of the methane recovery is included in the energy balance is included in the NIR.
Waste	SWD: - correct the references for DOC and T1/2 and compare the chosen values with any available country specific studies. Document all assumptions made (DOC content in waste fractions) and provide references in the NIR	Draft ARR2012 §140	The improvements are included in the NIR tab 8.1
Waste	Include information on how much of the recovered methane from SWD is used for energy production and flared for the time series	Draft ARR2012 §139	Information is included in the NIR, tab. 7.5
Waste	Analyse all end-uses including if sewage sludge is or has been landfilled and describe it in NIR	Draft ARR2012 §141	Emissions of CH4 from deposited sewage sludge have been included in the inventory for all years since 1990
Waste	clarify to what extent waste is imported and how this and exported waste has been considered in the estimation of emissions and describe any differences between the waste statistics and the inventory data	Draft ARR2012 §142	It is clarified in the NIR that no organic waste is imported for landfilling Waste incineration in the waste accounts includes export, and is thus not comparable with the emission inventory as a substantial amount is exported to Sweden for incineration
Waste	include information on the amount of nitrate-N discharged + emissions from biological treatment including documentation for the CS EF	Draft ARR2012 §143	Data for the amount of nitrogen that is removed in the biological step in the actual waste water plants is obtained from Statistics Norway's waste water statistics. Documentation for EF is included in the NIR
Waste	Recommends to include the updated values for protein consumption	Draft ARR2012 §144	The estimation of emissions of N2O has been updated with new estimates of the daily per capita protein intake for 2009-2010. Small decrease in emission for all years.

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Waste	Improve description in the NIR including presenting the time series for the amounts of waste incinerated. The information should include information that the incinerated amounts have been collected from the plants and that the information in the waste statistics are not the source of the emission calculation.	Draft ARR2012 §149	Information is included in the energy chapter
LULUCF	Provide land-use change matrixes and a consistent time-series of land-use changes when data is available.	ARR2011, §76, draft ARR2012, §§111, 114a and 114b.	Updated land-use change matrixes for 1990-2011 and 2010-2011 are provided. The updated and consistent time-series for 1990-2011 for all land use and land-use change categories includes land use and C stock changes for areas at higher altitudes and the county of Finnmark (§114a) and updated land-use data by reclassifying sample plots by old maps and photographs (§ 114 b).
LULUCF	Provide updated uncertainty estimates	ARR2011 § 20, draft ARR2012, §§27 and 113	Uncertainties in area and carbon change estimates for living biomass in the LULUCF sector and for elected activities under the KP are provided in the 2013 NIR.
LULUCF	Investigate the change in soil C stock on land converted to settlement and if relevant use correct notation key.	ARR2011, §84	A tier 1 method was implemented to estimate all SOC changes on land in conversion, including land converted to settlements. Further improvements are also planned.
LULUCF	Report on the progress of all the planned improvement before 2014 submission	Draft ARR2012, §114	Documentation has been provided of all improvements that have been made under recalculations and remaining improvements are listed under planned improvements in the NIR.
LULUCF	Improve soil C stock change estimates for forest remaining forest with Yasso07	Draft ARR2012, §114c	The new model was implemented on plot-level estimates for mineral soil on forest land remaining forest land.
LULUCF	Estimates of the dead wood pool for LULUCF	Draft ARR2012, §114d	A Tier 2 method is used to estimate C changes in dead organic matter for all forest-

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			related land-use changes.
LULUCF	Improving methods for mineral and organic soils for cropland remaining cropland and grassland remaining grassland	ARR2010, §74, ARR2011 §83, and draft ARR2012, §114e	Methods have been revised and improved. For mineral soils: a new Tier 1 method for grassland remaining grassland and a new Tier 2 for cropland remaining cropland. For organic soils: The classification of cultivated organic soils has been changed from being reported partly under grassland and partly under cropland to being completely reported under cropland.
LULUCF	Separate calculation of liming for limestone and dolomite	ARR2010 §71, ARR2011 §82, draft ARR2012, §§114f and 128	Activity data for liming on agricultural lands have been separated for limestone and dolomite.
LULUCF	Improve the description of the recalculations and recommendations that have been fulfilled in the NIR and describe them at the level of aggregation where they appear	Draft ARR2012, §§29, 42 and 115	The description is improved.
LULUCF & LULUCF-KP	Strengthen QA/QC to correct and avoid inconsistency	Draft ARR2012 §§32, 117 and 159	Internal QA/QC procedures have been strengthened at NFLI and this work will continue. Also external QA was elicited for grassland remaining grassland – mineral soils as the method was changed.
LULUCF	Reduce incompleteness by reducing NE notations, Table 5 Information Items	Draft ARR2012, §118	Notations keys were consistently implemented according to principles specified in chapter 7. Table 5 “Information items” was filled out. Several other categories, previously noted NE, now have estimates.
LULUCF	Update the EF used for organic forest soils to one representing Nordic conditions	Draft ARR2012, §121	A Swedish EF has been used for organic soils on forest land.
LULUCF	Separate estimation of organic and mineral soils on Land converted to Forest land and DOM pool	ARR2011 §79, §80, and draft ARR2012, §122	Areas of organic soils are estimated for land-use conversion to and from forest land. Drained organic soils are

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			estimated.
LULUCF	Enhance description of the method used and the time of the transition period	Draft ARR2012, §124	The vast majority of chapter 7 has been rewritten. The 20-yr conversion has been applied.
LULUCF	Provide new definitions and estimates of cropland and grassland with respect to organic soils and new estimates of emissions	Draft ARR2012, §126	Grassland has been redefined and the whole area of cultivated histosols is now reported under cropland. The emission factor was evaluated but no better option is identified.
LULUCF	Divide between productive and unproductive forest for biomass burning	Draft ARR2012, §130	Separate estimates of biomass volume for productive and unproductive forest have been used.
LULUCF-KP	Include uncertainty estimates as for LULUCF-KP	ARR2010, ARR2011, §100, draft ARR2012, §153	Tables with uncertainty estimates for area and C stock changes for KP activities are included in chapter 11.
LULUCF-KP	Use updated NFI data for KP reporting of activities	ARR2011 §95 and draft ARR2012, §154	The updated data from the NFI has been incorporated for ARD and FM activities.
LULUCF-KP	Provide additional information, area times-series for ARD and FM activities and uncertainty estimates for emissions/removals as well as for the land areas.	Draft ARR2012, §155	Additional information is included as suggested. Also time-series tables of areas and emissions for AR, D and FM activities, and uncertainty estimates for emissions/removals as well as for the land areas, have been included.
LULUCF-KP	Provide information on how Yasso07 disaggregate the pools of SOM, DOM (litter and dead wood) for KP activities	ARR2011 §§98, 101, 102 and draft ARR2012, §156	The methodological description has been improved.
LULUCF-KP	Ensure all requirements of 15/CMP are fulfilled	Draft ARR2012, §157	A separate section entitled <i>Information that activities under Art. 3.4 are not accounted for under Art. 3.3.</i> is included in chapter 11,
LULUCF-KP	Provision of key category analysis results in the NIR and in table NIR-3 of the CRF	ARR2010, §16, ARR2011, §18 and draft ARR2012, §§23 and 158	Results of key category analysis have been presented in the NIR and in table NIR-3 of the CRF
LULUCF-KP	Inclusion of all emissions under relevant activities and provide consistent use of notation keys	ARR2011 §99 and §103 and draft ARR2012, §160	Have reported emissions from liming and N ₂ O from cultivation of new cropland under deforestation. Under afforestation, we have reported

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			biomass burning and fertilization. Drainage is reported for forest management. Not mandatory for ARD.
LULUCF-KP	Reconsideration of the interpretation of human-induced AR activities	ARR2011 §97 and draft ARR2012, §162	A new interpretation has been given and the afforested area has been reduced due to the exclusion of other land converted to forest.
Article 3, paragraph 14 of the Kyoto Protocol	Report any changes in its information provided under Article 3, paragraph 14	ARR2011, §111 and draft ARR2012, §172	Chapter 15 now includes changes in information.

Some areas for further improvements have been identified by ERTs and Norwegian experts. Table 9.12 gives an overview of the planned improvements.

Table 9.12. Plan for improvements for the Norwegian GHG inventory

Sector/issue	ERT recommendation/self-initiated	Source	Plan for improvement
Cross-cutting (Transparency)	Prioritize the improvement of the transparency of the NIR, taking into account the detailed comments under the cross-cutting and sectoral sections of the review report (strong recommendation)	Draft ARR2012, §39 and ARR2011, §27	Although many of the implemented improvements listed in table 9.12 have made the 2013 NIR is more transparent, we will continuously consider how to maintain and increase the transparency.
Cross-cutting (uncertainties)	Address transparently in the NIR and discuss the very low uncertainty estimates for CH ₄ .	ARR2011, §19	No follow-up yet decided.
Cross-cutting (Archiving and documentation)	Document and archive all necessary information on country-specific methods, disaggregated EFs, parameters and AD.	Draft ARR2012, §40	A project with the aim to improve the documentation of all emission factors is ongoing at Statistics Norway.
Cross-cutting (recalculations and time-series consistencies)	Describe how time-series consistency is ensured.	ARR2011, §23	Time-series consistency is maintained when recalculations are done. We will describe this better in the 2014 NIR.
Energy	Investigate the treatment and allocation of carbon monoxide (CO) gas used for fuel combustion under the chemicals category and provide more detailed documentation in the NIR.	ARR2010, §34	We are considering having a project on this issue, but it has not yet been prioritized. The projects for 2013 have not yet been decided.
Energy	Include a discussion in the NIR on time-series consistency	Draft AAR2012, §52	This issue will be looked into to NIR2014.
Energy	Provide balances showing that all non-energy use of fuels is accounted for in the industrial processes sector and complete CRF table 1.A(d)	Draft AAR2012, §§ 60 and 61	This issue will be looked into to NIR2014.
Energy	Improve the transparency of the NIR by including more detailed information on the AD	Draft AAR2012, §47	This issue will be looked into to NIR2014.
Energy	The values of the CO ₂ IEFs	ARR2012,	This issue will be looked

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	for liquid, solid and other fuels under other (manufacturing industries and construction) are unusual, considering the fuel mix reported in the energy balance and the inter-annual fluctuations	§64	into to NIR2014.
Energy	Inter-annual variations in the CO ₂ IEFs for other fuels for public electricity and heat production.	ARR2012, §66	This issue is the shift in CO ₂ EF from 1995 to 1996 for the fossil part of carbon in waste combusted in district heating plants. This issue is explained in the NIR but will be looked further into to NIR2014.
Energy	CO ₂ IEF for liquid fuels for iron and steel	ARR2012, §67	This issue will be looked into to NIR2014.
Energy	The values of the CO ₂ IEFs for liquid, solid and other fuels under other (manufacturing industries and construction) are unusual, considering the fuel mix reported in the energy balance and the inter-annual fluctuations	ARR2012, §69	This issue will be looked into to NIR2014.
Energy , off road			Norway started late spring 2012 a project with the aim to consider and improve the methodology etcetera used to calculate emissions from motorized equipment. Due to some unlucky circumstances we did not manage to finalize the project before publishing this year inventory. We now plan to finalize the project so the result can be included in the 2014 submission.
Energy	ERT ask for improved description of methodology and explanation of the rationality for reporting under current categories.	Draft ARR2012 §72	The description is to some extent elaborated in NIR 2013 but we will look further into the description for improvements in NIR 2014.
Industrial processes, transparency	Include more information about the AD and EFs and a discussion on the inter-annual fluctuations in the	Draft AAR2012, §81, ARR2010,	We will consider how to include more information on AD for the NIR 2014. The EFs used by the

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	IEFs.	§48	plants often will change annually and that fluctuations in the IEFs may be unavoidable. Nevertheless, we will continuously consider more discussions on the inter-annual fluctuations in the IEFs for the 2014 NIR.
Agriculture, animal population data	Parts of the inventory (estimations of N ₂ O from manure (4B) and CH ₄ from enteric fermentation from cattle (4A1 and 4A2) was improved and this required a new set of activity data (animal numbers). In the parts of the inventory that was not improved, the old set of animal data was maintained. This has resulted in different sets of animal data in the various estimations. In the CRF, only the new set of animal numbers is reported.		The inconsistency in animal numbers will be resolved in the 2014 submission.
Agriculture, manure management	A project with the aim to revise the Norwegian CH ₄ conversion factors (MCF) for the manure storage systems in use is ongoing at the Norwegian University of Life Sciences (UMB). The maximum CH ₄ producing capacity (B ₀) is also planned to be revised for cattle manure.	Draft ARR2012, §99	The results from the project are planned to be implemented in the 2014 submission.
Agriculture, manure management	Statistics Norway conducts a survey of the manure distribution between different manure management system that are planned to be finished in 2014.	Draft ARR2012, §102	An update of the manure distribution between different manure management systems will be made when the results of a survey conducted by Statistics Norway in 2013-2014 are available.
Agriculture, manure management	According to the IPCC good practice guidance (p.4.70), N in manure should not be adjusted to the N that volatilizes as ammonia when estimating emissions from manure management. Norway	Draft ARR2012, §101	Norway plans to review the calculations before the 2014 submission.

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	needs to correct this.		
Agriculture, manure management and emissions from agricultural soils	Norway needs to improve the documentation of the NH ₃ emission model.	Draft ARR2012, §103	Norway plans to improve the documentation in future submissions.
Waste	The ERT recommends that the Party improve the transparency of the NIR by including information on AD, calculation parameters and country-specific methodologies used.	Draft ARR2012 §133	Consider for NIR 2014
Waste	Encourage implementing QA procedures for the waste sector	Draft ARR2012 §134	Consider for NIR 2014
Waste	Recommends that the Party provide justification for the use of default ipcc guidelines and the rationale for not using the results of the country-specific studies.	Draft ARR2012 §136	Consider for NIR 2014
Waste	Recommends to describe the assumptions used when converting the data from the waste statistics to be used in the emission model	Draft ARR2012 §137	Consider for NIR 2014
Waste	Report on the recovery of CH ₄ from wastewater handling in CRF tabel 6.b and in the energy balance	Draft ARR2012 §145	Consider for NIR 2014
Waste	explore whether CH ₄ emissions from industrial wastewater facilities occur and report in the inventory	ARR2011 §92 Draft ARR2012, §145	Not done for Chemical Industry NIR2014
Waste	Include information related to time series consistency at source category level	ERT	Consider for NIR 2014
LULUCF	Uncertainty estimates for LULUCF	Draft ARR2012, §113	We plan to develop quantitative uncertainty estimates for soil C on Forest
LULUCF	Improve soil C stock change estimated for land converted to forest land and forest land remaining forest land with Yasso07	Draft ARR2012, §114c	Plan to incorporate Yasso07-based estimates for land converted to forest land during 2013. The initial value used in the simulation on forest land remaining forest land will also be improved.
LULUCF LULUCF-KP	Inclusion of dead wood pool for LULUCF and KP	Draft ARR2012,	Improve the estimation of identifying the dead

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	reporting	§114d	wood, litter and soil pools of the total C stock simulated by Yasso07
LULUCF	Improving methods for organic soils for cropland remaining cropland and grassland remaining grassland	Draft ARR2012, §114e	Evaluation of the area estimate of cultivated organic soils and possible improvement.
LULUCF	Improving methods for mineral soils for cropland remaining cropland	Draft ARR2012, §114e	A Tier 3 method using the ICBM model is planned for cropland remaining cropland.
LULUCF LULUCF-KP	Reconsider the use of the adjustment factor and explore different methods.	Draft ARR2012, §116, §120, §164	Explore other alternatives to the current model-based interpolation.
LULUCF	Justification that undisturbed organic forest soils are in balance.	Draft ARR2012, §121	Plan to provide explanation in next submission based on a literature review.
LULUCF LULUCF-KP	Disaggregate the land-use category other land. Reclassify the areas that have potential to become forest	Draft ARR2012, §127 and §162	Explore how to provide sub-categories of other land.
LULUCF	Verify and justify the assumption that all CO ₂ from liming applied to lakes is released.	Draft ARR2012, §129	Plan to evaluate by literature review this assumption.
LULUCF	Provide information on flooded lands (wetlands) as soon as possible	ARR2010 §78 and ARR2011 §85	This has not been accomplished due to lack of data. We will include emissions estimates in the 2014 submission, if necessary activity data is available.
LULUCF	Strengthen QA/QC to correct and avoid inconsistency	Draft ARR2012, §117	Continue to improve our QC procedures and elicit QA when necessary (e.g. methodological changes).

10 Other (CRF sector 7) (if applicable)

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Part II: Supplementary information required under article 7, paragraph 1

11 KP-LULUCF

11.1 General information

The information provided in this chapter is in accordance with the instructions and requirements given by Decision 15/CP.10 (FCCC/CP/2004/10/Add.2), Decision 15/CMP.1 (paragraphs 5–9), and Decision 16/CMP.1. Norway has chosen commitment-period accounting. Descriptions of how data collected for reporting under the UNFCCC could be used for the Kyoto Protocol reporting are 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 the “National Greenhouse Gas Inventory System in Norway” (see Annex VI).

Areas where afforestation and reforestation (AR) and deforestation (D) activities have occurred in Norway are small compared to the area of forest management (FM). Estimated C sequestration for the activity FM is substantial (Table 11.1).

Reported emission and removals from areas under the KP activities includes the following sources and sinks: carbon stock changes in above-ground biomass, below-ground biomass, litter, dead wood, mineral soils and organic soils, N₂O emissions from N fertilization, N₂O emissions from drainage of soil, N₂O from disturbance associated with land-use conversion to cropland, CO₂ emissions from lime application, and GHG emissions from biomass burning.

Table 11.1 Time-series from 2008 to 2011 of areas and emissions reported for Article 3.3 and 3.4 under the Kyoto Protocol.

	2008	2009	2010	2011
Areas (kha)				
Afforestation/reforestation	38	43	44	47
Deforestation	93	101	108	117
Forest management	12 065	12 057	12 051	12 046
Net emissions (Gg CO ₂ yr ⁻¹)				
Afforestation/reforestation	-584	-714	-505	-655
Deforestation	2 394	2 414	2 962	2 803
Forest management	-28 431	-26 075	-28 234	-31 686

Methods and activity data used to calculate the emissions reported under KP-LULUCF are identical to those applied in the UNFCCC reporting (chapter 7) and are in accordance with the Good Practice Guidance for Land use, Land-use Change and Forestry (2003), chapter 4: Supplementary methods and good practice guidance arising from the Kyoto Protocol. For the time period 1990-2010, the land areas reported for AR and FM activities are identical to those reported for land converted to forest land and forest land remaining forest land in the UNFCCC reporting. Land classified for the activity deforestation is the sum of forest land converted to cropland, grassland, wetlands, settlements, and other land (Table 11.2).

For 2011, the areas do not correspond to those reported under the UNFCCC due to the 20-year in conversion rule, where areas are classified for 20 years in transition (as land in conversion) before they can enter a “remaining” land-use category. Specifically, this means that the area of land converted to forest land in 1990 will enter the forest land remaining forest land category in 2011. However, for KP-LULUCF reporting, the areas reported for the AR and D activities shall remain in transition category for the whole reporting period (and thus not be reported as a FM activity after 20 years).

Due to the fact, that only human-induced land-use changes are reported, it is not always the case that the annual difference in the area of deforestation is equal to the annual difference in the area of FM (Table 11.3). In some years (1999, 2001, 2003, 2005, 2010, and 2011) not all land-use changes were human-induced.

Table 11.2 Land-use change matrix with the classification of KP activities and corresponding land use. The following notation is used for classification of land-use changes. AR: Article 3.3 afforestation/reforestation. D: Article 3.3 deforestation, FM: Article 3.4 forest management.

	Forest	Cropland	Grassland	Wetlands	Settlements	Other
Forest	Forest Management FM	Human induced D	Human induced D	Human induced ¹ D	Human induced D	Human induced D
Cropland	Human induced AR ³		Human induced	Human induced	Human induced	Human induced
Grassland	Human induced AR ³	Human induced		Human induced	Human induced	Human induced
Wetlands	Not human induced ²	Human induced	Human induced		Human induced	Human induced
Settlements	Human induced AR	Human induced	Human induced	Human induced		Human induced
Other	Not human induced ²	Human induced	Human induced	Human induced	Human induced	

¹Forest land flooded because of constructed reservoirs

²Conversion from wetland and other land to forest land is considered human-induced only when actual evidence of management is present.

³Includes agricultural areas that have been abandoned. The abandonment is considered to be an active change in management of those areas.

A full time-series of the areas considered for AR, D, and FM activities from 1990 to 2011 is presented in Table 11.3.

Table 11.3 Time-series from 1990 to 2011 of areas (ha) classified under afforestation/reforestation (AR), deforestation (D), and forest management (FM) activities.

Year	Area (ha)		
	Afforestation/Reforestation	Deforestation	Forest Management
1990	1 552	3 395	12 151 454
1991	3 104	6 789	12 148 059
1992	4 656	10 184	12 144 664
1993	6 209	13 579	12 141 270
1994	7 761	16 973	12 137 875
1995	9 313	20 368	12 134 480
1996	10 865	23 763	12 131 086
1997	12 417	27 157	12 127 691
1998	13 969	30 552	12 124 296
1999	15 772	37 041	12 118 709
2000	17 574	43 259	12 112 490
2001	19 557	51 010	12 105 190
2002	23 612	55 787	12 100 413
2003	25 054	63 808	12 093 294
2004	27 758	71 018	12 086 084
2005	30 912	78 498	12 079 505
2006	33 166	82 644	12 075 359
2007	33 887	86 068	12 071 934
2008	38 032	92 918	12 065 085
2009	42 989	101 479	12 056 523
2010	44 431	108 149	12 050 755
2011	46 504	116 891	12 045 608

11.1.1 Definition of forest and other criteria

Forest land is defined according to the Global Forest Resources Assessment (FRA) 2005 (Table 11.4). Forest land is land with tree-crown cover of more than 10 % and the trees should be able to reach a minimum height of 5 m at maturity in situ. Minimum area and width for forest land considered in the Norwegian inventory is 0.1 ha and 4 m, respectively, causing a small discrepancy from the definition in FRA 2005 (0.5 ha and 20 m). Young natural stands and all plantations established for forestry purposes, as well as forests that are temporarily unstocked, e.g. as a result of harvest or natural disturbances, are included under forest land.

Table 11.4 Parameters for the definition of forest land in IPCC 2003, the Global Forest Resources Assessment (FRA) 2005 and in the National Forest Inventory (NFI).

Parameters	Range IPCC 2003	Selected value FRA 2005	National values NFI
Minimum land area	0.05–1 ha	0.5 ha	0.1 ha
Minimum crown cover	10–30%	>10%	>10%
Minimum height	2–5 m	5 m	5 m
Minimum width		20 m	4 m

11.1.2 Elected activities under Article 3.4

In accordance with Paragraph 6 of the Annex to Decision 16/CMP.1, Norway has decided to elect forest management under Article 3.4 of the Kyoto Protocol, for inclusion in its accounting of the first commitment period. The government's policy is that Norway will meet the commitment under Article 3.1 without the use of RMUs issued on the basis of forest management activities.

11.1.3 Description of how the definitions of each activity under Article 3.3 and 3.4 have been applied consistently over time

The Norwegian National Forest Inventory (NFI) provides data for land use, land-use change and forestry for the greenhouse gas reporting related to Article 3.3 and Article 3.4. Detailed description of the NFI can be found in the LULUCF chapter in section 7.2.

The information about the areas subject to afforestation/reforestation (AR) and deforestation (D) is based on the NFI, which has been carried out continuously since 1986. Land use obtained between 1986 and 1993 serves as the baseline for the land use and living biomass by 31.12.1989. Because no data from permanent sample plots exists before 1986 and relatively small changes have been detected with respect to forest land, we have chosen not to take into account changes that may have occurred prior to 1990. This implies that biomass stock changes on land assigned to the AR activity are underestimated, but the biomass changes are included for the FM activity.

AR activities refer to the conversion of non-forested land to a forested state and are reported as one group (IPCC 2003, section 4.2.5.1). Only areas where active management resulted in the conversion to forest are considered AR. Deforestation refers to the conversion of forested land to a non-forested state (IPCC 2003, section 4.2.5.1).

All forests in Norway are considered managed and this includes recreation areas, protected areas, and nature reserves. All forests in Norway are used either for wood harvesting, protecting and protective purposes, recreation, and/or to a greater or smaller extent for hunting and picking berries, and are therefore subject to the FM activity.

11.1.4 Descriptions of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified

Norway has decided to elect only forest management under Article 3.4 of the Kyoto Protocol, for inclusion in its accounting for the first commitment period.

11.2 Land-related information

11.2.1 Spatial assessment units used for determining the area of the units of land under article 3.3

The activity data used for determining the area of the units of land under Article 3.3 are the 250 m² large NFI sample plots. A land conversion can be detected as soon as 20 % or more of the plot area is converted to another land use class. Since 1986, all plots are classified according to a national land cover and land-use classification system, which is consistently translated to the UNFCCC land-use categories.

The NFI database provides activity data for the entire country. However, there is no time series of field observations in Finnmark County and the mountain forest stratum. Information from maps, registers, and old and new aerial photographs were used to determine the land use

of each plot in the base year 1990. The models used to back-cast the living biomass on these sample plots, were based on the methods described in the LULUCF chapter (Chapter 7).

11.2.2 Methodology used to develop the land transition matrix

The land-use change matrix is based upon changes in the land-use category of the sample plots surveyed in a given year. Changes in land use are recorded for the year the land use is observed. A full NFI cycle, i.e., plots observed over a 5-year period, are used for estimating areas of land-use categories.

11.2.3 Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

All the NFI plots are geo-referenced, and each plot has a unique identification code. The coordinates of these plots are classified information. However, a list of sample plots is open for the review team upon request. The approximate spatial distribution of the areas under different activities is given in Figure 11.1.

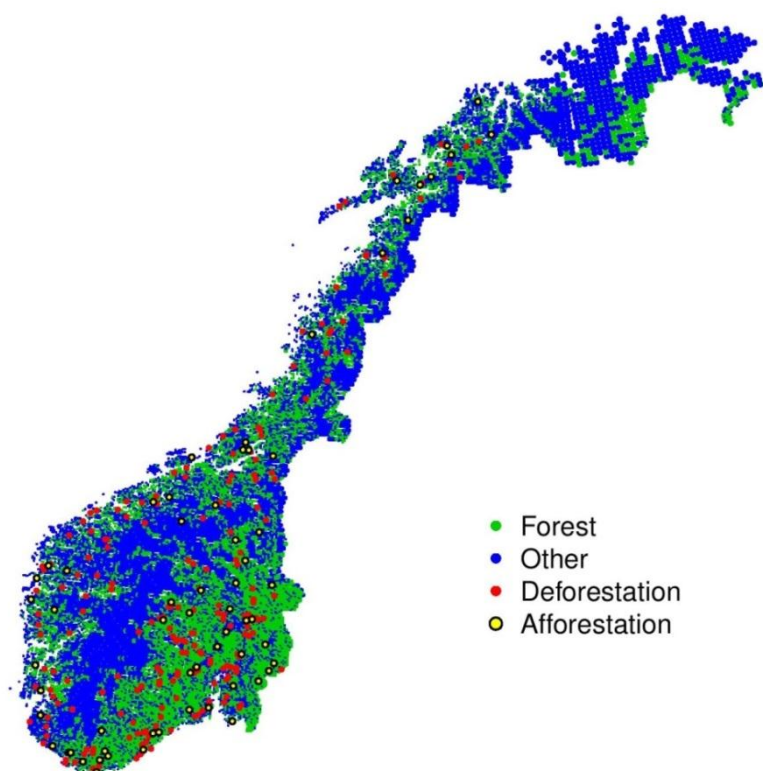


Figure 11.1 Spatial distribution (approximate location of sample plots) of afforestation and deforestation activities from 1990 to 2011. Plots with afforestation and deforestation activity are plotted with an increased symbol size to improve their visibility. "Forest" is areas under forest management, while "Other" is all other types of land-use categories (other land, wetland, etc.).

11.3 Activity specific Information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

The methods used for estimation of C stock changes and GHG emissions are identical to those described in chapter 7 for the UNFCCC reporting. We here provide only a brief description.

11.3.1.1 Description of the methodologies and the underlying assumptions used

Living biomass

Afforestation/reforestation, deforestation and forest management activities

The estimates reported are calculated by using the activity data and methods for forest land remaining forest land described in chapter 7. The estimates are based on trees observed on the NFI sample plots with >50 mm DBH (diameter at breast height). Swedish allometric regression models for Norway spruce, Scots pine, and birch are applied to estimate the single tree biomass based on DBH and height as input parameters (Marklund, 1988; Petersson and Ståhl, 2006). As opposed to chapter 7 where total living biomass is estimated, above- and below-ground biomass are estimated separately for KP. Above-ground biomass is defined as the sum of the biomass estimates for the tree fractions stem wood, stem bark, living branches, dead branches, needles or leaves and stump based on models by Marklund (1988). Below-ground biomass is defined as the estimate for the tree fractions stump and roots down to a root diameter of 2 mm (Petterson and Ståhl, 2006) minus the estimate for the stump (Marklund, 1988). See Table 11.5 for a list of biomass models used.

Estimates of biomass changes are based on 1/5th of the sample plots observed in the reference year.

Table 11.5 Biomass models used to estimate above- and below ground biomass. In Marklund's (1988) models, the notation "G" indicates Norway spruce, "T" Scots pine and "B" deciduous (birch).

Component	Reference and specific model
Dead branches	Marklund (1988), G20, T22, B16
Living branches	Marklund (1988), G12, T12, B11
Needles and leaves	Marklund (1988), G16, T18 For deciduous: stem biomass x (0.011/0.52), de Wilt <i>et al.</i> (2006)
Bark	Marklund (1988), G8, T10, B8
Stem	Marklund (1988), G5, T6, B5
Stump	Marklund (1988), G26, T28 (for Scots pine and for deciduous)
Stump and roots (>2 mm)	Petterson and Ståhl (2006), Bi (for Norway spruce, Scots pine and deciduous)

Dead wood and litter

Afforestation and deforestation activities

Carbon stock changes in dead wood and litter were estimated using a Tier 2 method using the IPCC equation 3.3.4 (IPCC, 2003) where changes in C stocks are equal to the difference between the mean C stock at the beginning and at the end of the inventory period divided by 20 years. The mean national C stocks of litter and dead wood in forests were estimated as the mean of the simulated C stocks, in specific chemical pools, for all the NFI plots of forest land remaining forest land from 1990 to 2011 using Yasso07. The mean national C stocks were 2.17 Mg C ha⁻¹ for dead wood and 20.30 Mg C ha⁻¹ for litter. For all other land-use classes they were assumed to be zero.

Forest management activities

The dynamic decomposition model Yasso07 (Tuomi *et al.*, 2011; Tuomi *et al.*, 2009) was applied for forest management on mineral soil, thus a Tier 3 method was used. The model was applied to the time series for each of approximately 11 200 NFI plots and scaled up to the country level by using the same method as described for living biomass in chapter 7. The model output provides estimates of the change in the total soil organic C stocks (sum of dead wood, litter and soil organic matter). The changes in the total soil organic C stocks were

distributed to each of the three pools: dead wood, litter and soil organic matter. This was done by allocating specific chemical soil components to specific pools by using the information about the size of the litter input, as well as its origin, as either above-ground or below-ground litter (Figure 11.2). The change in the total soil organic C stock was attributed to dead wood (16.9 %), litter (82.7 %), and soil organic matter (0.4 %), i.e. the soil sink/source category.

Origin	Above ground					Below ground				
Chemical component	A	W	E	N	H	A	W	E	N	H
Non woody	LITTER									
Fine woody										
Coarse woody	DEAD WOOD									SOIL

Figure 11.2 Conceptual definition of soil pools based on the chemical composition of Yasso07 output for total soil C stock change. AWENH is defined as: Acid soluble, Water soluble, Ethanol soluble, Non-soluble and Humus.

Soils

Afforestation and deforestation activities

In the default methodology, changes in soil organic carbon (SOC) is estimated by $\Delta\text{SOC} = (\text{SOC}_0 - \text{SOC}_{0-T}) / D$, where D is the time dependency of the stock change factors and by default is 20 years. The SOC stock at any time can be estimated as the product of the soil C reference stock (SOC_{REF}), the stock change factors (F) and the area (A) according to: $\text{SOC} = \text{SOC}_{\text{REF}} \times F \times A$. Stock change factors (land-use, management and input factors) for forest are by default equal to one. The mean national SOC stock estimate for forest was therefore $109.4 \text{ Mg C ha}^{-1}$, based on the SOC reference stocks per soil type provided by the IPCC in Table 2.3; (IPCC, 2006a) for the cold temperate moist climate. The distribution of soil types for forests in Norway was based on national registrations (de Wit and Kvindesland, 1999; Grønlund and Solbakken, 1987). The distribution of the IPCC soil types for Norwegian forests was 12 % as wetland soils, 77 % as spodic soils, and 11 % as high-activity clay (HAC) soils. Thus, the mean national SOC stock for forest was $(0.12 \times 87 + 0.77 \times 115 + 0.11 \times 95) \text{ Mg C ha}^{-1} = 109.4 \text{ Mg C ha}^{-1}$. For the other land-use classes, reference C stocks were 0 Mg C ha^{-1} for settlements and other lands, $76.9 \text{ Mg C ha}^{-1}$ for croplands, $98.4 \text{ Mg C ha}^{-1}$ for grasslands and 87 Mg C ha^{-1} for wetlands. For more details on the method, see section 7.4.2. Emissions resulting from deforestation due to land conversions to settlements were substantial with reported C stock changes larger than 400 Gg C yr^{-1} . The assumptions that the SOC stock in settlements is zero likely leads to overestimated emissions for deforested conditions (and overestimation for AR activities).

Forest management activities

The dynamic decomposition model Yasso07 (Tuomi et al., 2011; Tuomi et al., 2009) was used, thus the methodology is the same as for dead wood and litter. Only the changes in C stock that are attributed to the humus component from below-ground litter decomposition are used to estimate C stock changes in the soil sink/source category (see Figure 11.2 and method description for dead wood and litter). The full description of the model and method is found in chapter 7 under forest land remaining forest land (section 7.4.1). This includes the biomass models and the turnover rates applied, the chemical litter composition, assumptions on litter input size, the climatic data applied and the Yasso07 parameter set used.

11.3.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

No omissions were made of any C pools or GHG emissions. However, CO₂ emissions from biomass burning caused by wildfires were reported as IE, because C stock changes due to burning are accounted for in the stock change method used for above-ground and below-ground biomass estimates for AR, D, and FM (IE in NIR 1). Controlled biomass burning does not occur on land subjected to AR, D, and FM activities.

11.3.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

Indirect and natural GHG emissions and removals have not been factored out.

11.3.4 Changes in data and methods since the previous submission (recalculations)

The whole time series from 2008 to 2011 was recalculated for all estimated emissions and removals under the Kyoto protocol. This section describes recalculated changes occurring for the year 2010.

KP.A.3.3 Afforestation and Reforestation

Units of land not harvested since the beginning of the commitment period

C stock changes

Carbon uptake increased by 64 % in 2010 as the combined result of reduced C gains in below- and above-ground biomass (222 % and 203 %, respectively) and increased C sequestration in mineral soils (128 %), as well as in litter and dead wood (previously included in the soils estimate).

- In the revised database, conversions from wetland or other land to forest are considered as a natural expansion of the forest if there is no direct evidence of management. This is a change based on a recommendation from the ERT. For above- and below-ground biomass, this change reduced the afforested area from 379 kha to 43 kha.
- For all land-use change categories except “Other to Forest land” and “Wetland to Forest land” the changes in the areas were almost exclusively due to the updated time series and general quality control of the time series data.
- For soils, litter, and dead wood, the difference in C stock changes was due to methodological changes.

Non-CO₂ emissions from fertilization and biomass burning

- Previously, emissions from these sources were accounted for under Forest management due to the lack of precise activity data. In this submission, we used an area-weighted factor to allocate a portion of the emissions under Article 3.3.

Units of land harvested since the beginning of the commitment period

- Previously, this category was not separated from “Units of land not harvested since the beginning of the commitment period” due to the lack of data. The revised NFI database allowed separate estimates for all C stock changes.

KP.A.3.3 Deforestation

C stock changes

Total emissions reported for deforestation increased by 60 % in 2010.

- This was only marginally due to the revised NFI database, as the area of deforestation in 2010 was reduced from 113 kha to 101 kha.

- The methodological changes with the Tier 1 method used for mineral soils and the Tier 2 method for litter and dead wood were responsible for an increase in C losses.

Non-CO₂ emissions from disturbance and liming of agricultural land

- Both source categories were not reported last year. An inclusion of the categories this year resulted in increased emissions.

KP.A.3.4 Forest Management

C stock changes

Total C uptake was reduced by 29 % for 2010 estimates.

- Changes in biomass estimates were only minor, and were caused by a larger area under FM (12 050 kha) compared to the previous submission (11 734 kha).
- The implementation of the Yasso07 model resulted in reduced soil C sequestration of 82 % from 2 618 Gg SOC yr⁻¹ to 1 441 Gg SOC yr⁻¹ for mineral soil, litter and dead wood combined, which was the major cause of the changed estimate.

Non-CO₂ emissions from fertilization, biomass burning, and drainage

- Emissions from fertilization increased by 16 % due to the improvements mentioned above.
- The separation of productive and non-productive forest resulted in increased CH₄ and N₂O emissions of 10 %.
- Drainage-related N₂O emissions were just slightly affected due to the update of activity data.

Recalculations for source specific C stock changes for AR, D, and FM for are shown in Table 11.6. In the 2012 submission, emissions for AR. KP.A.1.2 *Units of land harvested since the beginning of the commitment period* were not estimated, and this was done in the current submission. Therefore all estimates for this category were increased by 100 % (not shown in the table).

Table 11.6 Recalculation changes in C stocks per activity and source/sink category for 2010.

Activity	Source/sink	Current submission (ΔC Gg yr ⁻¹)	Previous submission (ΔC Gg yr ⁻¹)	Change %
Afforestation KP.A.1.1	Above-ground biomass	23.76	72.95	-207
Afforestation KP.A.1.1	Below-ground biomass	6.96	22.97	-230
Afforestation KP.A.1.1	Mineral soil + litter + dead wood	158.41	-30.13	119
Deforestation KP.A.1.3	Above-ground biomass	-182.28	-192.41	-6
Deforestation KP.A.1.3	Below-ground biomass	-44.66	-50.58	-14
Deforestation KP.A.1.3	Mineral soil + litter + dead wood	-458.16	-78.61	86
Forest Management KP.B.1	Above-ground biomass	5 356.86	5 859.46	-9
Forest Management KP.B.1	Below-ground biomass	1 364.04	1 524.28	-12
Forest Management KP.B.1	Mineral soil + litter + dead wood	1 441.4	2 618.96	-82

11.3.5 Uncertainty estimates

As biomass model errors were found to be negligible (Breidenbach et al., 2013), only sampling errors are reported. Sampling errors for proportions (areas) and totals (carbon change) are estimated according to standard sampling methodology (see chapter 7; section 7.2.3). The sample plots in the NFI are systematically distributed. Since random sampling is assumed in all estimates, the variances are conservative estimates.

Uncertainties in terms of sampling errors for area estimates by activity and carbon stock change estimates are given in Table 11.7 and Table 11.8, respectively. Due to the small areas, uncertainties for AR and D activities are especially large.

Table 11.7 Uncertainties of area estimates by KP-activity in 2011 based on sample plots observed between 2007 and 2011. (SE = standard error).

KP-Activity	Area (kha)	2 SE (%)
Afforestation/ Reforestation	47	26
Deforestation	117	15
Forest management	12046	2

Table 11.8 Carbon stock change estimates from 2010 to 2011 and associated uncertainties for KP categories (AG = above ground, BG = below ground, SE = standard error).

	AG gains (Gg)	AG losses (Gg)	BG gains (Gg)	BG losses (Gg)	AG gains 2SE (%)	AG losses 2SE (%)	BG gains 2SE (%)	BG losses 2SE (%)
Afforestation/ Reforestation	28	NO	9	NO	80.1	-	77.6	-
Deforestation	8	-114	2	-36	197.1	77.5	200.0	75.0
Forest management	9128	-2762	2301	-746	6.2	26.4	6.0	24.1

11.3.6 Information on other methodological issues

The methods used to estimate emissions and removals from afforestation, reforestation and deforestation (ARD) activities are the same as those used for the UNFCCC reporting

11.3.6.1 The year of the onset of an activity, if after 2008

Not applicable for this submission.

11.4 Article 3.3

11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

The NFI covers the period of consideration. The permanent plots were installed from 1986 until 1993. From 1994 and onwards the plots have been monitored continuously. By assessing the land cover and land use on each plot, the NFI records land-use changes to and from forest land.

In order to be included as ARD activities under Article 3.3, land-use changes must be considered as directly human-induced. For ARD, land-use changes are considered directly human-induced in the following two cases: (1) all conversion from land-use categories considered as managed (cropland, grassland and settlements) to forest land, and (2) conversion from wetland or other land (non-managed lands) to forest land, when actual

evidence of management is present. Such evidence consists of planting and ditching, which can both be documented via the current status of the forest combined with aerial photos. Land-use changes from wetland or other land to forest land is considered as a natural expansion of the forest if there is no direct evidence of management.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Young natural stands and all plantations established for forestry purposes, as well as forests that are temporarily unstocked as a result of e.g. harvest or natural disturbances, are included under forest management and not treated as deforestation. The NFI teams assess land cover and land use according to national criteria (see Table 7.6 in chapter 7) that are defined in the field instruction³². They are also trained to distinguish between forest management operations and land-use change. As a general rule the area will be considered temporarily unstocked if the stumps and ground vegetation are still present, and there are no other construction work done on the area. The area is considered deforested if the ground vegetation is removed e.g. if the area is leveled, and/or another construction work is done on the area.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested.

Not applicable for this submission.

11.5 Article 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

The NFI covers the period of consideration. The permanent plots were installed from 1986 until 1993. From 1994 and onwards the plots have been monitored continuously.

11.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

Norway has not elected Cropland Management, Grazing Land Management and Revegetation, and have therefore used the notation key NA in Table NIR 1.

11.5.3 Information that demonstrates that emissions by sources and removals by sinks resulting from elected Article 3.4 activities are not accounted for under Article 3.3 activities

Only emissions from areas recorded as having had directly human-induced conversions from another land-use class to forest land (AR), and from forest land to any other land-use class (D) are reported under Article 3.3 (see section 11.4.1). How deforestation (D) is distinguished from harvesting or other forest disturbance followed by regrowth (FM) is described in section 11.4.2. Thus, only areas identified as forest land remaining forest land, with no human-induced changes in land use (see Table 11.2) are reported as FM activities under Article 3.4.

11.5.4 Information relating to Forest Management

³² Landsskogtakseringen 2011. Landsskogtakseringens feltinstruks 2011. Håndbok fra Skog og landskap 01/2011: 119 s + vedlegg.

For the purpose of the reporting under the Kyoto Protocol the definition of forest is in accordance with the definition in section 11.1.1 above.

All forests in Norway are managed, either for wood harvesting, protecting and protective purposes, recreation, and/or to a greater or smaller extent for hunting and picking berries. On more marginal and less productive forest land, the intensity of the various management practices will decrease, but will still be present. Hence, all forests in Norway are defined as managed and can be ascribed to the forest management activity.

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4.

According to the IPCC guidelines, the key-category analysis (KCA) for KP can be based on the assessment made for the UNFCCC inventory. Both Tier 1 and Tier 2 assessments are made for the whole inventory including LULUCF. All key categories identified by the Tier 2 analysis were also identified by the Tier 1 analysis. Therefore, we present only the Tier 2 results. Translation of land-use categories reported under the convention is simple for FM and AR, see Table 11.2.

The results of the key category analysis (see chapter 1.5 for details) are presented in Table 11.9, where values in bold indicate a key category. Emissions/removals reported under forest management activity have key categories for living biomass and organic soils, both for the level and trend assessment. Litter and dead wood are also key categories with respect to the level assessment for both 1990 and 2011. For ARD activities, all sink/source categories are identified as key with respect to the trend assessment (Table 11.9).

Determination of key categories under deforestation is based on expert judgement. For above- and below-ground biomass, both grassland converted to forest (living biomass) and land converted to settlements (living biomass) are key categories under the convention reporting. The majority of the area of land converted to settlements is forest land, which would fall under deforestation activities. This is also the reason why mineral soil and dead organic matter are considered key sink/source categories.

Table 11.9 Key sink/source categories for the KP-LULUCF reporting. Values in bold indicate key categories

Activity	Source category	Level assessment 1990	Level assessment 2011	Trend assessment 1990-2011	Key category
FM	AG & BG biomass	12.13	20.38	28.56	Yes
FM	Organic soils	19.90	16.66	10.78	Yes
FM	Litter & dead wood	13.05	7.57	0.15	Yes
AR	AG & BG biomass	0.35	0.86	1.41	Yes
AR	Mineral soils	0.05	1.44	3.05	Yes
AR	Litter & dead wood	0.01	0.28	0.60	Yes
D	AG & BG biomass	-	-	-	Yes*
D	Mineral soils	-	-	-	Yes*
D	Litter & dead wood	-	-	-	Yes*

- no quantitative values available; * based on expert judgment

11.7 Information relating to Article 6

There are no Article 6 activities concerning the LULUCF sector in Norway.

12 Information on accounting of Kyoto units

12.1 Background information

Norway's Standard Electronic Format (SEF) report for 2012 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF can be found in annex VIII to this document. The file is named SEF_NO_2013_1_16-40-27 12-3-2013.xls.

12.2 Summary of information reported in the SEF tables

There were 271,550,980 AAUs in Norway's national registry at the end of the year 2012. Of these units, 198,411,925 units were held in Party holding accounts; 187,268 units in entity holding accounts; 40,440 units in other cancellation accounts and 72,911,347 units in the retirement account.

There were 1,092,924 ERUs in the registry at the end of 2012. The Party holding accounts held 522,869 ERUs; the entity holding accounts held 226,537 ERUs and the retirement account held 343,518 ERUs.

There were 11,041,200 CERs in the registry at the end of 2012. 6,092,122 CERs were held in Party holding accounts; 1,066,641 CERs were held in entity holding accounts; 111,914 CERs were held in other cancellation accounts and 3,770,523 CERs were held in the retirement account.

The registry did not contain any RMUs, tCERs or ICERs. The following account types did not contain any units:

- Article 3.3/3.4 net source cancellation accounts
- Non-compliance cancellation accounts
- tCER replacement account for expiry
- ICER replacement account for expiry
- ICER replacement account for reversal of storage
- ICER replacement account for non-submission of certification report

The total amount of the units in the registry at the end of 2012 corresponded to 283,685,104 tonnes of CO₂ eq. Norway's assigned amount is 250,576,797 tonnes of CO₂ eq.

12.3 Discrepancies and notifications

Annual Submission Item	Reporting information
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	No discrepant transactions occurred in 2012.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2012.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2012.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2012.
15/CMP.1 annex I.E paragraph 17 Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review, ref information given to submission item 15/CMP.1 annex I.E paragraph 12.

12.4 Publicly accessible information

Information relating to the Norwegian registry which is deemed to be public information can be accessed via the webpage of the Norwegian registry – www.kvoteregister.no/publicreports.

In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below:

Account Information (Paragraph 45) and Account holders authorised to hold Kyoto units in their account (Paragraph 48)

In light of the amendments of Regulation (EC) No 2216/2004 introduced by Article 78 of Regulation (EC) No 920/2010 (EU Registries Regulation³³) and for security reasons, it is considered that the account representative information as required in paragraph 45 and paragraph 48 is held as confidential. This information is therefore not publicly available.

JI projects in Norway (Paragraph 46)

No information on Article 6 (Joint Implementation) projects is publicly available as conversion to an ERU under an Article 6 project did not occur in Norway in 2012.

Holding and transaction information of units (Paragraph 47)

General remarks

Holding and transaction information is provided on a holding type level due to more

³³ Norway is one of three EFTA states which have signed an agreement with the EU creating the European Economic Area – the EEA agreement. All new relevant EU legislation is (with minor exceptions) dynamically incorporated into the Agreement and thus applies throughout the EEA. Any reference to EU legislation in this chapter thus applies to Norway

detailed information being declared confidential by EU Regulation, ref. paragraph 47(a), 47(d), 47(f) and 47(l).

Article 10 of Regulation (EC) 2216/2004, provides that “All information, including the holdings of all accounts and all transactions made, held in the registries and the Community independent transaction log shall be considered confidential for any purpose other than the implementation of the requirements of this Regulation, Directive 2003/87/EC or national law.”

Paragraph 47I

Norway does not host JI projects. Therefore no ERUs have been issued on the basis of Article 6 projects.

Paragraph 47I

Norway does not perform LULUCF activities and therefore does not issue RMUs.

Paragraph 47(g)

No ERUs, CERs, AAUs and RMUs were cancelled on the basis of activities under Article 3, paragraphs 3 and 4 in 2012.

Paragraph 47(h)

No ERUs, CERs, AAUs and RMUs were cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 in 2012.

Paragraph 47k

There is no previous commitment period to carry ERUs, CERs, and AAUs over from.

12.5 Calculation of the commitment period reserve (CPR)

The reporting of the calculation of the commitment period reserve, pursuant to decision 18/CMP.1, annex I.E is as follows:

The commitment period reserve is the lower of the two values given by 90 percent of the assigned amount and five times 100 percent of the total emissions in the most recently reviewed inventory. In the report of the review of the Initial Report, the assigned amount was determined to be 250,576,797 tonnes CO₂ equivalents. 90 percent of the assigned amount is 225,519,117 tonnes CO₂ equivalents. The inventory for the year 2009, submitted in 2011, is the most recently reviewed inventory for Norway (FCCC/ARR/2011/NOR). The total emissions in 2009 amounted to 51,292,431 tonnes CO₂ equivalents. Five times 51,292,431 tonnes CO₂ equivalents amounts to 256,462,155 tonnes CO₂ equivalents. The value of 90 percent of the assigned amount is lower than the value of five times 100 percent of the total emissions in 2009. Therefore, the commitment period reserve is 225,519,117 tonnes CO₂ equivalent (90 percent of the assigned amount).

13 Information on changes in the National System

13.1 Changes in the National Greenhouse Gas Inventory System

Comprehensive information regarding the national greenhouse gas inventory system in Norway can be found in Annex V.

Annex V reflects the following changes in Norway's national system:

- Enhanced routines are implemented for quality control of the common reporting format data that includes more rounds with checks by the Climate and Pollution agency, the Forest and Landscape Institute and Statistics Norway to ensure the correctness of the data and the consistency between the data provided in the NIR and in the CRF tables.
- A LULUCF-specific plan for QA/QC was developed internally at the Forest and Landscape Institute. The plan had two objectives 1) to ensure that emission estimates and data contributing to the inventory are of high quality and 2) to facilitate an assessment of the inventory, in terms of quality and completeness.

14 Information on changes in national registry

Directive 2009/29/EC adopted in 2009, provides for the centralization of the EU ETS operations into a single European Union registry operated by the European Commission as well as for the inclusion of the aviation sector. At the same time, and with a view to increasing efficiency in the operations of their respective national registries, the EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway decided to operate their registries in a consolidated manner in accordance with all relevant decisions applicable to the establishment of Party registries - in particular Decision 13/CMP.1 and decision 24/CP.8.

With a view to complying with the new requirements of Commission Regulation 920/2010 and Commission Regulation 1193/2011, in addition to implementing the platform shared by the consolidating Parties, the registry of EU has undergone a major re-development. The consolidated platform which implements the national registries in a consolidated manner (including the registry of EU) is called Consolidated System of EU registries (CSEUR) and was developed together with the new EU registry on the basis the following modalities:

- (1) Each Party retains its organization designated as its registry administrator to maintain the national registry of that Party and remains responsible for all the obligations of Parties that are to be fulfilled through registries;
- (2) Each Kyoto unit issued by the Parties in such a consolidated system is issued by one of the constituent Parties and continues to carry the Party of origin identifier in its unique serial number;
- (3) Each Party retains its own set of national accounts as required by paragraph 21 of the Annex to Decision 15/CMP.1. Each account within a national registry keeps a unique account number comprising the identifier of the Party and a unique number within the Party where the account is maintained;
- (4) Kyoto transactions continue to be forwarded to and checked by the UNFCCC Independent Transaction Log (ITL), which remains responsible for verifying the accuracy and validity of those transactions;
- (5) The transaction log and registries continue to reconcile their data with each other in order to ensure data consistency and facilitate the automated checks of the ITL;
- (6) The requirements of paragraphs 44 to 48 of the Annex to Decision 13/CMP.1 concerning making non-confidential information accessible to the public would be fulfilled by each Party individually;
- (7) All registries reside on a consolidated IT platform sharing the same infrastructure technologies. The chosen architecture implements modalities to ensure that the consolidated national registries are uniquely identifiable, protected and distinguishable from each other, notably:
 - (a) With regards to the data exchange, each national registry connects to the ITL directly and establishes a distinct and secure communication link through a consolidated communication channel (VPN tunnel);

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- (b) The ITL remains responsible for authenticating the national registries and takes the full and final record of all transactions involving Kyoto units and other administrative processes such that those actions cannot be disputed or repudiated;
- (c) With regards to the data storage, the consolidated platform continues to guarantee that data is kept confidential and protected against unauthorized manipulation;
- (d) The data storage architecture also ensures that the data pertaining to a national registry are distinguishable and uniquely identifiable from the data pertaining to other consolidated national registries;
- (e) In addition, each consolidated national registry keeps a distinct user access entry point (URL) and a distinct set of authorisation and configuration rules.

Following the successful implementation of the CSEUR platform, the 28 national registries concerned were re-certified in June 2012 and switched over to their new national registry on 20 June 2012. During the go-live process, all relevant transaction and holdings data were migrated to the CSEUR platform and the individual connections to and from the ITL were re-established for each Party.

The table below provides high level descriptions of significant changes implemented in the Norwegian registry in 2012. Detailed information on items where changes have occurred is attached in annex VIII.³⁴

Reporting Item	Reported information
15/CMP.1 annex II.E paragraph 32.(a): Change of name or contact	<p>The previous registry administrators were replaced by three new administrators:</p> <ul style="list-style-type: none"> • Carina Jacobsen Heimdal • Katja Ekroll Jahren • Ida Bjørkum <p>Georg Nicholas Nelson left the agency in July 2012, while Tor Egil Tønnessen Kjenn went on parental leave in October 2012.</p>

³⁴ Norway is one of three EFTA states which have signed an agreement with the EU creating the European Economic Area – the EEA agreement. All new relevant EU legislation is (with minor exceptions) dynamically incorporated into the Agreement and thus applies throughout the EEA. Any reference to EU legislation in this chapter thus applies to Norway.

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Reporting Item	Reported information
15/CMP.1 annex II.E paragraph 32.(b) : Change of cooperation arrangement	<p>The EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway have decided to operate their registries in a consolidated manner. The Consolidated System of EU registries was certified on 1 June 2012 and went to production on 20 June 2012.</p> <p>A complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. This description includes:</p> <ul style="list-style-type: none"> • Readiness questionnaire • Application logging • Change management procedure • Disaster recovery • Manual Intervention • Operational Plan • Roles and responsibilities • Security Plan • Time Validation Plan • Version change Management <p>The documents above are provided as part of Annex VIII. These documents contain sensitive information and cannot be made publicly available.</p> <p>A new central service desk was also set up to support the registry administrators of the consolidated system. The new service desk acts as 2nd level of support to the local support provided by the Parties. It also plays a key communication role with the ITL Service Desk with regards notably to connectivity or reconciliation issues.</p>

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Reporting Item	Reported information
15/CMP.1 annex II.E paragraph 32.(c) : Change to database or the capacity of national registry	<p>In 2012, the EU registry underwent a major redevelopment with a view to comply with the new requirements of Commission Regulation 920/2010 and Commission Regulation 1193/2011 in addition to implementing the Consolidated System of EU registries (CSEUR).</p> <p>The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is in Annex VIII. These documents contain sensitive information and cannot be made publicly available.</p> <p>During certification, the consolidated registry was notably subject to connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the Data Exchange Standard (DES). All tests were executed successfully and lead to successful certification on 1 June 2012.</p>
15/CMP.1 annex II.E paragraph 32.(d) : Change of conformance to technical standards	<p>The overall change to a Consolidated System of EU Registries triggered changes the registry software and required new conformance testing. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is in Annex VIII. These documents contain sensitive information and cannot be made publicly available.</p> <p>During certification, the consolidated registry was notably subject to connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the DES. All tests were executed successfully and lead to successful certification on 1 June 2012.</p>
15/CMP.1 annex II.E paragraph 32.(e): Change of discrepancies procedures	<p>The overall change to a Consolidated System of EU Registries also triggered changes to discrepancies procedures, as reflected in the updated manual intervention document and the operational plan. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is in Annex VIII. These documents contain sensitive information and cannot be made publicly available.</p>

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Reporting Item	Reported information
15/CMP.1 annex II.E paragraph 32.(f): Change of security	The overall change to a Consolidated System of EU Registries also triggered changes to security, as reflected in the updated security plan. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is in Annex VIII. These documents contain sensitive information and cannot be made publicly available.
15/CMP.1 annex II.E paragraph 32.(g): Change of list of publicly available information	No change in publicly available information occurred during the reporting period.
15/CMP.1 annex II. E paragraph 32.(h): Change of Internet address	<p>The new internet address of the Norwegian registry is: https://ets-registry.webgate.ec.europa.eu/euregistry/norway/index.xhtml</p> <p>At the same time, Norway's registry administrators continue to use the dedicated registry website Kvoteregister.no for sharing information with users and publishing the publicly available information.</p>
15/CMP.1 annex II.E paragraph 32.(i): Change of data integrity measures	The overall change to a Consolidated System of EU Registries also triggered changes to data integrity measures, as reflected in the updated disaster recovery plan. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is in Annex VIII. These documents contain sensitive information and cannot be made publicly available.
15/CMP.1 annex II.E paragraph 32.(j) : Change of test results	On 2 October 2012 a new software release (called V4) including functionalities enabling the auctioning of phase 3 and aviation allowances, a new EU ETS account type (trading account) and a trusted account list went into Production. The trusted account list adds to the set of security measures available in the CSEUR. This measure prevents any transfer from a holding account to an account that is not trusted.
Previous Annual Review recommendations, ref FCCC/ARR/2011/NOR	<p>There are no recommendations related to registry operations in the review report FCCC/ARR/2011/NOR.</p> <p>No notices or recommendations are stated in section 1.2 Summary of Findings of the SIAR Part 2 Report IAR/2011/NOR/.</p>

15 Information on minimization of adverse impacts in accordance with Article 3. Para 14

Norway approaches the report on activities under Article 3.14 mainly from the perspective of being a major exporter of fossil fuels. However, Norway is also involved in several initiatives that contribute to technology transfer and capacity building to developing countries in shifting the energy mix away from fossil fuels to more renewable energy systems, including The Clean Energy for Development Initiative and the International Energy and Climate Initiative. These initiatives are reported on here as relevant activities under Article 3.14 of the Kyoto Protocol.

Setting a price on greenhouse gas emissions:

Most international analyses point to carbon pricing as the most important policy instrument in the work to combat climate change. Carbon pricing motivates initiatives to reduce emissions, finance climate measures and stimulates development of new technology. In its economic, energy and environmental policies Norway therefore strives to have an approach where prices reflect costs, including for externalities. The reflection of the costs of externalities with respect to emissions of greenhouses gases is undertaken through levies and participation in of an emissions trading scheme. Following the expansion of the European Emissions Trading System (EU-ETS) system in 2013, about 80 per cent of the domestic emissions will be subject to mandatory allowances or a CO₂ tax. A description of the structure of levies on energy commodities, as well as design of the emissions trading scheme, can be found in chapter 4 of the Fifth National Communication (NC 5).

Norway believes that the best way to reduce emissions on a global scale in line with the two degree target is to set a global price on carbon. A global price on carbon is the most efficient way to ensure cost effectiveness of mitigation actions between different countries and regions and secure equal treatment of all emitters and all countries. This will help minimize adverse impacts of mitigation.

During 2008-2012, Norway has pledged to over-fulfill its Kyoto Protocol commitment by ten percent. In 2006, The Norwegian Parliament authorized the Ministry of Finance to procure emissions credits from Clean Development Mechanism (CDM) and Joint Implementation (JI) projects to obtain emission reductions acknowledged by the Kyoto protocol. Norway's commitment under the second commitment period under the Kyoto Protocol, 2013-2020, implies a sustained credit need. Norway will thus be a significant contributor to the development of the carbon market, also in the years to come. For more information on Carbon Neutral Norway, see NC 5 chapter 4.3.1.9 and www.carbonneutralnorway.no.

Changes in 2012:

The Government decided in 2012 to increase the CO₂ tax by NOK 200 per tonne of CO₂ for the offshore petroleum activities. Based on the current price of allowances in the EU ETS, this yields an overall carbon price in the petroleum sector which the Government believed to be reasonable. If the price of allowances in the EU ETS increases over time, it provides a basis for reducing the CO₂ tax so that the overall carbon price remains at about the same level.

Unsafe and unsound technologies:

Norway does not intend to subsidize environmentally unsound and unsafe technologies. There is an ongoing and increasing emphasis on fossil fuel subsidies in the international context. Norway sees phasing out fossil fuel subsidies as a crucial element for short term climate action. We need to address this issue in both developing countries and developed countries. There is a need for international exchange of policies and experience on addressing subsidy reform. Norway supports and contributes to work done on this issue in several foras, such as the IMF, WB, IEA and OECD. Norway is also developing a strategy for our international work for reform of fossil fuel subsidies.

Changes in 2012:

There have been no significant changes to the policy implementation of unsafe and unsound technologies in 2012.

Cooperation on carbon capture and storage

Due to its large mitigation potential, Norway has prioritized the development of carbon capture and storage as a mitigation option. As a petroleum producer Norway strives to reduce the emissions from the production and refining of petroleum. The national carbon capture and storage projects already in operation, the Sleipner and Snøhvit projects, and the approved Gudrun project, are in the petroleum sector. Norway has taken steps to disseminate information and lessons learned. These efforts are made both through international fora such as the Carbon Sequestration Leadership Forum and Clean Energy Ministerial, and through bilateral cooperation with both developing and developed countries. The results from the Sleipner Project are made available to interested parties.

The Storting (Norwegian parliament) has endorsed an action plan for dissemination of information on carbon capture and storage as a mitigation option. Four geographical areas have been given priority: Southern Africa, Indonesia, China and the Gulf States (Saudi Arabia, Kuwait, The United Arab Emirates and Qatar). In November 2011, the Norwegian Ministry of Petroleum and Energy and the Administrative Centre for China's Agenda 21 of the People's Republic of China entered into an agreement on the funding of the China-EU Cooperation on Near Zero Emission Coal Project Phase IIA. The 4 Kingdom Initiative with the Kingdom of Saudi Arabia, the United Kingdom and the Kingdom of the Netherlands are exploring alternative uses for CO₂ and serve as an informal forum where government representatives and technical experts from the four kingdoms meet, share their experiences and explore potential areas of cooperation. Norway is currently co-funding The World Bank CCS Trust Fund for Capacity Building and The Carbon Sequestration Leadership Forum's Capacity Building Trust Fund for CCS. Norway has also supported the South African CCS center.

In addition the Norwegian petroleum company Statoil ASA, which operates the Norwegian storage projects, is a partner in the Algerian carbon capture and storage project in Salah. The South African energy company Sasol is a partner in a test centre for CO₂ capture (Technology Centre Mongstad, please view NC 5 chapter 4.3.9).

Changes in 2012:

The Technology Centre Mongstad started operation in May 2012. Two different capture technologies - amine- and the ammonia-based CO₂ capture, are being tested. The technology centre is designed to have a capture capacity of 100,000 tonnes of CO₂ per year. The size of the facility, its flexibility and its design allow different types of test to be performed. It has

access to flue gas produced by the thermal power station and the cracking plant at the oil refinery. The CO₂ content of the gases from these sources is 3.5% and 13% respectively. Both sources of flue gas can be piped to both the amine- and the ammonia-based CO₂ capture plants. In addition, the facility is able to adjust the concentration of CO₂ in the flue gas by enriching exhaust gas from the thermal power station with captured CO₂. This allows testing of the CO₂ captured from flue gases with different concentrations of CO₂. The technology centre is therefore able to test CO₂ capture technologies which are relevant to both coal- and gas-fired power stations, as well as refineries and other industrial operations. The South African energy company Sasol is a partner in the Technology Centre Mongstad.

Cooperation with developing countries related to fossil fuels – “Oil for Development”

The Norwegian Oil for Development (OfD) initiative aims at assisting developing countries, at their request, in their efforts to manage petroleum resources in a way that generates economic growth and promotes the welfare of the whole population in an environmentally sustainable way. A description of the OfD programme can be found at www.norad.no.

Decades of experience in the oil and gas sector has given Norway valuable expertise on how to manage petroleum resources in a sustainable way. The Norwegian expertise could be useful for developing countries with petroleum resources, or countries that are in the exploration phase.

OfD takes a holistic approach through capacity and institution building of public authorities in the partner countries. OfD's assistance covers technical assistance in the following areas: the establishment of legal frameworks, administration and supervision mechanisms, licensing and tendering processes, public/ private interfaces of petroleum governance, local content and industrial development. In the environmental management area, impact assessment studies are emphasized, so as to consider the potential social and environmental impacts that petroleum activities may have. Moreover, reducing emissions from gas flaring is another crucial element. Revenue management considers the establishment of government take systems, taxation, anti-corruption and petroleum funds.

By end of 2012, Norway is primarily working with eight countries; Angola, Ghana, Mozambique, Sudan, South-Sudan, Timor-Leste and Uganda, while 16 countries receive limited assistance. These are Bolivia, Cuba, Iraq, Ivory Coast, Kenya, Lebanon, Liberia, Nicaragua, Nigeria, São Tomé and Príncipe, Sierra Leone and Tanzania..

The OfD initiative was launched in 2005. However, Norway through the Norwegian Petroleum Directorate and other agencies has assisted developing countries with petroleum resources for almost 30 years. A Steering Committee has been established to formulate strategic direction, guidelines and priorities for the OfD. The Steering Committee consists of the Ministry of Foreign Affairs (Chair), the Ministry of Petroleum and Energy, the Ministry of Finance and the Ministry of the Environment. The OfD secretariat is part of the Norwegian Agency for Development Cooperation (Norad), and is responsible for the coordination and implementation of the initiative. The Norwegian embassies play an essential role in the OfD, as they have extensive development cooperation responsibilities. The resources allocated to OfD grew from about NOK 80 million in 2006 to NOK 205 million in 2008 and NOK 340 million in 2011.

Key implementing agencies include the Norwegian Petroleum Directorate, the Climate and Pollution Agency, the Directorate for Nature Management and the Petroleum Safety Authority. Petrad (International programme for petroleum management and administration) and a range of consultancies and research institutions are also involved.

National and international NGOs are involved in the OfD initiative. These organizations are involved in building civil society's capacity on issues related to governance and petroleum activities in OfD partner countries. Moreover, Norway gives priority to the Extractive Industries Transparency Initiative (EITI). OfD also works with the World Bank, International Monetary Fund, African Development Bank and the UNDP. The Norwegian oil and gas industry is also drawn upon in transferring expertise and knowledge.

Changes in 2012:

The cooperation with some countries have been completed (Afghanistan, Bangladesh, Ecuador, Vietnam) while discussion is on-going on possible cooperation with some other countries. The resources allocated to OfD increased in 2012 compared to previous year.

Cooperation with developing countries related to renewable energy – “Clean energy for Development”

Energy has been at the core of Norway's development assistance policy for several years. . There has been a steady increase in funds allocated to clean energy activities during recent years, both within multilateral and bilateral development assistance. In 2011 the Norwegian assistance to clean energy for development amounted to approximately NOK 1.5 billion. Seven core countries receive the larger amount of the funding (Ethiopia, Liberia, Mozambique, Nepal, Tanzania, Timor Leste and Uganda), but the Initiative is also engaged in 30 other countries at a smaller scale.

Increased focus on energy issues and its importance in the climate agenda, coupled with a significant increase of funds allocated to energy related activities within Norwegian development aid, required better coordination of Norwegian efforts. The Clean Energy for Development Initiative was launched in 2007 to address these challenges, with the following overarching goal:

”To increase access to clean energy at an affordable price based on the long-term management of natural resources and efficient energy use. It is also intended to contribute to sustainable economic and social development in selected partner countries and to international efforts to reduce greenhouse gas emissions.”

Source: “Clean Energy for Development Initiative – Policy Platform”

Through the Clean Energy for Development Initiative Norwegian funds contribute to poverty reduction by supporting rural electrification with for example solar power, or through support to efficient wood fuel - or charcoal stoves.

Key features of the Initiative:

- In order to reach the goals set forth in the Clean Energy for Development Initiative, funds are often utilised to assist in developing a well functioning framework of institutions, policies, rules and regulations in the energy sector. Capacity building and institutional strengthening is therefore of great significance for the overall Norwegian energy efforts. In several of the countries where Norway engages in the energy sector, assistance and expertise from key partners is crucial to support the capacity building and institutional strengthening activities.
- The Clean Energy for Development Initiative is accommodating the private sector in various ways. The main tools for direct support to the private sector are the funding mechanisms of Norfund, GIEK and Norad's Section for Private Sector Development.

Public-private partnerships are essential, and support is also given to infrastructure projects (e.g. transmission lines), capacity building, regulatory reforms and research projects to facilitate for private investments and improve the investment climate.

- Results management is a priority within the Clean Energy for Development Initiative; to ensure and communicate the effects of development programmes/projects and to develop best practice systems. Projects and programmes develop results management systems and logical models to create a basis for evaluating effects of the intervention. The various programmes and activities are reviewed and assessed regularly. Smaller scale reviews are undertaken throughout the project cycles as part of their results management systems, while larger scale assessments are undertaken in a more strategic manner.

Changes in 2012:

There have been no significant changes to the Clean Energy for Development program in 2012.

The International Energy and Climate Initiative – “Energy+”

In order to promote increased access to energy and at the same time reducing greenhouse gas emissions in developing countries, Norway has initiated a new International Energy and Climate Initiative – “Energy+”. The initiative was launched at the Energy For All conference in Oslo 10.-11. October by the Norwegian Prime Minister and the UN Secretary-General. The initiative focuses on increasing the use of renewable energy resources and increasing energy efficiency in developing countries, and thereby reducing the reliance on fossil fuel consumption.

Energy+ is based on a result based sector level approach. The Initiative will provide results based financing to developing countries based on results in the form of increased access and reduced emissions relative to a business as usual baseline, and measures taken to support these goals through a phased approach. Energy+ aims to incentivize private sector actors to significantly increase investments in renewable energy and energy efficiency in developing countries, targeting the entire energy sector. Through the Initiative developing countries and private sector are be given incentives to shift the energy sector to low-carbon platforms by providing financial, technological and technical incentives. Public funds spent wisely can achieve considerable impact by leveraging private capital through carefully considered, targeted interventions to develop commercially viable renewable energy and energy efficiency business opportunities. The Initiative will also work to mobilize additional financial resources with the purpose of increasing access to renewable energy and improving energy efficiency.

An international partnership, with more than 30 partner countries and organizations, has been established. Currently, about 55 countries and institutions have signed up the voluntary and non-binding Energy+ Partnership. The Energy+ Partnership is open to all and comprises countries and institutions that agree with and aim to work towards the principles stated in the Energy+ Guiding Principles.

Through the Energy+ partnership, activities in and agreements with the following developing countries have been established: Ethiopia, Kenya, Liberia, India, Bhutan, South Africa

(through the South African Renewables Initiative – SARI). New partnerships are under discussion. Denmark has agreed to take the lead in developing an Energy+ program in Nepal. Discussions are ongoing with partners interested in joining the existing Energy+ country partnerships, e.g. in Ethiopia and Kenya. See http://www.regjeringen.no/en/dep/ud/campaigns/energy_plus.html?id=672635 for more information.

Changes in 2012:

In June 2012, Norway entered into three bilateral partnerships:

- **Ethiopia:** Norway entered into a five-year 500 million NOK agreement with Ethiopia to support efforts to increase access to sustainable energy in rural areas.
 - 17% of population access to electricity. Install 9 million new improved cookstoves by 2015. Emission reduction of 14 Mt CO₂/year. Total costs for cookstoves program about USD 47 million.
- **Kenya:** Norway entered into a five-year 250 million NOK agreement with Kenya to support increased access to sustainable energy and reduced greenhouse gas emissions through replacement of kerosene lamps with solar lanterns, as well as production and distribution of improved cook stoves and more efficient and environmentally friendly cooking.
 - 23 % of population access to electricity. “Kerosene Free Kenya» program. Use 3 million ton of kerosene – annual cost USD 500 million. Emission reduction of 400 000 tCO₂e/year.
- **Liberia:** Norway entered into a five-year 100 million NOK agreement with Liberia to support the development and implementation of a National Energy and Climate Plan in line with other plans in the energy sector that promote increased deployment of renewable energy to generate electricity and more efficient production and use of energy. The partnership will also support increased access to electricity and access to fuel efficient cook stoves.
 - 2% of population access to electricity. Replace diesel generators and heavy fuel oil with renewable energy. Emission reduction of 520 000 tCO₂e/year.

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Climate and Pollution Agency

The Climate and Pollution Agency reports to the Ministry of the Environment and has 325 employees, based mainly in Oslo. We implement government policy on pollution. We act as advisors, guardians and stewards for the environment. Our most important fields of work include climate change, chemicals, marine and freshwater environment, waste management, air quality and noise. Our vision is a future without pollution.

We are working to

- reduce greenhouse gas emissions
- reduce the spread of hazardous substances harmful to health and the environment
- achieve integrated and ecosystem-based management of the marine and freshwater environment
- increase waste recovery and reduce emissions from waste
- reduce the harmful effects of air pollution and noise

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