



CLIMATE AND  
POLLUTION  
AGENCY

Greenhouse Gas Emissions 1990-2010

May 25, 2012

# 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 2012 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 2012 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.

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Oslo, 25 May 2012

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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) 2012 for the period 1990-2010.

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

Emissions of the following greenhouse gases are covered in this report: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF<sub>6</sub>). In addition, the inventory includes calculations of emissions of the precursors NO<sub>x</sub>, NMVOC, and CO, as well as for SO<sub>2</sub>. Indirect CO<sub>2</sub> emissions originating from the fossil part of CH<sub>4</sub> 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 2010, the total emissions of greenhouse gases in Norway amounted to 53.9 million tonnes CO<sub>2</sub> equivalents, without emissions and removals from Land-Use, Land-Use Change and Forestry (LULUCF). From 1990 to 2010 the total emissions increased by more than 8 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 increased by 2.4 per cent between 2009 and 2010. The increase was mainly due to economic growth causing higher emissions in almost all sectors. In 2010, CO<sub>2</sub> 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 SF<sub>6</sub> together accounted for approximately 2 per cent of the total GHG emissions.

In 2010 the land-use category forest land contributed with a total amount of sequestration of 35.9 million tonnes CO<sub>2</sub> equivalents. The remaining land-use categories showed net emissions of 2.9 million tonnes CO<sub>2</sub> equivalents. The most important category was grassland with total emissions of about 1.7 million tonnes of CO<sub>2</sub>. This gave a net removal from the LULUCF sector of 32.9 million tonnes CO<sub>2</sub> equivalents.

The net greenhouse gas emissions, including all sources and sinks were 21 million tonnes CO<sub>2</sub> equivalents in 2010, a decrease of almost 50 per cent from the net figure in 1990.

## National Inventory Report 2012 - Norway

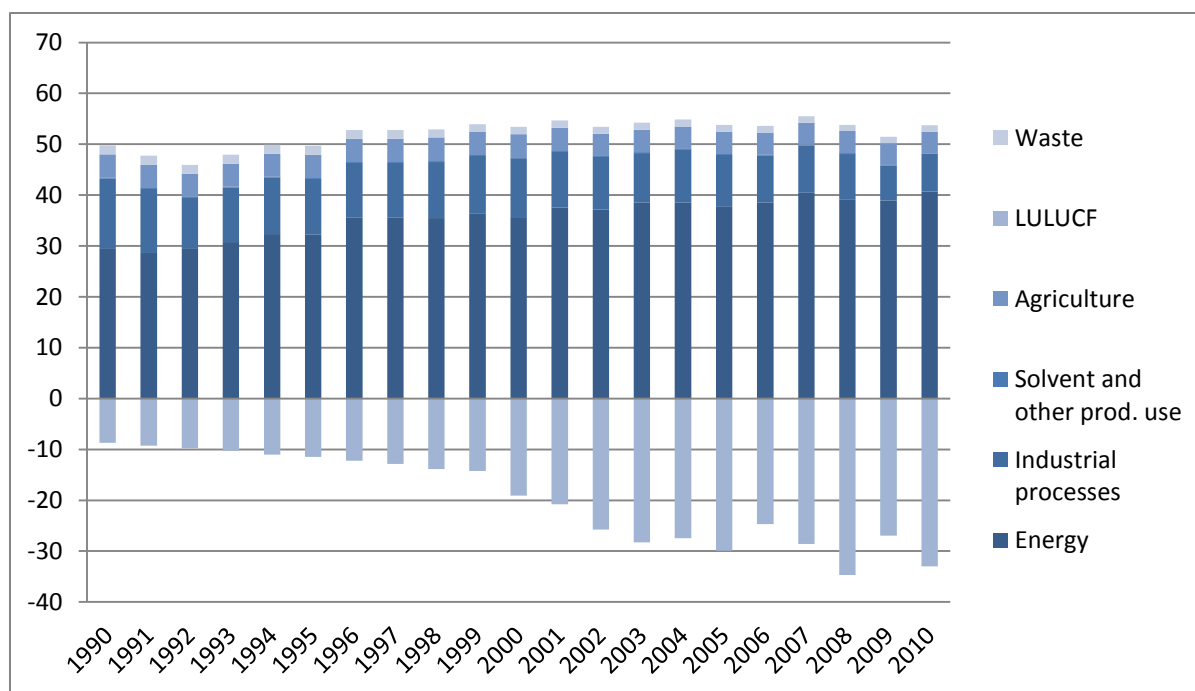


Figure E.S.1. Total emissions of all GHG from the different source categories. 1990-2010. Mtonnes CO<sub>2</sub> equivalents.

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 1990-2010.

Table E.S.1. Emissions and removals of greenhouse gases 1990-2010.

| Gas  | CO <sub>2</sub> | CH <sub>4</sub> | N <sub>2</sub> O | PFC             |                               |     | SF <sub>6</sub> | HFK    |     |      |     |       |     |      |      |       | Total without LULUCF    |
|------|-----------------|-----------------|------------------|-----------------|-------------------------------|-----|-----------------|--------|-----|------|-----|-------|-----|------|------|-------|-------------------------|
|      |                 |                 |                  | CF <sub>4</sub> | C <sub>2</sub> F <sub>6</sub> | 218 |                 | 23     | 32  | 125  | 134 | 134a  | 143 | 143a | 152a | 227ea | Mt CO <sub>2</sub> -eq. |
| Year | Mtonnes         | ktonnes         | ktonnes          | tonnes          |                               |     | tonnes          | tonnes |     |      |     |       |     |      |      |       |                         |
| 1990 | 34.8            | 222.2           | 15.4             | 467.4           | 36.2                          | 0.0 | 91.9            | 0.0    | 0.0 | 0.0  | 0.0 | 0.0   | 0.0 | 0.0  | 0.1  | 0.0   | 49.8                    |
| 1991 | 33.3            | 224.2           | 14.9             | 416.5           | 31.0                          | 0.0 | 86.9            | 0.0    | 0.0 | 0.0  | 0.0 | 0.0   | 0.0 | 0.0  | 0.4  | 0.0   | 47.7                    |
| 1992 | 34.2            | 226.9           | 13.1             | 321.6           | 21.4                          | 0.0 | 29.4            | 0.0    | 0.0 | 0.0  | 0.0 | 0.2   | 0.0 | 0.0  | 0.7  | 0.0   | 46.0                    |
| 1993 | 35.8            | 229.9           | 13.8             | 324.3           | 20.6                          | 0.0 | 30.7            | 0.0    | 0.0 | 0.0  | 0.0 | 1.8   | 0.0 | 0.0  | 0.8  | 0.0   | 47.9                    |
| 1994 | 37.7            | 233.1           | 14.1             | 286.9           | 18.3                          | 0.0 | 36.4            | 0.0    | 0.0 | 0.5  | 0.0 | 5.4   | 0.0 | 0.2  | 0.8  | 0.0   | 49.9                    |
| 1995 | 37.8            | 231.8           | 14.2             | 283.3           | 18.1                          | 0.0 | 24.9            | 0.0    | 0.0 | 2.4  | 0.0 | 10.2  | 0.0 | 1.5  | 1.0  | 0.0   | 49.7                    |
| 1996 | 41.0            | 232.3           | 14.4             | 258.5           | 16.2                          | 0.0 | 23.5            | 0.0    | 0.0 | 5.5  | 0.0 | 16.7  | 0.0 | 3.9  | 1.5  | 0.0   | 52.8                    |
| 1997 | 41.1            | 233.0           | 14.4             | 229.9           | 15.1                          | 0.0 | 22.1            | 0.0    | 0.1 | 9.7  | 0.0 | 24.6  | 0.0 | 6.9  | 2.4  | 0.1   | 52.8                    |
| 1998 | 41.3            | 226.5           | 14.5             | 209.8           | 13.3                          | 0.0 | 28.2            | 0.1    | 0.3 | 14.8 | 0.0 | 35.7  | 0.0 | 10.5 | 5.6  | 0.1   | 52.9                    |
| 1999 | 42.1            | 219.3           | 15.1             | 196.2           | 12.3                          | 0.0 | 34.3            | 0.1    | 0.6 | 20.0 | 0.0 | 50.2  | 0.0 | 14.9 | 8.7  | 0.2   | 53.9                    |
| 2000 | 41.7            | 225.4           | 14.4             | 186.4           | 11.6                          | 0.0 | 36.8            | 0.1    | 1.0 | 26.2 | 0.0 | 64.4  | 0.0 | 20.5 | 12.4 | 0.2   | 53.4                    |
| 2001 | 43.1            | 225.7           | 14.1             | 187.5           | 11.9                          | 0.0 | 30.8            | 0.1    | 1.5 | 33.4 | 0.0 | 78.8  | 0.0 | 27.1 | 16.4 | 0.3   | 54.7                    |
| 2002 | 42.2            | 217.7           | 14.7             | 201.3           | 14.0                          | 0.0 | 9.7             | 0.1    | 2.3 | 39.2 | 0.0 | 95.2  | 0.0 | 32.3 | 19.3 | 0.5   | 53.4                    |
| 2003 | 43.6            | 222.2           | 14.2             | 125.6           | 10.1                          | 0.0 | 9.6             | 0.1    | 3.0 | 42.4 | 0.0 | 111.8 | 0.0 | 34.3 | 22.8 | 0.8   | 54.2                    |
| 2004 | 44.0            | 221.3           | 14.7             | 122.1           | 9.4                           | 0.0 | 11.3            | 0.1    | 3.8 | 45.3 | 0.1 | 127.6 | 0.0 | 35.9 | 27.0 | 1.0   | 54.8                    |
| 2005 | 43.1            | 212.4           | 14.9             | 116.7           | 7.6                           | 0.0 | 12.8            | 0.1    | 4.5 | 47.8 | 0.1 | 149.1 | 0.4 | 37.3 | 31.8 | 1.1   | 53.8                    |
| 2006 | 43.5            | 206.0           | 13.8             | 102.1           | 8.6                           | 0.0 | 8.6             | 0.1    | 5.3 | 50.1 | 0.1 | 168.4 | 1.3 | 38.6 | 38.9 | 1.2   | 53.6                    |
| 2007 | 45.5            | 212.9           | 13.3             | 111.7           | 10.3                          | 0.0 | 3.0             | 0.1    | 6.4 | 52.4 | 0.1 | 193.3 | 1.7 | 40.0 | 35.4 | 1.2   | 55.5                    |
| 2008 | 44.4            | 207.2           | 11.7             | 104.7           | 10.0                          | 0.0 | 2.5             | 0.1    | 7.6 | 55.0 | 0.1 | 226.9 | 1.7 | 41.8 | 38.4 | 1.2   | 53.8                    |
| 2009 | 42.9            | 205.9           | 10.0             | 49.8            | 5.8                           | 0.0 | 2.5             | 0.1    | 8.6 | 57.0 | 0.1 | 281.5 | 1.7 | 43.4 | 39.7 | 1.3   | 51.5                    |
| 2010 | 45.5            | 206.9           | 9.9              | 27.3            | 3.0                           | 0.0 | 0.0             | 0.2    | 9.3 | 60.1 | 0.1 | 300.4 | 1.8 | 44.5 | 43.3 | 1.5   | 53.9                    |

Source: Statistics Norway/Climate and Pollution Agency

The proportion of CO<sub>2</sub> emissions of the national total greenhouse gas emissions has increased from about 70 per cent in 1990 to more than 84 per cent in 2010. The increased proportion of CO<sub>2</sub> relative to other gases is due to growth in the CO<sub>2</sub> emissions during this period, as well as a reduction in emissions of N<sub>2</sub>O, PFCs and SF<sub>6</sub> gases because of implemented environmental measures and/or technological improvements. This trend is illustrated in Table E.S.2.

Table E.S.2 Emissions in million tonnes CO<sub>2</sub> equivalents in 1990, 2009, 2010 and changes (per cent) between 1990-2010 and 2009-2010 (without LULUCF)

| Year              | CO <sub>2</sub> | CH <sub>4</sub> | N <sub>2</sub> O | PFCs    | SF <sub>6</sub> | HFCs  | Total  |
|-------------------|-----------------|-----------------|------------------|---------|-----------------|-------|--------|
| 1990              | 34.8            | 4.7             | 4.7              | 3.4     | 2.2             | 0.0   | 49.8   |
| 2009              | 42.9            | 4.3             | 3.0              | 0.4     | 0.1             | 0.7   | 51.3   |
| 2010              | 45.5            | 4.4             | 3.1              | 0.2     | 0.1             | 0.7   | 53.9   |
| Changes 1990-2010 | 30.6 %          | 6.9 %           | -35.5 %          | -93.9 % | -96.6 %         | -     | 8.24 % |
| Change 2009-2010  | 6 %             | 0.5 %           | -1.2 %           | -45.6 % | 21.7 %          | 5.5 % | 4.71 % |

Source: Statistics Norway/Climate and Pollution Agency

About 51 per cent of the methane emissions in 2010 originated from agriculture, and 25 per cent originated from landfills. The total methane emissions decreased by about 0.5 per cent from 2009 to 2010.

In 2010, agriculture and nitric acid production contributed to 67 per cent and 12 per cent of the total N<sub>2</sub>O-emission respectively. Due to technical improvements in production of nitric acid, and despite increased production, the total emissions of N<sub>2</sub>O have decreased by 36 per cent since 1990.

The decrease in PFC emissions was almost 45 per cent from 2009 to 2010, resulting in a total reduction of 94 per cent since 1990. PFC emissions originate primarily from the production of aluminium, where technical measures have been undertaken to reduce them. CO<sub>2</sub> emissions from aluminium production have increased since 1990 due to increased production.

SF<sub>6</sub> emissions have been reduced by 97 per cent from 1990 to 2010, mainly because of technological improvements and the closure of a magnesium production plant and a magnesium recycling foundry.

HFC emissions increased by 6 per cent in 2010 compared to 2009. 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 CO<sub>2</sub> sequestration from the LULUCF category was 32.9 million tonnes in 2010. Since 1990 there has been an increase in carbon stored in living biomass, dead organic matter and in soils in Norway, more than doubling the net sequestration of CO<sub>2</sub> 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 2010.

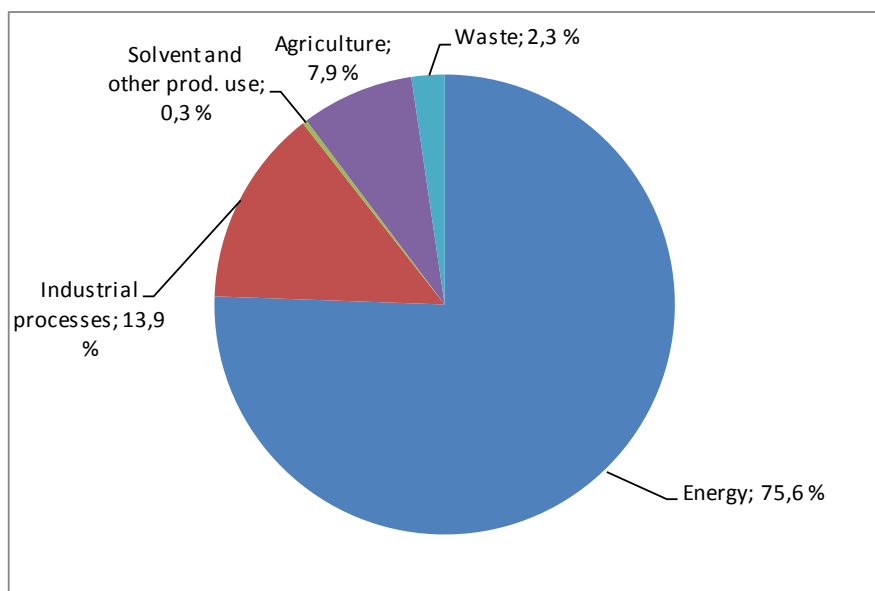


Figure E.S.2. Emissions by IPCC sector in 2010.

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 76 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 2010 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.

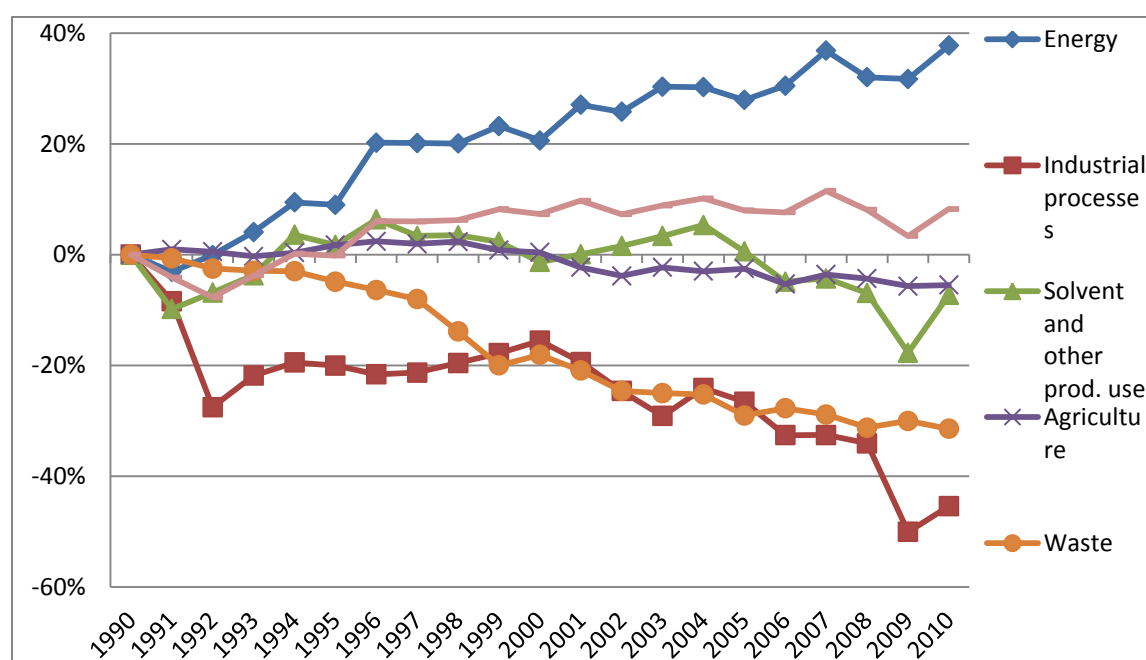


Figure E.S.3. Changes in GHG emissions by IPCC sector 1990-2010 compared to 1990.

Source: Statistics Norway/Climate and Pollution Agency

From 1990 to 2010 the increase in the emissions from the energy sector was almost 38 per cent, or more than 11 million tonnes, mainly due to higher activity in the offshore and transport sectors. The energy sector's emissions increased by 4.6 per cent from 2009 to 2010. Between 1990 and 2010 there have been temporary emission reductions in e.g. 1991 and 2005 and again in 2008 and 2009, when the energy sector emissions decreased by less than 1 per cent.

Emissions from transport showed an overall increase of about 36 per cent from 1990 to 2010, while the emissions decreased by more than 5 per cent from 2009 to 2010. The share of transport in the total GHG emissions has increased from 22 per cent in 1990 to almost 28 per cent in 2010. Road transportation accounts for more than 67 per cent of the total mobile emissions, while emissions from navigation and civil aviation accounts for 4 and 7 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 11 per cent of the emissions from the source transport.



Industrial processes contributed to almost 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 CO<sub>2</sub> and other greenhouse gases such as N<sub>2</sub>O (fertilizer production) and PFCs (aluminium production). Between 1990 and 2010 emissions from industrial processes experienced an overall decrease by over 55 per cent. This is mainly due to reduced PFC emissions from the production of aluminium and SF<sub>6</sub> 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 2010 to about 8 per cent to the total emissions of greenhouse gases. This corresponds to 4.3 million tonnes CO<sub>2</sub> equivalents, which is 0.2 per cent lower than in 2009. This sector has experienced an emission reduction of about 5 per cent over the period 1990-2010. The dominant sources of GHGs are agricultural soils (N<sub>2</sub>O) and enteric fermentation (CH<sub>4</sub>) from domestic animals. These sources contributed to about 45 and 44 per cent respectively of the sector's emissions.

The waste sector contributed with 2 per cent of total Norwegian greenhouse gas emissions in 2010. The emissions of greenhouse gases from the waste sector were relatively stable during the 1990s. From 1998 the emissions declined, and in 2010 they were about 31 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 SO<sub>2</sub>**

Nitrogen oxides (NO<sub>x</sub>), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) are not greenhouse gases, but they have an indirect effect on the climate through their influence on greenhouse gases, in particular ozone. Sulphur dioxide (SO<sub>2</sub>) 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<sub>x</sub> emissions have decreased by approximately 3 per cent from 1990 to 2010, primarily because of stricter emission regulations directed towards road traffic, which counteracted increased emissions from oil and gas production and from navigation. From 2009 to 2010 the total NO<sub>x</sub> emissions decreased by more than 3 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 2010, and are now 51 per cent lower than in 1990. From 2009 to 2010 the emissions of NMVOC decreased by 1 per cent.

Over the period 1990-2010 emissions of CO decreased by approximately 55 per cent. This is explained primarily by the implementation of new emissions standards for motor vehicles.

Emissions of SO<sub>2</sub> were reduced by 63 per cent from 1990 to 2010. 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 CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O as well as fluorinated greenhouse gases not controlled by the Montreal Protocol (HFCs, PFCs and SF<sub>6</sub>), 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 2012 together with the associated Common Reporting Format (CRF) tables are Norway's contribution to the 2012 round of reporting under the Convention, and it covers emissions and removals for the period 1990-2010.

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 (CO<sub>2</sub>);
- Methane (CH<sub>4</sub>);
- Nitrous oxide (N<sub>2</sub>O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs);
- Sulphur hexafluoride (SF<sub>6</sub>).

Aggregated emissions and removals of greenhouse gases expressed in CO<sub>2</sub>-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 CO<sub>2</sub> emissions originating from the fossil part of CH<sub>4</sub> 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<sub>x</sub>, NMVOC, CO and SO<sub>2</sub>, 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 (2011a).

Since the introduction of annual technical reviews of the national inventories by independent experts in 2000, Norway has undergone nine desk/centralized reviews, in 2000, 2001, 2003, 2004, 2005, 2008, 2009, 2010 and 2011. An in-country review was held in Oslo in October 2002. The Initial Report and Norway's 2006 greenhouse gas inventory submission was reviewed in an in-country review 23-28 April 2007. The recommendations from these reviews have been incorporated in this report to the extent possible.

## **1.2 Institutional arrangement for inventory preparation**

The Norwegian greenhouse gas inventory has been produced in more than two decades as an 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; Climate and Pollution Agency, Statistics Norway and The Norwegian Forest and Landscape Institute, work together to fulfill the requirements for the national system. The allocation of responsibilities for producing estimates of emissions and removals, QA/QC and archiving is presented in more detail in Annex V. An overview of institutional responsibilities and cooperation is shown in Figure 1.1.

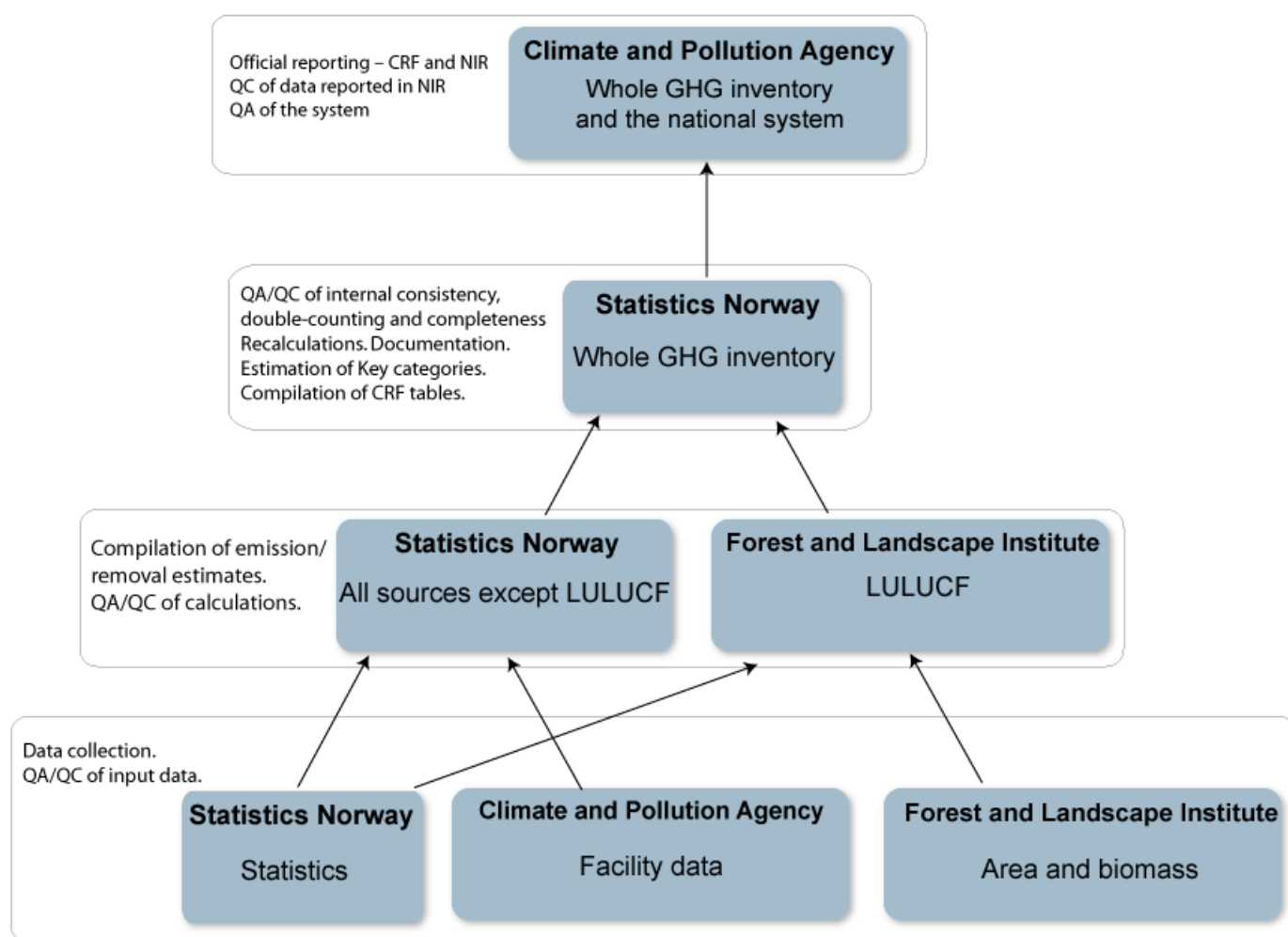


Figure 1.1. Overview of institutional responsibilities and cooperation

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 2011. Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants” (Statistics Norway 2011a). 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 2012, not published) which is due to be published in 2012 has also been used in the preparation for this inventory. Information on the methods and framework for the production of data for the LULUF 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 SO<sub>2</sub>, NO<sub>x</sub>, 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 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). They have developed a calculation system in the form of computer programs that uses the SAS system software, FORTRAN and R 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.

In light of the importance of the forest sector, the National Forest Inventory (NFI) is used as the most important source of information of forestry and 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 are for the first time included in the estimates for the LULUCF sector in this inventory submission. The estimates for areas above the coniferous limit and in Finnmark County, may be recalculated in future greenhouse gas inventories as more information, e.g. from NFI, maps, old and new aerial photos, may be 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 1988 and Petersson and Ståhl 2006). These equations provide biomass estimates for various tree biomass components: stem, 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 CO<sub>2</sub> 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 Yasso, as described in detail by Liski et al. (2005), and for Norwegian conditions by de Wit et al. (2006), is used to calculate changes in carbon stock in dead organic matter and in soil for forest land remaining forest land. The Yasso07, a newer version of the model, has been used to obtain estimates of soil organic carbon for lands converted to forest land and forest land converted to other lands (Liski et al. 2009, Tuomi and Liski 2009, Tuomi et al. 2009, [www.ymparisto.fi/syke/yasso](http://www.ymparisto.fi/syke/yasso)). 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, Statistics Norway, Norwegian Meteorological Institute and Bioforsk. We assume the models are relevant for Norwegian conditions. The calculations are hence done in accordance to a Tier 3 method.

#### **1.4.4 Data sources**

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

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

*Emission factors* – these originate from reports on Norwegian conditions and are either estimated from measurements or elaborated in special investigations. However, international default data are used in cases where emission factors are highly uncertain (e.g. N<sub>2</sub>O from agriculture, CH<sub>4</sub> and N<sub>2</sub>O from stationary combustion, CH<sub>4</sub> and N<sub>2</sub>O 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 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 41 key categories. Key categories in the Land use, land use change and forestry sector (LULUCF) was 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 CO<sub>2</sub> 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 2010 | Trend assessment Tier 2 1990-2010 | Method (Tier) 2010 |
|--|---|------------------|------------------------------|------------------------------|-----------------------------------|--------------------|
| <i>Tier 2 key categories (large contribution to the total inventory uncertainty)</i> |   |                  |                              |                              |                                   |                    |
| 4D1  | Direct soil emissions                                   | N <sub>2</sub> O | <b>29.23</b>                 | <b>25.57</b>                 | <b>10.18</b>                      | Tier 1a            |
| 1A   | Stationary Fuel Combustion (1A1-1A2-1A4), Gaseous Fuels | CO <sub>2</sub>  | <b>4.37</b>                  | <b>10.01</b>                 | <b>14.25</b>                      | Tier 2             |
| 1A3b   | Road Transportation                                     | CO <sub>2</sub>  | <b>4.65</b>                  | <b>5.68</b>                  | <b>2.54</b>                       | Tier 2             |
| 4D3  | Indirect emissions                                      | N <sub>2</sub> O | <b>5.40</b>                  | <b>4.99</b>                  | <b>1.14</b>                       | Tier 1a            |
| 4A   | Enteric Fermentation                                    | CH <sub>4</sub>  | <b>5.31</b>                  | <b>4.69</b>                  | <b>1.66</b>                       | Tier 1/2*          |
| 1A3d   | Navigation  | CO <sub>2</sub>  | <b>3.59</b>                  | <b>4.11</b>                  | <b>1.28</b>                       | Tier 2             |
| 1B2a   | Oil (incl. oil refineries, gasoline distribution)       | CO <sub>2</sub>  | <b>4.80</b>                  | <b>3.99</b>                  | <b>2.16</b>                       | Tier 2             |
| 6A   | Solid Waste Disposal on Land                            | CH <sub>4</sub>  | <b>6.34</b>                  | <b>3.79</b>                  | <b>6.60</b>                       | Tier 2             |
| 2F   | Consumption of Halocarbons and Sulphur Hexafluoride     | HFCs             | 0.00                         | <b>3.63</b>                  | <b>9.22</b>                       | Tier 2             |
| 1A3e   | Other (snow scooters, boats, motorized equipment)       | CO <sub>2</sub>  | <b>1.61</b>                  | <b>3.07</b>                  | <b>3.68</b>                       | Tier 2             |
| 1B2c   | Venting and Flaring                                     | CH <sub>4</sub>  | <b>1.15</b>                  | <b>2.56</b>                  | <b>3.56</b>                       | Tier 2             |
| 1A   | Stationary Fuel Combustion (1A1-1A2-1A4), Liquid Fuels  | CO <sub>2</sub>  | <b>2.88</b>                  | <b>2.29</b>                  | <b>1.55</b>                       | Tier 2             |
| 1A3a   | Civil Aviation  | CO <sub>2</sub>  | <b>1.44</b>                  | <b>2.14</b>                  | <b>1.76</b>                       | Tier 2             |
| 1A4  | Other sectors - Mobile Fuel Combustion                  | CO <sub>2</sub>  | <b>2.00</b>                  | <b>1.86</b>                  | 0.40                              | Tier 2             |
| 2C3  | Aluminium Production                                    | CO <sub>2</sub>  | <b>1.55</b>                  | <b>1.78</b>                  | 0.56                              | Tier 2             |
| 1A3e   | Other (snow scooters, boats, motorized equipment)       | N <sub>2</sub> O | 0.73                         | <b>1.68</b>                  | <b>2.38</b>                       | Tier 2             |
| 1A   | Stationary Fuel Combustion (1A1-1A2-1A4), Other Fuels   | CO <sub>2</sub>  | 0.32                         | <b>1.62</b>                  | <b>3.30</b>                       | Tier 2             |
| 1B2c   | Venting and Flaring                                     | CO <sub>2</sub>  | <b>1.69</b>                  | <b>1.56</b>                  | 0.36                              | Tier 2             |
| 4D2  | Animal production                                       | N <sub>2</sub> O | <b>1.75</b>                  | <b>1.46</b>                  | <b>0.77</b>                       | Tier 1a            |
| 1A   | Stationary Fuel Combustion (1A1-1A2-1A4), Biomass       | CH <sub>4</sub>  | <b>0.97</b>                  | <b>1.30</b>                  | <b>0.83</b>                       | Tier 2             |
| 6B   | Wastewater Handling                                     | N <sub>2</sub> O | <b>0.91</b>                  | <b>1.14</b>                  | 0.56                              | Tier 1             |
| 4B   | Manure Management                                       | N <sub>2</sub> O | <b>1.07</b>                  | <b>0.96</b>                  | 0.29                              | Tier 1             |
| 1B2a   | Oil (incl. oil  | CH <sub>4</sub>  | 0.69                         | <b>0.90</b>                  | 0.52                              | Tier 2             |

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|  |   |                  |             |      |              |             |
|--|---|------------------|-------------|------|--------------|-------------|
|  | refineries, gasoline distribution)                        |                  |             |      |              |             |
| 1A   | Stationary Fuel Combustion (1A1-1A2-1A4), Solid Fuels     | CO <sub>2</sub>  | <b>0.91</b> | 0.80 | 0.30         | Tier 2      |
| 1A   | Stationary Fuel Combustion (1A1-1A2-1A4), Gaseous Fuels   | CH <sub>4</sub>  | 0.31        | 0.65 | <b>0.85</b>  | Tier 2      |
| 1A3d   | Navigation  | CH <sub>4</sub>  | 0.03        | 0.41 | <b>0.94</b>  | Tier 2      |
| 2C3  | Aluminium Production                                      | PFCs             | <b>7.12</b> | 0.40 | <b>17.20</b> | Tier 2      |
| 1B2b   | Natural Gas   | CH <sub>4</sub>  | 0.02        | 0.33 | <b>0.78</b>  | Tier 2      |
| 2B2  | Nitric Acid Production                                    | N <sub>2</sub> O | <b>1.30</b> | 0.21 | <b>2.79</b>  | Tier 2      |
| 2B4  | Carbide Production  | CO <sub>2</sub>  | 0.44        | 0.08 | <b>0.92</b>  | Tier 2      |
| <i>Tier 1 key categories (large contribution to the total emissions)</i> |   |                  |             |      |              |             |
| 4B   | Manure Management   | CH <sub>4</sub>  | 0.79        | 0.78 | 0.05         | Tier 2      |
| 2C2  | Ferroalloys Production                                    | CO <sub>2</sub>  | 0.80        | 0.63 | 0.44         | Tier 2      |
| 2B1  | Ammonia Production  | CO <sub>2</sub>  | 0.40        | 0.26 | 0.35         | Tier 2      |
| 2D2  | Food and Drink  | CO <sub>2</sub>  | 0.10        | 0.24 | 0.35         | Tier 2      |
| 1A5b   | Military – Mobile   | CO <sub>2</sub>  | 0.29        | 0.16 | 0.35         | Tier 2      |
| 2C1  | Iron and Steel Production <sup>1</sup>                    | CO <sub>2</sub>  | 0.04        | 0.06 | 0.04         | Tier 2      |
| 2A1  | Cement Production   | CO <sub>2</sub>  | 0.05        | 0.05 | 0.01         | Tier 2      |
| 2A2  | Lime Production   | CO <sub>2</sub>  | 0.00        | 0.01 | 0.03         | Tier 2      |
| 2C4  | SF <sub>6</sub> Used in Aluminium and Magnesium Foundries | SF <sub>6</sub>  | 0.06        | .    | .            | Tier 2      |
| <i>Qualitative key categories</i>  |   |                  |             |      |              |             |
| 1B1a   | Coal Mining and Handling                                  | CH <sub>4</sub>  | 0.43        | 0.22 | 0.53         | Tier 2      |
|  | Capture and storage                                       | CO <sub>2</sub>  |             |      |              | CS (Tier 2) |

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

<sup>1)</sup> Due to a reallocation after the key category analysis was performed, 2C1 - Iron and Steel Production should be replaced as key by 2B5 Other Chemical Industry.

There are two new categories that are identified as key, both at tier 1. The source 2A2 - Lime Production is now included due to increased activity in the sector. The source 2D2 – “Food and Drink” – CO<sub>2</sub> is again included in the list of tier 1 key categories. This category has been in and out of the list for several years as the emissions vary from year to year. In addition, the source 2C2 - Ferroalloys Production was now identified as key only at tier 1. Due to a reallocation of a plant from 2C1 - Iron and Steel Production to 2B5 - Other Chemical Industry after the key category analysis was performed, the latter should replace the former as a tier 1 key category. This reallocation is not reflected in the tables and is indicated by footnotes.

Table 1.2 lists the LULUCF identified as key categories. Compared to earlier submission, one source has been excluded as key: *5B1 - Cropland remaining Cropland, Reduced tillage, Soils*

- CO<sub>2</sub>. The change is due to an updating of activity data due to new data and continuous quality control of the data bases used.

The source 5B1 *Cropland remaining Cropland – liming* - is not included in the list of Tier 1 as it has been in previous submissions. This may be due to the reduction of total amount of lime applied over the years, and that these emissions are negligible.

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

|  | Source category  | Gas             | Level assessment Tier 2 1990 | Level assessment Tier 2 2010 | Trend assessment Tier 2 1990-2010 | Method (Tier) 2010 |
|--|--|-----------------|------------------------------|------------------------------|-----------------------------------|--------------------|
| <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 <sub>2</sub> | <b>6.37</b>                  | <b>19.86</b>                 | <b>26.79</b>                      | Tier 3             |
| 5A1  | Forest Land remaining Forest Land, Forest inventory area, Dead Biomass   | CO <sub>2</sub> | <b>6.80</b>                  | <b>8.51</b>                  | <b>9.15</b>                       | Tier 3             |
| 5C1  | Grassland remaining Grassland, Histosols, Soils                          | CO <sub>2</sub> | <b>12.49</b>                 | <b>7.85</b>                  | <b>4.90</b>                       | Tier 2*            |
| 5A1  | Forest Land remaining Forest Land, Forest inventory area, Soils, Mineral | CO <sub>2</sub> | <b>5.09</b>                  | <b>6.16</b>                  | <b>6.53</b>                       | Tier 3             |
| 5E2  | Land converted to Settlements, Living biomass                            | CO <sub>2</sub> | <b>0.75</b>                  | <b>2.18</b>                  | <b>2.91</b>                       | Tier 3             |
| 5A1  | Forest Land remaining Forest Land, Forest inventory area, Soils, Organic | CO <sub>2</sub> | <b>2.54</b>                  | <b>1.97</b>                  | <b>1.57</b>                       | Tier 1             |
| 5B1  | Cropland remaining Cropland, Histosols, Soils                            | CO <sub>2</sub> | <b>1.39</b>                  | <b>0.87</b>                  | 0.54                              | Tier 2             |
| 5E2  | Land converted to Settlements, Soils                                     | CO <sub>2</sub> | 0.10                         | 0.65                         | <b>0.93</b>                       | Tier 3             |
| 5A2  | Land converted to Forest Land, Living biomass                            | CO <sub>2</sub> | 0.01                         | 0.58                         | <b>0.89</b>                       | Tier 3             |
| <i>Tier 1 key categories (large contribution to the total emissions):</i>            |  |                 |                              |                              |                                   |                    |
| 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 VI. All three institutions have prepared a QA/QC report, according to the plan. These document to what extent the QA/QC procedures have been followed. These reports are available for the Expert Review Team for inspection.

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

### **1.6.2 Verification studies**

In general, the final inventory data provided by Statistics Norway are checked and verified by 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 (for details, see Chapter 6 on Agriculture).

### **1.6.3 Confidentiality issues**

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

## **1.7 Uncertainty evaluation**

### **1.7.1 Introduction**

The uncertainty in the Norwegian greenhouse gas emission inventory has been investigated by a tier 2 analysis in 2011 and the results are described in section 1.7 and in Annex II in the NIR 2012. 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 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.

### 1.7.2 Uncertainty in emission levels

The estimated uncertainties of the levels of total emissions and in each gas are shown in Table 1.3 and Table 1.4.

*Table 1.3. Uncertainties in emission levels. Each gas and total GWP weighted emissions. Excluding the LULUCF sector.*

| 1990             | $\mu$ (mean)     | Fraction of total emissions | Uncertainty $2\sigma$ (per cent of mean) |
|------------------|------------------|-----------------------------|--|
| Total            | 50 mill. Tonnes  | 1                           | 5  |
| CO <sub>2</sub>  | 35 mill. Tonnes  | 0.70                        | 3  |
| CH <sub>4</sub>  | 4.7 mill. Tonnes | 0.09                        | 17                                       |
| N <sub>2</sub> O | 4.7 mill. Tonnes | 0.10                        | 40                                       |
| HFC              | 18 tonnes        | 0.00                        | 50                                       |
| PFC              | 3.4 mill. Tonnes | 0.07                        | 21                                       |
| SF <sub>6</sub>  | 2.2 mill. Tonnes | 0.04                        | 2  |
| 2009             | $\mu$ (mean)     | Fraction of total emissions | Uncertainty $2\sigma$ (per cent of mean) |
| Total            | 51 mill. Tonnes  | 1                           | 4  |
| CO <sub>2</sub>  | 43 mill. Tonnes  | 0.84                        | 2  |
| CH <sub>4</sub>  | 4.3 mill. Tonnes | 0.08                        | 14                                       |
| N <sub>2</sub> O | 3.0 mill. Tonnes | 0.06                        | 58                                       |
| HFC              | 708 ktonnes      | 0.01                        | 48                                       |
| PFC              | 379 ktonnes      | 0.01                        | 20                                       |
| SF <sub>6</sub>  | 64 ktonnes       | 0.00                        | 56                                       |

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*Table 1.4. Uncertainties in emission levels. Each gas and total GWP weighted emissions. Including the LULUCF sector.*

| <b>1990</b>      | <b><math>\mu</math> (mean)</b> | <b>Fraction of total emissions</b> | <b>Uncertainty <math>2\sigma</math> (per cent of mean)</b> |
|------------------|--------------------------------|------------------------------------|--|
| Total            | 41 mill. tonnes                | 1                                  | 7  |
| CO <sub>2</sub>  | 26 mill. tonnes                | 0.64                               | 9  |
| CH <sub>4</sub>  | 4.7 mill. tonnes               | 0.11                               | 16   |
| N <sub>2</sub> O | 4.7 mill. tonnes               | 0.12                               | 38   |
| HFC              | 18 tonnes                      | 0.00                               | 50   |
| PFC              | 3.4 mill. tonnes               | 0.08                               | 21   |
| SF <sub>6</sub>  | 2.2 mill. tonnes               | 0.05                               | 1  |
|                  |                                |                                    |  |
| <b>2009</b>      | <b><math>\mu</math> (mean)</b> | <b>Fraction of total emissions</b> | <b>Uncertainty <math>2\sigma</math> (per cent of mean)</b> |
| Total            | 26 mill. tonnes                | 1                                  | 17   |
| CO <sub>2</sub>  | 17 mill. tonnes                | 0.67                               | 23   |
| CH <sub>4</sub>  | 4.3 mill. tonnes               | 0.16                               | 14   |
| N <sub>2</sub> O | 3.1 mill. tonnes               | 0.12                               | 55   |
| HFC              | 708 ktonnes                    | 0.03                               | 48   |
| PFC              | 379 ktonnes                    | 0.01                               | 20   |
| SF <sub>6</sub>  | 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 CO<sub>2</sub> 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 SF<sub>6</sub> emissions, which has increased from 2 to 56 per cent of the mean. However, the SF<sub>6</sub> emissions are strongly reduced because magnesium production was closed down. The figures for the emission of SF<sub>6</sub> from magnesium production was quite well known, but now a larger part of the SF<sub>6</sub> emissions comes from sources with higher uncertainty. For N<sub>2</sub>O there is also a considerable increase in the uncertainty between the years. One reason for the change can be found in that N<sub>2</sub>O from the production of synthetic fertilizer with a quite low uncertainty contributes to a smaller part of the total N<sub>2</sub>O 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 N<sub>2</sub>O 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 N<sub>2</sub>O 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 CO<sub>2</sub> is increased, while the share of N<sub>2</sub>O 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.

### 1.7.3 Uncertainty in emission trend

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

*Table 1.5. Uncertainty of emission trends. 1990-2009. Excluding the LULUCF sector.*

|                  | Per cent change<br>( $(\mu_{2004}-\mu_{1990}) \cdot 100 / \mu_{1990}$ ) | Uncertainty<br>( $2 \cdot \sigma \cdot 100 / \mu_{1990}$ ) |
|------------------|---|--|
| Total            | 3   | 3  |
| CO <sub>2</sub>  | 23  | 3  |
| CH <sub>4</sub>  | -9  | 10   |
| N <sub>2</sub> O | -36   | 11   |
| HFC              | -   | -  |
| PFC              | -89   | 17   |
| SF <sub>6</sub>  | -97   | 0  |



Table 1.6. Uncertainty of emission trends. 1990-2009. Including the LULUCF sector.

|                  | Per cent change<br>( $(\mu_{2004}-\mu_{1990}) \cdot 100 / \mu_{1990}$ ) | Uncertainty<br>( $2 \cdot \sigma \cdot 100 / \mu_{1990}$ ) |
|------------------|---|--|
| Total            | -37   | 7  |
| CO <sub>2</sub>  | -33   | 10   |
| CH <sub>4</sub>  | -9  | 10   |
| N <sub>2</sub> O | -36   | 12   |
| HFC              | -   | -  |
| PFC              | -89   | 19   |
| SF <sub>6</sub>  | -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  $\pm 3$  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 CO<sub>2</sub> 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  $\pm 7$  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 nine desk/centralized reviews, in the years 2000-2011. An in-country review was held in Oslo in 2002. The Initial Report and Norway's 2006 greenhouse gas inventory submission was reviewed in an in-country review in April 2007. The 2011 submission of NIR and CRF were reviewed in a centralized review in September 2011. Norway has not yet received the draft review report from that review.

The ERT's main conclusions from the review of the 2010 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 2010 inventory submission is complete in terms of years, sectors and gases, in line with the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (hereinafter referred to as the IPCC good practice guidance) and the Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories. (hereinafter referred to as the UNFCCC reporting guidelines).*

*Some minor categories are still not included in the 2010 inventory submission, such as a number of carbon stock changes in different pools and subcategories in the LULUCF sector (e.g. the carbon stock change in dead organic matter and the carbon stock change in soils for*

land converted to forest land). However, fewer subcategories were reported as not estimated (.NE.) under the LULUCF sector in the 2010 inventory submission than in the 2009 inventory submission, and in the other sectors all categories are estimated except for N<sub>2</sub>O from industrial wastewater. The ERT encourages Norway to continue to make efforts to estimate emissions for the subcategories that are currently reported as "NE". **Norway continuously strives to estimate emissions that are reported as NE. With regards to some of the LULUCF subcategories, chapter 7.3.2 explains that the model applied is not designed for obtaining dead organic matter and soil organic carbon for disaggregated areas of land-use categories.**

*The ERT noted the detection of a blank cell in CRF table 1.A(b) as reported in the 2010 status report for Norway. The ERT recommends that Norway fill in the blank cell in the CRF table for its next annual submission. **We have not found any blank cell in CRF table 1.A(b).***

*The ERT commends Norway for making progress on the completeness of its inventory and for submitting, for the first time, data for several categories as recommended in previous review reports (e.g. CH<sub>4</sub> and N<sub>2</sub>O from oil flaring and potential emissions of SF<sub>6</sub>)."*

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 CH<sub>4</sub> from agricultural waste, after it is applied to soils. In the IPCC Guidelines it is written that "Agricultural soils may also emit CH<sub>4</sub>", but no calculation methodology is proposed. **(Comment: As far as we know there is no calculation method for this in (IPPC 1997b) or GPG (IPCC 2000). From our knowledge there is no other party reporting CH<sub>4</sub> 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 place. 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.

## **1.9 Implemented and planned improvements**

### **1.9.1 Implemented improvements since NIR 2011**

Table 1.17 gives a brief overview of the improvements implemented since the 2011 submission.

Table 1.17. Overview of the improvements implemented since the 2011 submission.

| Recommended improvements                              | Improvement in NIR 2012   |
|---|---|
| Sectoral versus reference approach                    | Norway is continuously working to reduce the gap between the SA and RA estimates. In response to the ERT of the 2011 NIR, we have initiated steps to improve quality control, transparency and revising RA.         |
| Energy: Fugitives                                     | A figure showing the number of exploration wells in the oil and gas sector in the period 1990-2010 is included in section 3.4 Fugitive Emissions from Oil and Natural Gas – 2B, section 3.4.1.                      |
| Energy: Public electricity and heat production        | New method. As one pulp and paper producing plant also produces electricity, the use of factor calculations of emissions instead of reported figures for CH <sub>4</sub> and N <sub>2</sub> O has been implemented. |
| Industrial processes: lime production                 | The NIR now provides information about the types of lime produced in Norway. Revised data has improved the time series for the IEF.   |
| Industrial processes: production of nitric acid       | The NIR now provides more explanations for the trends of emissions and IEFs.  |
| Industrial processes: titanium dioxide production     | Emissions previously reported under <i>2C1 Pig iron</i> , have been moved to <i>2B5 Titanium dioxide production</i> .   |
| Industrial processes: production of iron and steel    | The NIR now better explains how we have distributed the combustion and process emissions from the plant. There is also more information concerning the AD.  |
| Industrial processes: production of ferroalloys       | A table with information about the activity data for the years 2005-2010 are now included.  |
| Industrial processes: production of primary aluminium | Information about the shares of various technologies is now provided.   |
| Industrial processes: production of calcium carbide   | The notation key in the CRF has been changed to NO after 2002.  |
| Agriculture: enteric fermentation                     | In the NIR, the reference to a better description of the tier 2 methodology used for calculating CH <sub>4</sub> from enteric fermentation from cattle and sheep has been improved.                                 |
| Agriculture: manure                                   | The nitrogen excretion factors for pigs and poultry and the emission factors for NH <sub>3</sub> losses from the manure of sheep and goats in barns have been revised.  |
| Agriculture: burning of crop residues                 | The burning of the residues of oilseed has been included in the inventory.  |
| Solid waste disposal                                  | The emissions have been recalculated due to revised figures on waste disposed at landfills.   |

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|   |   |
|---|---|
| National registry   | A change to the message flow for external transfers was introduced which reduces the risk of discrepant transactions occurring in the Norwegian registry. The implementation of the two-man rule (AAR) to propose and approve transactions was finalized in January 2011. In addition, other security enhancements were also implemented in 2011. |
| Improve working procedures internally                                     | Is being improved continuously  |
| Further strengthen QA/QC procedures in three institutions                 | Is being improved continuously. Dedicated projects are ongoing in the Forest and Landscape Institute and Statistics Norway  |
| Improvements in completeness, transparency and consistency of CRF and NIR | There is a continuous process for improving completeness, transparency and consistency of CRF and NIR so also in the 2012 submission. Several improvements in reducing number of empty cells, better use of notation keys, more activity data and documentation boxes, better explanations of trends etc. was performed.                          |
| Transparency: More explanations in trends and on background data          | Trends are mainly described in Chapter 2, and in the sector chapters.   |
| National system   | The Climate and Pollution Agency has started to build up a physical and electronic library with the most important methodology reports.   |

### 1.9.2 Planned improvements

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

Some areas for further improvements have been identified by Norway and some relevant issues have been identified by the ERT during earlier reviews and some based on experiences we have gained during the centralized review in September 2011. The key elements are listed in table 1.18.

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*Table 1.18. Plan for improvements for the Norwegian GHG inventory*

| <b>Issues for improvements</b>   | <b>Plan for improvements</b>   |
|--|--|
| Independent peer reviews, and for industrial associations and relevant research institutions to review the NIR | When there are methodological changes, relevant associations and institutions are being consulted.   |
| Comparing data with data from other countries  | When there are methodological changes, data is compared with those of other countries.   |
| Inventory management: All staff to be familiar with archiving and documentation structure                      | Improved continuously and in particular in connection with new personnel taking part in the inventory preparation.   |
| Uncertainty: Improve the links between methodological changes and uncertainty estimates                        | This is an issue in the continuous work of improving the inventory.  |
| National Registry  | The Norwegian registry will be migrated to the new EU ETS Union Registry in June 2012.   |
| Sectoral versus reference approach   | We continue the work aiming to reduce the difference between RA and SA as explained in our response to the Saturday Paper from the ERT reviewing the NIR 2011.   |
| Energy   | In 2012 a project will be started with the aim to improve consistency between different sources for energy data and between estimated emissions of greenhouse gases and energy balance.  |
| Energy: Navigation   | <p>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 opportunity to use data from this project in the greenhouse gas inventory will be investigated. There is 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.</p> <p>We will also look into the possibilities to use data from the National Account to allocate consumption of fuels between international and domestic shipping.</p> |
| Combustion of waste in district heating plants   | The CO <sub>2</sub> EF for the fossil part of waste combusted was revised to 2011 submission. This year the EF will be evaluated and we will specifically look at the time serie for the EF.   |
| CO <sub>2</sub> EF for oil products  | The EFs used today will be evaluated.  |

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|  |   |
|--|---|
| Energy: Road transportation  | A new road emission model has been implemented this year and further improvement of the model will be considered before next year submission. The report with a complete documentation of the new model has not been finalized to the 2012 submission due to personnel being on leave.  |
| Energy: off-road machinery   | A project have been started to evaluate and update the calculation model and the plan is to complete this work in time for the 2013 submission.   |
| Industrial processes : HFC model                                     | A project on updating activity data and the calculation model was started in 2011 and is continuing through 2012. A first draft for updating activity data for the years 2005-2009 was generated in 2011 by combining the two data sources. In 2012 the calculation model will be moved to a new platform because of the lack of flexibility in the current Excel-based model.                    |
| Industrial processes: soda ash use                                   | During the centralized review of the 2011 NIR, the ERT asked for information confirming that no soda ash use takes place in Norway. A first examination indicates that we have some use of soda ash in Norway. We will look further into this and plan to report these emissions in the 2013 submission.  |
| Industrial processes: plastic  | The ERT has noted an unstable and increasing trend from 2006 for the CO <sub>2</sub> emissions from plastic. A preliminary assessment is that the increase may be due to inconsistencies with regards to where emissions from flaring have been allocated. We intend to look into this in time for the submission of the 2013 NIR.  |
| Industrial processes: consumption of halocarbons and SF <sub>6</sub> | During the centralized review of the 2011 NIR, a small error in the emission factor for HFC-134 and Perfluoropentane (C <sub>3</sub> F <sub>8</sub> ) was discovered. This does not have consequences for the size of emissions, but will result in a shift in the time series. We intend to reallocate these emissions in the 2013 submission.   |
| Industrial processes: chemicals                                      | The ERT has recommended Norway to 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. We intend to look into this in time for the submission of the 2013 NIR.  |
| Agriculture: B <sub>0</sub> , MCF                                    | A project with the aim to revise the Norwegian CH <sub>4</sub> conversion factors (MCF) for the manure storage systems in use is ongoing at the Norwegian University of Life Sciences (UMB). The maximum CH <sub>4</sub> producing capacity (B <sub>0</sub> ) is also planned to be revised for cattle manure. The results from the project are planned to be implemented in the 2013 submission. |

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|   |   |
|---|---|
| Agriculture: manure storage systems   | New information about the use of manure storage systems from the Sample survey of agriculture 2011 performed by Statistics Norway is planned to be implemented in the inventory before the 2013 submission.   |
| Agriculture: nitrogen excretion factors and VS  | A project with the aim to update the Norwegian nitrogen excretion factors and the values for manure excreted for the different animal species are ongoing at the Norwegian University of Life Sciences (UMB). The results from the project are planned to be implemented in the 2013 submission.  |
| Agriculture: nitrogen leaching and run-off  | The national $Frac_{LEACH}$ factor is under revision and the results of the study is planned to be implemented in the 2013 submission.  |
| LULUCF: The extent of the area of forest and other wooded land at higher altitudes  | The data collection to confirm the extent of the area of forest and other wooded land at higher altitudes was finalized in 2009. The preliminary results included in this submission is planned to be further improved until the reporting in 2014.   |
| LULUCF: Including Finnmark County   | A full forest inventory on plots in a 3x3 km grid in coniferous forest areas and in a 9x9 km grid in birch forest areas in Finnmark County started in 2005 and was conducted in 2011, but not in time for the results to be included in this submission. The preliminary results included in this submission is planned to be further improved until the reporting in 2014. |
| LULUCF: Improve the information of land cover and land-use of plots in the 3x3 km grid that was assessed in the earlier inventories | In 2007 national aerial photographs started to be used to supplement the field survey to update and check land cover statistics and land cover change statistics. In addition this information will among others be used to make a reliable back-casting of biomass and land-use classes for newly established inventory plots back to 1990.                                |
| LULUCF: Survey of dead wood at all inventory plots  | The NFI started in 2010 a survey of dead wood on the ground at all inventory plots in the entire country. The results will be used in the inventory consecutively when available.   |
| LULUCF: Cropland and grassland  | Within 2013 it is planned to evaluate the methods used for assessing emissions and removals for cropland and grassland.   |

|                             |   |
|-----------------------------|---|
| <p>LULUCF: Forest soils</p> | <p>It is planned to improve the estimates of net change in soil organic carbon for mineral soils at forest land remaining forest land, land converted to forest land and forest land converted to other land-use categories. It is planned to use the Yasso07 model for these calculations. Furthermore, it is planned to update all the required input values covering the entire country when they are available from the NFI and research projects, at latest for the reporting in 2014.</p> |
|-----------------------------|---|



## 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 53.9 million tonnes in 2010, which is an increase of approximately 2.4 million tonnes compared to 2009. From 2000 the emissions increased and reached its peak point at 55.5 million tonnes in 2007. From 2007 to 2009 the emissions decreased by more than 7 percent. Between 1990 and 2010 the total greenhouse gas emissions have increased by almost 2.5 million tonnes, or by more than 8 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 7 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 2010 the land-use category forest land remaining forest land was the major contributor to the total amount of sequestration with 35.4 million tonnes CO<sub>2</sub>. Land converted to forest land contributed with 0.4 million tonnes CO<sub>2</sub>. The total net CO<sub>2</sub> removal from the LULUCF sector was 32.9 million tonnes in 2010.

The net greenhouse gas emissions including all sources and sinks are approximately 20.9 million tonnes in 2010. The total contribution from different sources from 1990 to 2010 is illustrated in Figure 2.1 and in Table 2.1.

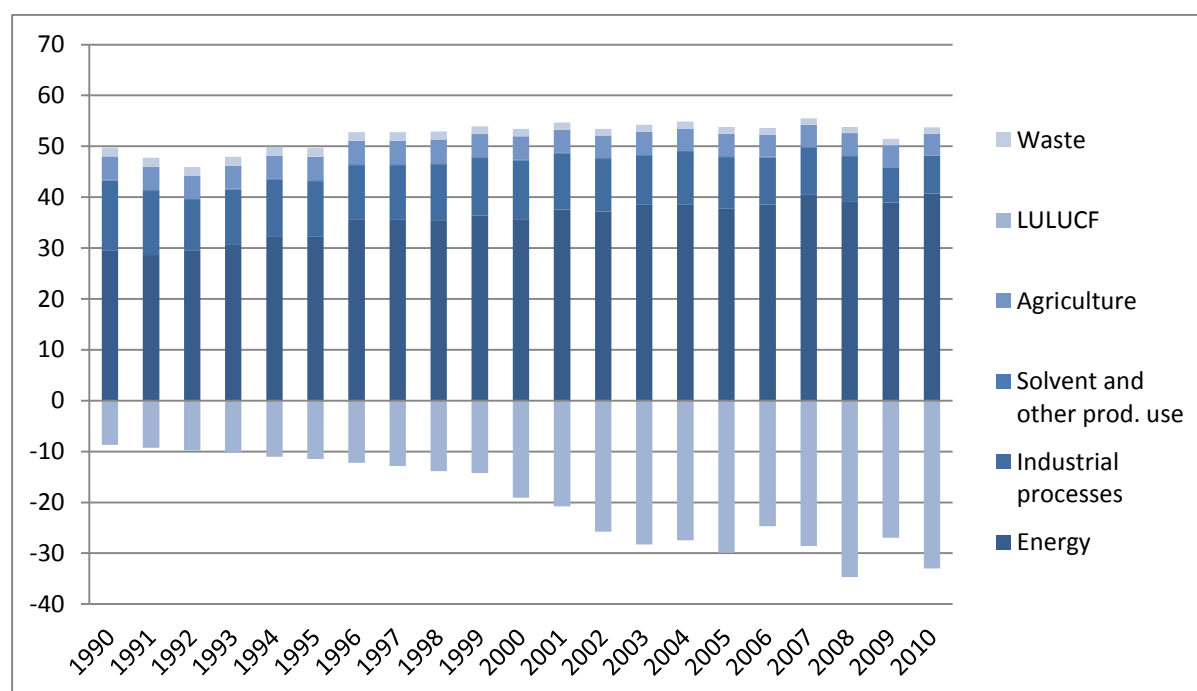


Figure 2.1. Total emissions of all GHG emissions calculated in Mtonnes CO<sub>2</sub> equivalents from the different sectors from 1990 to 2010.

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 1990-2010. The emissions are given in million tonnes CO<sub>2</sub> equivalents.*

| <b>Year</b> | <b>Energy</b> | <b>Industrial processes</b> | <b>Solvent and other prod. use</b> | <b>Agriculture</b> | <b>LULUCF</b> | <b>Waste</b> | <b>Total - without LULUCF</b> |
|-------------|---------------|-----------------------------|------------------------------------|--------------------|---------------|--------------|-------------------------------|
| <b>1990</b> | 29.6          | 13.7                        | 0.2                                | 4.5                | -8.7          | 1.8          | 49.8                          |
| <b>1991</b> | 28.6          | 12.6                        | 0.2                                | 4.6                | -9.3          | 1.8          | 47.7                          |
| <b>1992</b> | 29.5          | 9.9                         | 0.2                                | 4.5                | -9.7          | 1.8          | 46.0                          |
| <b>1993</b> | 30.8          | 10.7                        | 0.2                                | 4.5                | -10.3         | 1.8          | 47.9                          |
| <b>1994</b> | 32.4          | 11.0                        | 0.2                                | 4.5                | -11.0         | 1.8          | 49.9                          |
| <b>1995</b> | 32.2          | 11.0                        | 0.2                                | 4.6                | -11.4         | 1.7          | 49.7                          |
| <b>1996</b> | 35.5          | 10.7                        | 0.2                                | 4.6                | -12.2         | 1.7          | 52.8                          |
| <b>1997</b> | 35.5          | 10.8                        | 0.2                                | 4.6                | -12.8         | 1.7          | 52.8                          |
| <b>1998</b> | 35.5          | 11.0                        | 0.2                                | 4.6                | -13.8         | 1.6          | 52.9                          |
| <b>1999</b> | 36.4          | 11.3                        | 0.2                                | 4.6                | -14.2         | 1.5          | 53.9                          |
| <b>2000</b> | 35.7          | 11.6                        | 0.2                                | 4.5                | -19.1         | 1.5          | 53.4                          |
| <b>2001</b> | 37.6          | 11.0                        | 0.2                                | 4.4                | -20.8         | 1.4          | 54.7                          |
| <b>2002</b> | 37.2          | 10.3                        | 0.2                                | 4.3                | -25.7         | 1.4          | 53.4                          |
| <b>2003</b> | 38.5          | 9.7                         | 0.2                                | 4.4                | -28.2         | 1.4          | 54.2                          |
| <b>2004</b> | 38.5          | 10.4                        | 0.2                                | 4.4                | -27.4         | 1.4          | 54.8                          |
| <b>2005</b> | 37.8          | 10.1                        | 0.2                                | 4.4                | -29.9         | 1.3          | 53.8                          |
| <b>2006</b> | 38.6          | 9.2                         | 0.2                                | 4.3                | -24.6         | 1.3          | 53.6                          |
| <b>2007</b> | 40.5          | 9.2                         | 0.2                                | 4.4                | -28.6         | 1.3          | 55.5                          |
| <b>2008</b> | 39.0          | 9.0                         | 0.2                                | 4.3                | -34.7         | 1.3          | 53.8                          |
| <b>2009</b> | 38.9          | 6.8                         | 0.2                                | 4.3                | -27.0         | 1.3          | 51.5                          |
| <b>2010</b> | 40.7          | 7.5                         | 0.2                                | 4.3                | -32.9         | 1.2          | 53.9                          |

*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.

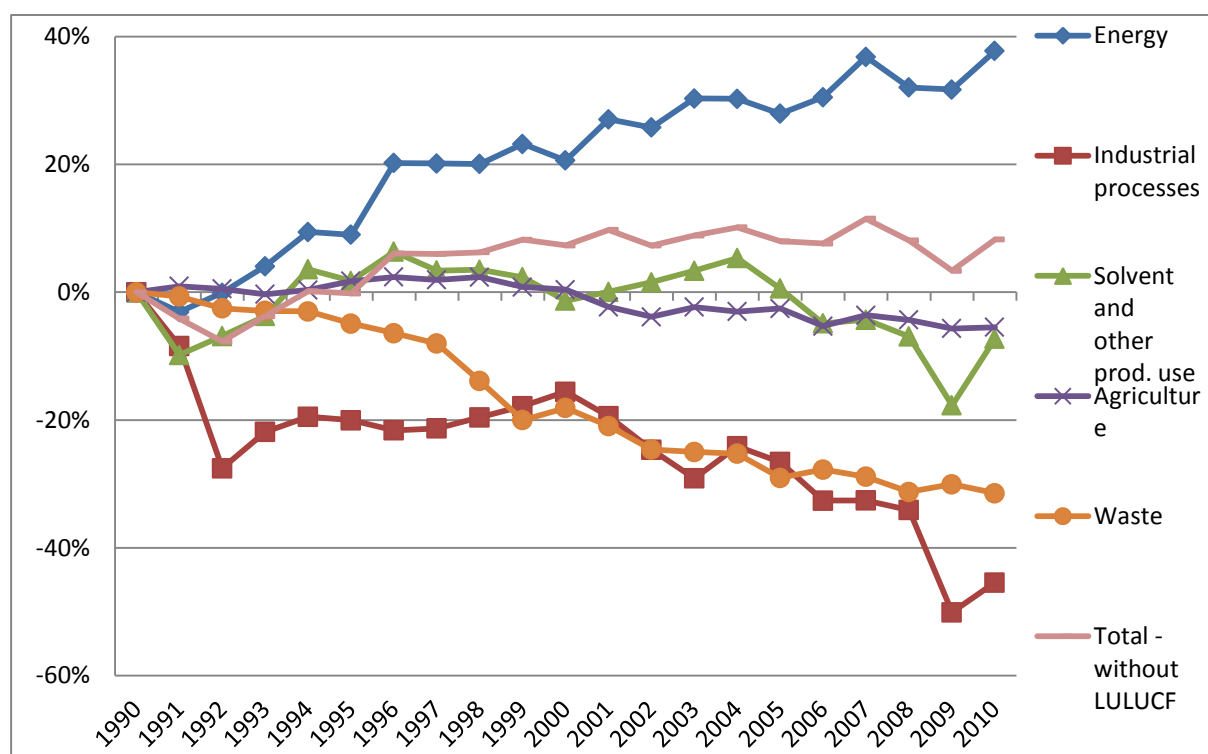


Figure 2.2 Changes in total greenhouse gas emissions by UNFCCC source categories during the period 1990-2010 compared to 1990.

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 CO<sub>2</sub> 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 more than 7 per cent. Looking at the overall trend from 1990 to 2010, it can be seen that the emissions increased by about 8 per cent.

The downward trend in the early 1990's has been primarily due to the decreased consumption of gasoline and fuel oils as well as reduced production of metals. Contributors to this development were the low economic activity during that time and the CO<sub>2</sub>-tax, which was implemented with effect from 1991.

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. The reduction outweighs increased emissions from road traffic and from the production of fertilizer as well as from aluminum production and from the consumption of HFCs.

Emissions in 2003 moved again upward by 1.5 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 almost 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, however, the 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 almost 2 mtonnes CO<sub>2</sub>- equivalents, mostly because of reduced emissions from road traffic and coastal navigation. From 2008 to 2009 the emissions decreased by almost 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.

## 2.2 Emission trends by gas

As shown in Figure 2.3, CO<sub>2</sub> is by far the largest contributor to the total GHG emissions, followed by CH<sub>4</sub>, N<sub>2</sub>O, and then the fluorinated gases PFCs, SF<sub>6</sub> and HFCs. In 2010 the relative contributions to the national totals from the different gases were: CO<sub>2</sub> 84 per cent, CH<sub>4</sub> 8 per cent, N<sub>2</sub>O 6 per cent and fluorocarbons (PFCs, SF<sub>6</sub> and HFCs) 2 per cent. The relative share of CO<sub>2</sub> has increased by approximately 1 per cent each year during the period 2005-2010, from about 80 per cent in 2005 up to 84 per cent in 2010.

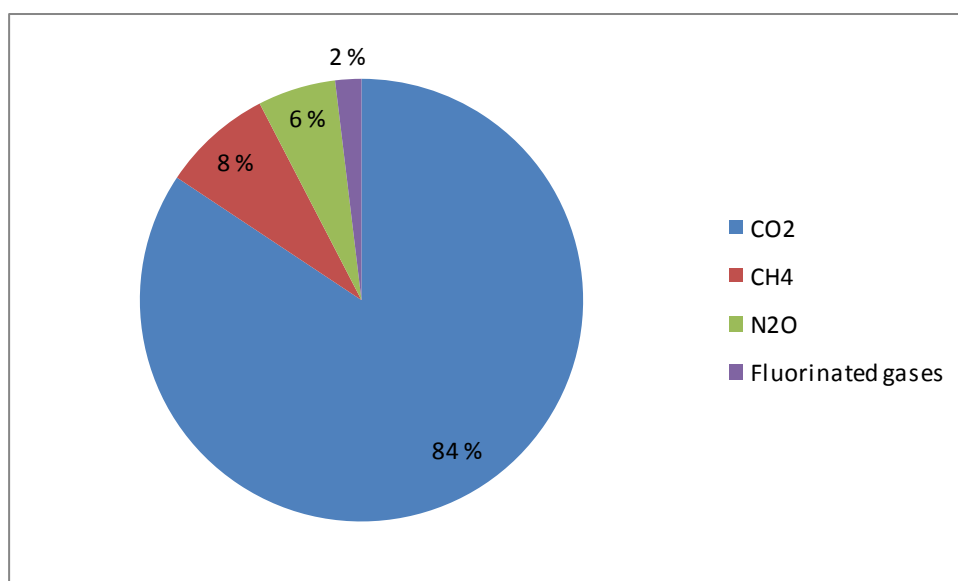


Figure 2.3. Distribution of emissions of greenhouse gases in Norway by gas, 2010.

Source: Statistics Norway/Climate and Pollution Agency

Table 2.2 presents emission figures for all direct greenhouse gases, expressed in absolute emission figures and total CO<sub>2</sub> equivalents.

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*Table 2.2 Emissions of greenhouse gases in Norway during the period 1990-2010. Units: CO<sub>2</sub> and CO<sub>2</sub> eq. in Mtonnes (Mt), CH<sub>4</sub> and N<sub>2</sub>O in ktonnes (kt) and other gases in tonnes (t).*

| Gas  | CO2     | CH4     | N2O     | PFK    |      |     | SF6    | HFK    |     |      |     |       |     |      |      |       | Total without LULUCF |
|------|---------|---------|---------|--------|------|-----|--------|--------|-----|------|-----|-------|-----|------|------|-------|----------------------|
|      |         |         |         | CF4    | C2F6 | 218 |        | 23     | 32  | 125  | 134 | 134a  | 143 | 143a | 152a | 227ea | Mt CO2-eq.           |
| Year | Mtonnes | ktonnes | ktonnes | tonnes |      |     | tonnes | tonnes |     |      |     |       |     |      |      |       |                      |
| 1990 | 34.8    | 222.2   | 15.4    | 467.4  | 36.2 | 0.0 | 91.9   | 0.0    | 0.0 | 0.0  | 0.0 | 0.0   | 0.0 | 0.0  | 0.1  | 0.0   | 49.8                 |
| 1991 | 33.3    | 224.2   | 14.9    | 416.5  | 31.0 | 0.0 | 86.9   | 0.0    | 0.0 | 0.0  | 0.0 | 0.0   | 0.0 | 0.0  | 0.4  | 0.0   | 47.7                 |
| 1992 | 34.2    | 226.9   | 13.1    | 321.6  | 21.4 | 0.0 | 29.4   | 0.0    | 0.0 | 0.0  | 0.0 | 0.2   | 0.0 | 0.0  | 0.7  | 0.0   | 46.0                 |
| 1993 | 35.8    | 229.9   | 13.8    | 324.3  | 20.6 | 0.0 | 30.7   | 0.0    | 0.0 | 0.0  | 0.0 | 1.8   | 0.0 | 0.0  | 0.8  | 0.0   | 47.9                 |
| 1994 | 37.7    | 233.1   | 14.1    | 286.9  | 18.3 | 0.0 | 36.4   | 0.0    | 0.0 | 0.5  | 0.0 | 5.4   | 0.0 | 0.2  | 0.8  | 0.0   | 49.9                 |
| 1995 | 37.8    | 231.8   | 14.2    | 283.3  | 18.1 | 0.0 | 24.9   | 0.0    | 0.0 | 2.4  | 0.0 | 10.2  | 0.0 | 1.5  | 1.0  | 0.0   | 49.7                 |
| 1996 | 41.0    | 232.3   | 14.4    | 258.5  | 16.2 | 0.0 | 23.5   | 0.0    | 0.0 | 5.5  | 0.0 | 16.7  | 0.0 | 3.9  | 1.5  | 0.0   | 52.8                 |
| 1997 | 41.1    | 233.0   | 14.4    | 229.9  | 15.1 | 0.0 | 22.1   | 0.0    | 0.1 | 9.7  | 0.0 | 24.6  | 0.0 | 6.9  | 2.4  | 0.1   | 52.8                 |
| 1998 | 41.3    | 226.5   | 14.5    | 209.8  | 13.3 | 0.0 | 28.2   | 0.1    | 0.3 | 14.8 | 0.0 | 35.7  | 0.0 | 10.5 | 5.6  | 0.1   | 52.9                 |
| 1999 | 42.1    | 219.3   | 15.1    | 196.2  | 12.3 | 0.0 | 34.3   | 0.1    | 0.6 | 20.0 | 0.0 | 50.2  | 0.0 | 14.9 | 8.7  | 0.2   | 53.9                 |
| 2000 | 41.7    | 225.4   | 14.4    | 186.4  | 11.6 | 0.0 | 36.8   | 0.1    | 1.0 | 26.2 | 0.0 | 64.4  | 0.0 | 20.5 | 12.4 | 0.2   | 53.4                 |
| 2001 | 43.1    | 225.7   | 14.1    | 187.5  | 11.9 | 0.0 | 30.8   | 0.1    | 1.5 | 33.4 | 0.0 | 78.8  | 0.0 | 27.1 | 16.4 | 0.3   | 54.7                 |
| 2002 | 42.2    | 217.7   | 14.7    | 201.3  | 14.0 | 0.0 | 9.7    | 0.1    | 2.3 | 39.2 | 0.0 | 95.2  | 0.0 | 32.3 | 19.3 | 0.5   | 53.4                 |
| 2003 | 43.6    | 222.2   | 14.2    | 125.6  | 10.1 | 0.0 | 9.6    | 0.1    | 3.0 | 42.4 | 0.0 | 111.8 | 0.0 | 34.3 | 22.8 | 0.8   | 54.2                 |
| 2004 | 44.0    | 221.3   | 14.7    | 122.1  | 9.4  | 0.0 | 11.3   | 0.1    | 3.8 | 45.3 | 0.1 | 127.6 | 0.0 | 35.9 | 27.0 | 1.0   | 54.8                 |
| 2005 | 43.1    | 212.4   | 14.9    | 116.7  | 7.6  | 0.0 | 12.8   | 0.1    | 4.5 | 47.8 | 0.1 | 149.1 | 0.4 | 37.3 | 31.8 | 1.1   | 53.8                 |
| 2006 | 43.5    | 206.0   | 13.8    | 102.1  | 8.6  | 0.0 | 8.6    | 0.1    | 5.3 | 50.1 | 0.1 | 168.4 | 1.3 | 38.6 | 38.9 | 1.2   | 53.6                 |
| 2007 | 45.5    | 212.9   | 13.3    | 111.7  | 10.3 | 0.0 | 3.0    | 0.1    | 6.4 | 52.4 | 0.1 | 193.3 | 1.7 | 40.0 | 35.4 | 1.2   | 55.5                 |
| 2008 | 44.4    | 207.2   | 11.7    | 104.7  | 10.0 | 0.0 | 2.5    | 0.1    | 7.6 | 55.0 | 0.1 | 226.9 | 1.7 | 41.8 | 38.4 | 1.2   | 53.8                 |
| 2009 | 42.9    | 205.9   | 10.0    | 49.8   | 5.8  | 0.0 | 2.5    | 0.1    | 8.6 | 57.0 | 0.1 | 281.5 | 1.7 | 43.4 | 39.7 | 1.3   | 51.5                 |
| 2010 | 45.5    | 206.9   | 9.9     | 27.3   | 3.0  | 0.0 | 0.0    | 0.2    | 9.3 | 60.1 | 0.1 | 300.4 | 1.8 | 44.5 | 43.3 | 1.5   | 53.9                 |

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 1990–2010, and for 2009-2010.

*Table 2.3. Emissions in Mtonnes CO<sub>2</sub> equivalents and changes in per cent for each greenhouse gas.*

| Year                     | CO <sub>2</sub> | CH <sub>4</sub> | N <sub>2</sub> O | PFCs    | SF <sub>6</sub> | HFCs | Total  |
|--------------------------|-----------------|-----------------|------------------|---------|-----------------|------|--------|
| <b>1990</b>              | 34.8            | 4.7             | 4.7              | 3.4     | 2.2             | 0.0  | 49.8   |
| <b>2009</b>              | 42.9            | 4.3             | 3.0              | 0.4     | 0.1             | 0.7  | 51.3   |
| <b>2010</b>              | 45.5            | 4.4             | 3.1              | 0.2     | 0.1             | 0.7  | 53.9   |
| <b>Changes 1990-2010</b> | 30.6 %          | 6.9%            | -35.5 %          | -93.9 % | -96.6 %         | -    | 8.24 % |
| <b>Change 2009-2010</b>  | 6 %             | 0.5 %           | -1,2%            | -45.6 % | 21.7 %          | 5.5% | 4.71%  |

Source: Statistics Norway/Climate and Pollution Agency

As seen in table 2.2 and 2.3, there has been a significant increase in CO<sub>2</sub> emissions and a significant decrease in emissions of fluorocarbons in the period from 1990 to 2010, except for HFCs which has increased from almost 0 to 0,7 Mtonnes CO<sub>2</sub> equivalent during the period. The fluorocarbons constituted a larger fraction of the greenhouse gas emission total in the early 1990s than that in 2010, while CO<sub>2</sub> represented a smaller share in 1990 than in 2010.

The emissions of CH<sub>4</sub> and N<sub>2</sub>O 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 2010.

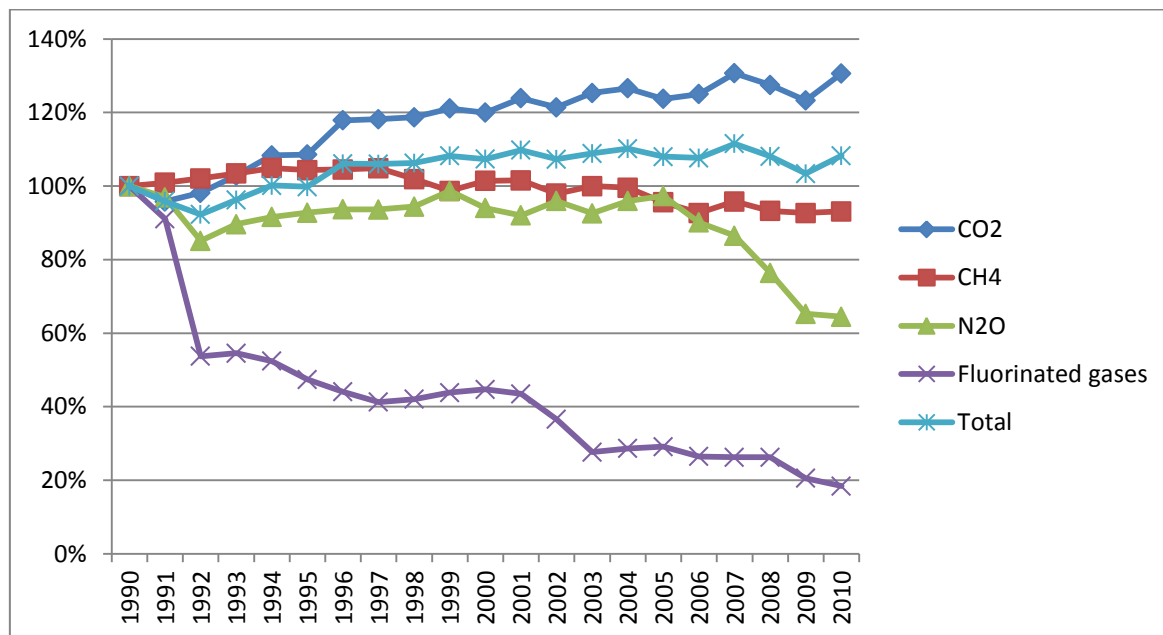


Figure 2.4. Changes in emissions of greenhouse gases by gas in Norway 1990-2010, compared to 1990.

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 CO<sub>2</sub> emissions went up 4.71 per cent from 2009 to 2010, largely because of increased emissions of CO<sub>2</sub>

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

### 2.2.1 Carbon dioxide (CO<sub>2</sub>)

The Norwegian CO<sub>2</sub> emissions originate primarily from industrial sources related to oil and gas extraction, the production of metals, and the transport sector. A relatively large share of the transport-related emissions originates from coastal navigation and the fishing fleet. Since generation of electricity is almost exclusively hydroelectric, emissions from stationary combustion are dominated by industrial sources and internal energy use.

The distribution of CO<sub>2</sub> emissions on various categories is shown in Figure 2.5.

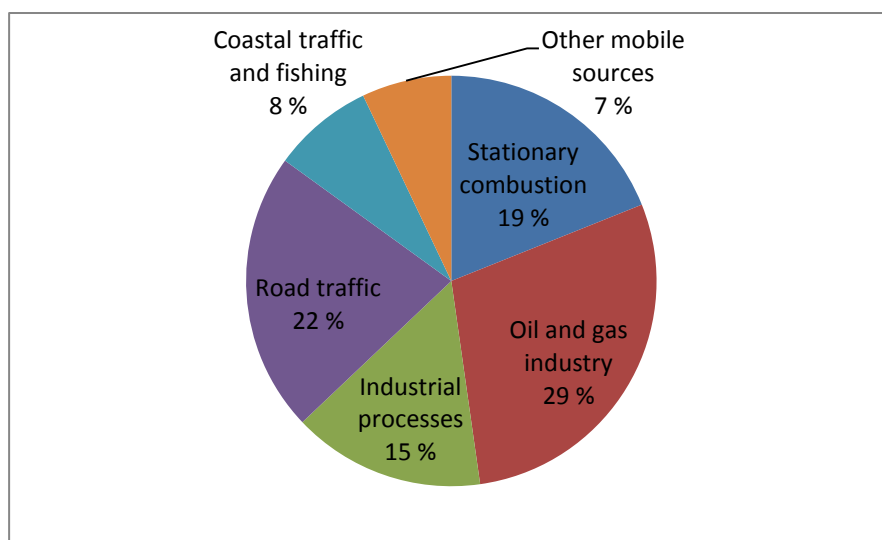


Figure 2.5. Distribution of CO<sub>2</sub> emissions in Norway by source in 2010.

Source: Statistics Norway/Climate and Pollution Agency

Table 2.4 lists CO<sub>2</sub> emissions from each source category for the whole period 1990-2010. The change in emissions from 1990 to 2010 compared to 2010 is displayed in Figure 2.6.

Table 2.4. CO<sub>2</sub> emissions (million tonnes) from different source categories for the period 1990-2010.

| 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                  | 33.3  |
| 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 | 8.4                   | 10.0                 | 7.8                  | 8.6          | 3.9                         | 2.5                  | 41.3  |
| 1999 | 8.2                   | 10.6                 | 7.8                  | 8.5          | 4.1                         | 3.0                  | 42.1  |
| 2000 | 7.1                   | 11.9                 | 8.2                  | 8.4          | 3.7                         | 2.5                  | 41.7  |
| 2001 | 7.5                   | 12.8                 | 7.8                  | 8.9          | 3.5                         | 2.7                  | 43.1  |
| 2002 | 7.4                   | 12.6                 | 7.2                  | 8.9          | 3.4                         | 2.7                  | 42.2  |
| 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                  | 44.0  |
| 2005 | 6.9                   | 13.2                 | 7.4                  | 9.6          | 3.4                         | 2.6                  | 43.1  |
| 2006 | 7.5                   | 12.9                 | 7.0                  | 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                 | 7.2                  | 10.0         | 3.2                         | 3.0                  | 44.4  |
| 2009 | 7.7                   | 13.0                 | 6.0                  | 9.8          | 3.5                         | 2.9                  | 42.9  |
| 2010 | 8.6                   | 13.1                 | 6.9                  | 10.0         | 3.6                         | 3.2                  | 45.5  |

Source: Statistics Norway/Climate and Pollution Agency

In the period from 1990 to 2010 the total emissions of CO<sub>2</sub> increased by 30.6 per cent, or by 10.6 million tonnes. The increases in natural gas use in gas turbines in the oil and gas extraction industry have been the most important contributor to the overall CO<sub>2</sub> increase.

In 2010 the total Norwegian emissions of CO<sub>2</sub> were 45.5 million tonnes, which is an increase of 2.6 million tonnes, or 6 per cent less than in 2009. The sector which is contributing to the majority of the decreased emissions, is industrial processes, with a decrease of over 1 million tonnes, or more than 16 per cent decrease from 2008 to 2009.

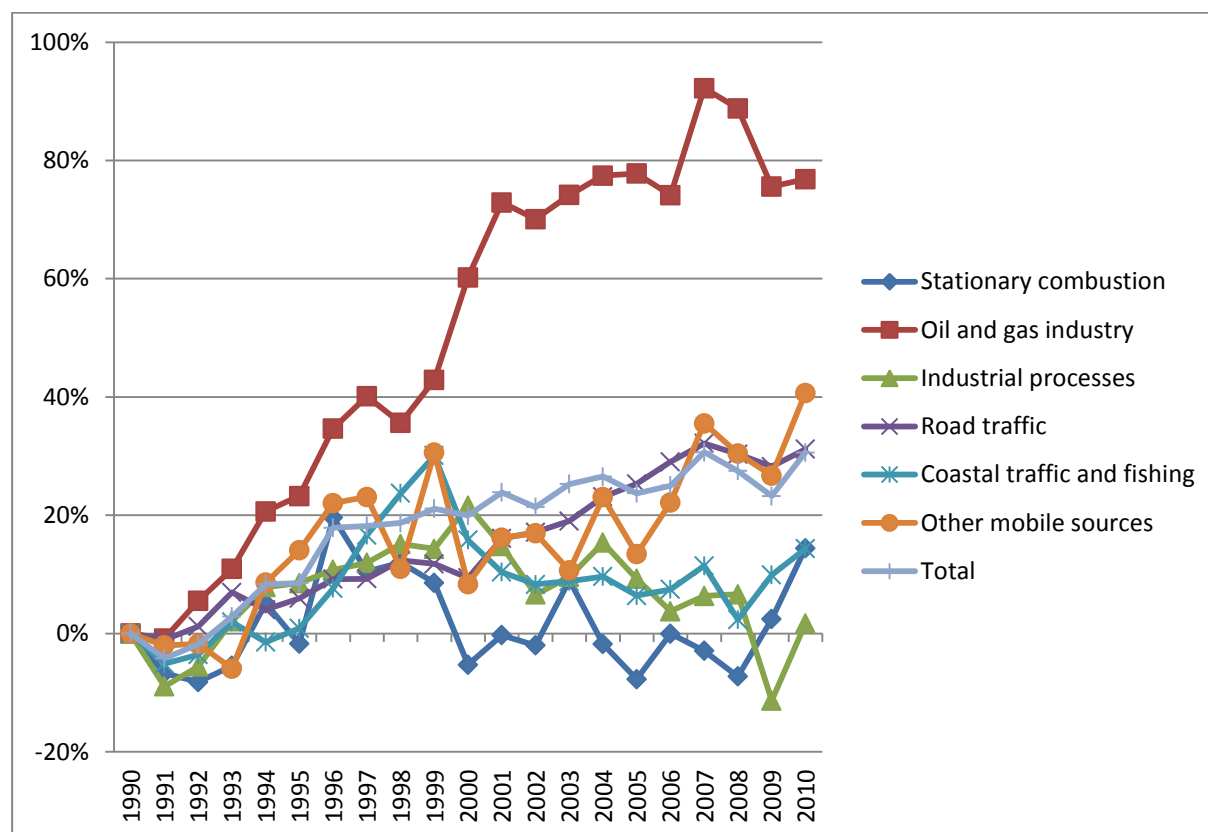


Figure 2.6. Changes in Norwegian CO<sub>2</sub> emissions 1990-2010 for major sources compared to 1990.

Source: Statistics Norway/Climate and Pollution Agency.

Emissions from the oil- and gas industry have increased by about 77 per cent since 1990 as a result of large increases in production volume of oil and gas and the export of natural gas in pipelines. However, emissions per unit produced oil/gas have been decreasing, because of technical and administrative improvements partly induced by a CO<sub>2</sub> taxation regime established in 1991. Nevertheless, this trend has been counteracted in the last few years, due to technical factors related to a shift to older and more marginal oil and gas fields and shift in production from oil to gas. Production of gas is more energy demanding than production of oil. The emissions from oil and gas increased by 1.3 million tonnes from 2006 to 2007, but from 2007 to 2009 the total CO<sub>2</sub>-emissions from this sector decreased by almost the same amount, 1.2 million tonnes. From 2009 to 2010 emissions increases again with almost 0.1 tonnes.

Road transportation has had an increase of 31 per cent CO<sub>2</sub> emission from 1990 to 2010. Although emissions from gasoline vehicles decreased by almost 33 per cent during this period, this fall was counteracted by the significant shift from gasoline to diesel vehicles. Although modern cars have lower emissions per driven km, this has been outweighed by more km driven and larger cars.



Emissions of CO<sub>2</sub> from coastal traffic and fishing are 14 per cent higher in 2010 than in 1990, mainly due to higher activity in the petroleum sector. The substantial increase in the production of Norwegian oil and gas in the North Sea during the 1990s resulted in increased traffic of supply boats to and from the oil platforms until 1999, after which the emissions have been quite stable.

CO<sub>2</sub> emissions from industrial processes increased by 2 per cent from 1990 to 2010, and the sector contributed with 15 per cent of total CO<sub>2</sub> emissions. Approximately 60 per cent of the CO<sub>2</sub> emissions from this sector are from metal production.

The CO<sub>2</sub> emissions from stationary combustion are approximately 19 per cent of the total CO<sub>2</sub> emissions. They have increased by 14 per cent compared to 1990, or by nearly 12 per cent from 2009 to 2010. The latter is both due to increased emissions from gas fired, combined heat and power plant and increased emissions from combustion in production of ferroalloys. The emissions from heating oil, gas for heating etcetera is sensitive to winter temperatures and fuel prices, since many heating systems have the possibility to switch to oil when electricity prices are high.

### 2.2.2 Methane (CH<sub>4</sub>)

About 51 per cent of the methane emissions in 2010 originated from agriculture, and 25 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 15 per cent of the total methane emissions in 2010, the largest fraction of which is releases of methane (venting) during the loading and unloading operations offshore. Other sources include emissions from among others petrol cars, domestic heating, coal mining and oil refineries.

Figure 2.7 illustrates the distribution of Norwegian CH<sub>4</sub>-emissions in 2010.

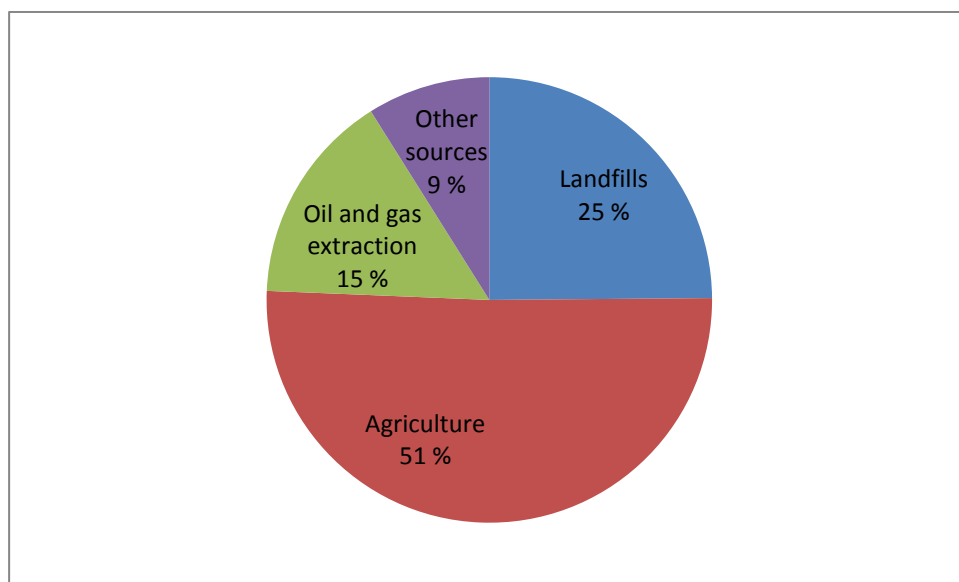


Figure 2.7. Distribution of Norwegian CH<sub>4</sub> emissions in 2010.

Source: Statistics Norway/Climate and Pollution Agency

The methane figures from 1990 to 2010, distributed on the different categories are displayed in table 2.5.

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*Table 2.5. Emissions of CH<sub>4</sub> in Norway 1990-2010. The emissions are given in ktonnes CH<sub>4</sub>.*

| Year | Sectors   |             |                      |               |       |
|------|-----------|-------------|----------------------|---------------|-------|
|      | Landfills | Agriculture | Oil and gas industry | Other sources | Total |
| 1990 | 80.1      | 109.0       | 15.4                 | 17.7          | 222.2 |
| 1991 | 79.6      | 110.6       | 17.5                 | 16.5          | 224.2 |
| 1992 | 78.1      | 110.8       | 22.5                 | 15.5          | 226.9 |
| 1993 | 77.6      | 109.3       | 26.1                 | 16.8          | 229.9 |
| 1994 | 77.4      | 111.1       | 27.8                 | 16.8          | 233.1 |
| 1995 | 75.6      | 112.3       | 27.6                 | 16.3          | 231.8 |
| 1996 | 74.0      | 112.7       | 28.6                 | 16.9          | 232.3 |
| 1997 | 72.3      | 112.1       | 32.0                 | 16.7          | 233.0 |
| 1998 | 67.2      | 113.0       | 30.0                 | 16.2          | 226.5 |
| 1999 | 61.9      | 112.6       | 28.1                 | 16.7          | 219.3 |
| 2000 | 64.3      | 111.0       | 33.1                 | 17.1          | 225.4 |
| 2001 | 61.7      | 108.9       | 38.3                 | 16.8          | 225.7 |
| 2002 | 59.0      | 106.7       | 34.9                 | 17.1          | 217.7 |
| 2003 | 58.4      | 109.3       | 35.8                 | 18.7          | 222.2 |
| 2004 | 58.0      | 107.3       | 39.1                 | 16.8          | 221.3 |
| 2005 | 54.6      | 108.1       | 33.7                 | 16.0          | 212.4 |
| 2006 | 55.5      | 104.3       | 30.4                 | 15.8          | 206.0 |
| 2007 | 54.2      | 106.2       | 34.4                 | 18.0          | 212.9 |
| 2008 | 51.8      | 106.0       | 32.1                 | 17.2          | 207.2 |
| 2009 | 52.6      | 105.3       | 30.8                 | 17.3          | 205.9 |
| 2010 | 51.5      | 105.1       | 31.9                 | 18.5          | 206.9 |

Source: Statistics Norway/Climate and Pollution Agency

The total methane emissions decreased by about 0.5 per cent from 2009 to 2010. During the period 1990-2010 the total CH<sub>4</sub> emissions decreased by almost 7 per cent. Table 2.5 and figure 2.8 show that this decrease is primarily due to decreased emissions from waste treatment, which more than compensated for the growth in emissions from the oil- and gas industry.

The waste volumes have grown during the period from 1990 to 2010, but this effect has been more than offset by increased recycling and incineration of waste and increased burning of methane from landfills.

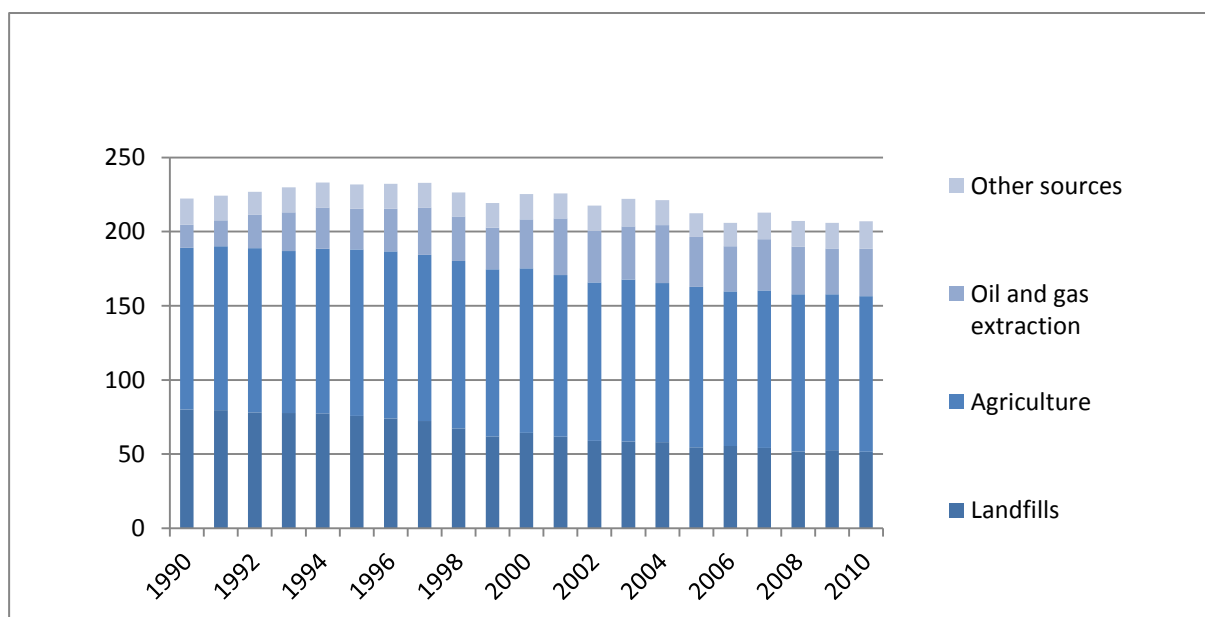


Figure 2.8. CH<sub>4</sub> emissions (ktonnes) for major Norwegian sources between 1990 and 2010.

Source: Statistics Norway/Climate and Pollution Agency

### 2.2.3 Nitrous oxide (N<sub>2</sub>O)

Figure 2.9 shows that 67 per cent of the Norwegian emissions of N<sub>2</sub>O 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 12 per cent of the total. The contribution from road traffic amounted to 2 per cent in 2010. Included under “other” are emissions from e.g. fuel combustion, manure management and waste-water handling.

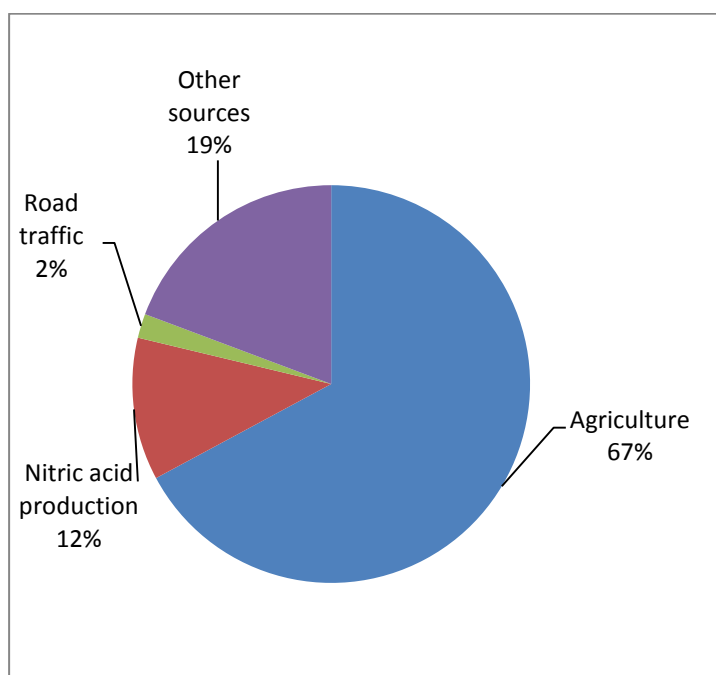


Figure 2.9. Distribution of Norwegian N<sub>2</sub>O emissions by major sources in 2010.

Source: Statistics Norway/Climate and Pollution Agency

The emissions of N<sub>2</sub>O have been relatively stable over the years, the exception being nitric acid production. During the period 1990–2010 the total N<sub>2</sub>O emissions decreased by 36 per cent. From 2009 to 2010 there was a decrease in the emission by approximately 1 per cent, which is due to lower emissions from the fertilizer industry. 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 in 2008 and 2009. Emissions of N<sub>2</sub>O from production of nitric acid decreased by 23 per cent from 2009 to 2010.

*Table 2.6. Emissions of N<sub>2</sub>O (ktonnes) in Norway by major sources 1990-2010.*

| Year | Agriculture | Nitric acid production | Road traffic | Other sources | Total |
|------|-------------|------------------------|--------------|---------------|-------|
| 1990 | 7.1         | 6.7                    | 0.2          | 1.4           | 15.4  |
| 1991 | 7.1         | 6.2                    | 0.2          | 1.4           | 14.9  |
| 1992 | 7.1         | 4.4                    | 0.2          | 1.3           | 13.1  |
| 1993 | 7.1         | 5.1                    | 0.2          | 1.4           | 13.8  |
| 1994 | 7.1         | 5.3                    | 0.2          | 1.5           | 14.1  |
| 1995 | 7.2         | 5.3                    | 0.2          | 1.6           | 14.2  |
| 1996 | 7.2         | 5.2                    | 0.3          | 1.7           | 14.4  |
| 1997 | 7.2         | 5.2                    | 0.3          | 1.7           | 14.4  |
| 1998 | 7.2         | 5.4                    | 0.3          | 1.6           | 14.5  |
| 1999 | 7.0         | 6.2                    | 0.3          | 1.6           | 15.1  |
| 2000 | 7.1         | 5.6                    | 0.3          | 1.5           | 14.4  |
| 2001 | 6.8         | 5.4                    | 0.3          | 1.6           | 14.1  |
| 2002 | 6.8         | 6.2                    | 0.3          | 1.5           | 14.7  |
| 2003 | 6.8         | 5.5                    | 0.3          | 1.6           | 14.2  |
| 2004 | 6.9         | 6.0                    | 0.3          | 1.6           | 14.7  |
| 2005 | 6.9         | 6.3                    | 0.2          | 1.6           | 14.9  |
| 2006 | 6.7         | 5.2                    | 0.2          | 1.7           | 13.8  |
| 2007 | 6.8         | 4.4                    | 0.2          | 1.8           | 13.3  |
| 2008 | 6.7         | 3.0                    | 0.2          | 1.8           | 11.7  |
| 2009 | 6.6         | 1.5                    | 0.2          | 1.7           | 10.0  |
| 2010 | 6.6         | 1.1                    | 0.2          | 1.9           | 9.9   |

*Source: Statistics Norway/Climate and Pollution Agency*

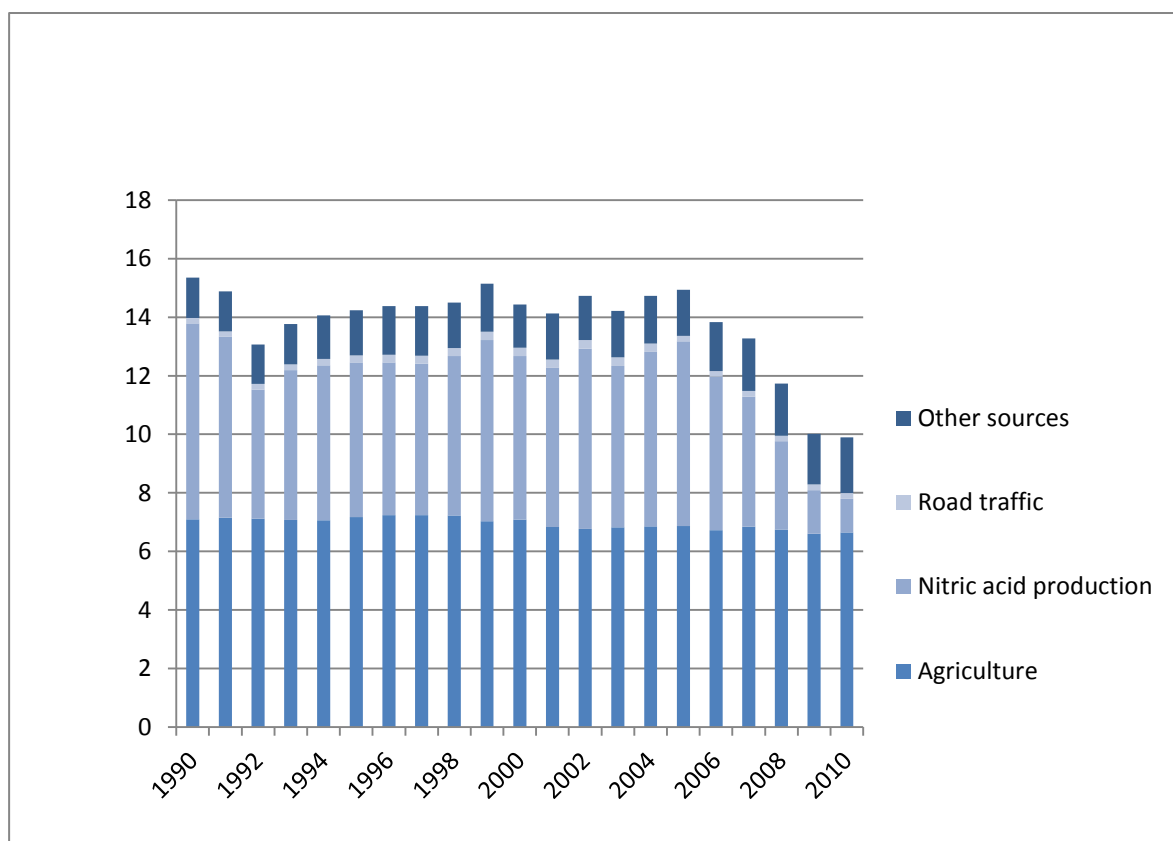


Figure 2.10. Changes in  $N_2O$  emissions for major Norwegian sources between 1990 and 2010.

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 2010 were reported at 27 and 3 tonnes respectively, corresponding to a total of 0.2 million tonnes  $CO_2$  equivalents.

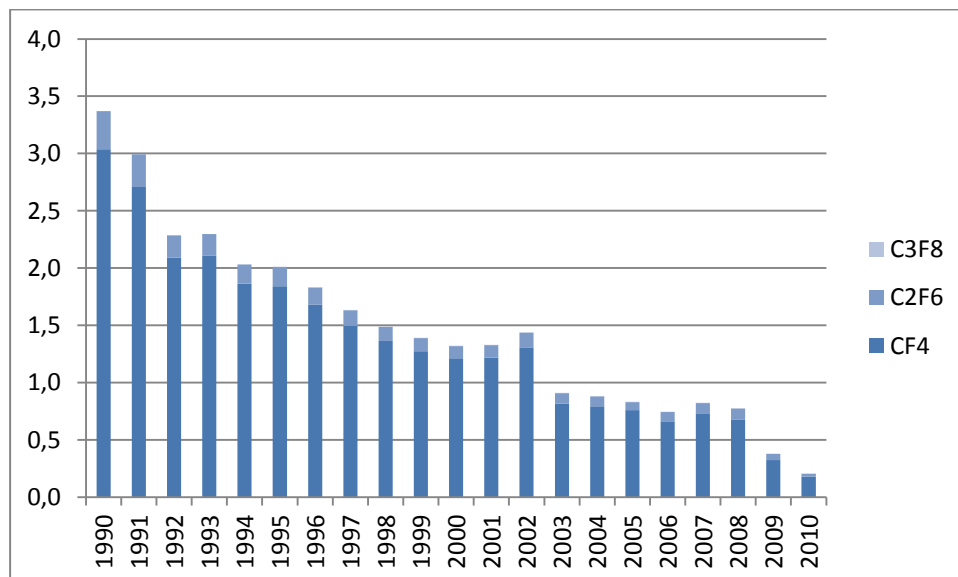
The total emissions of PFCs decreased by 94 per cent in the period 1990-2010 following a steady downward trend as illustrated in Figure 2.11. The emission of  $CF_4$  decreased by 94 per cent, while the emission of  $C_2F_6$  decreased by 92 per cent in the same period. PFCs reduction is caused by improved technology and process control which has led to a significant decrease in the amount of PFCs emitted per tonne aluminium produced during the period 1990-2010. The PFC emissions were 46 per cent lower in 2010 compared to 2009. In 1990, the emissions of PFCs were 3.88 kg  $CO_2$  equivalents per tonne aluminium produced. In 2010, this is reduced 0.19 kg per tonne aluminium. This is a reduction of 95.2 per cent from 1990 to 2010.

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*Table 2.7. Emissions of PFCs in Norway 1990-2010 in tonnes. Total CO<sub>2</sub> eq. are in million tonnes.*

| Year | PFK14 (CF <sub>4</sub> ) | PFK116 (C <sub>2</sub> F <sub>6</sub> ) | PFK218 (C <sub>3</sub> F <sub>8</sub> ) | Total CO <sub>2</sub> eq. |
|------|--------------------------|---|---|---------------------------|
| 1990 | 467.4                    | 36.2                                    | -                                       | 3.37                      |
| 1991 | 416.5                    | 31.0                                    | -                                       | 2.99                      |
| 1992 | 321.6                    | 21.4                                    | -                                       | 2.29                      |
| 1993 | 324.3                    | 20.6                                    | -                                       | 2.30                      |
| 1994 | 286.9                    | 18.3                                    | -                                       | 2.03                      |
| 1995 | 283.3                    | 18.1                                    | 0.0                                     | 2.01                      |
| 1996 | 258.5                    | 16.2                                    | 0.0                                     | 1.83                      |
| 1997 | 229.9                    | 15.1                                    | 0.0                                     | 1.63                      |
| 1998 | 209.8                    | 13.3                                    | 0.0                                     | 1.49                      |
| 1999 | 196.2                    | 12.3                                    | 0.0                                     | 1.39                      |
| 2000 | 186.4                    | 11.6                                    | 0.0                                     | 1.32                      |
| 2001 | 187.5                    | 11.9                                    | 0.0                                     | 1.33                      |
| 2002 | 201.3                    | 14.0                                    | 0.0                                     | 1.44                      |
| 2003 | 125.6                    | 10.1                                    | 0.0                                     | 0.91                      |
| 2004 | 122.1                    | 9.4                                     | 0.0                                     | 0.88                      |
| 2005 | 116.7                    | 7.6                                     | 0.0                                     | 0.83                      |
| 2006 | 102.1                    | 8.6                                     | 0.0                                     | 0.74                      |
| 2007 | 111.7                    | 10.3                                    | 0.0                                     | 0.82                      |
| 2008 | 104.7                    | 10.0                                    | 0.0                                     | 0.77                      |
| 2009 | 49.8                     | 5.8                                     | 0.0                                     | 0.38                      |
| 2010 | 27.3                     | 3.0                                     | 0.0                                     | 0.21                      |

*Source Statistics Norway/Climate and Pollution Agency*



*Figure 2.11. Emissions (million tonnes CO<sub>2</sub>-eq) of PFCs in Norway 1990-2010.*

*Source: Statistics Norway/Climate and Pollution Agency*

### 2.2.5 Sulphur hexafluoride (SF<sub>6</sub>)

Up till 2006 the largest source of SF<sub>6</sub> emissions in Norway was magnesium production. The consumption of SF<sub>6</sub> was reduced through the 1990s due to improvements in technology and process management and reduced production. In 2010, the SF<sub>6</sub> emissions were more than 97 per cent lower than in 1990. The reduction in the SF<sub>6</sub> 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 SF<sub>6</sub> as tracer gas.

The main other use of SF<sub>6</sub> 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 increased with about 22 per cent up to 2010.

*Table 2.8 SF<sub>6</sub> emissions (tonnes) in Norway 1990-2010.*

| 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 | 2.4 | 0.0                              | 0.7   | 3.1   |

*Source Statistics Norway/Climate and Pollution Agency.*

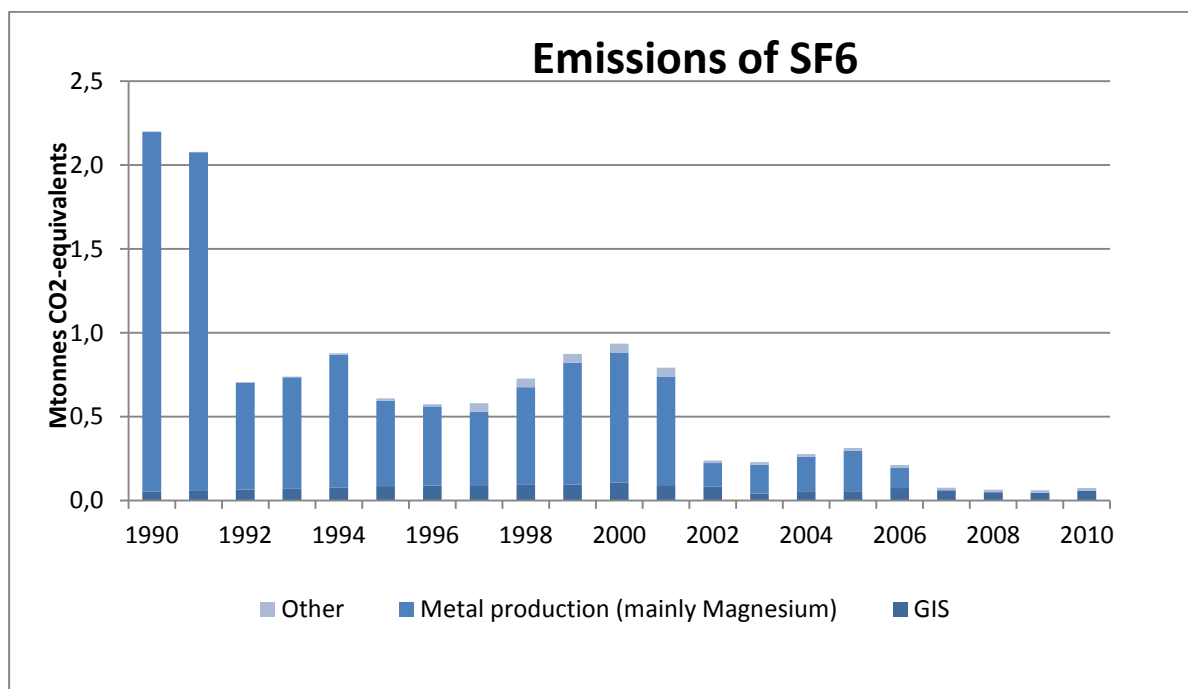


Figure 2.12. Emissions of SF<sub>6</sub> (Mtonnes CO<sub>2</sub> eq.) in Norway 1990-2010.

Source: Statistics Norway/Climate and Pollution Agency

### 2.2.6 Hydrofluorocarbons (HFCs)

The total actual emissions from HFCs used as substitutes for ozone depleting substances amounted to 0.75 million tonnes of CO<sub>2</sub> equivalents in 2010. Compared to the emissions in 2009, this represents an increase of about 6 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 1990-2010. 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 CO<sub>2</sub>-eq.) in Norway 1990-2010 calculated using the Tier 2 methodology.*

| Year | HFK23 | HFK32 | HFK125 | HFK134 | HFK134a | HFK143 | HFK143a | HFK152a | HFK227ea | Total<br>in Mtonnes<br>CO <sub>2</sub> eq. |
|------|-------|-------|--------|--------|---------|--------|---------|---------|----------|--|
| 1990 | 0.0   | 0.0   | 0.0    | 0.0    | 0.0     | 0.0    | 0.0     | 0.1     | 0.0      | 0.00                                       |
| 1991 | 0.0   | 0.0   | 0.0    | 0.0    | 0.0     | 0.0    | 0.0     | 0.4     | 0.0      | 0.00                                       |
| 1992 | 0.0   | 0.0   | 0.0    | 0.0    | 0.2     | 0.0    | 0.0     | 0.7     | 0.0      | 0.00                                       |
| 1993 | 0.0   | 0.0   | 0.0    | 0.0    | 1.8     | 0.0    | 0.0     | 0.8     | 0.0      | 0.00                                       |
| 1994 | 0.0   | 0.0   | 0.5    | 0.0    | 5.4     | 0.0    | 0.2     | 0.8     | 0.0      | 0.01                                       |
| 1995 | 0.0   | 0.0   | 2.4    | 0.0    | 10.2    | 0.0    | 1.5     | 1.0     | 0.0      | 0.03                                       |
| 1996 | 0.0   | 0.0   | 5.5    | 0.0    | 16.7    | 0.0    | 3.9     | 1.5     | 0.0      | 0.05                                       |
| 1997 | 0.0   | 0.1   | 9.7    | 0.0    | 24.6    | 0.0    | 6.9     | 2.4     | 0.1      | 0.09                                       |
| 1998 | 0.1   | 0.3   | 14.8   | 0.0    | 35.7    | 0.0    | 10.5    | 5.6     | 0.1      | 0.13                                       |
| 1999 | 0.1   | 0.6   | 20.0   | 0.0    | 50.2    | 0.0    | 14.9    | 8.7     | 0.2      | 0.18                                       |
| 2000 | 0.1   | 1.0   | 26.2   | 0.0    | 64.4    | 0.0    | 20.5    | 12.4    | 0.2      | 0.24                                       |
| 2001 | 0.1   | 1.5   | 33.4   | 0.0    | 78.8    | 0.0    | 27.1    | 16.4    | 0.3      | 0.30                                       |
| 2002 | 0.1   | 2.3   | 39.2   | 0.0    | 95.2    | 0.0    | 32.3    | 19.3    | 0.5      | 0.36                                       |
| 2003 | 0.1   | 3.0   | 42.4   | 0.0    | 111.8   | 0.0    | 34.3    | 22.8    | 0.8      | 0.40                                       |
| 2004 | 0.1   | 3.8   | 45.3   | 0.1    | 127.6   | 0.0    | 35.9    | 27.0    | 1.0      | 0.44                                       |
| 2005 | 0.1   | 4.5   | 47.8   | 0.1    | 149.1   | 0.4    | 37.3    | 31.8    | 1.1      | 0.48                                       |
| 2006 | 0.1   | 5.3   | 50.1   | 0.1    | 168.4   | 1.3    | 38.6    | 38.9    | 1.2      | 0.52                                       |
| 2007 | 0.1   | 6.4   | 52.4   | 0.1    | 193.3   | 1.7    | 40.0    | 35.4    | 1.2      | 0.57                                       |
| 2008 | 0.1   | 7.6   | 55.0   | 0.1    | 226.9   | 1.7    | 41.8    | 38.4    | 1.2      | 0.62                                       |
| 2009 | 0.1   | 8.6   | 57.0   | 0.1    | 281.5   | 1.7    | 43.4    | 39.7    | 1.3      | 0.71                                       |
| 2010 | 0.2   | 9.3   | 60.1   | 0.1    | 300.4   | 1.8    | 44.5    | 43.3    | 1.5      | 0.75                                       |

*Source Statistics Norway/Climate and Pollution Agency*

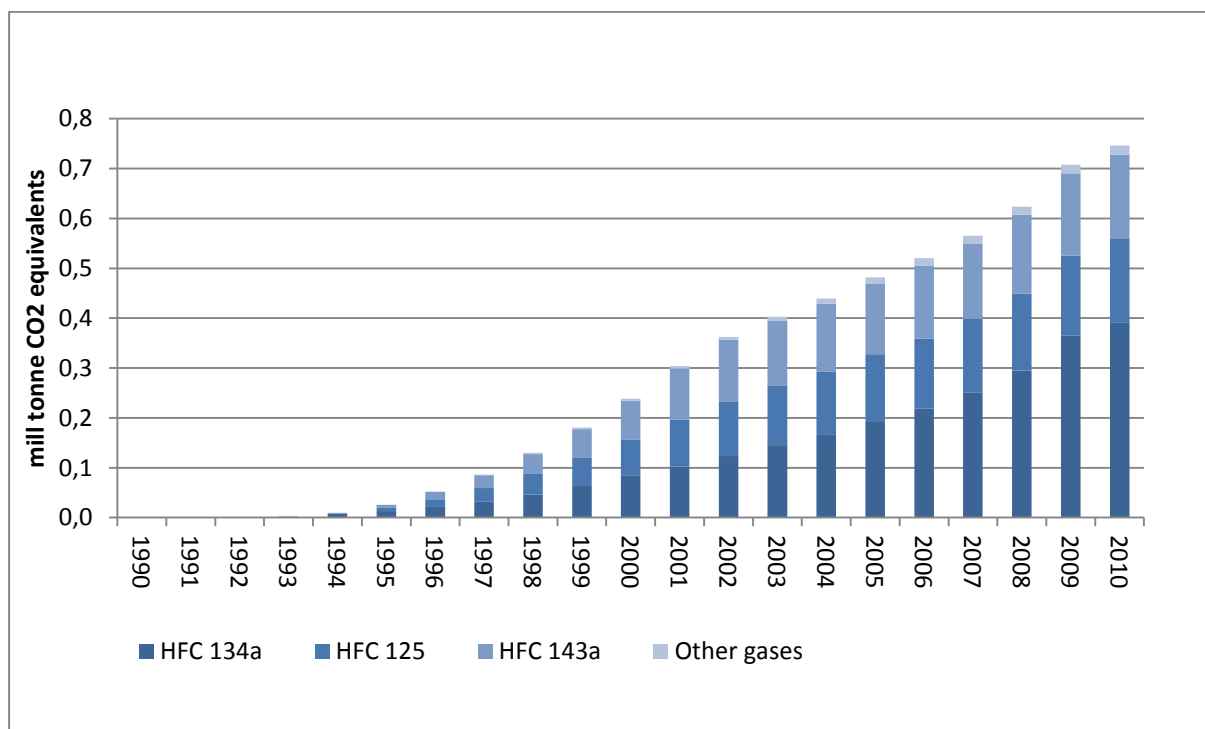


Figure 2.13. Actual emissions of HFCs (Mtonnes CO<sub>2</sub>-eq.) in Norway 1990-2010.

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 2010 in IPCC classification of sources. The Energy sector is by far the most important, contributing with 75.6 per cent of the total emissions.

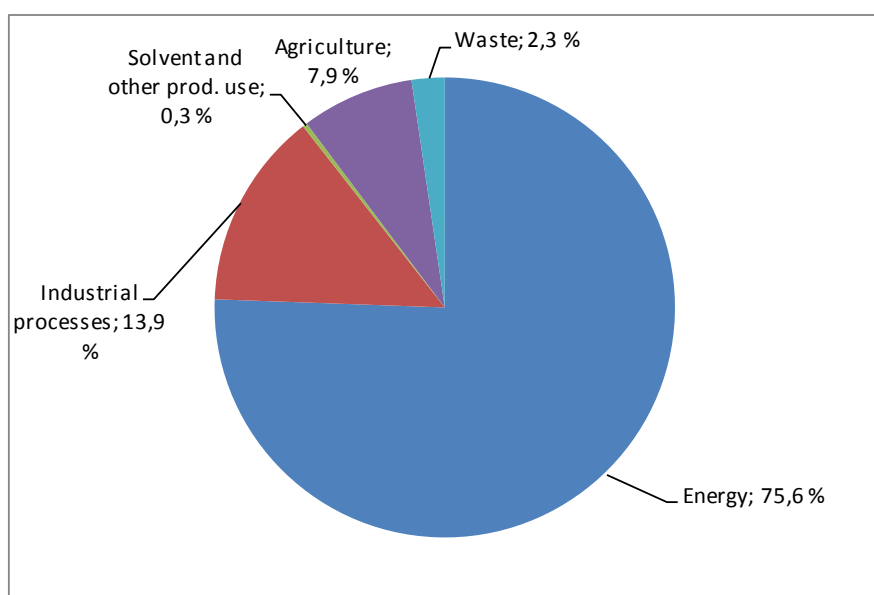


Figure 2.14. Total emissions of GHG in Norway in 2010 by sources.

Source: Statistics Norway/Climate and Pollution Agency

Figure 2.15 shows the changes in greenhouse gas emissions by sectors in the period 1990 to 2010. 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.

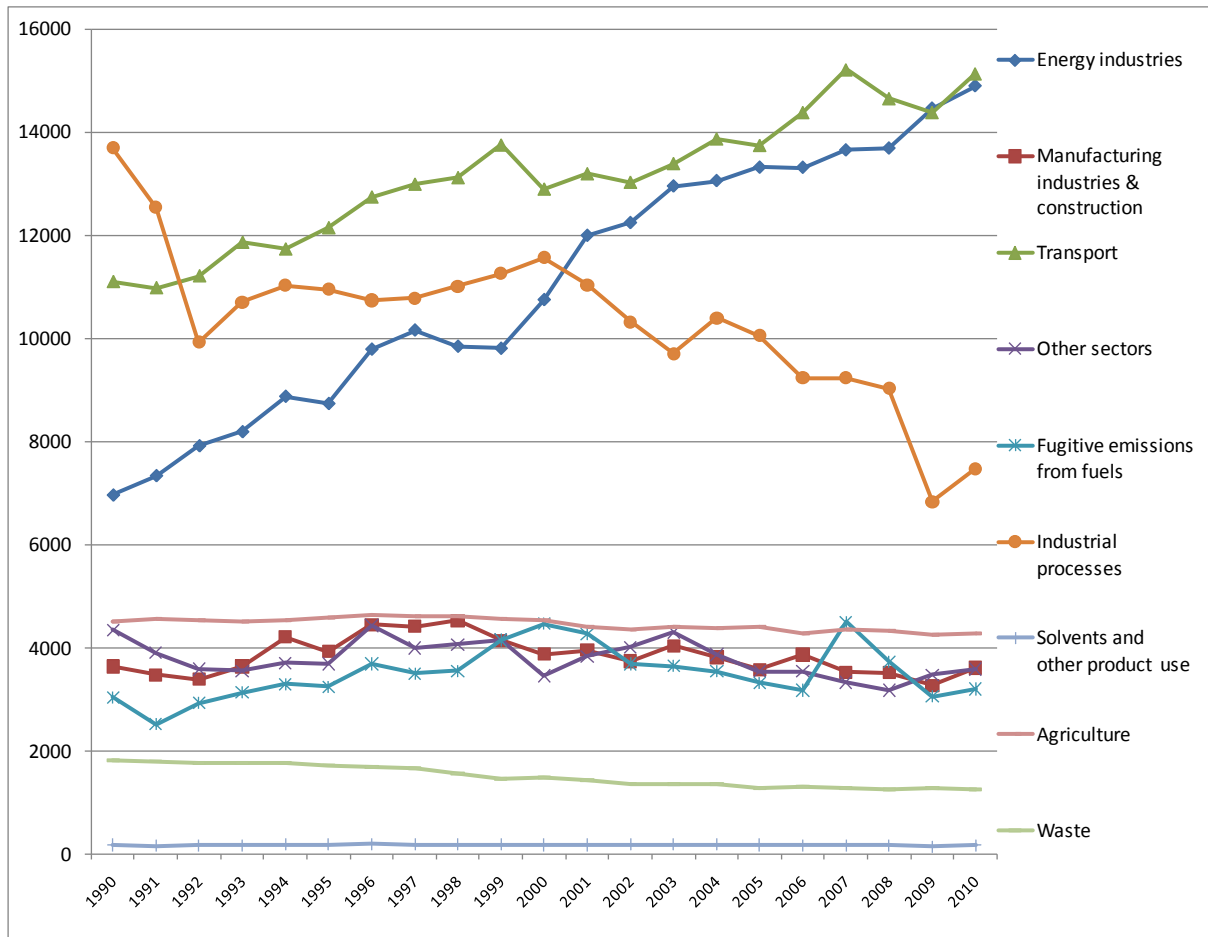


Figure 2.15. Development of emissions of all GHG (Mtonnes CO<sub>2</sub> eq.) from the different sectors.

Source: Statistics Norway/Climate and Pollution Agency

### 2.3.2 Energy

Figure 2.16 displays the distribution of GHG emissions in 2010 on the main sub categories within the energy sources.

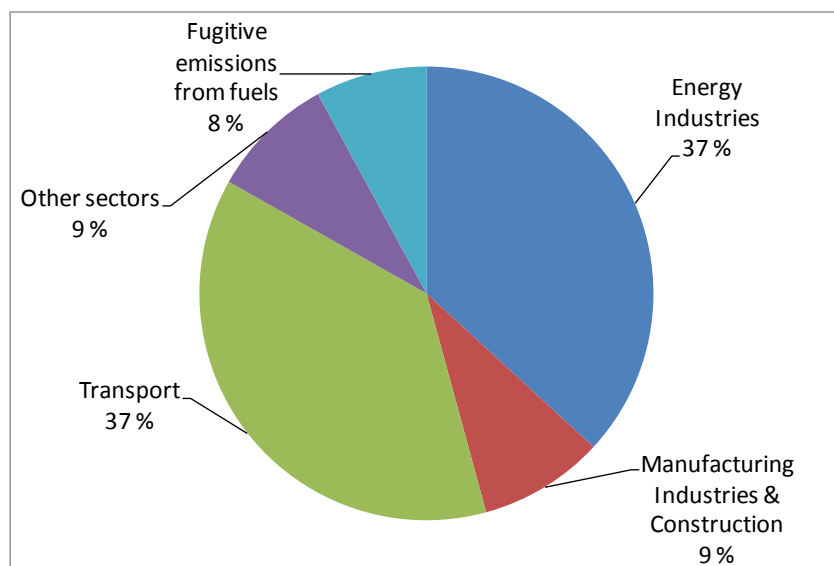


Figure 2.16. Greenhouse gas emissions in 2010 from the energy sector distributed on the different source categories.

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.

Within the energy sector emissions from Energy Industries were in 2009, for the first time since 1990, higher than the emissions in Transport, though marginally. In 2010 the energy sector had 36.8 per cent of the sectors emissions, while the transport sector had approximately 37.5 per cent. The energy sector is almost completely dominated by fuel combustion in the oil and gas extraction and related activities.

The total emissions of greenhouse gases from the energy sector over the period 1990-2010 are listed in Table 2.10. The emission changes detected in the various source categories in the energy sector between 1990 and 2010 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 CO<sub>2</sub>-eq.) from the energy sector in Norway 1990-2010.*

| Year | Energy Industries | Manufacturing Industries & Construction | Transport | Other sectors <sup>1</sup> | Fugitive emissions from fuels | Total |
|------|-------------------|---|-----------|----------------------------|-------------------------------|-------|
| 1990 | 7.0               | 3.6                                     | 11.1      | 4.3                        | 3.0                           | 29.6  |
| 1991 | 7.3               | 3.5                                     | 11.0      | 3.9                        | 2.5                           | 28.6  |
| 1992 | 7.9               | 3.4                                     | 11.2      | 3.6                        | 2.9                           | 29.5  |
| 1993 | 8.2               | 3.6                                     | 11.9      | 3.6                        | 3.1                           | 30.8  |
| 1994 | 8.9               | 4.2                                     | 11.7      | 3.7                        | 3.3                           | 32.4  |
| 1995 | 8.7               | 3.9                                     | 12.1      | 3.7                        | 3.2                           | 32.2  |
| 1996 | 9.8               | 4.5                                     | 12.7      | 4.4                        | 3.7                           | 35.5  |
| 1997 | 10.2              | 4.4                                     | 13.0      | 4.0                        | 3.5                           | 35.5  |
| 1998 | 9.9               | 4.5                                     | 13.1      | 4.1                        | 3.6                           | 35.5  |
| 1999 | 9.8               | 4.1                                     | 13.8      | 4.2                        | 4.2                           | 36.4  |
| 2000 | 10.8              | 3.9                                     | 12.9      | 3.5                        | 4.5                           | 35.7  |
| 2001 | 12.0              | 4.0                                     | 13.2      | 3.8                        | 4.3                           | 37.6  |
| 2002 | 12.2              | 3.7                                     | 13.0      | 4.0                        | 3.7                           | 37.2  |
| 2003 | 13.0              | 4.0                                     | 13.4      | 4.3                        | 3.7                           | 38.5  |
| 2004 | 13.1              | 3.8                                     | 13.9      | 3.9                        | 3.5                           | 38.5  |
| 2005 | 13.3              | 3.6                                     | 13.7      | 3.5                        | 3.3                           | 37.8  |
| 2006 | 13.3              | 3.9                                     | 14.4      | 3.5                        | 3.2                           | 38.6  |
| 2007 | 13.7              | 3.5                                     | 15.2      | 3.3                        | 4.5                           | 40.5  |
| 2008 | 13.7              | 3.5                                     | 14.7      | 3.2                        | 3.7                           | 39.0  |
| 2009 | 14.5              | 3.3                                     | 14.4      | 3.5                        | 3.1                           | 38.9  |
| 2010 | 14.9              | 3.6                                     | 15.1      | 3.6                        | 3.2                           | 40.7  |

*Source: Statistics Norway/Climate and Pollution Agency*

<sup>1</sup> 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).

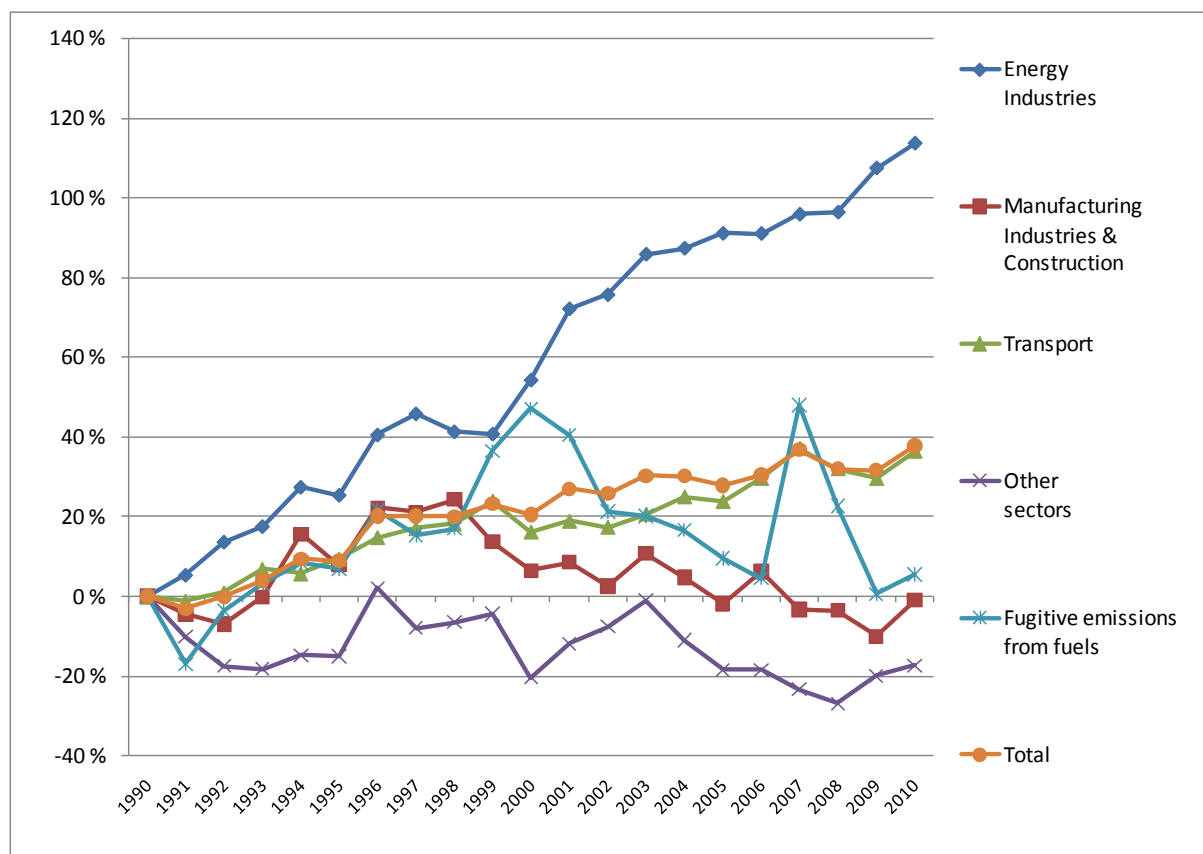


Figure 2.17. Changes in emissions in the various source categories in the energy sector between 1990 and 2010 compared to the 1990 level.

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 38 per cent from 1990 to 2010, primarily due to increased activity in the sectors of oil and gas extraction and transport, specifically road transport. The energy sector's emissions increased by 4.6 per cent from 2009 to 2010. 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 1 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** have increased by almost 114 per cent from 1990 to 2010, and 3 per cent from 2009 to 2010. The increase in 2010 was due to that the CO<sub>2</sub> emissions from gas fired electricity power plants increased by approximately half a million ton. The main emission source, however is the oil and gas extraction sector. 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 2010 the emissions from energy use in offshore oil and gas extraction contributed with more than 20 per cent of the total GHG emissions in Norway. In 1990 the corresponding

contribution was 11 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 combustion<sup>2</sup> 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 0.9 per cent from 1990 to 2010, while the increase from 2009 to 2010 also was more than 20 per cent.

Emissions from **Transport** showed an overall increase by more than 36 per cent from 1990 to 2010, while the emissions increased by more than 5 per cent from 2009 to 2010. The share of transport in the total GHG emissions has increased from 22 per cent in 1990 to about 28 per cent in 2010. Road transportation accounts for almost 67 per cent of the total mobile emissions, while emissions from navigation and civil aviation accounts for some 14 and 7 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 11 per cent of the emissions from the source transport, and it has increased by 107 per cent in the period 1990-2010.

Emissions of GHG from road traffic increased by 30 per cent from 1990 to 2010. Between 2008 and 2010 emissions increased by almost 2 per cent. Road traffic contributed to the total national GHG emissions by almost 19 per cent. This trend is mainly due to increased activity in goods transport and taxi industry, as a response to higher economic activity compared to 2008 and 2009. The decrease from 2007 to 2009 could in addition to decreased activity also be explained by switching from petrol to diesel driven personnel cars due to the CO<sub>2</sub> differentiated tax on new personnel cars that was implemented in 2007. In addition the consumption of bio diesel and bioethanol increased and hence the CO<sub>2</sub> emission.

Emissions from navigation increased by around 26 % per cent from 1990 to 2010, mainly because of increased activity related to the oil- and gas extraction sector. Navigation contributed to the total national GHG emissions by 4 per cent in 2010.

Emissions from civil aviation have increased by more than 60 per cent since 1990. The substitution of older planes with new and more energy efficient planes has played an important role to limit the emission growth. Civil aviation contributed to the total national GHG emissions by about 2 per cent in 2010. The average annual growth in emissions in the period 1990-2010 was 2.4 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 substantially higher in the 90ies than it has been the last ten years.

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<sup>2</sup> 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.

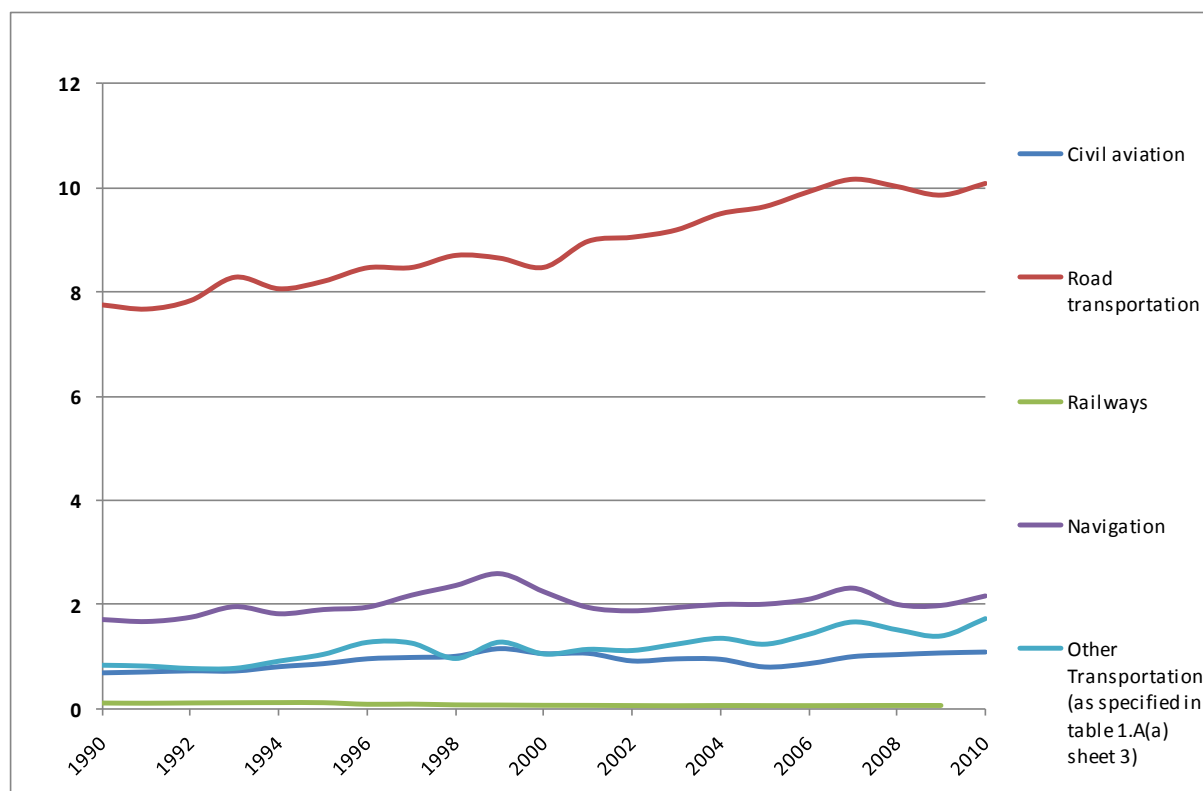


Figure 2.18. Changes in CO<sub>2</sub>-emissions from different modes of transport in 1990-2010.

Source: Statistics Norway/Climate and Pollution Agency.



Table 2.11. Total emissions of greenhouse gases from the transport sector in Norway 1990-2009. Million tonnes CO<sub>2</sub> 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                | 0.11     | 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           | 9.65                | 0.05     | 2.01       | 1.24                 | 13.75           |
| 2006 | 0.87           | 9.94                | 0.05     | 2.10       | 1.43                 | 14.39           |
| 2007 | 1.01           | 10.18               | 0.05     | 2.31       | 1.67                 | 15.22           |
| 2008 | 1.05           | 10.04               | 0.05     | 2.00       | 1.52                 | 14.66           |
| 2009 | 1.08           | 9.87                | 0.05     | 1.98       | 1.40                 | 14.39           |
| 2010 | 1.10           | 10.10               | 0.04     | 2.16       | 1.74                 | 15.14           |

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 emission from this sector was 3.6 million tonnes CO<sub>2</sub> equivalents in 2010. The emissions decreased by more than 17 percent from 1990 to 2010 and increased by 3.2 percent during 2020. The latter was due to increased activity in fisheries. Fuel combustion in agriculture, forestry and fisheries accounts for about 56 per cent of the emissions of this sector.

Greenhouse gas emissions from residential sources accounted in 2010 for about 22 per cent of this sector's total. Emissions were about 47 per cent less in 2010 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

Emissions from commercial/institutional sources make up the last 2 per cent of this category. There has been about 2 per cent decrease from 1990 to 2010, and an increase of around 1 per cent from 2009 to 2010.

The source category termed **Fugitive emissions from fuels** refers to emissions from oil and gas activities such as flaring of natural gas, leakages and venting of methane. Indirect CO<sub>2</sub> emissions from NMVOC emitted during the loading and unloading of oil tankers are also accounted for in this category. Fugitive emissions from fuels contribute 6 per cent to the total GHG emissions in Norway in 2010 and with 8 per cent of the GHG emissions in the energy sector. The emissions in the sector increased by about 5 percent from 2009 to 2010.

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 almost 14 per cent of the national greenhouse gas emissions in 2010. The emissions from this source category have decreased by 55 per cent from 1990 to 2010 and increased by 9.3 per cent from 2009 to 2010.

Metal production is the main source of process related industrial emissions for both CO<sub>2</sub> and other greenhouse gases such as N<sub>2</sub>O (fertiliser production), SF<sub>6</sub> (magnesium foundries) and PFCs (aluminium production), contributing with about 61 per cent of the total emissions from Industrial processes. Mineral Product and Chemical Industry are the two other main contributing sectors in 2010 with about 14 and 12 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 2010. Table 2.11 provides figures for the total greenhouse gas emissions from the Industry sector for the same period.

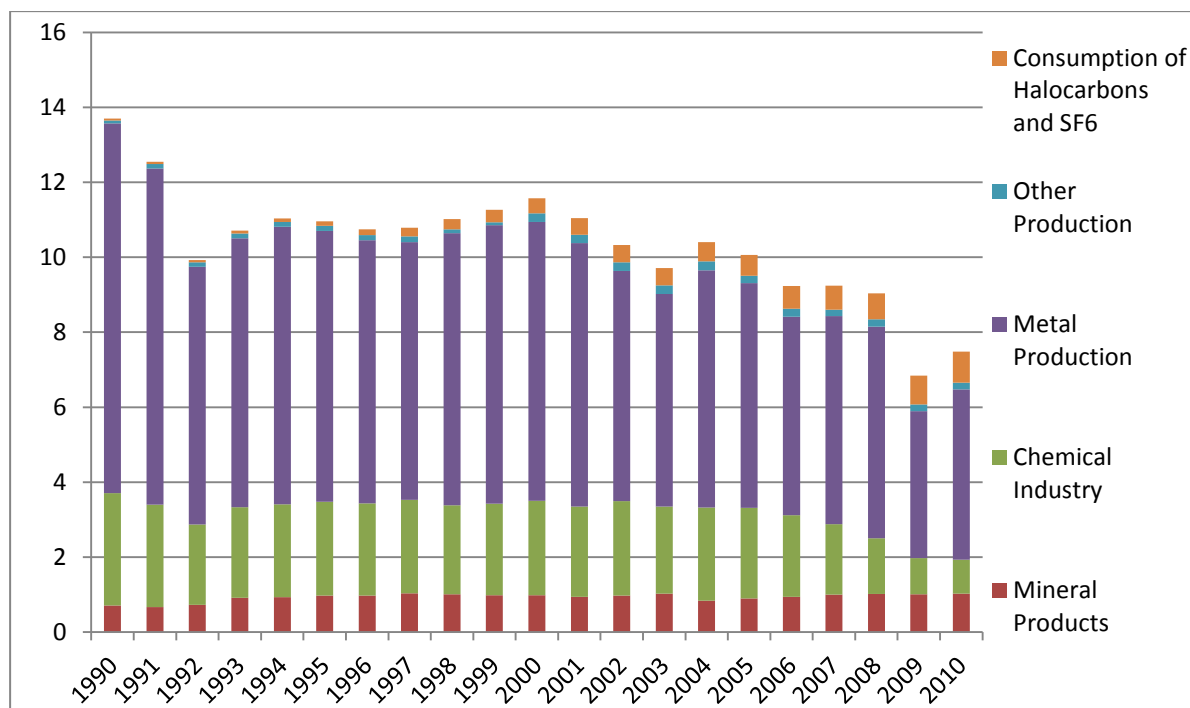


Figure 2.19. Total greenhouse gas emissions (Mtonnes CO<sub>2</sub>-eq.) in the industrial source categories in Norway during the period 1990-2010.

Source: Statistics Norway/Climate and Pollution Agency

Table 2.12. Total greenhouse gas emissions (Mtonnes CO<sub>2</sub>-eq.) from the industry sector in Norway 1990-2010.

| Year | Mineral Products | Chemical Industry | Metal Production | Other Production | Consumption of Halocarbons and SF <sub>6</sub> | Total |
|------|------------------|-------------------|------------------|------------------|--|-------|
| 1990 | 0.7              | 3.0               | 9.9              | 0.1              | 0.1  | 13.7  |
| 1991 | 0.7              | 2.7               | 9.0              | 0.1              | 0.1  | 12.6  |
| 1992 | 0.7              | 2.1               | 6.9              | 0.1              | 0.1  | 9.9   |
| 1993 | 0.9              | 2.4               | 7.2              | 0.1              | 0.1  | 10.7  |
| 1994 | 0.9              | 2.5               | 7.4              | 0.1              | 0.1  | 11.0  |
| 1995 | 1.0              | 2.5               | 7.2              | 0.1              | 0.1  | 11.0  |
| 1996 | 1.0              | 2.5               | 7.0              | 0.1              | 0.2  | 10.7  |
| 1997 | 1.0              | 2.5               | 6.9              | 0.2              | 0.2  | 10.8  |
| 1998 | 1.0              | 2.4               | 7.3              | 0.1              | 0.3  | 11.0  |
| 1999 | 1.0              | 2.4               | 7.4              | 0.1              | 0.3  | 11.3  |
| 2000 | 1.0              | 2.5               | 7.4              | 0.2              | 0.4  | 11.6  |
| 2001 | 0.9              | 2.4               | 7.0              | 0.2              | 0.4  | 11.0  |
| 2002 | 1.0              | 2.5               | 6.1              | 0.2              | 0.5  | 10.3  |
| 2003 | 1.0              | 2.3               | 5.7              | 0.2              | 0.5  | 9.7   |
| 2004 | 0.8              | 2.5               | 6.3              | 0.2              | 0.5  | 10.4  |
| 2005 | 0.9              | 2.4               | 6.0              | 0.2              | 0.6  | 10.1  |
| 2006 | 0.9              | 2.2               | 5.3              | 0.2              | 0.6  | 9.2   |
| 2007 | 1.0              | 1.9               | 5.6              | 0.2              | 0.6  | 9.2   |
| 2008 | 1.0              | 1.5               | 5.6              | 0.2              | 0.7  | 9.0   |
| 2009 | 1.0              | 1.0               | 3.9              | 0.2              | 0.8  | 6.8   |
| 2010 | 1.0              | 0.9               | 4.5              | 0.2              | 0.8  | 7.5   |

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 2010, and the sector contributed with approximately 61 per cent of the emissions from Industrial Processes. The largest contributor to the GHG emissions from Metal Production in 2010 is aluminium production and ferroalloys.

There are seven plants in Norway producing aluminium. PFCs emissions from production of aluminium contributed in 1990 to almost 7 per cent of the total GHG emissions in Norway. The share of the total in 2010 is reduced to around 0.5 per cent. Emissions of PFCs have decreased with almost 94 per cent from 1990 to 2010 and between 2009 and 2010 the emissions have decreased by 46 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 2010.

The GHG emissions (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) from ferroalloy production accounted for more than 5 per cent of the national total GHG emissions in 1990 and 4 per cent in 2010, a decrease by almost 15 per cent since 1990. From 2009 to 2010 GHG emissions from ferroalloys increased by approximately 50.2 per cent.

SF<sub>6</sub> 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 SF<sub>6</sub> emissions is due to the closing down of production of cast magnesium in 2002, improvements in the GIS-sector and an almost end in the use of SF<sub>6</sub> 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 2 per cent in 2010. The emissions from the sector increased with 45 per cent from 1990-2010, mainly due to increased production of clinker and lime. Emissions increased by 1.8 per cent from 2009-2010. Cement is produced in two plants in Norway, releasing CO<sub>2</sub> emissions from coal and waste used in direct fired furnaces, and from carbon in limestone. In 2010, the CO<sub>2</sub> emissions from clinker 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. From 1990-2001 the CO<sub>2</sub> emissions from clinker production increased by 18 per cent, and from 2009 to 2010 the CO<sub>2</sub> emission increased by 10.4 per cent.

**The chemical industry** accounted for 12 per cent of the emissions in this sector. The emissions decreased with more than 70 per cent in the period 1990-2010. From 2009 to 2010 the emissions decreased by almost 6.2 per cent. In Norway, this category includes primarily production of fertilizers and silicon carbide. These processes release N<sub>2</sub>O (from nitric acid production) and CO<sub>2</sub> (from production of ammonia and carbides). The N<sub>2</sub>O emissions from production of nitric acid accounted for 0.7 per cent of the total GHG emissions in 2010, and approximately 5 per cent of the GHG emissions in sector Industrial processes. The N<sub>2</sub>O emissions have decreased by almost 83 per cent from 1990 to 2010 while the production of nitric acid increased by more than 24 per cent. The emission reduction is due to improved technology in the nitric acid production. Corresponding changes from 2009 to 2010 was a decrease in N<sub>2</sub>O emissions by almost 23 per cent and more than 43 per cent increase in production.

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 SF<sub>6</sub>**. The emissions constitute almost 11 per cent of the emissions from the industry sector, and from 2009 to 2010 the emissions increased by some 7 per cent. The tax on HFCs introduced in 2003 has moderated this growth somewhat (Statistics Norway (2007b)). Electrical switchgears and the use of SF<sub>6</sub> as trace gas are the most important sources of non-process emissions of SF<sub>6</sub>. Norway does not manufacture halocarbons or SF<sub>6</sub>.

#### 2.3.4 Solvent and other product use

Use of solvents and products containing solvents result in emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidize to CO<sub>2</sub>.

In 2010, the total emissions from solvents and other product use were about 0.2 million tonnes of CO<sub>2</sub> equivalents. This represented approximately 0.3 per cent of the total GHG emissions in 2010. The emissions have decreased by around 7 per cent compared to 1990 and have increased by almost 13 per cent from 2009.

### 2.3.5 Agriculture

In 2010, about 8 per cent of the total Norwegian emissions of greenhouse gases (GHG) originated from agriculture. This corresponds to approximately 4.3 million tonnes CO<sub>2</sub> equivalents. The emissions from agriculture are quite stable with minor fluctuations. The emissions are about 5 per cent lower in 2010 than in 1990, and 0.2 per cent lower than in 2009.

The sectors clearly largest sources of GHGs are “agricultural soils” (N<sub>2</sub>O) from domestic animals, contributing with 45 per cent, and “enteric fermentation” (CH<sub>4</sub>), contributing with 44 per cent of the sectors emissions. Manure management contributes with 10 per cent. These sources are also key categories.

Enteric fermentation contributed with 1892 Ktonnes CO<sub>2</sub> equivalents in 2010, which is approximately 4 per cent of the national GHG emissions. Enteric fermentation constitutes 86 per cent of the overall CH<sub>4</sub> emissions from agriculture.

CH<sub>4</sub>-emissions due to **manure management** amounted to 315 Ktonnes CO<sub>2</sub> equivalents, and N<sub>2</sub>O-emissions due to manure management amounted to 130 Ktonnes CO<sub>2</sub> equivalents in 2010. In 2010, manure management emitted 1 per cent of the Norwegian emissions of GHGs. Emissions of GHGs from manure management increased by more than 3 per cent in the period 1990-2010 and increased by almost 0.1 % from 2009 to 2010.

The emissions of N<sub>2</sub>O in Norway from **agricultural soils** amounted to 1.9 million tonnes, calculated in CO<sub>2</sub> equivalents. They accounted for about 63 per cent of the total Norwegian N<sub>2</sub>O emissions in 2010 or about 3.6 per cent of the total Norwegian GHG emissions that year.

Emissions of N<sub>2</sub>O from agricultural soils are a key category because of uncertainty, both in level and trend. During the period 1990-2009 emissions decreased by 6.5 per cent. From 2009 to 2010 the emissions increased by 0.6 per cent.

Table 2.13. Total greenhouse gas emissions (Mtonnes CO<sub>2</sub>-eq.) from the agricultural sector in Norway 1990-2010.

| Year | Enteric Fermentation | Manure Management | Agricultural Soils | Field Burning of Agricultural Residues | Total |
|------|----------------------|-------------------|--------------------|--|-------|
| 1990 | 2.0                  | 0.4               | 2.1                | 0.0                                    | 4.5   |
| 1991 | 2.0                  | 0.4               | 2.1                | 0.0                                    | 4.6   |
| 1992 | 2.0                  | 0.4               | 2.1                | 0.0                                    | 4.5   |
| 1993 | 2.0                  | 0.4               | 2.1                | 0.0                                    | 4.5   |
| 1994 | 2.0                  | 0.5               | 2.0                | 0.0                                    | 4.5   |
| 1995 | 2.0                  | 0.5               | 2.1                | 0.0                                    | 4.6   |
| 1996 | 2.0                  | 0.5               | 2.1                | 0.0                                    | 4.6   |
| 1997 | 2.0                  | 0.5               | 2.1                | 0.0                                    | 4.6   |
| 1998 | 2.0                  | 0.5               | 2.1                | 0.0                                    | 4.6   |
| 1999 | 2.0                  | 0.5               | 2.0                | 0.0                                    | 4.6   |
| 2000 | 2.0                  | 0.5               | 2.0                | 0.0                                    | 4.5   |
| 2001 | 2.0                  | 0.5               | 2.0                | 0.0                                    | 4.4   |
| 2002 | 1.9                  | 0.4               | 2.0                | 0.0                                    | 4.3   |
| 2003 | 2.0                  | 0.4               | 2.0                | 0.0                                    | 4.4   |
| 2004 | 1.9                  | 0.4               | 2.0                | 0.0                                    | 4.4   |
| 2005 | 2.0                  | 0.4               | 2.0                | 0.0                                    | 4.4   |
| 2006 | 1.9                  | 0.4               | 2.0                | 0.0                                    | 4.3   |
| 2007 | 1.9                  | 0.4               | 2.0                | 0.0                                    | 4.4   |
| 2008 | 1.9                  | 0.4               | 2.0                | 0.0                                    | 4.3   |
| 2009 | 1.9                  | 0.4               | 1.9                | 0.0                                    | 4.3   |
| 2010 | 1.9                  | 0.4               | 1.9                | 0.0                                    | 4.3   |

### 2.3.6 Source: Statistics Norway/Climate and Pollution Agency

### 2.3.7 Waste

The waste sector, with emissions of 1.2 million tonnes CO<sub>2</sub> equivalents in 2020, accounted for 2 per cent of the total GHG emissions in Norway.

The sector includes emissions from landfills (CH<sub>4</sub>), wastewater handling (CH<sub>4</sub> and N<sub>2</sub>O) and small scale waste incineration (CO<sub>2</sub> and CH<sub>4</sub>). 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 87 per cent of the sector's total emissions. Wastewater handling accounts for 13 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 2010 the emissions were about 31 per cent lower than in 1990. The total amount of waste generated has increased by about 42 per cent from 1995 to 2009, 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 2009 was 5 per cent lower than in 2008. This was the first year since 1995, when the waste account first was produced that the amount of waste generated was reduced. In 2010 the amount of waste generated increased again, by about 3 percent.

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

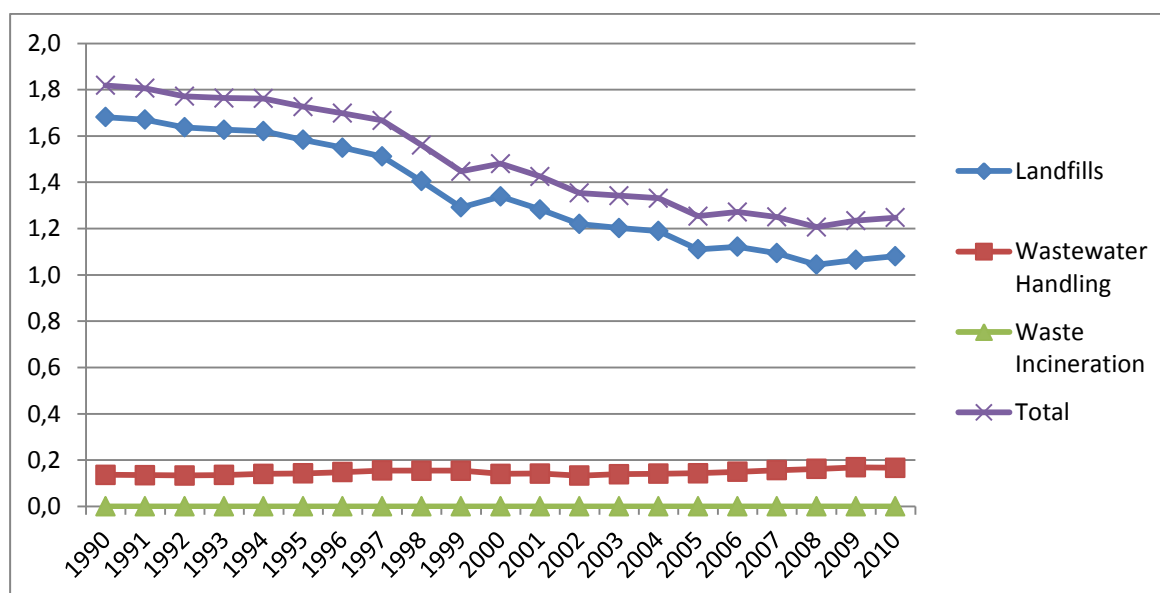


Figure 2.20. Total emissions of greenhouse gases (Mtonnes CO<sub>2</sub>-eq.) in Norway from the waste sector 1990-2010.

Source: Statistics Norway/Climate and Pollution Agency

Table 2.14. Emissions (Mtonnes CO<sub>2</sub>-eq.) from the waste sector in Norway 1990-2010.

| Year | Landfills | Wastewater Handling | Waste Incineration | Total |
|------|-----------|---------------------|--------------------|-------|
| 1990 | 1.7       | 0.1                 | 0.0                | 1.8   |
| 1991 | 1.7       | 0.1                 | 0.0                | 1.8   |
| 1992 | 1.6       | 0.1                 | 0.0                | 1.8   |
| 1993 | 1.6       | 0.1                 | 0.0                | 1.8   |
| 1994 | 1.6       | 0.1                 | 0.0                | 1.8   |
| 1995 | 1.6       | 0.1                 | 0.0                | 1.7   |
| 1996 | 1.6       | 0.1                 | 0.0                | 1.7   |
| 1997 | 1.5       | 0.2                 | 0.0                | 1.7   |
| 1998 | 1.4       | 0.2                 | 0.0                | 1.6   |
| 1999 | 1.3       | 0.2                 | 0.0                | 1.5   |
| 2000 | 1.3       | 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                | 1.4   |
| 2005 | 1.1       | 0.1                 | 0.0                | 1.3   |
| 2006 | 1.2       | 0.1                 | 0.0                | 1.3   |
| 2007 | 1.1       | 0.2                 | 0.0                | 1.3   |
| 2008 | 1.1       | 0.2                 | 0.0                | 1.3   |
| 2009 | 1.1       | 0.2                 | 0.0                | 1.3   |
| 2010 | 1.1       | 0.2                 | 0.0                | 1.2   |

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.

## 2.4 Land Use Change and Forestry

In 2010 the net sequestration was calculated at 32.9 million CO<sub>2</sub> equivalents, which would offset 61 per cent of the total greenhouse gas emissions in Norway that year. The average annual net sequestration from the LULUCF sector was about 19.6 million tonnes CO<sub>2</sub> equivalents for the period 1990-2010.

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 2010 are shown in Figure 2.21.



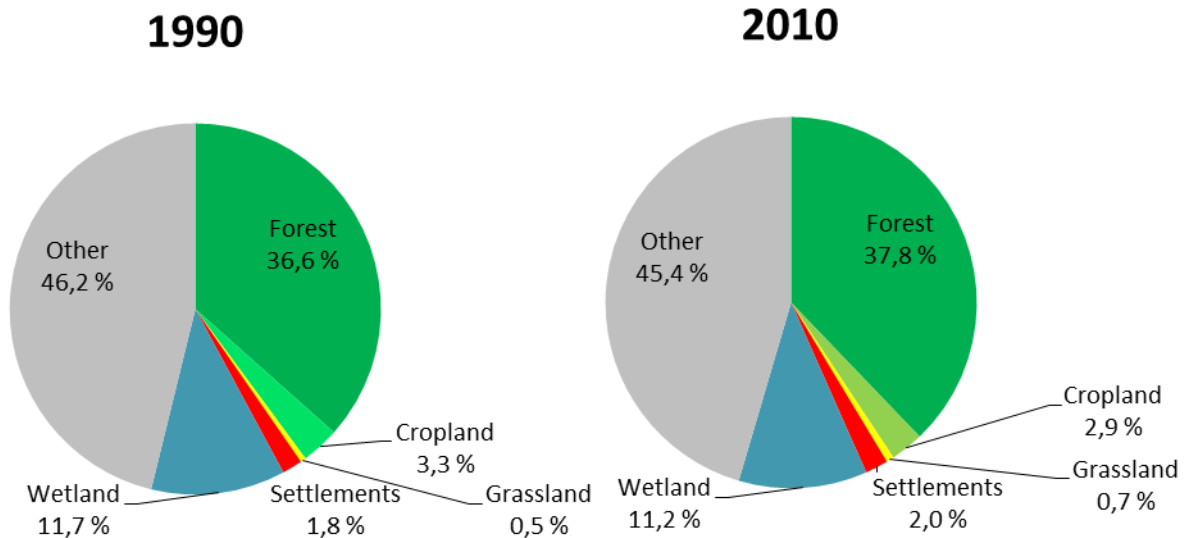


Figure 2.21. Area (%) distribution between the IPCC land-use categories, 1990 and 2010.

Source: The Norwegian Forest and Landscape Institute.

A key finding from these preliminary data is that changes in land-use from 1990 to 2010 are quite small; the area of forest land, grassland and settlements have slightly increased, while the other land-use categories have decreased.

In 2010 the land-use category forest land remaining forest land was the major contributor to the total amount of sequestration with 35.4 million tonnes CO<sub>2</sub>, while land converted to forest land contributed with 0.4 million tonnes CO<sub>2</sub>. From 1990 to 2010 the total net sequestration of CO<sub>2</sub> increased by 280 per cent. The explanation for this growth is an increase in standing volume and gross increment, while the amount of CO<sub>2</sub> 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 2010.

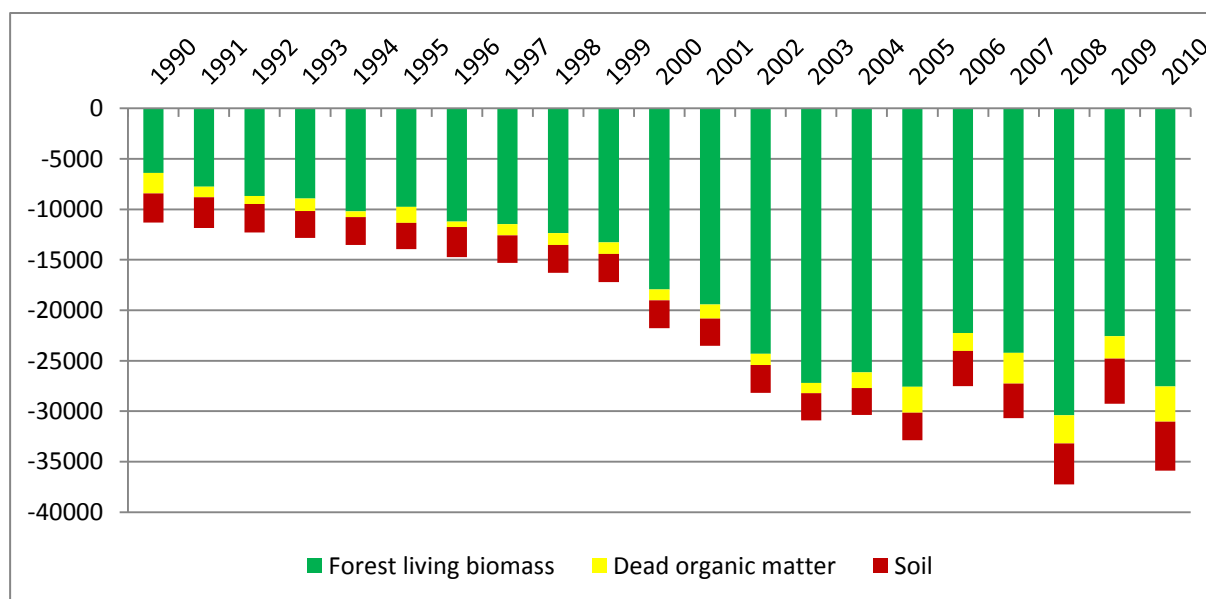


Figure 2.22. Net CO<sub>2</sub> removals (Mtonnes CO<sub>2</sub> eq.) on forest land (entire country), dead organic matter and soil (area below the coniferous limit), 1990–2010.

Source: The Norwegian Forest and Landscape Institute.

All land-use categories other than forest remaining forest showed net emissions in 2010. In total the emissions were calculated to 2.9 million tonnes CO<sub>2</sub>. Of these farmed organic soils (mostly for grass production) contributed with CO<sub>2</sub> emissions of 1.6 million tonnes.

## 2.5 Emission trends for indirect greenhouse gases and SO<sub>2</sub>

Nitrogen oxides (NO<sub>x</sub>), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) are not greenhouse gases, but they have an indirect effect on the climate through their influence on greenhouse gases, in particular ozone. Sulphur dioxide (SO<sub>2</sub>) 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<sub>x</sub> emissions** have decreased with approximately 3 per cent from 1990 to 2010. This can primarily be explained by stricter emission regulations with regard to road traffic, which has given a reduction of almost 38 per cent since 1990. These reductions counteracted increased emissions from e.g. oil and gas production. From 2009 to 2010 the total NO<sub>x</sub> emissions decreased by over 3 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 2010, and are now 51 per cent lower than in 1990. From 2009 to 2010 the emissions of NMVOC have decreased by 1 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 55 per cent over the period 1990-2010. This is explained primarily by the implementation of new emission standards for motor vehicles.

**SO<sub>2</sub> emissions** were reduced by 63 per cent from 1990 to 2010. 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.

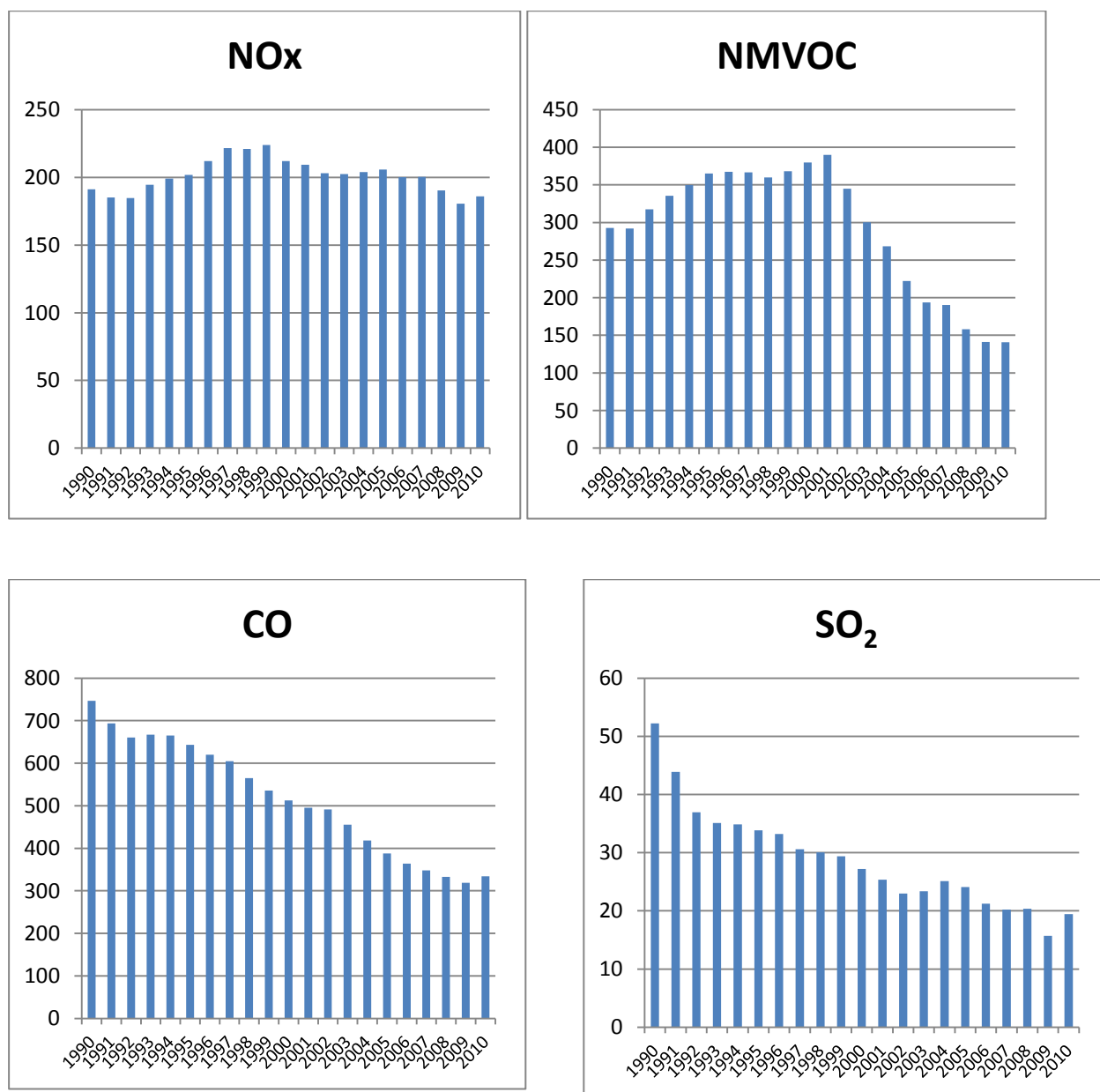


Figure 2.23. Emissions (Ktonnes) of NO<sub>x</sub>, NMVOC, CO and SO<sub>2</sub> in Norway 1990-2010.

Source: Statistics Norway/ Climate and Pollution Agency

## 3 Energy

### 3.1 Overview

The Energy sector included fugitive emissions accounted for 75.6 per cent of the Norwegian greenhouse gas emissions in 2010 that is a minor decrease from 75.7 per cent in 2009. In 1990 the Energy sector's share of the total greenhouse gas emissions was 59.4 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 37.7 per cent from 1990 to 2010, primarily due to increased activity in the sectors of oil and gas extraction and transport, specifically road transport. Between 1990 and 2010 there have been temporary emission reductions in the sector in e.g. 1991, 2005 and in 2009. The energy sector's emissions decreased by 3.7 per cent from 2007 to 2009 and increased 4.6 per cent from 2009 to 2010. Despite this reduction 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. Other sectors that contributed with more than 10 per cent to the growth were road transportation, navigation and motorized equipment. The reductions in 2009 were due to decreased emissions from e.g. road traffic, oil and gas production and the reduction was counteracted by increased emissions from especially electricity production but also from fisheries. Reduced emissions from road traffic was a result of the finance crises that started in the autumn 2008 and the activity then decreased in goods traffic and taxi traffic mainly.

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 2010 the emissions in the Transport sector was again highest.

#### Transport

The transport sector's total emissions in CO<sub>2</sub> equivalents was in 2010 15.1 million tonne whereas civil aviation contributed to 7.3, road transportation 66.7, railways 0.3, navigation 14.3 and off road vehicles and other machineries 11.5 per cent. The latter sectors share of total emissions from transport have increased from 8 per cent in 1990 to 11.5 per cent in 2010. 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. See more data in Section 3.2.5 about how road transportation has developed since 1990.

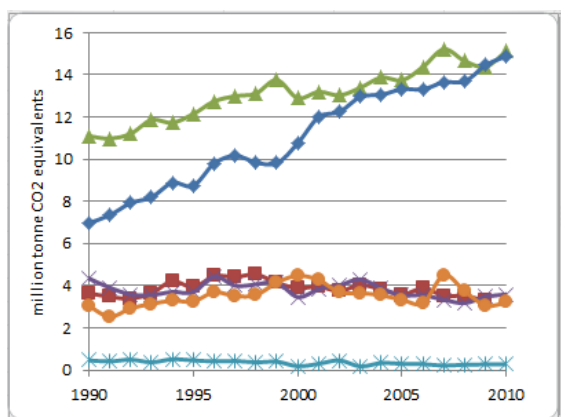


Figure 3.1a. Greenhouse gas emissions from energy sectors and fugitive emissions. 1990-2010. mill tonne CO<sub>2</sub> equivalents. Source: Statistics Norway and Climate and Pollution Agency.

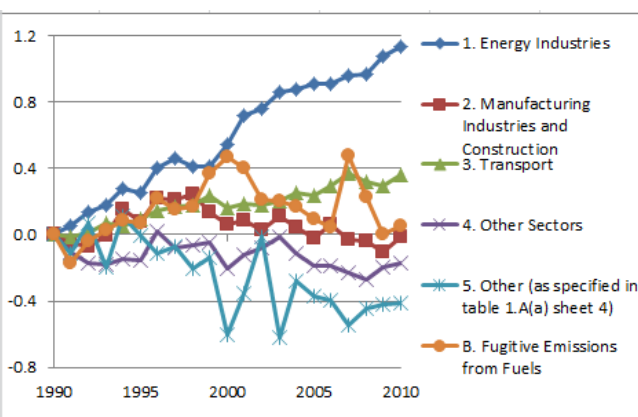


Figure 3.1b. Relative change in GHG emissions in the Energy sector and fugitive emissions. 1990=0. Source: Statistics Norway and Climate and Pollution Agency.

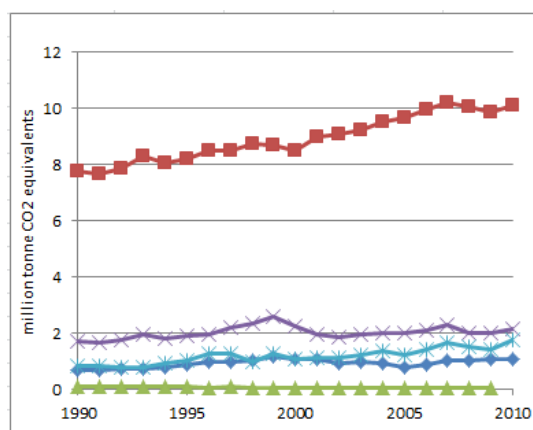


Figure 3.2a. Greenhouse gas emissions from transport sectors. 1990-2010. mill tonne CO<sub>2</sub> equivalents. Source: Statistics Norway and Climate and Pollution Agency.

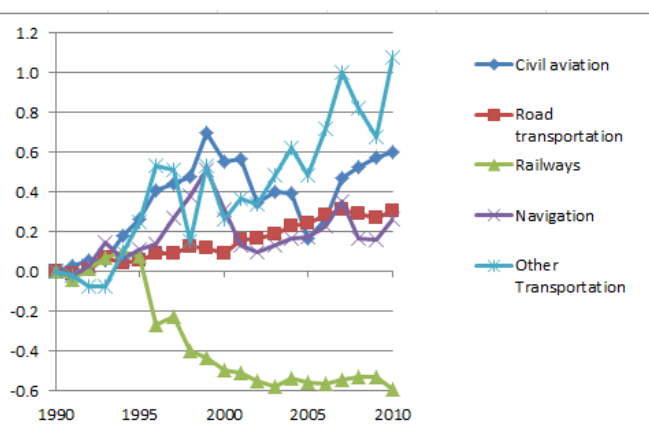


Figure 3.2b. Relative change in GHG emissions in the most important transport sectors. Civil aviation, road transportation, navigation and other transportation. 1990=0. Source: Statistics Norway/Climate and Pollution Agency.

### Key source categories

As indicated in Section 1.5, the Tier 2 key category analysis performed for the years 1990 and 2010 has revealed that in terms of total level and/or trend uncertainty the *key categories* in the Energy sector for 1990 and/or 2010 are, in CRF order, the following:

- Stationary Fuel Combustion, Solid Fuels – CO<sub>2</sub> (1A1-1A2-1A4)
- Stationary Fuel Combustion, Liquid Fuels – CO<sub>2</sub> (1A1-1A2-1A4)
- Stationary Fuel Combustion, Gaseous Fuels – CO<sub>2</sub> (1A1-1A2-1A4)
- Stationary Fuel Combustion, Gaseous Fuels – CH<sub>4</sub> (1A1-1A2-1A4)
- Stationary Fuel Combustion, Other Fuels – CO<sub>2</sub> (1A1-1A2-1A4)
- Stationary Fuel Combustion, Biomass – CH<sub>4</sub> (1A1-1A2-1A4)
- Other sectors, Mobile Fuel Combustion – CO<sub>2</sub> (1A4)
- Civil Aviation – CO<sub>2</sub> (1A3a)
- Road Transportation – CO<sub>2</sub> (1A3b)
- Navigation – CO<sub>2</sub> (1A3d)
- Navigation – CH<sub>4</sub> (1A3d) ok
- Other Transportation – CO<sub>2</sub> (1A3e)
- Other Transportation – N<sub>2</sub>O (1A3e)
- Fugitive Emissions from Oil – CO<sub>2</sub> (1B2a)
- Fugitive Emissions from Oil – CH<sub>4</sub> (1B2a)
- Fugitive Emissions from Natural gas – CH<sub>4</sub> (1B2b)
- Venting and Flaring – CO<sub>2</sub> (1B2c)
- Venting and Flaring – CH<sub>4</sub> (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 – CO<sub>2</sub> (1A5b).

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

An important issue, which is also elaborated in this sector, concerns the capture and storage of CO<sub>2</sub> 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

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

### Mode of presentation

The elaboration of the energy sector in the following starts with a description of emissions from the energy combustion sources (Section 3.2), followed by a description of fugitive

emissions (Section 3.3 and 3.4) and a discussion on the capture and storage of CO<sub>2</sub> 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 CO<sub>2</sub> emissions from CH<sub>4</sub> and NMVOC

Finally, the memo items of international bunker fuels and CO<sub>2</sub> 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 69.6 per cent of national total emissions in 2010. The emissions increased by 41.4 per cent between 1990 and 2010, 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 1.6 per cent from 2008 to 2009 and additional 4.6 per cent 2009 to 2010. While the emission from nearly all source categories within sector 1A decreased in 2009 except Public Electricity and Heat Production, almost all sectors increased its emissions in 2010. The change in 2010 was dominated by increased activity in Public Electricity and Heat Production (gas fired power plants and district heating), Manufacturing Industries and Construction (specifically non-ferrous metal), transport (specifically other transportation and also road transportation and navigation). Emissions from oil and gas extraction were nearly unchanged from 2009 to 2010.

The fuel combustion sector is dominated by the emissions of CO<sub>2</sub> which in 2010 contributed 98 per cent to the totals of this sector (1A).

This sector hosts thirteen 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.

#### **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.



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 <sup>3</sup>      | 0.85 tonne/m <sup>3</sup>              |
| Refinery gas                           | 48.6 GJ/tonne                               | ..                                     |
| Natural gas (dry gas) <sup>1</sup>     | 35.5 GJ/1000 Sm <sup>3</sup>                | 0.74 kg/Sm <sup>3</sup> (domestic use) |
| Natural gas (rich gas) <sup>1</sup>    | 40.3 GJ/1000 Sm <sup>3</sup>                | 0.85 kg/Sm <sup>3</sup> (off shore)    |
| Liquefied propane and butane (LPG)     | 46.1 GJ/tonne = 24.4 GJ/m <sup>3</sup>      | 0.53 tonne/m <sup>3</sup>              |
| Fuel gas                               | 50.0 GJ/tonne                               | ..                                     |
| Petrol                                 | 43.9 GJ/tonne = 32.5 GJ/m <sup>3</sup>      | 0.74 tonne/m <sup>3</sup>              |
| Kerosene                               | 43.1 GJ/tonne = 34.9 GJ/m <sup>3</sup>      | 0.81 tonne/m <sup>3</sup>              |
| Diesel oil, gas oil and light fuel oil | 43.1 GJ/tonne = 36.2 GJ/m <sup>3</sup>      | 0.84 tonne/m <sup>3</sup>              |
| Heavy distillate                       | 43.1 GJ/tonne = 37.9 GJ/m <sup>3</sup>      | 0.88 tonne/m <sup>3</sup>              |
| Heavy fuel oil                         | 40.6 GJ/tonne = 39.8 GJ/m <sup>3</sup>      | 0.98 tonne/m <sup>3</sup>              |
| Methane                                | 50.2 GJ/tonne                               | ..                                     |
| Wood                                   | 16.8 GJ/tonne = 8.4 GJ/solid m <sup>3</sup> | 0.5 tonne/solid m <sup>3</sup>         |
| 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.

<sup>1</sup> Sm<sup>3</sup> = 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 CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O.

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 CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O in the different energy sectors that is based on either estimated or reported emissions in 2010. For the source categories like Petroleum Refining, Manufacture of Solid Fuels and Other Energy Industries, mainly oil and gas extraction, and Iron and Steel more than 90 per cent of the categories emissions is based on reported CO<sub>2</sub> emissions. In 2010 92 per cent of the CO<sub>2</sub> emissions from Energy Industries were based on reported emissions and 49 per cent of the CO<sub>2</sub> emissions from Manufacturing Industries and Construction. The table is a result from an advice from the ERT reviewing Norway's 2010 submission.

Table 3.2. Overview of estimated and reported greenhouse gases CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O for energy combustion activities\*.

|   | CO <sub>2</sub> | CH <sub>4</sub> | N <sub>2</sub> O |
|---|-----------------|-----------------|------------------|
| <b>A. Fuel Combustion Activities (Sectoral Approach)</b>                                |                 |                 |                  |
| <b>1. Energy Industries</b>   |                 |                 |                  |
| 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              |
| <b>2. Manufacturing Industries and Construction</b>                                     |                 |                 |                  |
| 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                |
| <b>3. Transport</b>   |                 |                 |                  |
| 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                |
| <b>4. Other Sectors</b>   |                 |                 |                  |
| a. Commercial/Institutional   | E               | E               | E                |
| b. Residential  | E               | E               | E                |
| c. Agriculture/Forestry/Fisheries   | E               | E               | E                |
| <b>5. Other (Military)</b>  | 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).

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*Table 3.3. Share of total CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions in the energy sector based on estimated and reported emission estimates for 2010.*

|   | CO <sub>2</sub>  |                 | CH <sub>4</sub>  |                 | N <sub>2</sub> O |                 |
|---|------------------|-----------------|------------------|-----------------|------------------|-----------------|
|   | <i>Estimated</i> | <i>Reported</i> | <i>Estimated</i> | <i>Reported</i> | <i>Estimated</i> | <i>Reported</i> |
| <b>A. Fuel Combustion Activities (Sectoral Approach)</b>                                |                  |                 |                  |                 |                  |                 |
| <b>1. Energy Industries</b>   |                  |                 |                  |                 |                  |                 |
| a. Public Electricity and Heat Production   | 40 %             | 60 %            | 100 %            | 0 %             | 66 %             | 34 %            |
| b. Petroleum Refining   |                  | 100 %           | 82 %             | 18 %            | 100 %            |                 |
| c. Manufacture of Solid Fuels and Other Energy Industries                               | 2 %              | 98 %            | 1 %              | 99 %            | 100 %            |                 |
| <b>2. Manufacturing Industries and Construction</b>                                     |                  |                 |                  |                 |                  |                 |
| a. Iron and Steel   | 48 %             | 52 %            | 100 %            |                 | 100 %            |                 |
| b. Non-Ferrous Metals   | 100 %            |                 | 100 %            |                 | 100 %            |                 |
| c. Chemicals  | 13 %             | 87 %            | 97 %             | 3 %             | 71 %             | 29 %            |
| d. Pulp, Paper and Print  | 100 %            |                 | 84 %             | 16 %            | 84 %             | 16 %            |
| e. Food Processing, Beverages and Tobacco   | 100 %            |                 | 100 %            |                 | 100 %            |                 |
| f. Other (Oil drilling, construction, other manufacturing)                              | 53 %             | 47 %            | 100 %            |                 | 100 %            |                 |
| <b>3. Transport</b>   | 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%             |                 |
| <b>4. Other Sectors</b>   | 100%             |                 | 100%             |                 | 100%             |                 |
| a. Commercial/Institutional   | 100%             |                 | 100%             |                 | 100%             |                 |
| b. Residential  | 100%             |                 | 100%             |                 | 100%             |                 |
| c. Agriculture/Forestry/Fisheries   | 100%             |                 | 100%             |                 | 100%             |                 |
| <b>5. Other (Military)</b>  | 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 1990-2010 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> emissions. Other emissions are estimated by

Statistics Norway, using the same emission factors as for combustion of natural gas in turbines.

### Oil products

Total use of the different oil products is based on Statistics Norway's annual sales statistics for petroleum products. The data are considered very reliable since all major oil companies selling oil products have interest in and report to these statistics<sup>3</sup>. 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.

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<sup>3</sup> 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).

### 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 SO<sub>2</sub>, NO<sub>x</sub>, CO, NH<sub>3</sub>, 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 1990-2010 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. This more detailed presentation concerns, in particular, the years 1992-2010. For 1990 and 1991, balance sheets are presented in the old format, as technical problems did not allow preparation of a corresponding disaggregation in time for the NIR submission.

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

#### *CO<sub>2</sub>*

Emission factors for CO<sub>2</sub> are independent of technology and are based on the average carbon content of fuels used in Norway. The general emission factors for CO<sub>2</sub> 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/Sm<sup>3</sup> to 1.99 kg/Sm<sup>3</sup> in the current inventory and hence the emissions for the time series have been recalculated. The factor 2.34 kg/Sm<sup>3</sup> reflects offshore combustion of rich gas.

Bio fuels for transport are not handled as separate fuels. The consumption is included with gasoline and auto diesel. The CO<sub>2</sub> factors for these fuels are adjusted annually according to the bio fuel content.



Table 3.4. General emission factors for CO<sub>2</sub>.

|  | CO <sub>2</sub><br>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 <sup>3</sup> )  | 1.99 <sup>1</sup> (land)       |
| Natural gas (rich gas) (kg/Sm <sup>3</sup> ) | 2.34 <sup>1</sup> (off shore)  |
| LPG  | 3.00                           |
| Refinery gas                                 | 2.80                           |
| Blast furnace gas                            | 1.571                          |
| Fuel gas                                     | 2.50                           |
| Landfill gas                                 | 0                              |
| Biogas                                       | (2.75) <sup>2</sup>            |
| Fuel wood                                    | (1.8) <sup>2</sup>             |
| Wood waste                                   | (1.8) <sup>2</sup>             |
| Black liquor                                 | (1.8) <sup>2</sup>             |
| Municipal waste                              | 0.5417                         |
| Special waste                                | 3.20                           |

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

<sup>2</sup> Non-fossil emissions, not included in the inventory.

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

### Offshore operations

For all years up to 2002 emissions of CO<sub>2</sub> 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 2003-2010 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 CO<sub>2</sub> 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 CO<sub>2</sub> from the combustion of natural gas in turbines at offshore gas and oil fields.*

|           | Gas turbines offshore<br>kg CO <sub>2</sub> /Sm <sup>3</sup> natural gas burned |
|-----------|---|
| 1990-1994 | 2.34  |
| 1995      | 2.29  |
| 1996      | 2.30  |
| 1997      | 2.30  |
| 1998      | 2.31  |
| 1999      | 2.50  |
| 2000      | 2.48  |
| 2001      | 2.47  |
| 2002      | 2.45  |
| 2003      | 2.46  |
| 2004      | 2.43  |
| 2005      | 2.45  |
| 2006      | 2.43  |
| 2007      | 2.40  |
| 2008      | 2.38  |
| 2009      | 2.36  |
| 2010      | 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> and reduce the CO<sub>2</sub> content in the sales gas to a level that is low enough for the gas market. The CO<sub>2</sub> content in the CRAIER gas burnt in the boiler was in 2008, 2009 and 2010 1.71, 1.69 and 1.62 tonne CO<sub>2</sub>/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 2010 was 2.47 tonne CO<sub>2</sub> 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 CO<sub>2</sub> from the combustion of fuel gas at one gas terminal.*

|      | <b>Average content of CO<sub>2</sub> in natural gas<br/>t CO<sub>2</sub> / t gas</b> |
|------|--|
| 2010 | 2.65   |
| 2009 | 2.66   |
| 2008 | 2.65   |
| 2007 | 2.66   |
| 2006 | 2.67   |
| 2005 | 2.67   |
| 2004 | 2.68   |
| 2003 | 2.68   |
| 2002 | 2.68   |
| 2001 | 2.68   |
| 2000 | 2.73   |
| 1999 | 2.69   |
| 1998 | 2.73   |
| 1997 | 2.77   |
| 1996 | 2.84   |
| 1995 | 2.93   |
| 1994 | 2.93   |
| 1993 | 2.79   |
| 1992 | 2.94   |
| 1991 | 2.82   |
| 1990 | 2.70   |

*Source: Climate and Pollution Agency*

#### *CH<sub>4</sub> and N<sub>2</sub>O*

For CH<sub>4</sub> and N<sub>2</sub>O, information on emission factors is generally very limited, because, unlike the CO<sub>2</sub> 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 CH<sub>4</sub> and N<sub>2</sub>O emission factors used in the emission inventory for this source are listed in Tables 3.7 and 3.9, respectively. Tables 3.8 and 3.10 display the cases where emission factors other than the general ones were used in the calculations.

Table 3.7. General emission factors for CH<sub>4</sub>, stationary combustion. Unit: kg CH<sub>4</sub>/tonne fuel

| Source                              | Direct-fired furnaces | Gas turbines | Boilers     | Small stoves | Flares |
|-------------------------------------|-----------------------|--------------|-------------|--------------|--------|
| Coal                                | 0.028                 | -            | <b>0.28</b> | 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            | <b>0.4</b>  | -            | -      |
| Light fuel oils                     | -                     | -            | <b>0.4</b>  | 0.4          | -      |
| Heavy distillate                    | 0.04                  | -            | <b>0.4</b>  | 0.4          | -      |
| Heavy fuel oil                      | 0.04                  | -            | <b>0.4</b>  | -            | -      |
| Natural gas (1000 Sm <sup>3</sup> ) | <b>0.05</b>           | 0.91         | <b>0.2</b>  | -            | 0.24   |
| Refinery gas                        | 0.054                 | -            | 0.24        | -            | 0.28   |
| Blast furnace gas                   | 0.054                 | -            | <b>0.24</b> | -            | -      |
| Landfill gas                        | -                     | -            | 0.24        | -            | 0.37   |
| Fuel gas                            | <b>0.05</b>           | -            | 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                  | -            | <b>0.4</b>  | -            | -      |

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 CH<sub>4</sub>, stationary combustion.*

| <b>Emission factor<br/>(kg CH<sub>4</sub>/tonne fuel)</b> | <b>Fuel</b>                                   | <b>Source</b>         | <b>Sectors</b>  |
|---|---|-----------------------|---|
| 0   | Natural gas (1000 Sm <sup>3</sup> ), fuel gas | Direct fired furnaces | Manufacture of other mineral products<br>Manufacture of cement, lime and plaster  |
| 0.085   | Natural gas (1000 Sm <sup>3</sup> )           | Direct fired furnaces | Manufacture of plastics and synthetic rubber in primary forms,<br>manufacture of other organic basic materials                                |
| 0.03  | Coal  | Boilers               | Coal mining<br>Extraction of crude petroleum and natural gas<br>Oil refineries<br>Gas terminals<br>Production and distribution of electricity |
| 0.1   | Fuel oils incl. special waste                 | Boilers               | Industry incl. power supply   |
| 0.0425  | Natural gas (1000 Sm <sup>3</sup> )           | Boilers               | Coal mining<br>Extraction of crude petroleum and natural gas<br>Oil refineries<br>Gas terminals<br>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 N<sub>2</sub>O/tonne fuel) for N<sub>2</sub>O, 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 <sup>3</sup> ) | <b>0.02</b>           | 0.019        | 0.004   | -            | <b>0.02</b> |
| 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 3.10.*

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

*Table 3.10. Exceptions from the general factors for N<sub>2</sub>O, stationary combustion.*

| Emission factor<br>(kg N <sub>2</sub> O/1000<br>Sm <sup>3</sup> 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.

### 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. 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.

### 3.2.1.6 Recalculations

Most of the recalculations have been performed for 2009, because the energy figures for 2009 used in the previous inventory 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. In the following, *reported emissions* are defined as 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.

### 3.2.1.7 Planned improvements

There will in 2012 be 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. Planned activity that will improve the data quality for category 1A before NIR 2013 in addition to the above described improvement will be mentioned in the source category specific sections.

## 3.2.2 Energy industries (CRF source category 1A1)

### 3.2.2.1 Description

Energy industries include emissions from electricity and heat generation and distribution, extraction of oil and natural gas, coal production, gas terminals and oil refineries. Norway produces electricity mainly from hydropower, so emissions from electricity production are small compared to most other countries. Due to the large production of oil and gas, the emissions from combustion in energy production are high. 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 37.0 per cent of the sectoral totals and 27.6 per cent of the total emissions in Norway in 2010. The increase that took place during the period 1990-2010 is as high as 113.8 per cent and is attributed primarily to the increased activity in the oil and gas extraction sector but the increase in 2010 was due to that the CO<sub>2</sub> emissions from gas fired electricity power plants increased by approximately one million ton. GHG emissions in the sector in 2009 were 5.6 and in 2010 3 per cent above 2008 and 2009, respectively.

According to the Tier 2 key category analysis for 1990 and 2010, this sector is, in conjunction with sectors 1A2 and 1A4, a key category with respect to:

- Emissions of CO<sub>2</sub> from the combustion of liquid and gaseous fuels in both level and trend uncertainty
- Emissions of CO<sub>2</sub> from the combustion of Other fuels in level in 2010 and trend uncertainty and solid fuels are key category in level in 1990
- Emissions of CH<sub>4</sub> from the combustion of gaseous fuels in trend uncertainty and biomass in level in 1990 and 2010 and in trend

### **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 2011a). 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. 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 from energy utilization, reported in 1B2a Fugitive Emissions from Oil.

#### Waste incineration – CO<sub>2</sub> and CH<sub>4</sub>

Net CO<sub>2</sub> emissions from wood/ biomass burning are not considered in the Norwegian inventory, because the amount of CO<sub>2</sub> released during burning is the same as that absorbed by the plant during growth. Carbon emitted in compounds other than CO<sub>2</sub>, e.g. as CO, CH<sub>4</sub> and NMVOC, is also included in the CO<sub>2</sub> emission estimates. This double counting of carbon is in accordance with the IPCC guidelines (IPCC 1997b).



Waste incineration – N<sub>2</sub>O

Emissions of N<sub>2</sub>O are derived from the emissions of NO<sub>x</sub> 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<sub>x</sub> is subtracted and reported to UNFCCC as N<sub>2</sub>O (SFT 1996). Accordingly, the net NO<sub>x</sub> emissions constitute 97.5 per cent of the emissions reported by the plants. For some years, emissions of NO<sub>x</sub> 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. The data are considered to be of high quality.

Extraction of oil and natural gas

Production of oil and natural gas is the dominating sector for emissions from combustion in the energy industries in Norway. The Norwegian Petroleum Directorate reports annually the amounts of gas combusted in turbines and diesel burned in turbines and direct-fired furnaces on the oil and gas fields. The data are of high quality due to the CO<sub>2</sub> 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 CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are displayed in Tables 3.4, 3.7 and 3.9, respectively. Emission factors for CH<sub>4</sub> have been calculated by (SFT 1996).

CO<sub>2</sub> 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 CO<sub>2</sub> 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 2011a).

The factor 2.708 tonne CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub>/tonne fuel or tonne CO<sub>2</sub>/TJ. High hydrogen content leads to low emission factors as measured in

tonne CO<sub>2</sub>/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 CO<sub>2</sub>/TJ. In the Norwegian inventory, the emission factor varies in the range 45-60 tonne CO<sub>2</sub>/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  $\pm 3$  per cent of the mean for oil,  $\pm 4$  per cent for gas and  $\pm 5$  per cent of the mean for coal/coke and waste.

In the case of the emission factors for CO<sub>2</sub>, the uncertainty is  $\pm 3$  per cent of the mean for oil,  $\pm 7$  per cent for coal/coke and gas and  $\pm 30$  per cent of the mean for waste.

Emission factors for CH<sub>4</sub> and N<sub>2</sub>O are very uncertain. Distributions are strongly skewed with uncertainties which lie below and above the mean by a factor of 2 and 3, respectively.

### 3.2.2.6 Source specific QA/QC and verification

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

#### Extraction of oil and natural gas

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

#### Oil refineries

The CO<sub>2</sub> emissions reported from the refineries are compared with the emissions estimated by Statistics Norway on the basis of activity data and emission factors for the different energy carriers used.

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

### 3.2.2.7 Recalculations

#### *1A 1a Public electricity and heat production*

- Revised data. Reported N<sub>2</sub>O emissions from one district heating plant in 2008 has been somewhat increased. For two plants, reported figures for 2009 replaces previously used 2008 figures. There is a minor change in the reported N<sub>2</sub>O figure for 2009 for another plant. For yet another plant the figure on use of fuel oil in 2009 has been marginally reduced, causing corresponding emission reductions
- Revised data. Figures on use of wood waste at one district heating plant have been somewhat adjusted for 2006-2009, causing marginal emission changes
- Revised data. A minor reduction in use of light fuel oil in 2008 causes marginal emission reductions. This reduction should have been reflected in an increase in another sector, in order to include total sales in the energy statistics and emission calculations. Unfortunately, this transfer has not taken place, which means that total CO<sub>2</sub> emissions in 2008 are approximately 4 500 tonnes too small. The error will be corrected in the 2013 submission
- New method. As one pulp and paper producing plant also produces electricity, the use of factor calculations of emissions instead of reported figures for CH<sub>4</sub> and N<sub>2</sub>O as described under 1A2d, also cause emission changes for all years in 1A1a.

### *1A 1b Petroleum refining*

- Reallocation. Previously, the same key for distribution between flaring and energy utilisation of refinery gas was used for all years in the whole period 1990-2009. Now plant and year specific figures have been used instead. This causes a reallocation of emissions between 1A1b and 1B2c, but there is no change in total emissions. The reallocation causes higher emissions for 1A1b in 1991, 1995 and 2003-2009, whereas the emissions have been reduced in 1990, 1992-1994, and 1996-2002. Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are affected by the change
- Correction of error. The removal of a previous double counting for CO<sub>2</sub> and CH<sub>4</sub> in 2008 and 2009 has counteracted the emission increase caused by the reallocation mentioned above, and caused an overall reduction in CO<sub>2</sub> emissions for 2008 and a reduced increase for CH<sub>4</sub> in 2008 and for both CO<sub>2</sub> and CH<sub>4</sub> in 2009. The removal of a previous double counting for CO<sub>2</sub> and CH<sub>4</sub> in 2008 and 2009 has, in addition to the reallocation mentioned above, caused a further reduction in CO<sub>2</sub> and CH<sub>4</sub> emissions for these years.

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

- Reallocation/revised data. Part of the 2008 CO<sub>2</sub> figure for one plant, previously registered as emission from venting, has been reallocated to combustion. At the same time, parts of the CH<sub>4</sub> figures 2007-2009 for the same plant, previously registered as combustion emissions, have been reallocated to 1B2aiii. There are also changes in total CH<sub>4</sub> figures for this plant
- Correction of error: CO<sub>2</sub> and CH<sub>4</sub> for 1A1C (Manufacture of solid fuels and other energy industries) and 1A3D (National navigation) in 2005. In the previous submission, emissions from drilling at moveable offshore installations were reallocated from 1A3D to 1A1C. In that operation, a mistake was made for certain components in 2005. This mistake has now been corrected. Total emissions for the two sectors were reduced
- Reallocation: As part of the correction mentioned above, an amount of fuel oil was reallocated from 1A3D (National navigation) to 1A1C (Manufacture of solid fuels and other energy industries) in 2005. All components are affected. Total emissions for N<sub>2</sub>O for the two sectors were unchanged, whereas for CO<sub>2</sub> and CH<sub>4</sub> there was an additional correction as mentioned above

### **3.2.2.8 Planned improvements**

There is for the moment no planned activity that will improve the data quality for NIR 2013.

## **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 2011a). 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 6.7 per cent to the national GHG total in 2010.

Emission from the sector has decreased by 0.9 per cent from 1990 to 2010. Between 2009 and 2010 1A2's sectoral emissions increased by 10.2 per cent, about 334 Gg CO<sub>2</sub> equivalents.

Emissions from non-ferrous metals has increased by 62.3 per cent in 2010, 117 Gg CO<sub>2</sub> equivalents. All other sub-sectors in 1A2 have increased in the period. How the emissions from this industry have developed in 2010 gives a good indication of that the industry seems to have been recovered from the problems that occurred from the end of 2008 and 2009.

According to the Tier 2 key category analysis for 1990 and 2010, this sector is, in conjunction with sectors 1A1 and 1A4, a key category with respect to:

- Emissions of CO<sub>2</sub> from the combustion of liquid and gaseous fuels in both level and trend uncertainty
- Emissions of CO<sub>2</sub> from the combustion of Other fuels in level in 2010 and trend uncertainty and solid fuels are key category in level in 1990
- Emissions of CH<sub>4</sub> from the combustion of gaseous fuels in trend uncertainty and biomass in level in 1990 and 2010 and in trend

### **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 2010 these plants account for approximately half (49 per cent) of the CO<sub>2</sub> 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.

#### *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.

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 CO<sub>2</sub> /t gas and ethane the emissions factor 2.93 tonne CO<sub>2</sub> /tonne. Then a small amount of a light fuel gas (composition of 60 per cent H<sub>2</sub> and 40 per cent CH<sub>4</sub>) from a producer of plastic is used a few years with an emissions factor of 2.4 t CO<sub>2</sub> per tonne gas.

The blast furnace gas used as fuel has an emission factor of 0.714 t CO<sub>2</sub> 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 CO<sub>2</sub>/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 CO<sub>2</sub>/TJ.

#### 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.

### 3.2.3.5 Source specific QA/QC and verification

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

### 3.2.3.6 Recalculations

#### *Chemicals*

- Revised data. Reported figures on CH<sub>4</sub> from one plant have been adjusted downwards for 2005-2007
- Reallocation. CO<sub>2</sub> figures for one plant, previously registered as combustion emissions, have now been split between combustion and process. This causes an annual reduction in the size of 10-15 ktonne for all years 1990-2008.

#### *1A 2 d Pulp and paper*

- New method. Previously, reported emissions for CH<sub>4</sub> and N<sub>2</sub>O from two plants and CH<sub>4</sub> from another plant were used in the inventory. They have now been replaced by factor estimations based on registered use of different energy commodities for all years 1990-2009
- Revised data. A revised reported CH<sub>4</sub> figure for one plant in 2008 has caused an emission reduction.

*1A 2 f Other*

- Revised data. For two rock wool producing plants, there are minor changes in reported CO<sub>2</sub> figures for 2005-2008

### **3.2.3.7 Planned improvements**

There is for the moment no planned activity that will improve the data quality for NIR 2013.

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

### **3.2.4.1 Description**

In 2010 emissions from this source category were 7.3 per cent of the total emissions from transport and 2.0 per cent of the GHG national total. From 1990 to 2010 these emissions increased by 60.2 per cent due to activity growth. Emission fluctuations over time have been dictated by the activity growth rates. The GHG emissions from aviation in 2010 were 1.6 per cent higher (180Gg CO<sub>2</sub> equivalents) than in 2009. The average annual growth in emissions in the period 1990-2010 was 2.4 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 CO<sub>2</sub> emissions in level in 1990 and 2010 and in trend.

Emissions of CH<sub>4</sub> and N<sub>2</sub>O 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 CO<sub>2</sub> for the combustion of jet fuel and gasoline (Statistics Norway 2002a). The CO<sub>2</sub> emission factor used for aviation gasoline is 3.13 tonne CO<sub>2</sub>/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 CO<sub>2</sub>/tonne fuel.

For N<sub>2</sub>O 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 CH<sub>4</sub>, 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: CO<sub>2</sub>: tonne/tonne fuel, CH<sub>4</sub> and N<sub>2</sub>O: kg/tonne fuel.

| Source                           | CO <sub>2</sub>   |              | CH <sub>4</sub>   |                     | N <sub>2</sub> O               |
|----------------------------------|-------------------|--------------|-------------------|---------------------|--------------------------------|
|                                  | Aviation gasoline | Jet kerosene | Aviation gasoline | Jet kerosene        | Aviation gasoline/Jet kerosene |
| <b>Charter/scheduled flights</b> |                   |              |                   |                     |                                |
| <i>Domestic</i>                  |                   |              |                   |                     |                                |
| LTO (0-100 m)                    |                   | 3.15         |                   | 0.1854 <sup>1</sup> | 0.1                            |
| LTO (100-1000 m)                 |                   | 3.15         |                   | 0.0304 <sup>1</sup> | 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                            |
| <b>Helicopters</b>               |                   |              |                   |                     |                                |
| LTO (0-100 m)                    |                   | 3.15         |                   | 3.2 <sup>1</sup>    | 0.1                            |
| LTO (100-1000 m)                 |                   | 3.15         |                   | 3.2 <sup>1</sup>    | 0.1                            |
| Cruise (Above 1000)              |                   | 3.15         |                   | 0                   | 0.1                            |
| <b>Small aircraft</b>            |                   |              |                   |                     |                                |
| 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                            |

<sup>1</sup>Jet kerosene used on aircraft in the Defence Air Forces has an emission factor of 0.35 kg CH<sub>4</sub>/tonne.

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

*Table 3.12 Time series of variable CH<sub>4</sub> 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 <sub>4</sub> 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  $\pm 20$  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 CO<sub>2</sub> emission factors is  $\pm 3$  per cent. The uncertainty in the emission factors for CH<sub>4</sub> and N<sub>2</sub>O 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

#### 1A 3 a Civil aviation

- Correction of error. For 2007-2009, the key for distribution of jet fuel between airplanes and helicopters were, due to an error, previously not updated. The correction of this error has led to a minor shift between LTO and cruise, as the distribution between airplanes and helicopters in these groups differs. For CH<sub>4</sub>, also the emission factors vary between the two groups, causing a minor reduction in overall emissions from civil aviation.

### 3.2.4.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2013.

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

Road traffic accounted for 66.7 per cent of the total GHG emissions from transport and for 18.7 per cent of the national GHG total in 2010.

During the period 1990-2010 an increase in emissions of 30.1 per cent took place in road transportation. Whereof PCs share of the total increased emissions from road transportation was 20, LCVs 34 and HDVs 46 per cent.

Emissions from PC petrol were reduced by 34 per cent and PC diesel increased its emissions 10 times in the period 1990-2010.

The annual average growth in CO<sub>2</sub> emissions from road transportation in the period 1990-2010 was 1.3 per cent. Between 1990-2000 and 2000-2010 the annual average growth were 0.9 and 1.8 per cent, respectively.

**Passenger cars (PC).** Figure 3.3a shows that the total emissions from PCs have been stable all years from 1990 till 2001. From 2001 to 2006 the CO<sub>2</sub> emissions from PCs slightly increased by 6 per cent. In 2007 the emissions increased by 3 per cent and after that the emissions has been almost unchanged. So from 1990 emissions from PCs have increased by 9 percent while vehicle kilometers have increased by 35 per cent and the number of PCs has had slightly a higher growth, 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 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.

It is worth to mention that kilometers driven increased by 17 percent in 15 years, 1990-2005, and additional 18 percent in 2006-2010, mostly in 2007-2008.

Emissions from **light commercial vehicles** (LCV) and **heavy duty vehicles** (HDV) have increased with 108 and 63 per cent, respectively, in the period 1990-2010. See Figure 3.3c.

PC's contribution to total CO<sub>2</sub> emissions from road traffic has decreased from 68 per cent in 1990 to 56 per cent in 2010. While light commercial vehicles (LCV) and heavy duty vehicles (HDV) have increased their contribution to total emissions for road traffic from 10 and 15 percent and 23 and 26 per cent, respectively, in 1990 and 2010.

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 CO<sub>2</sub> emissions from PCs from 1990 to 2010 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 2010, road transportation is a key category with respect to: emissions of CO<sub>2</sub> in terms of uncertainty in both trend and level in 1990 and 2010.

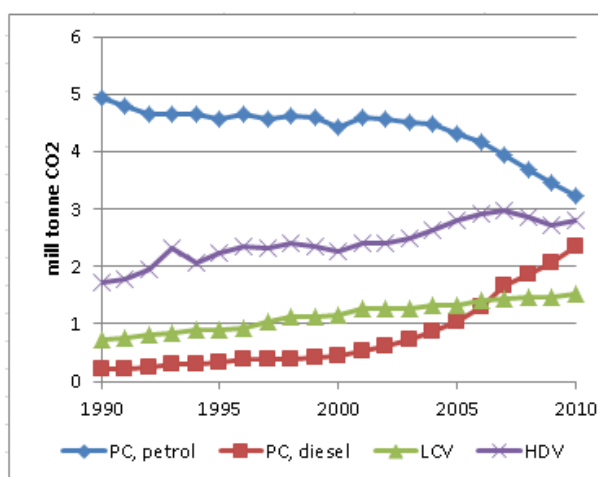


Figure 3.3a. Emissions of CO<sub>2</sub>. PC petrol and diesel, LCV and HDV

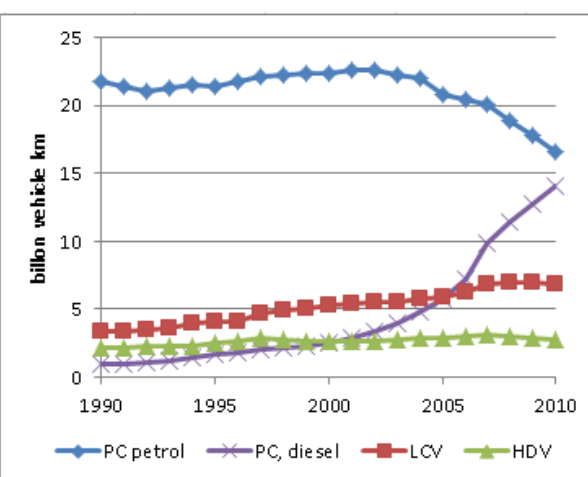


Figure 3.3b. Vehicle kilometre. PC petrol and diesel, LCV and HDV

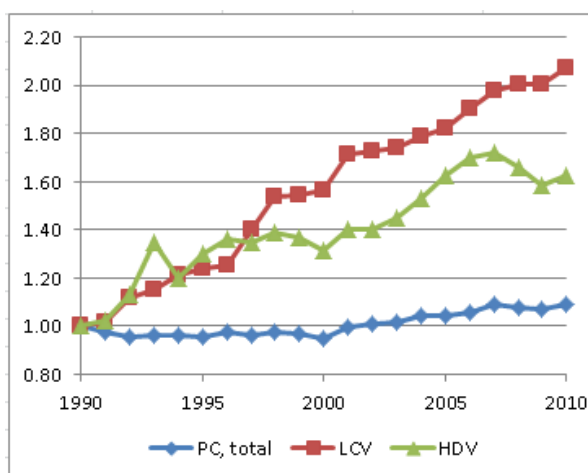


Figure 3.3c. Relative change in total CO<sub>2</sub> emissions from PC, LCV and HDV. 1990=1

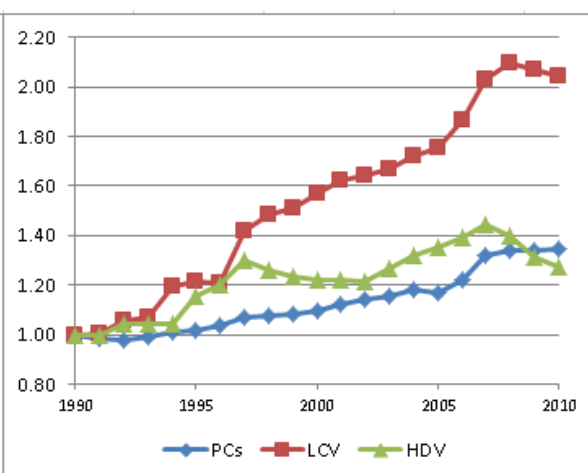
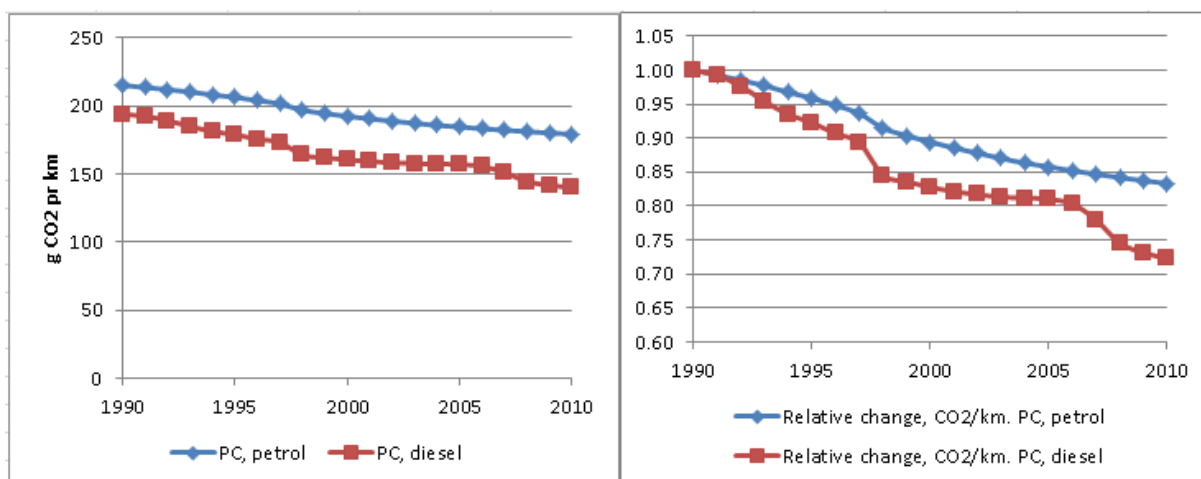
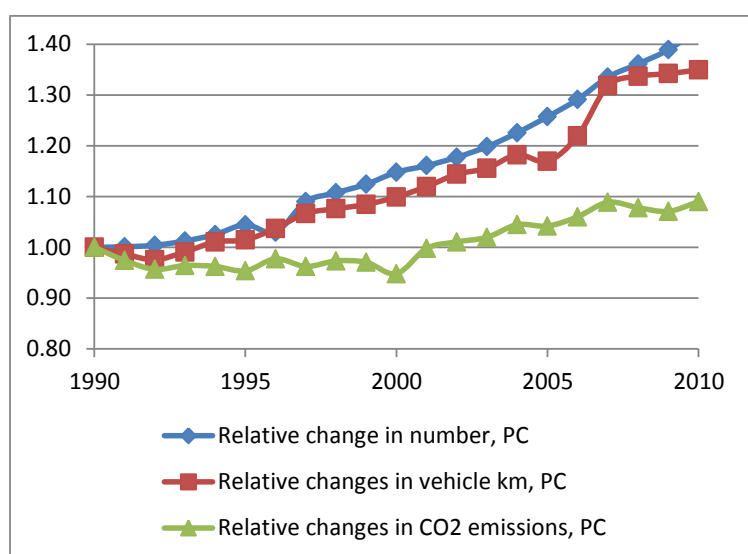


Figure 3.3d. Relative change in total vehicle km. PC, LCV and HDV. 1990=1

Figure 3.3e. Emissions of CO<sub>2</sub> . mill tonn. PC petrol and dieselFigure 3.3f. Relative change in CO<sub>2</sub> emission per km. PC petrol and diesel.Figure 3.3g. Relative change ein number of PCs and CO<sub>2</sub> emissions and vehicle kilometers.

### 3.2.5.1 Methodological issues

Total emissions of CO<sub>2</sub> 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 CO<sub>2</sub> 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 the 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.

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 |
|----------------------------------|------------------------|-----------|------------------------|
| <b>Passenger car</b>             | 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       | -                      |
| <b>Light commercial vehicles</b> | 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            |
| <b>Heavy goods vehicles</b>      | 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           |
| <b>Coach</b>                     | Coach Std <=18t        | Diesel    | Gross weight           |
|                                  | Coach 3-Axes >18t      | Diesel    | Gross weight           |
| <b>Urban bus</b>                 | 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           |
| <b>Motorcycles and mopeds</b>    | 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.
- *Number of vehicles*: the number of vehicles in the various categories and age groups is taken from the official register of the Norwegian Directorate of Public Roads. 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 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 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 2005-2008, 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 (102odel l. 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 a hourly basis.

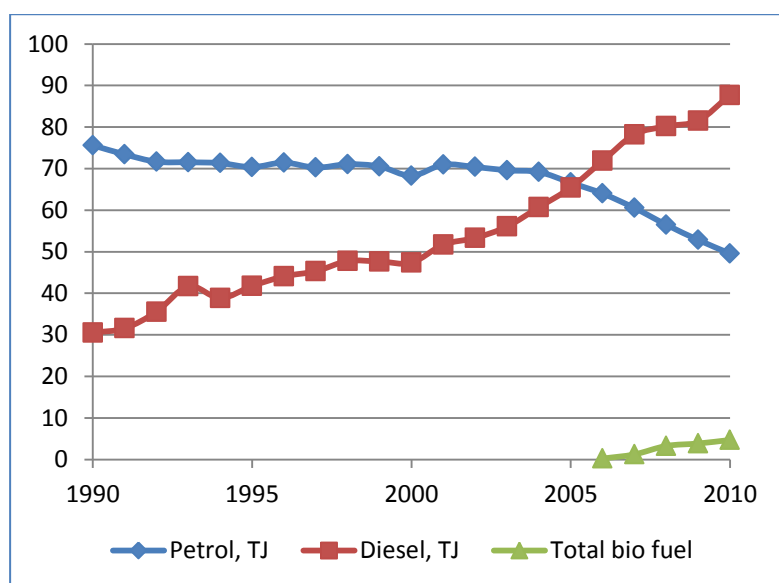


Figure 3.4. Consumption of gasoline, auto diesel and bio fuel for road transportation. 1999-2010. TJ.

Source: Statistics Norway

### 3.2.5.3 Emission factors

Emission factors (except CO<sub>2</sub>) 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.

Bio fuels for transport are not handled as separate fuels. The consumption is included with gasoline and auto diesel. The CO<sub>2</sub> factors for these fuels are adjusted annually according to the bio fuel content.

CO<sub>2</sub>

*Table 3.14. Average CO<sub>2</sub> emission from different vehicle classes, including cold start emissions and evaporation. 1990-2010. 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                      | 692                 |
| 1991 | 214            | 186                      | 489                 | 72         | 192           | 216                      | 694                 |
| 1992 | 212            | 186                      | 488                 | 73         | 189           | 217                      | 693                 |
| 1993 | 210            | 187                      | 488                 | 74         | 185           | 217                      | 804                 |
| 1994 | 208            | 187                      | 488                 | 76         | 181           | 217                      | 820                 |
| 1995 | 206            | 188                      | 488                 | 77         | 179           | 217                      | 795                 |
| 1996 | 204            | 189                      | 488                 | 79         | 176           | 216                      | 791                 |
| 1997 | 201            | 189                      | 488                 | 81         | 173           | 215                      | 777                 |
| 1998 | 197            | 192                      | 488                 | 82         | 164           | 217                      | 802                 |
| 1999 | 194            | 192                      | 489                 | 83         | 162           | 216                      | 817                 |
| 2000 | 192            | 191                      | 489                 | 84         | 160           | 215                      | 810                 |
| 2001 | 191            | 189                      | 489                 | 84         | 159           | 213                      | 810                 |
| 2002 | 189            | 188                      | 489                 | 83         | 158           | 210                      | 810                 |
| 2003 | 187            | 186                      | 489                 | 82         | 158           | 208                      | 812                 |
| 2004 | 186            | 185                      | 490                 | 82         | 157           | 205                      | 825                 |
| 2005 | 185            | 184                      | 490                 | 82         | 157           | 203                      | 850                 |
| 2006 | 183            | 183                      | 489                 | 82         | 156           | 200                      | 868                 |
| 2007 | 182            | 183                      | 489                 | 82         | 151           | 195                      | 876                 |
| 2008 | 181            | 182                      | 489                 | 82         | 144           | 190                      | 862                 |
| 2009 | 180            | 182                      | 488                 | 83         | 142           | 189                      | 860                 |
| 2010 | 179            | 182                      | 488                 | 83         | 140           | 189                      | 864                 |

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

CH<sub>4</sub> and N<sub>2</sub>O

In HBEFA (INFRAS 2009) the CH<sub>4</sub> emission factor for passenger cars using LPG is zero. While buses using CNG has zero for both CH<sub>4</sub> and N<sub>2</sub>O.

*Table 3.15. General CH<sub>4</sub> and N<sub>2</sub>O emission factors from use of natural gas and LPG for passenger cars and heavy duty vehicles*

| Source              | Fuel        | CH <sub>4</sub> kg/tonne | N <sub>2</sub> 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)

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*Table 3.16. Average N<sub>2</sub>O 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 | 0.0072         | 0.0068                | 0.0071              | 0.052 | 0.0013     | 0.0000        | 0.0000                | 0.0064              |
| 1991 | 0.0075         | 0.0068                | 0.0071              | 0.052 | 0.0013     | 0.0000        | 0.0000                | 0.0064              |
| 1992 | 0.0078         | 0.0069                | 0.0071              | 0.052 | 0.0013     | 0.0000        | 0.0000                | 0.0063              |
| 1993 | 0.0082         | 0.0072                | 0.0071              | 0.052 | 0.0014     | 0.0000        | 0.0000                | 0.0072              |
| 1994 | 0.0086         | 0.0076                | 0.0071              | 0.052 | 0.0014     | 0.0000        | 0.0000                | 0.0074              |
| 1995 | 0.0092         | 0.0083                | 0.0071              | 0.053 | 0.0014     | 0.0002        | 0.0004                | 0.0074              |
| 1996 | 0.0100         | 0.0090                | 0.0071              | 0.052 | 0.0015     | 0.0006        | 0.0010                | 0.0075              |
| 1997 | 0.0103         | 0.0097                | 0.0071              | 0.053 | 0.0015     | 0.0011        | 0.0014                | 0.0075              |
| 1998 | 0.0102         | 0.0103                | 0.0071              | 0.052 | 0.0015     | 0.0016        | 0.0020                | 0.0078              |
| 1999 | 0.0102         | 0.0108                | 0.0071              | 0.052 | 0.0016     | 0.0020        | 0.0025                | 0.0079              |
| 2000 | 0.0102         | 0.0113                | 0.0071              | 0.053 | 0.0016     | 0.0025        | 0.0030                | 0.0078              |
| 2001 | 0.0102         | 0.0122                | 0.0071              | 0.051 | 0.0016     | 0.0029        | 0.0033                | 0.0077              |
| 2002 | 0.0101         | 0.0131                | 0.0071              | 0.051 | 0.0016     | 0.0032        | 0.0035                | 0.0075              |
| 2003 | 0.0098         | 0.0116                | 0.0071              | 0.050 | 0.0015     | 0.0035        | 0.0037                | 0.0072              |
| 2004 | 0.0096         | 0.0116                | 0.0071              | 0.050 | 0.0015     | 0.0037        | 0.0038                | 0.0070              |
| 2005 | 0.0053         | 0.0102                | 0.0071              | 0.048 | 0.0015     | 0.0039        | 0.0040                | 0.0070              |
| 2006 | 0.0050         | 0.0099                | 0.0071              | 0.049 | 0.0015     | 0.0041        | 0.0041                | 0.0068              |
| 2007 | 0.0047         | 0.0095                | 0.0071              | 0.051 | 0.0016     | 0.0042        | 0.0042                | 0.0073              |
| 2008 | 0.0044         | 0.0090                | 0.0071              | 0.051 | 0.0016     | 0.0043        | 0.0043                | 0.0083              |
| 2009 | 0.0042         | 0.0084                | 0.0071              | 0.051 | 0.0016     | 0.0043        | 0.0043                | 0.0099              |
| 2010 | 0.0039         | 0.0078                | 0.0071              |       | 0.0016     | 0.0043        | 0.0043                | 0.0131              |

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

*Table 3.17 Average CH<sub>4</sub> 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 | 0.135          | 0.135                 | 0.093               | 12.913 | 0.210      | 0.007         | 0.007                 | 0.022               |
| 1991 | 0.130          | 0.135                 | 0.093               | 12.998 | 0.206      | 0.007         | 0.007                 | 0.022               |
| 1992 | 0.125          | 0.133                 | 0.093               | 13.025 | 0.201      | 0.006         | 0.007                 | 0.023               |
| 1993 | 0.120          | 0.129                 | 0.093               | 13.039 | 0.194      | 0.006         | 0.007                 | 0.022               |
| 1994 | 0.114          | 0.124                 | 0.093               | 13.075 | 0.185      | 0.006         | 0.007                 | 0.021               |
| 1995 | 0.108          | 0.117                 | 0.093               | 13.136 | 0.177      | 0.005         | 0.007                 | 0.020               |
| 1996 | 0.099          | 0.109                 | 0.093               | 12.934 | 0.167      | 0.005         | 0.006                 | 0.019               |
| 1997 | 0.091          | 0.103                 | 0.093               | 13.288 | 0.157      | 0.005         | 0.006                 | 0.017               |
| 1998 | 0.083          | 0.097                 | 0.093               | 12.915 | 0.147      | 0.004         | 0.006                 | 0.016               |
| 1999 | 0.075          | 0.091                 | 0.093               | 12.859 | 0.140      | 0.004         | 0.005                 | 0.014               |
| 2000 | 0.069          | 0.084                 | 0.093               | 13.198 | 0.136      | 0.004         | 0.005                 | 0.014               |
| 2001 | 0.063          | 0.076                 | 0.093               | 12.671 | 0.135      | 0.003         | 0.004                 | 0.013               |
| 2002 | 0.057          | 0.069                 | 0.093               | 12.652 | 0.137      | 0.003         | 0.004                 | 0.012               |
| 2003 | 0.051          | 0.064                 | 0.093               | 13.133 | 0.146      | 0.003         | 0.004                 | 0.011               |
| 2004 | 0.046          | 0.059                 | 0.093               | 14.283 | 0.159      | 0.002         | 0.003                 | 0.010               |
| 2005 | 0.042          | 0.055                 | 0.093               | 15.203 | 0.171      | 0.002         | 0.003                 | 0.010               |
| 2006 | 0.038          | 0.051                 | 0.093               | 16.440 | 0.179      | 0.002         | 0.002                 | 0.009               |
| 2007 | 0.035          | 0.048                 | 0.093               | 17.832 | 0.185      | 0.001         | 0.002                 | 0.009               |
| 2008 | 0.033          | 0.045                 | 0.093               | 18.582 | 0.190      | 0.001         | 0.002                 | 0.008               |
| 2009 | 0.031          | 0.043                 | 0.093               | 19.481 | 0.192      | 0.001         | 0.002                 | 0.007               |
| 2010 | 0.029          | 0.042                 | 0.093               |        | 0.194      | 0.001         | 0.001                 | 0.006               |

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

### 3.2.5.4 Uncertainties

The uncertainty in the activity data and the CO<sub>2</sub> emissions from road transportation is found to be  $\pm 5$  per cent and  $\pm 3$  per cent of the mean, respectively. In the case of CH<sub>4</sub> and N<sub>2</sub>O the uncertainty in the emission factors lies on  $\pm 45$  and  $\pm 65$ , 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 on the other.

However, the total consumption of auto diesel, and hence the CO<sub>2</sub> emission from this fuel, is well known. The uncertainty concerns the allocation between road and non-road use. For CH<sub>4</sub> and N<sub>2</sub>O the total emission is sensitive to the allocation due to different emission factors.

### **3.2.5.6 Recalculations**

#### *1A 3 b i-iii Road transport*

- Revised data. The consumption of auto diesel includes a certain amount of biodiesel. The emission factor for CO<sub>2</sub> is reduced to account for this effect. Due to revised figures on total sales of auto diesel for the year 2009, the emission factor for CO<sub>2</sub> has been upwards adjusted
- Revised data. The consumption of gasoline includes a certain amount of bioethanol, but until 2010 the amount has been insignificant. However, while gathering bioethanol data also information on 2008-2009 was obtained. The emission factor for CO<sub>2</sub> is reduced by ca. 0.1% to account for this effect.

### **3.2.5.7 Planned improvements**

The evaluation of the Norwegian road emission model started in 2008 and the new HBEFA model is now implemented as a part of the Norwegian greenhouse gas emission inventory. 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. In 2012 we will specifically look further into activity data for traffic and the time series for consumption of fuels. A documentation report for the new model is 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). The greenhouse gas emissions from this source category accounted for 0.3 per cent of the total emissions from transport in 2010. The emissions decreased by 59.0 per cent from 1990 to 2010.

### **3.2.6.2 Methodological issues**

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

### **3.2.6.3 Activity data**

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

### **3.2.6.4 Emission factors**

The emission factors used in this source category are displayed in Table 3.4 for CO<sub>2</sub> and Table 3.19 for CH<sub>4</sub> and N<sub>2</sub>O.

### **3.2.6.5 Uncertainties**

The consumption data are of high quality. Their uncertainty is estimated to be  $\pm 5$  per cent of the mean. The uncertainty in the emission factors for CO<sub>2</sub> is  $\pm 3$  per cent of the mean, whereas for CH<sub>4</sub> and N<sub>2</sub>O the uncertainty is below and above the mean by a factor of 2 and 3, respectively.

### **3.2.6.6 Source specific QA/QC and verification**

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

### **3.2.6.7 Recalculations**

There were performed no specific recalculations for this sector this year.

### **3.2.6.8 Planned improvements**

There is for the moment no planned activity that will improve the data quality for NIR 2013.

## **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 4.0 per cent of the national GHG total in 2010 and 14.3 per cent of emissions from transport. The emissions from shipping increased by 26.3 per cent from 1990 to 2010, mainly because of increased activity in the oil and gas extraction sector. GHG emissions in 2010 were 9.1 per cent higher than those of 2009. The average annual growth in GHG emissions from navigation from 1990 to 2010 was 1.2 per cent. Between 1990-2000 and 2000-2010 the annual average growth were 2.7 and – 0.4 per cent, respectively. The increased emissions in the 90ies can to 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 CO<sub>2</sub> emissions in level in 1990 and 2010 and trend uncertainty and for CH<sub>4</sub> 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<sub>x</sub>-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

#### CO<sub>2</sub>

For CO<sub>2</sub> 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

#### CH<sub>4</sub> and N<sub>2</sub>O

For liquid fuels the general/standard emission factors for CH<sub>4</sub> and N<sub>2</sub>O used in the emission inventory are taken from IPCC/OECD: 0.23 kg CH<sub>4</sub>/tonne fuel and 0.08 kg N<sub>2</sub>O/tonne fuel.

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

- CH<sub>4</sub>: 0.8 kg/tonne marine gas oil/diesel; 1.9 kg/tonne heavy fuel oil
- N<sub>2</sub>O: 0.02 kg/tonne marine gas oil/diesel.

Some natural gas is combusted in ferry transportation and offshore supply; the CH<sub>4</sub> 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 (Norddal 2010).

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

| Vessel category                                    | Methane emission factor (kg CH <sub>4</sub> / tonne LNG) | Methane emission factor (kg CH <sub>4</sub> / 1000 Sm <sup>3</sup> 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  $\pm 20$  per cent. With regard to emission factors the uncertainty for ships and fishing vessels is  $\pm 3$  per cent of the mean for CO<sub>2</sub>. For CH<sub>4</sub> and N<sub>2</sub>O 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

- Correction of error. Due to the use of a wrong figure for marine gas oil in ships used in oil and gas extraction in 2007 (32 300 tonnes too low), emissions from this source have increased by (per cent increase): CO<sub>2</sub> 4.7, CH<sub>4</sub> 1.4, N<sub>2</sub>O 1.3
- Correction of error: CO<sub>2</sub> and CH<sub>4</sub> for 1A1C (Manufacture of solid fuels and other energy industries) and 1A3D (National navigation) in 2005. In the previous submission, emissions from drilling at moveable offshore installations were reallocated from 1A3D to 1A1C. In that operation, a mistake was made for certain components in 2005. This mistake has now been corrected. Total emissions for the two sectors were reduced
- Reallocation: As part of the correction mentioned above, an amount of fuel oil was reallocated from 1A3D (National navigation) to 1A1C (Manufacture of solid fuels and other energy industries) in 2005. All components are affected. Total emissions for N<sub>2</sub>O for the two sectors were unchanged, whereas for CO<sub>2</sub> and CH<sub>4</sub> there was an additional correction as mentioned above



### 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 will be investigated. There is 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 will also look into the possibilities to use data from the National Account to allocate consumption of fuels between international and domestic shipping.

## 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 NFR/IPCC 1A1.

### 3.2.8.3 Motorized equipment

#### 3.2.8.3.1 Description

Emissions from this sector were 3.2 per cent of the national GHG total emissions in 2010. In the period 1990-2010, these emissions increased by 107.9 per cent. In 2010 emission levels were 7.8 per cent lower than those in 2008 and in 2010 23.9 per cent above 2009 level. .

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 2010, 1A4 Other sectors – Mobile fuel combustion is a key category with respect to emissions of CO<sub>2</sub> of level in 1990 and 2010. 1A3e Other (snow scooters, boats, motorized equipment) is key category with respect to

emissions of CO<sub>2</sub> in level in 1990 and 2010 and trend and with respect to N<sub>2</sub>O in level in 2010 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/m<sup>3</sup>. Note: Consumption has been kept fixed since 1994 based on a calculation by the Institute of Technology (Bang 1996).

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

Consumption of *auto diesel* is based on data from the energy accounts. Total use of auto diesel in motorized equipment is given as the difference between total sales and estimated use in other sources. From 2001, a certain fraction of the consumption in a number of industries is allocated to motorized equipment, based on the distribution of taxed and tax-free diesel – the latter is meant for use outside road transport. The distribution formulas are based on figures from the statistics on energy use in manufacturing industries or from the sales statistics. The statistics on energy use in manufacturing industries did not have such a split before 2001, and therefore distribution formulas for 2001 are used for 2000 and earlier years. It is important to bear in mind that the total consumption of auto diesel in motorized equipment is considered being of high quality since there is now road tax on this part of the auto diesel. So it is only the allocation between different consumers that might be questioned. There is CO<sub>2</sub> 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 <sub>4</sub> kg/tonne | N <sub>2</sub> 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  | <b>6</b>                 | 0.02                      |
| Motorized equipment 4 stroke | Motor gasoline  | <b>2.2</b>               | <b>0.07</b>               |
|                              | Auto diesel     | <b>0.17</b>              | 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 <sub>4</sub>  | 6.2                        | Motor gasoline | Motorized equipment 2 stroke | Agriculture   |
| CH <sub>4</sub>  | 3.7                        | Motor gasoline | Motorized equipment 4 stroke | Agriculture   |
| CH <sub>4</sub>  | 7.7                        | Motor gasoline | Motorized equipment 2 stroke | Forestry and logging  |
| CH <sub>4</sub>  | 8.1                        | Motor gasoline | Motorized equipment 2 stroke | Private households  |
| CH <sub>4</sub>  | 5.5                        | Motor gasoline | Motorized equipment 4 stroke | Private households  |
| CH <sub>4</sub>  | 0.18                       | Auto diesel    | Motorized equipment 4 stroke | Private households  |
| N <sub>2</sub> 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**

*1A3 e Other (snow scooters, boats, motorized equipment)*

- Revised data. A small rise in 2008 emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, due to the inclusion of a minor auto diesel figure for one plant.
- Reallocation. Due to a reallocation of auto diesel 2000-2009 between forestry and other mobile sources and machinery, there is a small increase of emissions of all components these years. The reallocation is due to an error in the estimation of diesel use in forestry, which has given too high figures for the years in question. As total use is defined as equal to total sales, the amounts subtracted from forestry have been transferred to 1A3eii.

#### **3.2.8.3.8 Planned improvements**

Norway has now started 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<sub>x</sub> where the emissions are dependent of technology. The project is planned to be finalized to the 2013 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 29 percent from 1990 to 2010 and increased in both 2009 and 2010, the latter year by 8 percent. In 2010 the emissions from the whole sector were 3.6 million tonne CO<sub>2</sub>-equivalents and constitute of 6.7 per cent of national total GHG that year. The sectors emissions decreased by 17.2 percent from 1990 to 2010 and increased by 3.2 percent during 2010 and the latter was due to increased activity in fisheries, combustion and motorized equipment. Throughout the period 1990-2010, 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 2010, this sector is, in conjunction with sectors 1A1 and 1A2, a key category with respect to:

- Emissions of CO<sub>2</sub> from the combustion of liquid and gaseous fuels in both level and trend uncertainty

- Emissions of CO<sub>2</sub> from the combustion of Other fuels in level in 2010 and trend uncertainty and solid fuels are key category in level in 1990
- Emissions of CH<sub>4</sub> from the combustion of gaseous fuels in trend uncertainty and biomass in level in 1990 and 2010 and in trend

### 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.

#### 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.

#### 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.

### 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  $\pm 20$  per cent of the mean for solid and liquid fuels, and  $\pm 30$  per cent of the mean for biomass and waste. For natural gas the amount is considered to be known with  $\pm 10$  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

- Correction of error. 1.6 ktonne of coal coke has been removed from this category in 2009. However, because of higher use of other energy goods, there is still an overall emission increase in 1A4a

#### 1A 4 b Residential

- Revised activity data. For the years 2005-2009 the amount of wood burned in private households has been revised due to a new weighting of figures from the survey used to calculate wood consumption. This has led to increased emissions of all components

included in the national inventory, included CH<sub>4</sub>, for 2007-2009 and reduced emissions 2005-2006.

#### *1A 4 c Agriculture/Forestry/Fishing*

- Reallocation. Due to a reallocation of auto diesel 2000-2009 between forestry and other mobile sources and machinery, there is a small decrease in emissions of all components these years. The reallocation is due an error in the estimation of diesel use in forestry, which has given too high figures for the years in question

#### **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 CO<sub>2</sub> 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**

There were performed no specific recalculations for this sector this year.

##### **3.2.10.2 Planned improvements**

There is for the moment no planned activity that will improve the data quality for NIR 2013

Table 3.21. Stationary and mobile emissions from military activities. 1990-2010.  
CO<sub>2</sub> in 1000 tonne, CH<sub>4</sub> and N<sub>2</sub>O in tonne.

|                            | CO <sub>2</sub> | CH <sub>4</sub> | N <sub>2</sub> O |
|----------------------------|-----------------|-----------------|------------------|
| <b>1990</b>                |                 |                 |                  |
| 1A5A Military – stationary | 62              | 7.9             | 0.6              |
| 1A5B Military – mobile     | 394             | 15.9            | 19.2             |
| <b>1991</b>                |                 |                 |                  |
| 1A5A Military – stationary | 53              | 6.7             | 0.5              |
| 1A5B Military – mobile     | 353             | 14.5            | 17.9             |
| <b>1992</b>                |                 |                 |                  |
| 1A5A Military – stationary | 60              | 7.2             | 0.6              |
| 1A5B Military – mobile     | 427             | 18.2            | 25.5             |
| <b>1993</b>                |                 |                 |                  |
| 1A5A Military – stationary | 44              | 5.6             | 0.4              |
| 1A5B Military – mobile     | 322             | 13.8            | 16.0             |
| <b>1994</b>                |                 |                 |                  |
| 1A5A Military – stationary | 51              | 6.4             | 0.5              |
| 1A5B Military – mobile     | 457             | 14.1            | 21.6             |
| <b>1995</b>                |                 |                 |                  |
| 1A5A Military – stationary | 48              | 6.1             | 0.5              |
| 1A5B Military – mobile     | 406             | 11.4            | 21.5             |
| <b>1996</b>                |                 |                 |                  |
| 1A5A Military – stationary | 62              | 7.9             | 0.6              |
| 1A5B Military – mobile     | 344             | 10.9            | 15.5             |
| <b>1997</b>                |                 |                 |                  |
| 1A5A Military – stationary | 74              | 9.2             | 0.7              |
| 1A5B Military – mobile     | 351             | 10.5            | 20.3             |
| <b>1998</b>                |                 |                 |                  |
| 1A5A Military – stationary | 50              | 6.2             | 0.5              |
| 1A5B Military – mobile     | 310             | 11.4            | 25.5             |
| <b>1999</b>                |                 |                 |                  |
| 1A5A Military – stationary | 50              | 6.3             | 0.5              |
| 1A5B Military – mobile     | 341             | 10.7            | 19.8             |
| <b>2000</b>                |                 |                 |                  |
| 1A5A Military – stationary | 41              | 5.1             | 0.4              |
| 1A5B Military – mobile     | 138             | 7.7             | 11.6             |
| <b>2001</b>                |                 |                 |                  |
| 1A5A Military – stationary | 54              | 6.9             | 0.5              |
| 1A5B Military – mobile     | 241             | 12.8            | 12.8             |
| <b>2002</b>                |                 |                 |                  |
| 1A5A Military – stationary | 44              | 5.5             | 0.4              |
| 1A5B Military – mobile     | 409             | 9.6             | 14.2             |
| <b>2003</b>                |                 |                 |                  |
| 1A5A Military – stationary | 58              | 7.3             | 0.6              |
| 1A5B Military – mobile     | 114             | 6.6             | 4.3              |
| <b>2004</b>                |                 |                 |                  |
| 1A5A Military – stationary | 45              | 5.7             | 0.4              |
| 1A5B Military – mobile     | 285             | 8.5             | 10.0             |
| <b>2005</b>                |                 |                 |                  |



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|                            | <b>CO<sub>2</sub></b> | <b>CH<sub>4</sub></b> | <b>N<sub>2</sub>O</b> |
|----------------------------|-----------------------|-----------------------|-----------------------|
| 1A5A Military – stationary | 37                    | 4.7                   | 0.4                   |
| 1A5B Military – mobile     | 252                   | 5.3                   | 8.9                   |
| <b>2006</b>                |                       |                       |                       |
| 1A5A Military – stationary | 39                    | 4.9                   | 0.4                   |
| 1A5B Military – mobile     | 239                   | 6.2                   | 8.5                   |
| <b>2007</b>                |                       |                       |                       |
| 1A5A Military – stationary | 32                    | 4.1                   | 0.3                   |
| 1A5B Military – mobile     | 177                   | 4.8                   | 6.8                   |
| <b>2008</b>                |                       |                       |                       |
| 1A5A Military – stationary | 32                    | 4.2                   | 0.4                   |
| 1A5B Military – mobile     | 221                   | 9.6                   | 12.9                  |
| <b>2009</b>                |                       |                       |                       |
| 1A5A Military – stationary | 36                    | 5.7                   | 0.7                   |
| 1A5B Military – mobile     | 228                   | 10.1                  | 13.2                  |
| <b>2010</b>                |                       |                       |                       |
| 1A5A Military – stationary | 42                    | 6.8                   | 0.9                   |
| 1A5B Military – mobile     | 226                   | 9.7                   | 13.9                  |

### 3.3 Fugitive Emissions from Coal Mining and Handling – 1B1a – CH<sub>4</sub> (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 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. 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 and 11 per cent in 2010. The emissions from mining were in 2010 therefore only 36 Gg CO<sub>2</sub> equivalents.

Figure 3.5 illustrate that the production of coal at Svalbard increased 31 per cent from 1990 to 2000. In 2001 the production almost doubled from 2000. There was a peak in the production in 2007 when the production was almost five times higher than in 1990 and in 2009 the coal production was reduced to being three times higher than in 1990. The production of coal in 2010 was 26.3 per cent lower than in 2009.

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 CO<sub>2</sub> emissions from the fire are estimated to approximately 3,000 tonne.

CH<sub>4</sub> from coal mining is not defined as a key category in the Tier 2 key category analysis nor in Tier 1 analysis. However, we regard coal mining as a key category due to change in trend in the coal production and the fact that the emission factor used for the Norwegian mines is in an order of magnitude less than IPCC's default factors.

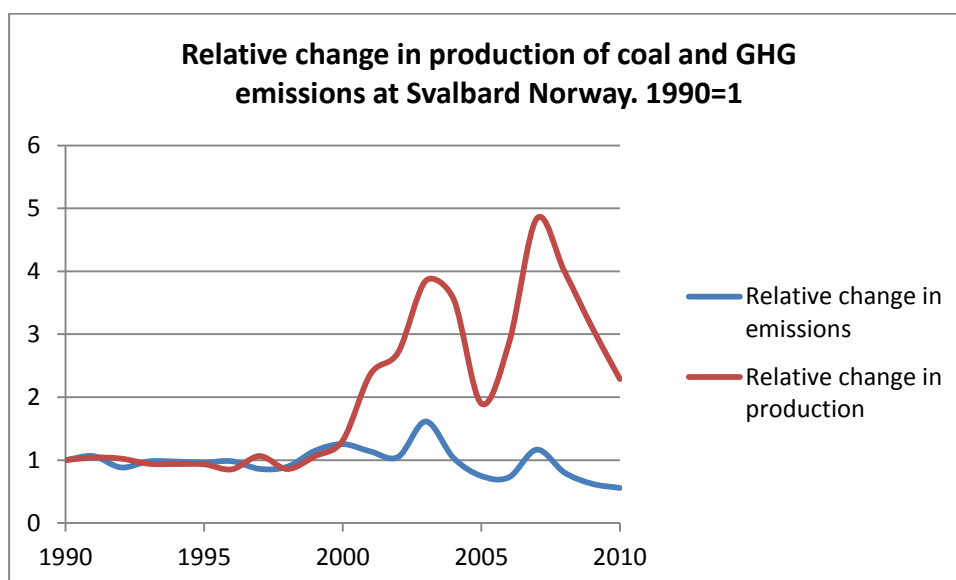


Figure 3.5. Coal productions in Norway. Relative change in production and GHG emissions. 1990-2009.

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 on indirect  $CO_2$ ).

#### $CH_4$

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

### 3.3.3 Activity data

Figures on Norwegian production (raw coal production) are reported by the plant to Statistics Norway. Russian figures are reported to the Norwegian authorities on Svalbard; these figures are, however, regarded as highly uncertain, consisting of a mixture of figures on production and shipments.

### 3.3.4 Emission factor

#### $CH_4$

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

The emissions of methane from coal mining were in the study measured in two steps. First, coal was sampled and the methane content in coal was analysed (IMC Technical Services Limited 2000). The sampling process started after a long period (a week) of continuous production. Small samples of coal were removed directly from the coalface as soon as

possible after a cut was taken. This was to minimize degassing losses in the samples if the face or heading had been standing for a long time.

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

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

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

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

For the Russian mine in Barentsburg, the emission factor for CH<sub>4</sub> 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 2009.

### **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 still on the agenda to evaluate the EF based on measurements that we use in the calculation today.

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

#### 3.4.1 Overview

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 production sold of oil, gas and NGL and condensate in the period 1974-2010. Maximum production of oil, gas and NGL and condensate was reached in 2004 and the production was then approximately 263 mill Sm<sup>3</sup> oil equivalents. This was an increase since 1990 of approximately 200 per cent. In 2010 the total production has decreased by 14 per cent compared to the all-time high production in 2004 and 4.1 per cent since 2009. The maximum production of oil was reached in 2001. Preliminary data show that the production of gas in 2010 was then for the first time higher than the production of oil. For more information about the Norwegian petroleum sector see the report Facts 2011 – The Norwegian petroleum sector published by the Ministry of Petroleum and Energy together with the Norwegian Petroleum Directorate (OED/NPD 2011).

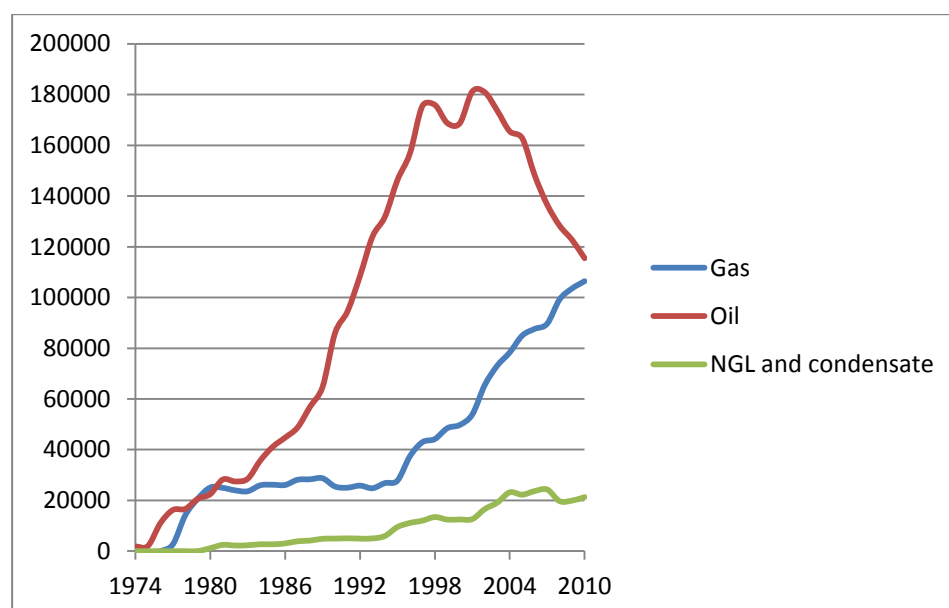


Figure 3.6. Net production sold of oil, gas and NGL and condensate. 1000 Sm<sup>3</sup> oe.

Source: Statistics Norway.

As response to the 2009 ERT review report 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 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 flaring from oil and gas exploration and production, gas terminals and refineries and 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 and natural gas contribute 5.9 per cent to the total GHG emissions in Norway in 2009 and 2010 and with 8.0 per cent of the GHG emissions in the energy sector.

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 6.6 per cent from 1990 to 2010 while e.g. the production of oil and gas increased by 84 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 sector were increased by 5.1 per cent from 2009 to 2010.

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. CO<sub>2</sub> emissions from the catalytic cracker in sector 2.B.2.a.iv Refining/Storage increased by nearly 30 per cent in 2009 due to increased production. In 2010 the emissions were on the same level.

In Figure 3.7a you will see the emissions from four source categories in absolute values and relative change in emissions compared to 1990, Figure 3.7b. The two source categories with highest emissions, flaring and fugitives from oil (Figure 3.7a), have been almost stabile (Figure 3.7b) in the period 1990-2010. 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 CO<sub>2</sub> equivalents.

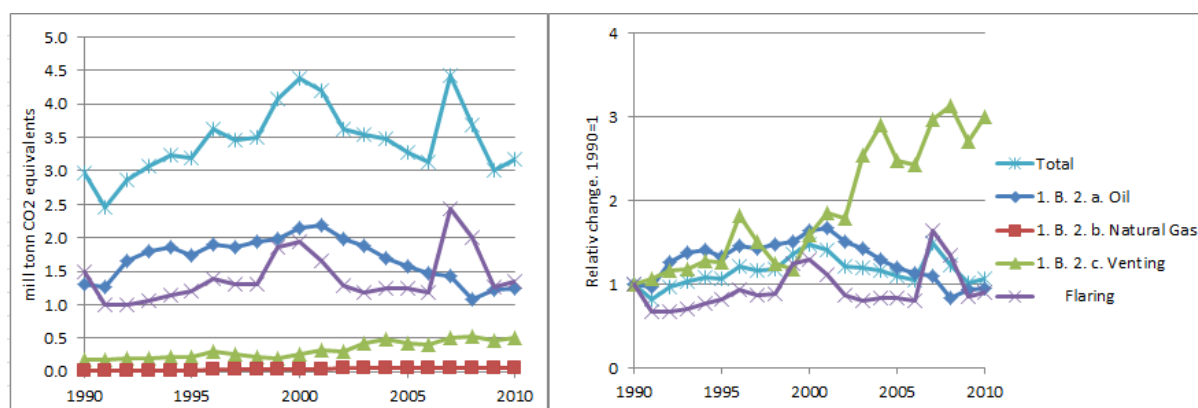


Figure 3.7a. Fugitive emissions from oil and gas production. Million tonne CO<sub>2</sub> equivalents.

Source: Statistics Norway and Climate and Pollution Agency

Figure 3.7b. Relative change in fugitive emissions in CO<sub>2</sub> equivalents from oil and gas production. 1990=1.

Source: Statistics Norway and Climate and Pollution Agency

In 2010 CO<sub>2</sub> from flaring off shore contributed with 1.8 per cent to the total GHG emissions in Norway. The CO<sub>2</sub> emissions from flaring off shore were 25 per cent lower in 2010 than it was in 1990 while the oil and gas production were more than 84 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.

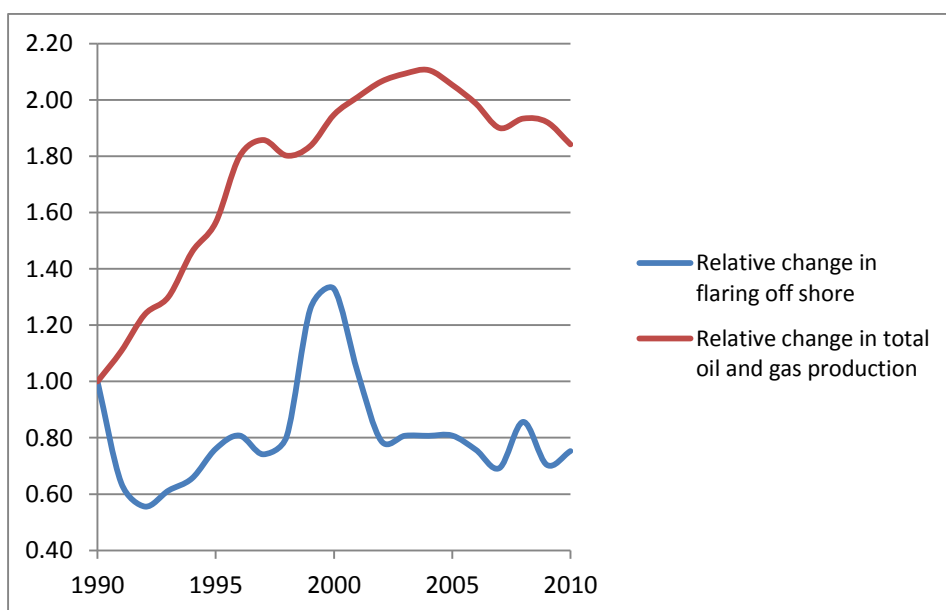


Figure 3.8a. Relative change in CO<sub>2</sub> emissions from flaring off shore and total production of oil and gas. 1990=1. Source: Statistics Norway and Climate and Pollution Agency

Figure 3.8b shows the number of exploration wells on the Norwegian continental shelf in the period 1990-2010. The activity has been high most of the year with 1994, 1999, 2002-2004 and especially 2005 as years with low activity. In average 33 exploration wells have been started each year from 1990.

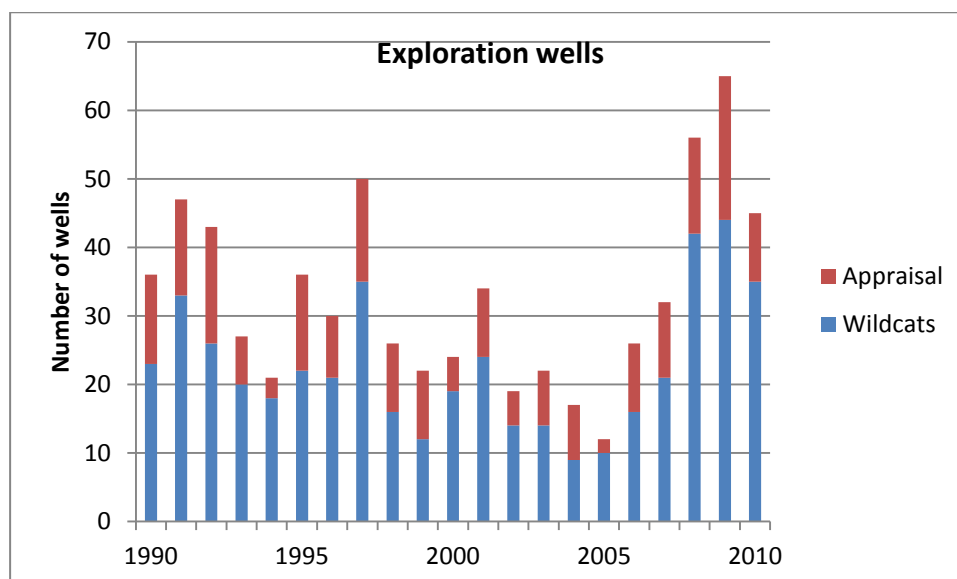


Figure 3.8b. Exploration wells. Number of wildcats and appraisal wells started. 1990-2010.  
Source: Norwegian petroleum directorate

Table 3.22a gives an overview over the calculations of the fugitive emissions of CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and NMVOC. The notation R/E in the table indicates that emission estimates is based on reporting from the entities or calculated by Statistics Norway; see e.g. section 1.4.4.2 about flaring. Basically the emission estimates are carried out by Statistics Norway up to about 2002. Table 3.22b shows the shares of total CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions in the sector based on estimated and reported emission estimates for 2010. From the table you see that for CO<sub>2</sub> and CH<sub>4</sub> more than 90 per cent of the emissions in the sector are based on reports from the plant, mainly off shore installations. N<sub>2</sub>O is based on estimates.

#### Sector 1.B.2.a Oil:

- CO<sub>2</sub>: 85 per cent is based on reports that are from catalytic cracker at one oil refinery and indirect CO<sub>2</sub> emissions from loading and storage of crude oil. The emissions from the latter source category are estimated based on reported emission of NMVOC and CH<sub>4</sub>.
- CH<sub>4</sub>: 100 per cent is based on reports from refineries and oil and gas installations

#### 1.B.2.b Natural gas:

- CO<sub>2</sub>: 100 per cent is estimated and is indirect CO<sub>2</sub> based on mostly reported CH<sub>4</sub> emissions from gas terminals
- CH<sub>4</sub>: 99 per cent of the emissions is based on reported emissions from gas terminals

#### 1.B.2.c Venting and flaring

- CO<sub>2</sub>: 96 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 CO<sub>2</sub> based on mostly reported CH<sub>4</sub> emissions from gas terminals



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- CH<sub>4</sub>: 99 per cent of the emissions are based on reported emissions from the oil and gas installations.

*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>B Fugitive emissions from fuels</b>   | <b>CO<sub>2</sub></b> | <b>CH<sub>4</sub></b> | <b>N<sub>2</sub>O</b> | <b>NMVOC</b> | <b>Method</b> | <b>Emission factor</b> | <b>Activity data</b> |
|--|-----------------------|-----------------------|-----------------------|--------------|---------------|------------------------|----------------------|
| <b>1.B.2.a Oil</b>                       |                       |                       |                       |              |               |                        |                      |
| 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           |               |                        |                      |
| <b>1.B.2.b Natural gas</b>               |                       |                       |                       |              |               |                        |                      |
| 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                         | IE                    | 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           |               |                        |                      |
| <b>1.B.2.c</b>                           |                       |                       |                       |              |               |                        |                      |
| <b>Venting</b>                           |                       |                       |                       |              |               |                        |                      |
| 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                   |
| <b>Flaring</b>                           |                       |                       |                       |              |               |                        |                      |
| i. Oil (well testing)                    | R/E                   | E                     | E                     | R/E          | Tier II       | CS                     | PS                   |
| ii. Gas                                  |                       |                       |                       |              |               |                        |                      |
| Gas and oil fields                       | R/E                   | R/E                   | E                     | R/E          | Tier II       | CS                     | PS                   |
| Gas terminals                            | R                     | R                     | E                     | R/E          | Tier I        | CS                     | CS                   |
| Refineries                               | R                     | R                     | R/E                   | E            | Tier I        | CS                     | CS                   |
| iii. Combined                            | IE                    | IE                    | IE                    | IE           | Tier I        | CS                     | CS                   |

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

|  | CO <sub>2</sub> |             | CH <sub>4</sub> |             | N <sub>2</sub> O |             |
|--|-----------------|-------------|-----------------|-------------|------------------|-------------|
|  | Estimated       | Reported    | Estimated       | Reported    | Estimated        | Reported    |
| <b>B Fugitive emissions from fuels</b> | <b>9 %</b>      | <b>91 %</b> | <b>4 %</b>      | <b>96 %</b> | <b>84 %</b>      | <b>16 %</b> |
| 1B1a a Coal Mining                     | 100 %           | 0           | 71 %            | 29 %        |                  |             |
| 1.B.2.a Oil                            | 15 %            | 85 %        | 0 %             | 100 %       |                  |             |
| 1.B.2.b Natural gas                    | 100 %           | 0 %         | 1 %             | 99 %        |                  |             |
| 1.B.2.c Venting and flaring            | 4 %             | 96 %        | 1 %             | 99 %        | 84 %             | 16 %        |

Table 3.22b. Fugitive emissions from oil and natural gas. Share of total CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions in the sector based on estimated and reported emission estimates for 2010.

### 3.4.2 Fugitive Emissions from Oil – CO<sub>2</sub>, CH<sub>4</sub> – 1.B.2.a (Key Category)

#### 3.4.2.1 Description

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

Loading, unloading and storage of crude oil on the oil fields offshore and at oil terminals on shore causes direct emissions of CH<sub>4</sub> and indirect emissions of CO<sub>2</sub> from oxidized NMVOC and CH<sub>4</sub>. Non-combustion emissions from Norway's two oil refineries (a third was closed down in 2000) include CO<sub>2</sub>, CH<sub>4</sub> and NMVOC. It is important to have in mind that included in source category 1.B.2.a.iv is CO<sub>2</sub> 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 CO<sub>2</sub> emissions.

Indirect emissions of CO<sub>2</sub> from loading and storage of crude oil, distribution of gasoline, direct CO<sub>2</sub> emissions from catalytic cracker at a refinery are *key category* in level in both 1990 and 2010 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 2010 for CH<sub>4</sub> 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*

From 2003, emission of CH<sub>4</sub> and NMVOC from loading and storage of crude oil on shuttle tankers included in the GHG Inventory are based on reported emission figures from the oil companies. Emissions, activity and to some extent emissions factors are reported from each field operator into the database Environmental Web. The database is operated by the Norwegian Petroleum Directorate, the Climate and Pollution Agency and <sup>1</sup>The Norwegian Oil Industry Association. In addition the field operators each year deliver a report where they describe the activities during the last year.

Before 2003 the reported emissions of CH<sub>4</sub> and NMVOC is calculated by Statistics Norway. The calculation was based on the field specific amounts of crude oil loaded and stored multiplied with field specific emission factors. Field specific activity data and emission factors (the latter only to 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.

Norway considers that the method for calculating the CH<sub>4</sub> and NMVOC emissions from loading and storage of crude oil is consistent for the period 1990-2005.

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

For the two Norwegian oil terminals on shore, the emissions from loading of crude oil are reported annually from the terminals to the Climate and Pollution Agency. At one of the terminals VRU for recovering NMVOC was installed in 1996. The calculation of the emissions of CH<sub>4</sub> and NMVOC at both terminals is based upon the amount of crude oil loaded and oil specific emission factor dependent of the origin of the crude oil loaded.

The reported indirect CO<sub>2</sub> emissions from the oxidation of CH<sub>4</sub> and NMVOC in the atmosphere see Section 3.6.3 for this source category is calculated by Statistics Norway.

#### *Refining/Storage – 1.B.2.A.iv*

The direct emissions of CO<sub>2</sub>, CH<sub>4</sub> 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 CH<sub>4</sub> emissions from the largest refinery. The CH<sub>4</sub> 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 CO<sub>2</sub> emissions originate from the coke on the catalyst that is burned off and from the coke calcining kilns. 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 CO<sub>2</sub> emissions from catalytic cracker and calcining kilns are calculated from the formula:

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

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

The indirect CO<sub>2</sub> from oxidized CH<sub>4</sub> 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 the 2010 submission 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*

For the years before 2003, emission factors used in the calculation of CH<sub>4</sub> and NMVOC emissions offshore are field 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. From 2003 the emission figures reported by the field operators are used in the inventory.

The evaporation rate varies from field to field and over time, and the emission factors are dependent on the composition of the crude oil as indicated by density and Reid vapour pressure (RVP). The VOC evaporation emission factors are obtained from measurements, which include emissions from loading and washing of shuttle tankers. For some fields the emission factors are not measured, only estimated. The CH<sub>4</sub> content of the VOC evaporated is also measured so that total emissions of VOC are split between CH<sub>4</sub> 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 CH<sub>4</sub> and NMVOC.

*Loading on shore:* The emission factors are considerably lower at one of Norway's two oil terminals than at the other, because the oil is transported by ship and therefore the lightest fractions have already evaporated. At the other terminal the oil is delivered by pipeline. The

latter terminal has installed VRU, which may reduce NMVOC emissions from loading of ships at the terminal by about 90 per cent. NMVOC emissions at this terminal are estimated to be more than 50 per cent lower than they would have been without VRU. However, the VRU technology is not designed to reduce methane and ethane emissions.

#### *Refining/Storage – 1.B.2.A.iv*

The CO<sub>2</sub> emissions from the catalytic cracker are calculated as described above under Methodological issues. The CO<sub>2</sub> 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.

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  $\pm 40$  per cent and in the activity data  $\pm 3$  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.

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. From 2003 Statistics Norway estimate emission based on activity data that the field operators monthly report to the Norwegian Petroleum Directorate and reported emission factors. When discrepancies are found between the two sets of data they are investigated and corrections are made if appropriate. If errors are found, the Climate and Pollution Agency contacts the plant to discuss the reported data and changes are made if necessary.

### **3.4.2.7 Recalculations**

#### *1 B 2 a iii Oil exploration, production, transport*

- Revised data. CH<sub>4</sub> emissions have been increased by 391 tonnes in 2009 due to a revised reported figure on loading of oil at one plant on shore
- Reallocation/revised data. Parts of CH<sub>4</sub> figures 2007-2009 for one plant, previously registered as combustion emissions, have been reallocated to 1B2aiii. There are also changes in total CH<sub>4</sub> emissions for this plant.

*1B 2a v Distribution of oil products*

- Revised data. Due to revised figures in the sales statistics for petroleum products, indirect emissions of CO<sub>2</sub> from petrol distribution in 2006-2009 have been somewhat altered. The figures for 2006 and 2007 have increased by 1 tonne, emissions in 2008 have been reduced by 20 tonnes and the figures for 2009 are 199 tonnes higher.

**3.4.2.8 Planned improvements**

There is for the moment no planned activity that will improve the data quality for NIR 2013.

**3.4.3 Fugitive Emissions from Natural Gas – CH<sub>4</sub> – 1.B.2.b (Key Category)**

**3.4.3.1 Description**

Sector 1.B.2.b covers fugitive emissions of CH<sub>4</sub> and NMVOC and indirect emissions of CO<sub>2</sub> 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.

CH<sub>4</sub> 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 CH<sub>4</sub> 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*

*CH<sub>4</sub>*

Emissions of CH<sub>4</sub> 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 CH<sub>4</sub> 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.

*Table 3.23. Emission factors for gas distribution.*

|                                      | CH <sub>4</sub><br>Emission<br>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 <sup>3</sup> 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 data. Revised figures on use of natural gas caused a minor decrease in CH<sub>4</sub> emissions in 2008 and an increase in 2009.

### 3.4.3.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2013.

### 3.4.4 Fugitive Emissions from Venting and Flaring – CO<sub>2</sub>, CH<sub>4</sub> – 1.B.2.c – (Key Category)

#### 3.4.4.1 Description

Included in sector *1.B.2.c Flaring* are emissions from flaring of gas off shore, at gas terminals and at refineries and the emissions is reported in sector 1.B.2.c.ii. Emission of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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 CO<sub>2</sub>, CH<sub>4</sub> and NMVOC from exploration and production drilling of gas and oil and reinjection of CO<sub>2</sub> at the Sleipner oil and gas field and Hammerfest LNG (Snøhvit gas-condensate field). The major source is cold vent and leakage of CH<sub>4</sub> and NMVOC from production drilling.

The sector *1.B.2.c Venting* includes emissions of CH<sub>4</sub> and NMVOC and hence indirect CO<sub>2</sub> 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. CO<sub>2</sub> emissions vented to the atmosphere when the injection of CO<sub>2</sub> has to stop for maintenance etcetera is reported in this sector. See Section 3.5 and Annex IV CO<sub>2</sub> 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 since 1996.

|                                      | 1996  | 1997  | 1998  | 1999  | 2000  | 2001  | 2002  | 2003  | 2004  | 2005  | 2006  | 2007  | 2008  | 2009  | 2010  |
|--------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Vented, mill tonne CO <sub>2</sub>   | 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 |
| Injected, mill tonne CO <sub>2</sub> | 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 |
| 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   |
| 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  |

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 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.

CO<sub>2</sub> and CH<sub>4</sub> from venting and flaring is *key category* with respect to level in 1990 and 2010 and only CH<sub>4</sub> 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 CH<sub>4</sub> 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 CO<sub>2</sub> emissions are calculated by Statistics Norway.



The vented CO<sub>2</sub> at Sleipner Vest and Hammerfest LNG (Snøhvit gas-condensate field) are measured.

#### *Flaring*

The CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 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 CO<sub>2</sub> and CH<sub>4</sub> 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 CH<sub>4</sub> and N<sub>2</sub>O from flaring of oil is estimated for all years by Statistics Norway based on the amount of oil well tested reported annually by the field operators and the same emission factors for the whole period.

Emissions of CO<sub>2</sub> from flaring at the four gas terminals that is included in the inventory are reported from the plant.

The refineries reports annually CO<sub>2</sub> 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*

Amounts of gas produced or handled at the platforms are reported from the Norwegian Petroleum Directorate and use in the QC of the reported emissions.

##### *Flaring*

Amounts of gas flared at offshore oil and gas installations are monthly reported by the operators to the 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). During the expert review of the NIR 2005 it was a subject whether the Efs we used were default factors or field specific.

Table 3.25. Default emission factors for cold vents and leakage at gas fields off shore.

|  | NMVOC                | CH <sub>4</sub>      |                    |
|--|----------------------|----------------------|--------------------|
|  | Emission factor      | Emission factor      | Calculation method |
| Emission source                        | [g/Sm <sup>3</sup> ] | [g/Sm <sup>3</sup> ] |                    |
| 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 <sup>4</sup>    | 0.4                  | 0.36                 |                    |
| Depressurization of equipment          | 0.005                | 0.016                |                    |
| Instrument flushing and sampling       | 0.00021              | 0.00005              |                    |
| Purge and blanket gas <sup>1</sup>     | 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                |                    |

<sup>1</sup> The gas source is standard fuel gas.

Source: Aker Engineering (1992).

### Flaring

CO<sub>2</sub>: From 2003, CO<sub>2</sub> emission figures reported by the oil companies to the Climate and Pollution Agency and the Norwegian Petroleum Directorate are used in the inventory. For the years 1990-02, average emission factors, based on field specific factors, are used, except for one field, for which a field specific factor is used for all years. In Table 3.24, the CO<sub>2</sub> emission factors for flaring off shore and at one gas terminals are shown. 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 2.50 and 2010 2.55 tonne CO<sub>2</sub>/tonne gas flared. For the two last gas terminals the average emissions factor in 2009 and 2010 were 1.94 and 1.77 and 2.93 (both years) ton CO<sub>2</sub> per tonne gas.

<sup>4</sup> The gas source is standard fuel 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 CH<sub>4</sub> and N<sub>2</sub>O from well testing off shore were not included in the inventory. Norway then estimated the emissions of CH<sub>4</sub> and N<sub>2</sub>O and presented the result for the expert review team. Our intention was to include emission estimates in the 2009 submission. But due to an omission this was not then done but as explained above these emissions are now included in the inventory.

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

|             | <b>Average<br/>emission<br/>factor for<br/>flaring at<br/>one gas<br/>terminal</b> | <b>Average<br/>emission<br/>factor for<br/>flaring off<br/>shore</b> |
|-------------|--|--|
|             | <b>tonne<br/>CO<sub>2</sub>/tonne<br/>natural gas</b>                              | <b>kg CO<sub>2</sub>/ Sm<sup>3</sup><br/>natural gas</b>             |
| <b>1990</b> | 2.70   | 2.34   |
| <b>1991</b> | 2.70   | 2.34   |
| <b>1992</b> | 2.70   | 2.34   |
| <b>1993</b> | 2.70   | 2.34   |
| <b>1994</b> | 2.70   | 2.34   |
| <b>1995</b> | 2.70   | 2.42   |
| <b>1996</b> | 2.70   | 2.34   |
| <b>1997</b> | 2.70   | 2.34   |
| <b>1998</b> | 2.70   | 2.34   |
| <b>1999</b> | 2.70   | 2.48   |
| <b>2000</b> | 2.70   | 2.52   |
| <b>2001</b> | 2.70   | 2.42   |
| <b>2002</b> | 2.70   | 2.47   |
| <b>2003</b> | 2.70   | 2.46   |
| <b>2004</b> | 2.70   | 2.52   |
| <b>2005</b> | 2.70   | 2.46   |
| <b>2006</b> | 2.69   | 2.44   |
| <b>2007</b> | 2.67   | 2.33   |
| <b>2008</b> | 2.67   | 2.33   |
| <b>2009</b> | 2.67   | 2.55   |
| <b>2010</b> | 2.65   | 2.57   |

*Source: Climate and Pollution Agency/Norwegian Petroleum Directorate*

Table 3.27. Emission factors for flaring in connection with well testing.

| Compounds (unit)          | unit/tonne flared oil | Source   | unit/kSm <sup>3</sup> flared natural gas | Source       |
|---------------------------|-----------------------|--|--|--------------|
| CO <sub>2</sub> (tonnes)  | 3.20                  | (SFT 1990)   | 2.34                                     | (SFT 1990)   |
| CH <sub>4</sub> (tonnes)  | 0.0004 <sup>2</sup>   | Same factors as for fuel oil used for boilers in manufacturing | 0.00024                                  | (IPCC 1997b) |
| N <sub>2</sub> O (tonnes) | 0.00003 <sup>2</sup>  |  | 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)   |

<sup>1</sup>The Norwegian Oil Industry Association

<sup>2006</sup> Same factor as used for fuel oil used for boilers in manufacturing

### 3.4.4.5 Uncertainties

The uncertainty in the amount of gas flared is in (Statistics Norway 2000) regarded as being low,  $\pm 1.4$  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 CO<sub>2</sub> emission factor for flaring is  $\pm 10$  (Statistics Norway 2000).

The uncertainty in the amount of gas flared is in regarded as being low,  $\pm 1.4$  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 CO<sub>2</sub> emission factor for flaring is  $\pm 4.5$  (Climate and Pollution Agency 2011a) and (Statistics Norway 2000).

The uncertainty in CH<sub>4</sub> and NM VOC emissions from venting and, hence, in the indirect emissions of CO<sub>2</sub>, is much higher than for flaring.

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

### 3.4.4.6 Source-specific QA/QC and verification

Statistics Norway collects the activity data used in the calculation from the 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.

#### **3.4.4.7 Recalculations**

##### *1B 2c1iii Venting combined*

- Revised data. New reported figures for two oil and gas extraction fields have increased the CH<sub>4</sub> emissions in 2009 by 444 tonnes. Indirect CO<sub>2</sub> emissions from CH<sub>4</sub> and NMVOC have increased by 4478 tonnes
- New data. CO<sub>2</sub> emissions in 2007 have risen by 70 500 tonnes, due to the inclusion of a previously not registered figure for one plant
- Reallocation. A part of the previously registered CO<sub>2</sub> figure for one plant has been reallocated to combustion.

##### *1B 2c2ii Flaring of gas*

- Reallocation. As mentioned above in 1A 1b the same key for distribution between flaring and energy utilisation of refinery gas previously has been used for all years in the whole period 1990-2009. Now plant and year specific figures have been used instead. This causes a reallocation of emissions between 1A1b and 1B2c, but there is no change in total emissions. The reallocation causes lower emissions for 1B2c in 1991, 1995 and 2003-2009, whereas the emissions have been increased in 1990, 1992-1994, and 1996-2002. Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are affected by the change
- Correction of error. The removal of a previous double counting for CO<sub>2</sub> and CH<sub>4</sub> in 2008 and 2009 has, in addition to the reallocation mentioned above, caused a further reduction in CO<sub>2</sub> and CH<sub>4</sub> emissions for these years
- Reallocation/revised data. Parts of the CH<sub>4</sub> figures 2007-2009 for one plant, previously registered as emissions from flaring, have been reallocated to process. There are also changes in total CH<sub>4</sub> figures for this plant.

#### **3.4.4.8 Planned improvements**

There is for the moment no planned activity that will improve the data quality for NIR 2013.

### 3.5 CO<sub>2</sub> capture and storage at oil and gas production fields (Key Category)

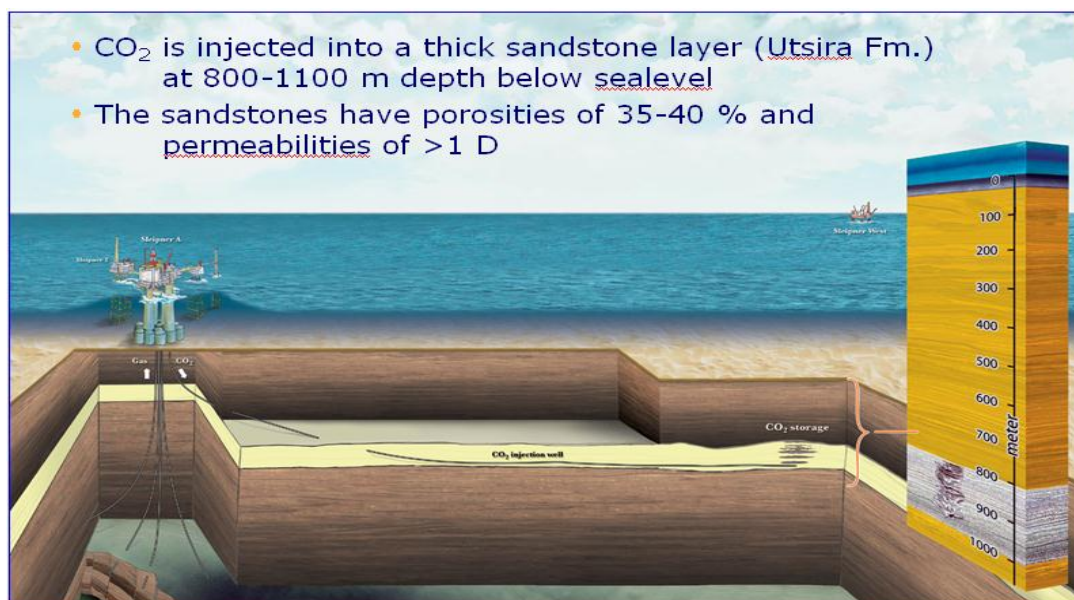
#### 3.5.1 CO<sub>2</sub> capture and storage at the oil and gas production field Sleipner Vest

##### 3.5.1.1 Description

The natural gas in the Sleipner Vest offshore gas-condensate field contains about 9 per cent CO<sub>2</sub>. The CO<sub>2</sub> content has to be reduced to about 2.5 per cent before transported to the consumers onshore. The CO<sub>2</sub> to be removed amounts about 1 million tonnes per year.

When this North Sea field was planned around 1990 the considerations were influenced by the discussions about strategies to reduce greenhouse gas emissions and a possible national tax on CO<sub>2</sub>-emissions (introduced in 1991 and extended in 1996). It was therefore decided that the removed CO<sub>2</sub> should be injected for permanent storage into a geological reservoir. The selection of an appropriate reservoir is essential for the success of geological storage of CO<sub>2</sub>. In their search for a suitable reservoir the companies were looking for a saline aquifer with reasonable high porosity and a cap rock above to prevent leakage. Furthermore the CO<sub>2</sub> should be stored under high pressure – preferably more than 800 meters below the surface. Under these conditions CO<sub>2</sub> is buoyant and less likely to move upwards than CO<sub>2</sub> in gaseous form.

The Utsira Formation aquifer, which is located above the producing reservoirs at a depth of 800 – 1000 meters below sea level, was chosen for CO<sub>2</sub> storage because of its shallow depth, its large extension (which guarantees sufficient volume), and its excellent porosity and permeability (which is well suited for high injectivity). The formation is overlain by a thick, widespread sequence of Hordaland Group shales, which should act as an effective barrier to vertical CO<sub>2</sub> leakage, see *Figure 3.9* below.



*Figure 3.9. CO<sub>2</sub> 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 CO<sub>2</sub> could not migrate back to the Sleipner A platform (SLA) and the production wells. This will both prevent corrosion problems in the production wells and

minimise the risk of CO<sub>2</sub> 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 CO<sub>2</sub> expected to migrate vertically to the sealing shales and horizontally along the saddle point of the structure. This will take the CO<sub>2</sub> away from other wells drilled from the Sleipner platform. A more detailed description of the reservoirs suitability for long term CO<sub>2</sub> storage is given in Annex IV.

The field and the injection program have been in operation since 1996. Statoil monitors the injected CO<sub>2</sub> with respect to leakages.

Investigations carried out so far show that the injected CO<sub>2</sub> has been kept in place without leaking out. In case unexpected CO<sub>2</sub> 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 CO<sub>2</sub> injected since the project started in 1996.

Table 3.28. CO<sub>2</sub> from the Sleipner field injected in the Utsira formation.

| Year                      | 1996 | 1997 | 1998 | 1999 | 2000 | 2001  | 2002 | 2003 | 2004 | 2005 |
|---------------------------|------|------|------|------|------|-------|------|------|------|------|
| CO <sub>2</sub> (ktonnes) | 70   | 665  | 842  | 971  | 933  | 1 009 | 955  | 914  | 750  | 858  |
| Year                      | 2006 | 2007 | 2008 | 2009 | 2010 |       |      |      |      |      |
| CO <sub>2</sub> (ktonnes) | 820  | 921  | 814  | 860  | 743  |       |      |      |      |      |

Source: The Climate and Pollution Agency.

When the injection has to stop for maintenance etc. the CO<sub>2</sub> is vented to the atmosphere. The amount vented to the atmosphere is included in the green house gas inventory reported under 1B2c – see 3.4.4. In 2010 this emission amounted to 932 tonnes CO<sub>2</sub>. The figures for the other years are given in Table 3.29.

Table 3.29. Emissions of CO<sub>2</sub> vented from the Sleipner Vest CO<sub>2</sub> –injection plant due to inaccessibility of the injection facility.

| Year                     | 1996   | 1997   | 1998   | 1999  | 2000  | 2001  | 2002  | 2003   | 2004   | 2005  |
|--------------------------|--------|--------|--------|-------|-------|-------|-------|--------|--------|-------|
| CO <sub>2</sub> (tonnes) | 81 000 | 29 000 | 4 195  | 9 105 | 8 318 | 3 050 | 7 567 | 23 910 | 21 377 | 6 191 |
| Year                     | 2006   | 2007   | 2008   | 2009  | 2010  |       |       |        |        |       |
| CO <sub>2</sub> (tonnes) | 2 471  | 6 413  | 13 569 | 4595  | 932   |       |       |        |        |       |

Source: The Climate and Pollution Agency

The status by 1.1.2011 is that 12.1 million tonnes CO<sub>2</sub> has been injected into the Utsira Formation and 0.22 million tonnes CO<sub>2</sub> has been vented.

The following Figure 3.10. Injected and vented CO<sub>2</sub> at Sleipner shows the yearly injected and vented volumes for the entire injection period on Sleipner.

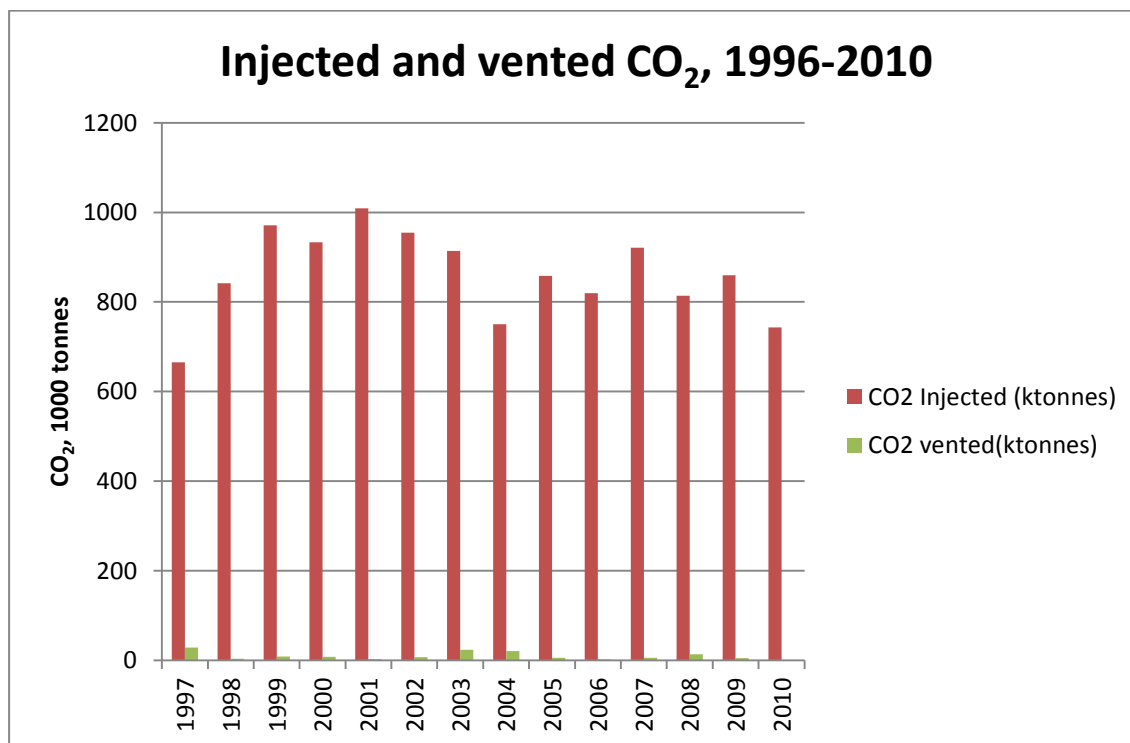


Figure 3.10. Injected and vented CO<sub>2</sub> at Sleipner Vest.

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

The Sleipner CO<sub>2</sub>-injection project is considered as the first industrial-scale, environmentally driven CO<sub>2</sub>-injection project in the world. In order to document what happens with the CO<sub>2</sub> 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 CO<sub>2</sub> 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.



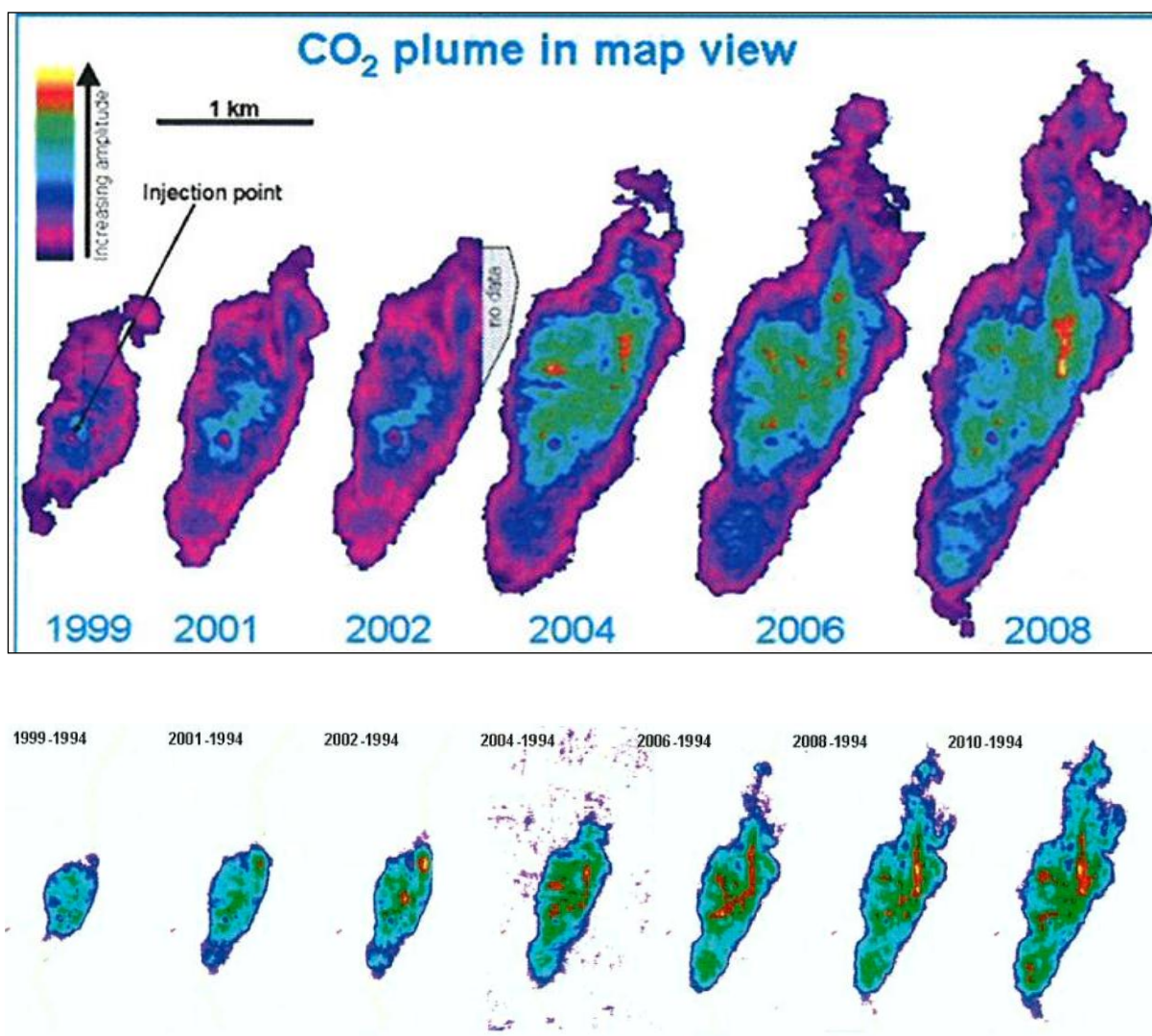


Figure 3.11. Results of seismic monitoring Sleipner Vest, 1998-2010.

Source: Statoil

The stored CO<sub>2</sub> has been monitored using time lapse seismic to confirm its behaviour and evaluate

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

The results show that neither of these eventualities has occurred. So far there are no signs of CO<sub>2</sub> 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 CO<sub>2</sub>-injection site” published at 7<sup>th</sup> 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 CO<sub>2</sub> 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 CO<sub>2</sub> plume at Sleipner, North Sea. In; DORÉ, A.G & VINING, B.A (eds) *Petroleum Geology: North-West Europe and Global Perspectives*, Proceedings of the 6<sup>th</sup> 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 CO<sub>2</sub> 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 CO<sub>2</sub> within the reservoir, both as high amplitude reflections and as a pronounced velocity pushdown (see Figure 3.11 and Figure 4 in Annex IV).

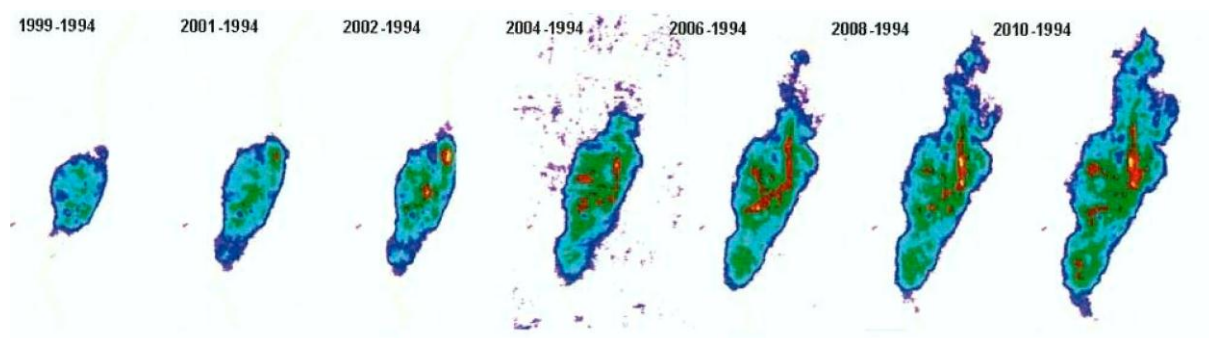


Figure 3.11. Results of seismic monitoring Sleipner Vest, 1998-2010.

Source: Statoil

The data also resolve a vertical CO<sub>2</sub> chimney, which is regarded the primary feeder of CO<sub>2</sub> in the upper part of the bubble.

Flow simulation models, which match the 4D seismic data reasonably well, have been used to predict the CO<sub>2</sub> behaviour, see Figure 3.12.

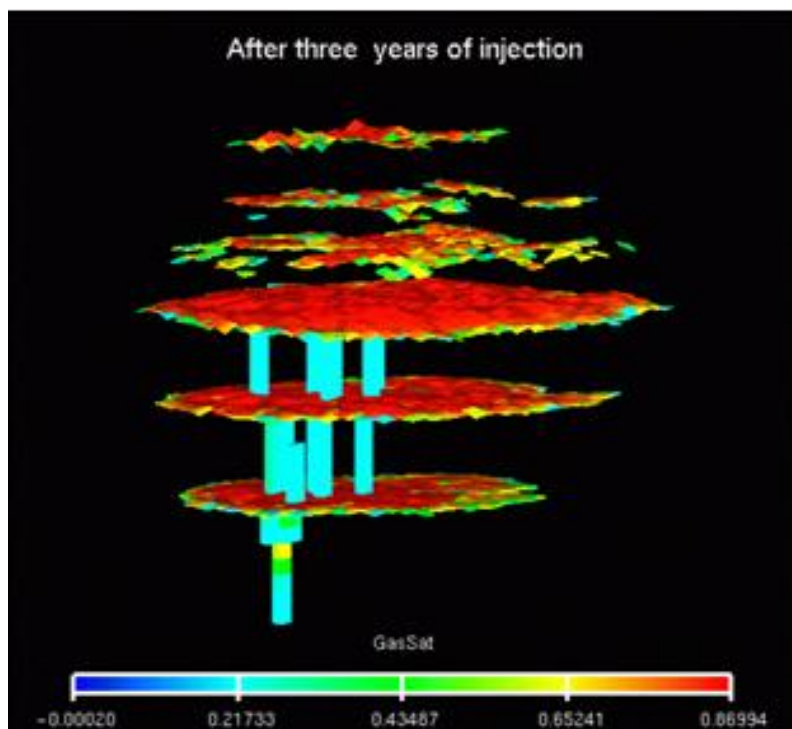


Figure 3.12. Flow simulation of CO<sub>2</sub> Sleipner Vest.

Source: Statoil

The results from the simulations indicate that cap rock shales provide a capillary seal for the CO<sub>2</sub> phase.

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

The time-lapse seismic images clearly show the development of the CO<sub>2</sub> plume, and also have been used to calculate the amount of CO<sub>2</sub> in the reservoir. The volume calculated from the observed reflectivity and velocity pushdown is consistent with the injected volume.

Other monitoring methods Statoil is running are monitoring the injected CO<sub>2</sub>, 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  $\pm 5$  per cent. The orifice meter used to meter the amount of CO<sub>2</sub> injected in the Utsira formation have  $\pm 3$  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 CO<sub>2</sub> is included in the emission licence for the Sleipner Vest field. According to the license Statoil is obliged to monitor the CO<sub>2</sub>-storage. Furthermore Statoil reports the amount of CO<sub>2</sub> emitted and the amount injected every year to The Climate and Pollution Agency. The injected CO<sub>2</sub> is so far proven to be removed from the atmosphere and hence it is not reported as in the emission inventory. When the injection have to stop for maintenance etc Statoil have to pay a CO<sub>2</sub>-tax for the emissions. These emissions are reported to the Norwegian Petroleum

directorate. In this national emissions inventory this amount of CO<sub>2</sub> vented is reported under 1B2c.

**3.5.1.5 *Planned improvements***

No specific planned improvements.

### 3.5.2 CO<sub>2</sub> 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 % CO<sub>2</sub>. Prior to the LNG production process at Hammerfest LNG, the CO<sub>2</sub> in the feed gas has to be removed as the gas is liquefied to LNG and stored at -163 °C. The CO<sub>2</sub> removed from the well stream is compressed and reinjected into the Tubåen formation on Snøhvit. About 0.7 Mtonnes CO<sub>2</sub> are removed from the feed gas every year at full production. A total of about 23 million tonnes CO<sub>2</sub> 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 CO<sub>2</sub>. Four structures were identified as possible candidates for CO<sub>2</sub> 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 CO<sub>2</sub> storage for the Snøhvit CO<sub>2</sub> storage project because the reservoir data was not sufficiently detailed and no current plans for exploration drilling (OED 2002).

In the EIA and the plan for development of Snøhvit and the LNG plant the recommended CO<sub>2</sub> storage solution was to inject CO<sub>2</sub> into the Snøhvit Tubåen Formation. Tubåen is expected to be able to store the expected amount of CO<sub>2</sub> (from the natural gas stream (23 million tonnes). The Tubåen formation is a saline aquifer lying around 100-200 metres below the gas cap at Snøhvit (OED 2002) and 2600 meter below sea level.

Hammerfest LNG (former Snøhvit LNG Statoil) was granted a permit pursuant to the Pollution Control Act to inject 730 000 tonnes of CO<sub>2</sub> per year into the Tubåen formation. The permit was issued on Sept. 13, 2004 by the Climate and Pollution Agency. 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.

It is unlikely that the injected CO<sub>2</sub> will come in contact with the gas cap in the main reservoir (Stø). This is because the Nordmela formation, a 100 metres thick formation with large shale intervals, lies between Tubåen and Stø.

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

During the first two years of injection, several challenges have occurred. These challenges and the ongoing work to address them is further described in 3.5.2.2.

Table 3.30. Key parameters for injection well F-2 H and Tubåen reservoir at the Snøhvit field.

| 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 CO<sub>2</sub> injection well F-2 H.*

The CO<sub>2</sub> injection well is located at the F-segment at the western part of the Snøhvit reservoir (Figure 3.13).

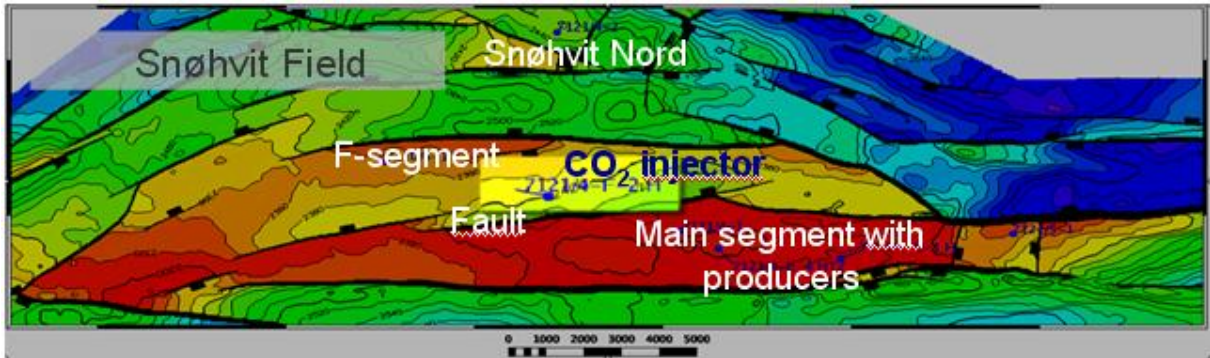


Figure 3.13. Location of the CO<sub>2</sub> well at the Snøhvit field.

Source: Statoil

The injection pipeline is 152 km long (Figure 3.14).

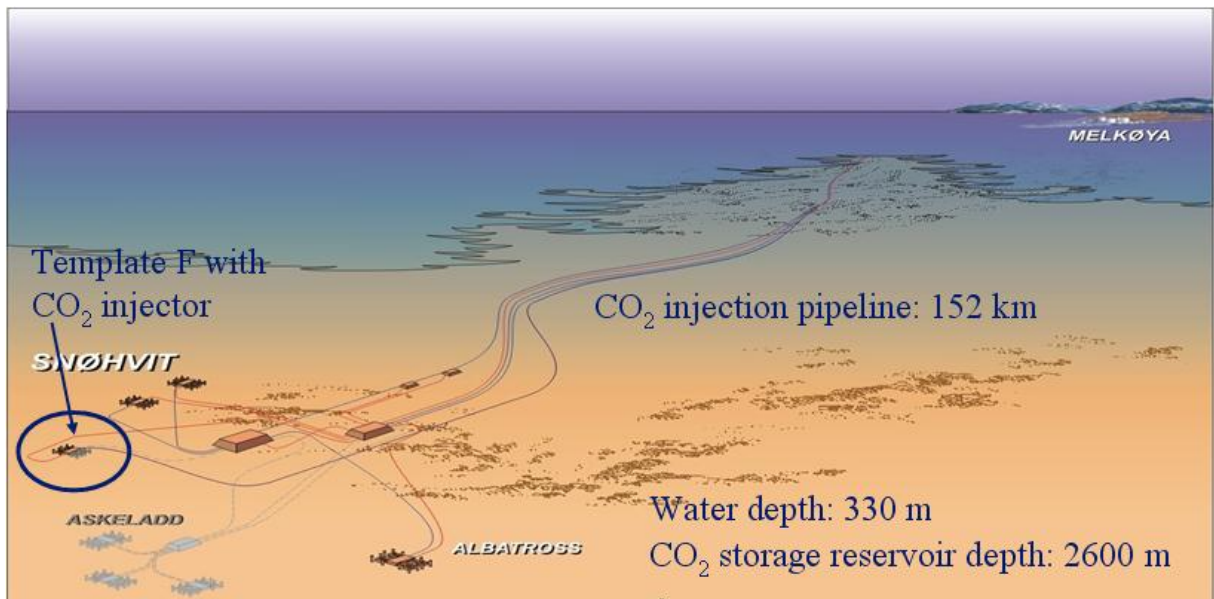


Figure 3.14. Snøhvit Field overview.

Source: Statoil

To keep the CO<sub>2</sub> as deep as possible, it was decided to perforate the mid and lower part of Tubåen as shown in Figure 3.15. If injection fails, additional perforations could be added in Tubåen, and/or bottom of Stø could be opened up for injection.

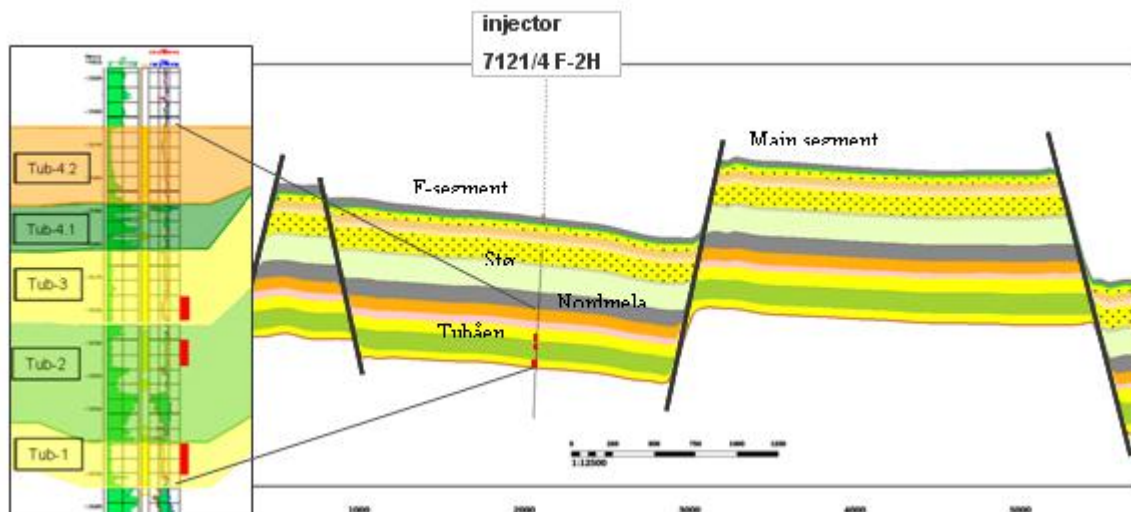


Figure 3.15. Cross-section of F-segment where CO<sub>2</sub> is injected, Snøhvit field/Tubåen and Stø formation.

Source: Statoil

#### CO<sub>2</sub> injection well specification

The completion design basis for the CO<sub>2</sub> injector is a perforated 7" liner. A downhole pressure and temperature gauge is installed.

#### CO<sub>2</sub> re-injection system

At Snøhvit, all facilities for separation and injection of CO<sub>2</sub> are placed onshore at the Hammerfest LNG process plant at Melkøya. CO<sub>2</sub> 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<sub>2</sub> is condensed and recompressed before re-injected into Tubåen. A schematic of the CO<sub>2</sub> re-injection system is shown in Figure 3.16.

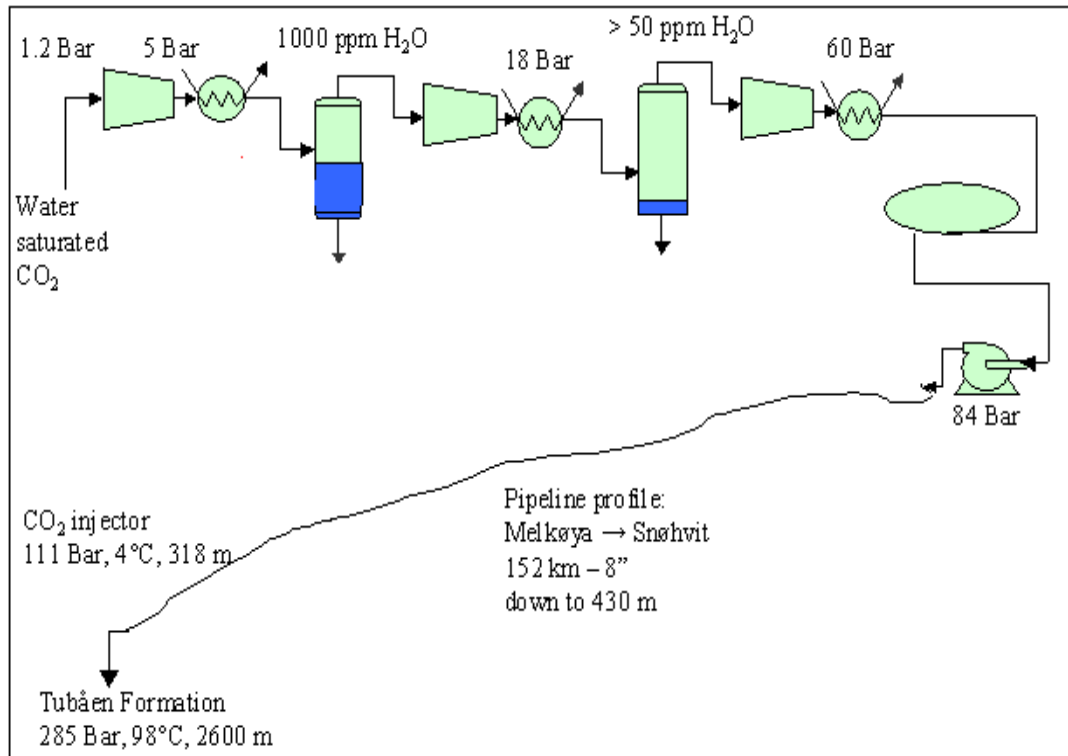


Figure 3.16. Schematic of the CO<sub>2</sub> injection system in the Snøhvit area.

Source: Statoil

CO<sub>2</sub> 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).

#### CO<sub>2</sub> well stream specification

- >99% CO<sub>2</sub>
- max 100 ppm (mol) H<sub>2</sub>S
- max 50 ppm (wt) H<sub>2</sub>O
- traces of HC and N<sub>2</sub>

#### CO<sub>2</sub> venting to atmosphere

CO<sub>2</sub> venting is foreseen in case of shut down of the CO<sub>2</sub> reinjection system. The maximum vent rate is almost equal to the CO<sub>2</sub> removal flow rate. A separate vent stack for the CO<sub>2</sub> is provided at the plant.

#### 3.5.2.2 CO<sub>2</sub> injection and vented CO<sub>2</sub>

CO<sub>2</sub>-injection at Snøhvit started in April 2008. Almost immediately after start up, challenges occurred. By mid December 2008, the main concern was low injectivity. This issue was resolved (in December 08), and since then the rise of reservoir pressure (near well) has been the main focus and concern.



The injection pressure (while injecting & shut-in) has risen significantly. A 3D/4D seismic survey focused around the injection well was acquired autumn 2009. Final results from the 4D analysis are available (see 3.5.2.4).

The main observation/fact is that existing perforation in the injection well does not communicate enough and/or with a large enough hydraulic volume (aquifer). No hydrocarbons or residuals hydrocarbons (HC) were found in Tubåen when the well was drilled.

The status by 1.1.2011 is that 966 ktonnes CO<sub>2</sub> has been injected into the Tubåen Formation and 143.2 ktonnes CO<sub>2</sub> has been vented (Table 3.31).

Table 3.31. Injected and vented CO<sub>2</sub> Hammerfest LNG/Snøhvit field

|                                    | 2008 | 2009 | 2010 | TOTAL |
|------------------------------------|------|------|------|-------|
| CO <sub>2</sub> injected (ktonnes) | 196  | 308  | 460  | 967   |
| CO <sub>2</sub> vented (ktonnes)   | 93   | 49   | 94   | 237   |
|                                    |      |      |      |       |

The following Figure 3.17 shows the yearly injected at in the Tubåen formation 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.

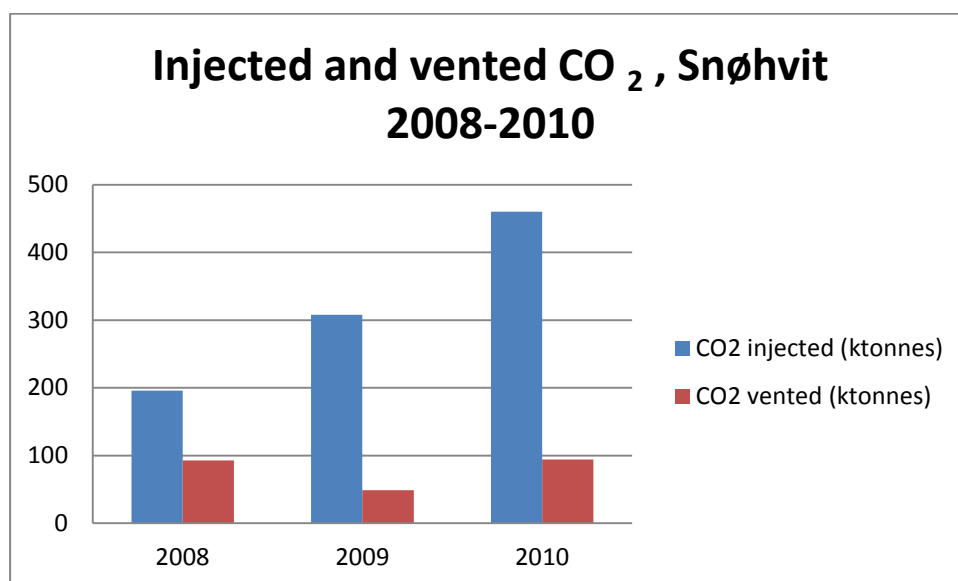


Figure 3.17. Injected and vented CO<sub>2</sub> at the Snøhvit field and Hammerfest LNG

Source: Statoil

### 3.5.2.3 Methodological issues and uncertainties in measurements

The reported data covers CO<sub>2</sub> emissions to the atmosphere, e.g. when the injection system is out of operation. These emissions are measured by a flow meter with an uncertainty of 3-5%.

Flow metering of the well stream to the CO<sub>2</sub> injector is measured by an orifice meter with an uncertainty of 3-5%. No manual or online analyses are done.

Gas composition of injected or vented gas from the CO<sub>2</sub> injector is controlled by analyses. This is primarily done as a quality assurance of the CO<sub>2</sub> removal system (system 22). For environmental reporting, the following values are used : 99.549 weight % CO<sub>2</sub>, 0.0066 weight % H<sub>2</sub>S, 0.331% CH<sub>4</sub> and 0.088 weight % nmVOC and the analysis performed on a regular basis from April 2010 to September 2010 confirm these values..

#### **3.5.2.4 Reservoir monitoring**

##### *Seismic monitoring*

Prior to the application for permits to inject CO<sub>2</sub> into the Tubåen formation compositional models have been built and used to simulate and evaluate the behavior of CO<sub>2</sub> injection. A 2D Seismic survey was carried out in 2006 in order to establish a 2D-4D reference for future seismic monitoring. The frequency of seismic surveys was not laid down as a permit condition, but it was anticipated that a monitoring program should be designed in accordance to the recommendations in the Best Practice Document on Monitoring (part of the SACS program) which was underway.

Due to the challenges related to rapid pressure increase in the CO<sub>2</sub> injection the 3D seismic was shot autumn 2009. This survey covers an 8kmx8km area centred about the injection well. The time lapse effect was evaluated by 4D processing this survey together with the 3D survey from 2003. Additionally a North West – South East 2D line passing through the injection well was also acquired. This line was a repetition of a 2D line from 2D/4D reference survey ST0608 acquired in 2006. Further plans for seismic monitoring will be made after consultations with the Climate and Pollution Agency when the challenges in the CO<sub>2</sub> well are clarified.

The 3D/4D seismic monitoring survey was shot from 24.August – 9.September 2009. A clear amplitude response is seen on the seismic in the lower part of Tubåen, up to 3 km<sup>2</sup> from the well. The upper two perforations give a response of about 600 m<sup>2</sup> (Figure 3.18). A likely interpretation of this result is that the main amount of CO<sub>2</sub> is flowing into the lower part of Tubåen.

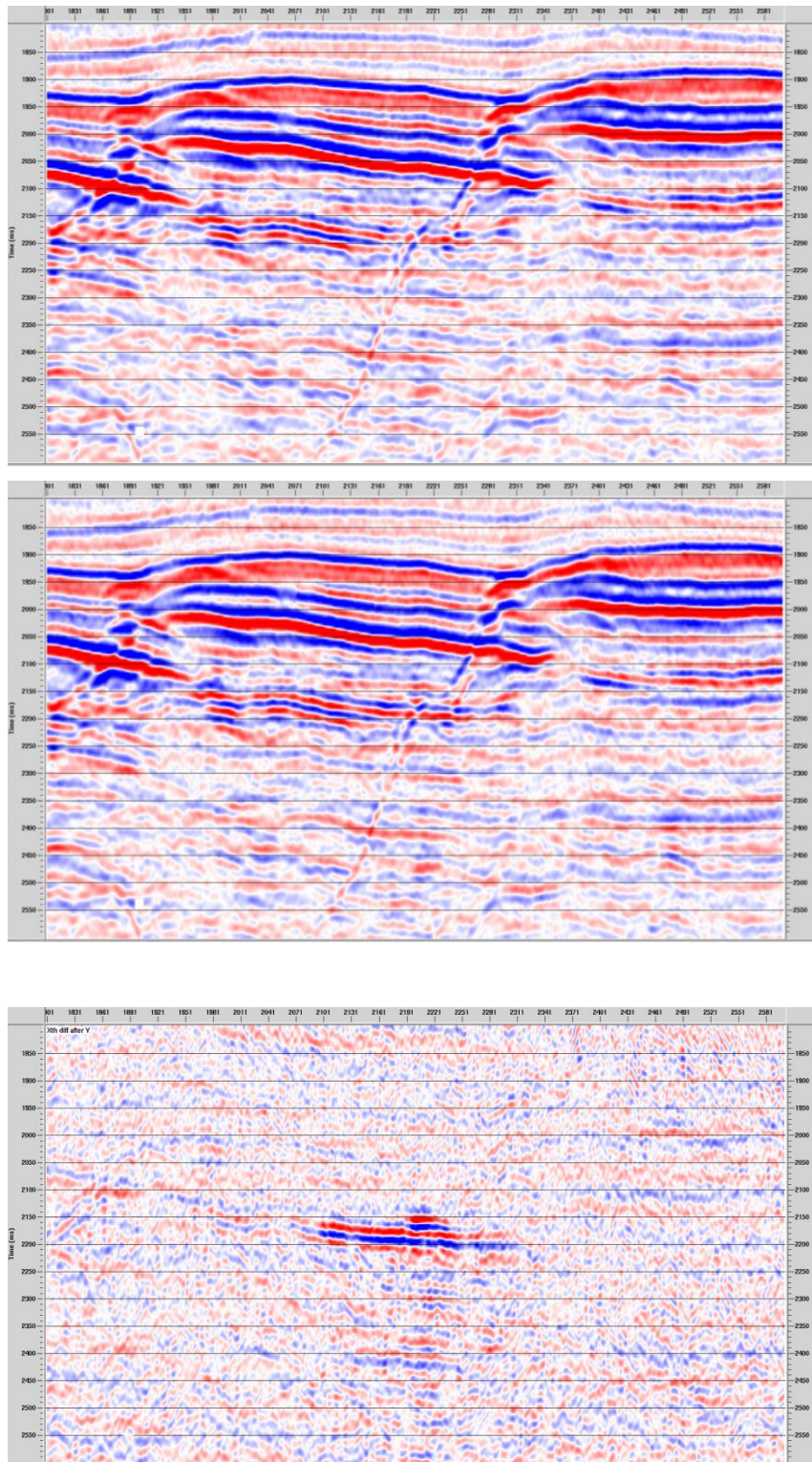


Figure 3.18. The first two figures shows the results from 2D seismic from 2006 and 2009 at Snøhvit CO<sub>2</sub> storage project. The last figure shows the 4 D difference between them.

Source: Statoil

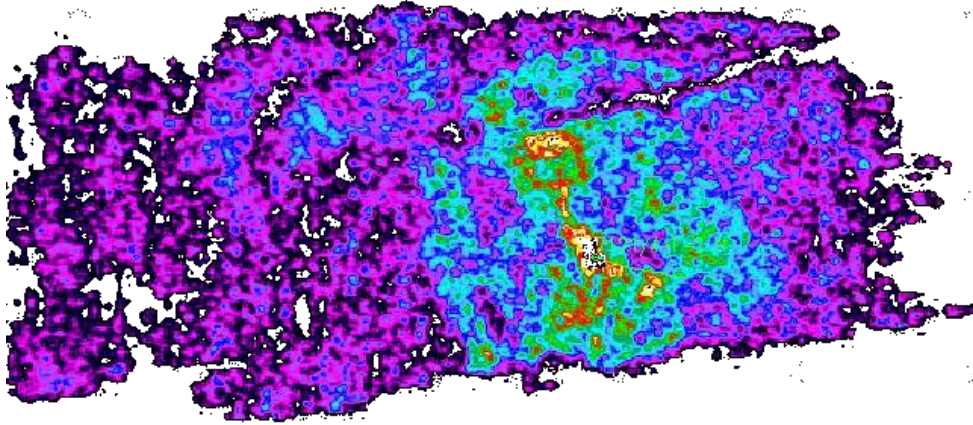


Figure 3.19. Shows the seismic 4D effect between 3D surveys acquired in 2003 and 2009 at Snøhvit CO<sub>2</sub> storage project, indicating pressure and CO<sub>2</sub> plume.

Source: Statoil

#### *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 gauge installed in the well, 800 meters above the reservoir. Actual bottom hole pressure is estimated based on gauge measurements and CO<sub>2</sub> PVT (pressure, volume, temperature).

An Eclipse 100 (“black oil”) simulation model is used for prediction pressure development in the well. CO<sub>2</sub> is modelled as a gas-phase given CO<sub>2</sub> properties injected into the water filled Tubåen reservoir. The base case model has 5 layers in Tubåen and includes a restriction implemented as a rectangular box around the well. Pressure match has been achieved by adjusting leakage out of the box, box volume and permeability values inside the box. Using the current model has proven difficult matching both pressure increase during production and pressure decrease during shut-ins. A weakness of the model is that it does not include temperature effects. These are likely in the near well area as the CO<sub>2</sub> injected is at 21°C into a reservoir of initially 98°C. Autumn 2010 an update of the injection model was initiated. This update is intended to have stronger bounds to seismic and geological interpretations and thereby be better suited for predicting pressure and fluid movement in the reservoir.

The cumulative CO<sub>2</sub> injection volume as per autumn 1.1.2011 is around 1.54 MRm<sup>3</sup>, corresponding to 966000 tonnes or 517MSm<sup>3</sup> of CO<sub>2</sub>. For the entire field-life, more than 30 mill Rm<sup>3</sup> of CO<sub>2</sub> is planned to be injected.

Figure 3.20 illustrates historic pressures and rates and the forecast from one of the models used. This prediction did not account for remedial actions planned for 2011. As can be seen from the figure reservoir fracturing pressure was predicted to be reached 4Q 2011.



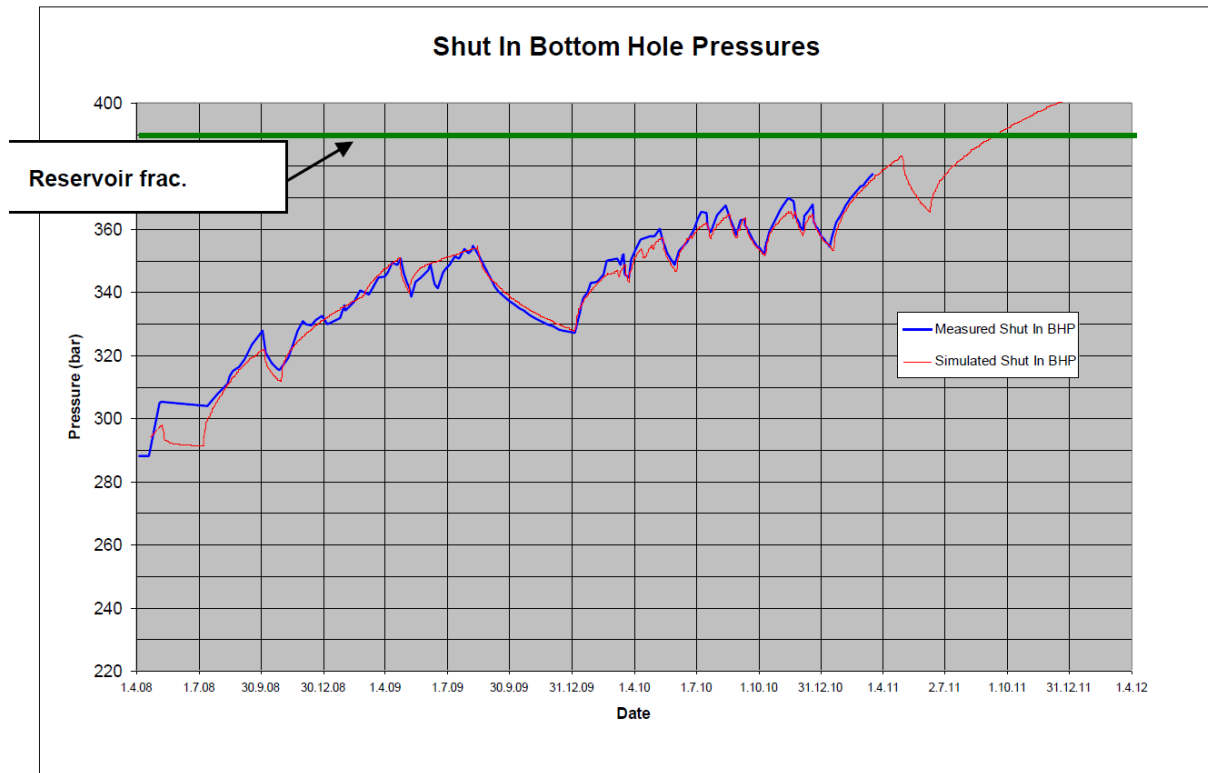


Figure 3.20. Modeling of historic rates/pressures & forecast Snøhvit CO<sub>2</sub> storage project. Source: Statoil

Further in this report is described an intervention operation done in the CO<sub>2</sub>-well. Since mid 2011 CO<sub>2</sub> 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 CO<sub>2</sub> 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 will be done and reported.

#### **3.5.2.5 Activities and future plans**

Since the reservoir pressure would reach fracture pressure some time in 4Q 2011, and intervention was scheduled for April 2011. The general idea was to have 8 wireline rounds to ensure good injectivity into Tubåen. After perforating the upper zone, it was concluded that extra perforation did not improve the injectivity of the well. The back up plan was to perforate the Stø formations, since this is the main producer formation that has good sand storage. The Stø formation was perforated and the injection currently takes place in this zone.

After having experienced no success with the extra perforation of Tubåen, the well was plugged with 2 x Hex plugg between Tubåen and Stø. The injection is from April 2011 into the bottom of the Stø formation which is a gas reservoir.

A seismic survey was run in September 2011, data is still being analysed. Weekly fall off tests are performed for surveillance performance of CO<sub>2</sub> injector well. A monitoring program

covering the period 2011-2020 has recently been presented to the environmental authorities for their assessment and comments.

The challenge with pressure increase in the CO<sub>2</sub> well has lead to a great effort to find solutions that makes the CO<sub>2</sub> injection as robust as possible. The authorities have been kept informed about the situation and the activities and measures planned. The following activities has been carried out

- Continuous monitoring of the pressure development in the well
- 4D interpretation and analysis
- Studies of injection in Tubåen based on results from 4D seismic including predictions on reservoir performance for Tubåen with or without additional perforations.
  - Analyse the limitation and how long we can inject CO<sub>2</sub> in Upper Tubåen
- Studies on possible Stø injection – consequences
- Planning for a well intervention in the injection well summer 2010
- 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 CO<sub>2</sub>-model-compositional simulations, 2004. If no HC is available, and F-2 connects a reservoir-volume of 330 mill. Rm<sup>3</sup>, fracture pressure will be reached after 150 days of injection.

The same document, supported by compositional simulation, indicates what will happen if CO<sub>2</sub> is injected into bottom of Stø in present well location. A figure from this document is copied below and indicates how CO<sub>2</sub> moves if injected into Stø.

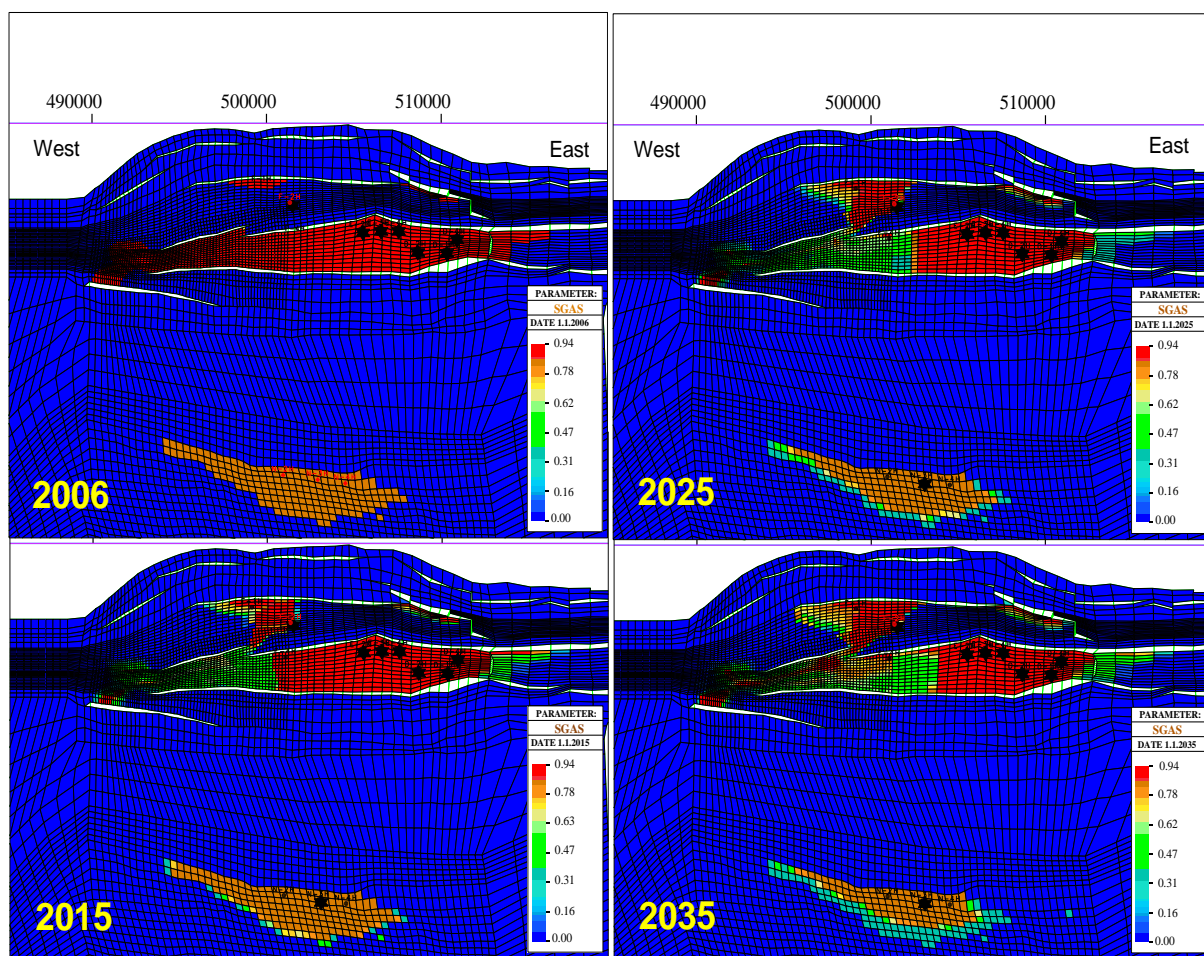


Figure 3.21. Lateral extent of the re-injected CO<sub>2</sub> and remaining hydrocarbon gas at bottom Stø level, option 1 location, at four different times.

Source: Statoil

Based on above Figure 3.21, injecting CO<sub>2</sub> into the Stø formation seems safe.

However, since this scenario occurred, more simulations and studies were carried out prior to the decision of injecting into Stø.

### 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 CO<sub>2</sub>-storage. So far there is no sign of emissions to the water column or the atmosphere from the injected CO<sub>2</sub>. Hence the CO<sub>2</sub> injected is not reported as emissions in the emission inventory. Statoil has to pay a CO<sub>2</sub>-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 CO<sub>2</sub> vented at Hammerfest LNG (Snøhvit CO<sub>2</sub> storage project) – is reported 1B2c.

Statoil reports the amount of CO<sub>2</sub> emitted and the amount injected every year to The Climate and Pollution Agency. In addition Statoil perform internal QA/QC for the ongoing CO<sub>2</sub> studies.

### **3.5.2.7 CO<sub>2</sub> projects outside Statoil ASA using Snøhvit data**

The EU project CO<sub>2</sub>ReMoVe 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 CO<sub>2</sub> migration to the upper gas field and lateral migration, potential flow through deteriorated wells and through undetected faults. The geochemical interaction between CO<sub>2</sub>, 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 CO<sub>2</sub> 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 review of the Norwegian greenhouse gas inventory submitted in 2011 the ERT raised potential problems with non-inventory elements of Norway's annual submission under the Kyoto Protocol. Norway was asked to explain the difference between Reference Approach (RA) and Sectoral Approach (SA). Norway has examined the differences and the results are explained in this section and in a new Annex IX in the NIR.

Norway has calculated energy consumption and CO<sub>2</sub> 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. In previous submissions we have used energy balance data reported to IEA in RA even if the energy balance reported in Annex III also in previous submissions have been the national energy balance. The supply data in RA are now consistent with the energy balance data used in the SA.

*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 CO<sub>2</sub> 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 CO<sub>2</sub> emissions are generally around 5 percentage points higher. The highest discrepancy for CO<sub>2</sub> is in 1999-2001, 2004-2006, and 2008-2010. For 2010, the difference for CO<sub>2</sub> is 41 per cent. The large discrepancies are primarily due to statistical differences in the energy balance, as shown below.



*Table 3.32 Comparison of fuel consumption and CO<sub>2</sub> emission data between the Reference Approach (RA) and the Sectoral Approach (SA). 1990-2010.*

| Year | Fuel Consumption              |         |                      | CO <sub>2</sub> emissions |         |                |
|------|-------------------------------|---------|----------------------|---------------------------|---------|----------------|
|      | RA, apparent consumption (PJ) | SA (PJ) | Difference RA-SA (%) | RA (Gg)                   | SA (Gg) | Difference (%) |
| 1990 | 342                           | 386     | -11.4                | 24 617                    | 25 946  | -5.1           |
| 1991 | 402                           | 382     | 5.3                  | 28 661                    | 25 557  | 12.1           |
| 1992 | 383                           | 389     | -1.5                 | 27 012                    | 26 048  | 3.7            |
| 1993 | 379                           | 405     | -6.2                 | 26 679                    | 27 049  | -1.4           |
| 1994 | 401                           | 425     | -5.6                 | 28 489                    | 28 432  | 0.2            |
| 1995 | 432                           | 423     | 2.1                  | 30 405                    | 28 336  | 7.3            |
| 1996 | 395                           | 461     | -14.3                | 27 951                    | 31 165  | -10.3          |
| 1997 | 450                           | 466     | -3.3                 | 31 752                    | 31 321  | 1.4            |
| 1998 | 508                           | 465     | 9.3                  | 35 575                    | 31 300  | 13.7           |
| 1999 | 569                           | 464     | 22.4                 | 40 089                    | 31 608  | 26.8           |
| 2000 | 657                           | 454     | 44.8                 | 46 193                    | 30 556  | 51.2           |
| 2001 | 613                           | 479     | 27.9                 | 41 872                    | 32 624  | 28.3           |
| 2002 | 510                           | 484     | 5.4                  | 35 470                    | 32 819  | 8.1            |
| 2003 | 547                           | 505     | 8.2                  | 37 866                    | 34 174  | 10.8           |
| 2004 | 650                           | 510     | 27.5                 | 45 900                    | 34 255  | 34.0           |
| 2005 | 612                           | 499     | 22.6                 | 42 994                    | 33 839  | 27.1           |
| 2006 | 641                           | 520     | 23.3                 | 45 509                    | 34 733  | 31.0           |
| 2007 | 529                           | 529     | -0.1                 | 35 994                    | 35 221  | 2.2            |
| 2008 | 641                           | 528     | 21.3                 | 44 006                    | 34 582  | 27.3           |
| 2009 | 631                           | 541     | 16.8                 | 43 041                    | 35 162  | 22.4           |
| 2010 | 755                           | 561     | 34.5                 | 51 750                    | 36 714  | 41.0           |

Source: Statistics Norway/Climate and Pollution Agency

We have also made a comparison of the RA and SA to the energy balance where we explain the differences between RA and SA. This is an answer to questions raised in the Saturday Paper by the ERT reviewing the Norwegian 2011 submission. The result from the comparison is shown in Table 3.33 and in Annex IX. The conclusion we can draw from this comparison is that statistical differences in the energy balance is the main reason for the deviation in energy consumption between RA and SA.

A summary of the *comparison of the Reference and Sectoral Approaches* to the energy balance is 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 result is that the difference between the energy consumption in RA and SA is mainly due to statistical differences in the energy balance (column *M*). 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 since 1992. For 1990-1991 the remaining difference is around -12 per cent.

Table 3.33. Overview over the Reference and Sectoral approaches for energy. PJ.

| 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-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 |
| 1)        | A  | B                                   | X<br>=D+P+R                                       | =A-D-X               |                                  | M  | E+O+Q             |  | T*                             | U  |
| 1990      | 431  | 386                                 | 90  | -44                  | -11 %                            | 1  | 6                 | -4   | -46                            | -12.0 %                                    |
| 1991      | 486  | 382                                 | 84  | 20                   | 5 %                              | 63                                       | 5                 | -4   | -44                            | -11.5 %                                    |
| 1992      | 465  | 389                                 | 82  | -6                   | -1 %                             | -9                                       | 10                | -4   | -2                             | -0.6 %                                     |
| 1993      | 470  | 405                                 | 91  | -25                  | -6 %                             | -28                                      | 10                | -5   | -2                             | -0.5 %                                     |
| 1994      | 500  | 425                                 | 99  | -24                  | -6 %                             | -20                                      | 7                 | -5   | -6                             | -1.5 %                                     |
| 1995      | 534  | 423                                 | 102   | 9                    | 2 %                              | 14                                       | 5                 | -5   | -6                             | -1.3 %                                     |
| 1996      | 500  | 461                                 | 105   | -66                  | -14 %                            | -59                                      | 5                 | -5   | -7                             | -1.6 %                                     |
| 1997      | 564  | 466                                 | 114   | -15                  | -3 %                             | -11                                      | 4                 | -5   | -4                             | -0.8 %                                     |
| 1998      | 629  | 465                                 | 121   | 43                   | 9 %                              | 43                                       | 5                 | -5   | -0                             | 0.0 %                                      |
| 1999      | 683  | 464                                 | 115   | 104                  | 22 %                             | 103                                      | 4                 | -6   | 2                              | 0.5 %                                      |
| 2000      | 773  | 454                                 | 115   | 203                  | 45 %                             | 200                                      | 7                 | -6   | 2                              | 0.5 %                                      |
| 2001      | 743  | 479                                 | 130   | 134                  | 28 %                             | 128                                      | 4                 | -7   | 9                              | 2.0 %                                      |
| 2002      | 631  | 484                                 | 121   | 26                   | 5 %                              | 29                                       | 2                 | -7   | 2                              | 0.4 %                                      |
| 2003      | 676  | 505                                 | 129   | 41                   | 8 %                              | 47                                       | -1                | -8   | 4                              | 0.9 %                                      |
| 2004      | 777  | 510                                 | 128   | 140                  | 27 %                             | 150                                      | 0                 | -8   | -2                             | -0.4 %                                     |
| 2005      | 735  | 499                                 | 123   | 113                  | 23 %                             | 122                                      | 2                 | -9   | -2                             | -0.5 %                                     |
| 2006      | 760  | 520                                 | 119   | 121                  | 23 %                             | 129                                      | 2                 | -9   | -1                             | -0.2 %                                     |
| 2007      | 653  | 529                                 | 124   | -1                   | 0 %                              | -2                                       | 8                 | -9   | 3                              | 0.5 %                                      |
| 2008      | 769  | 528                                 | 128   | 113                  | 21 %                             | 116                                      | 5                 | -10  | 2                              | 0.3 %                                      |
| 2009      | 743  | 541                                 | 111   | 91                   | 17 %                             | 91                                       | 6                 | -9   | 3                              | 0.6 %                                      |
| 2010      | 874  | 561                                 | 119   | 194                  | 35 %                             | 190                                      | 8                 | -11  | 7                              | 1.2 %                                      |

1) The column letters A, B, etc. refer to the more detailed tables in annex IX.

There are very large statistical differences in the Norwegian energy balance, and they fluctuate strongly between years. Due to the large production and export, small errors in the figures reported to Statistics Norway can amount to large discrepancies when compared to the relatively small consumption figures. In general, the end use statistics which is the foundation for the SA is considered to be reliable. Errors in the production and export data can be due to both measurement errors and systematic errors related to omissions, double counting, etc. A recent example is an error in gas exports that was discovered after the energy balance was

finalized: Gas export had been omitted from the foreign trade statistics for a number of new fields that deliver the gas through installations on the territory of neighbouring states. This error explains most of the change in the statistical difference for gas since 2008.

### **3.6.2 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.

### 3.6.3 Indirect CO<sub>2</sub> emissions from CH<sub>4</sub> 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 CO<sub>2</sub> emissions are formed. The emissions of CH<sub>4</sub> and NMVOC from some sources will partly be of fossil origin and should therefore be included. Indirect CO<sub>2</sub> emissions originating from the fossil part of CH<sub>4</sub> and NMVOC during fuel combustion are automatically included in the emission inventory. The corresponding emissions from non-combustion sources are accounted for in the inventory under the following source categories:

- Coal Mining and Handling – 1B1a
- Gas terminals – 1B2b
- Oil terminals – 1B2a
- Refineries – 1B2a
- Oil gas extraction activity – especially from loading of crude oil – 1B2a and 2B2c
- Distribution of oil products – 1B2a
- Silicon carbide – 2B4.1
- Calcium carbide – 2B4.2
- Methanol – 2B5.5
- Plastic – 2B.5
- Ferroalloys – 2C.2
- Solvent and other product use – 3.

The indirect CO<sub>2</sub> emissions from oxidized CH<sub>4</sub> and NMVOC are calculated from the content of fossil carbon in the compounds. The average amount of carbon is estimated to be 75 per cent in methane and 82 per cent in NMVOC. This leads to the emission factors 2.74 kg CO<sub>2</sub>/kg CH<sub>4</sub> and 3 kg CO<sub>2</sub>/kg NMVOC, calculated on basis of mass of molecules.

## **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 2010 CO<sub>2</sub> 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 CO<sub>2</sub> emissions. The CO<sub>2</sub> emissions from bunkers have increased by 28 per cent from 1990 to 2010.

During the period 1990-2010, emissions of CO<sub>2</sub> from marine bunkers decreased by 6 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 1997-2010.

The CO<sub>2</sub> emissions from international air traffic bunkered in Norway was in 2010 1.4 million tonne that is all time high emission level. Due to variations in the activity level, CO<sub>2</sub> emissions from international air traffic varied during the period 1990-2010, as well. These emissions have been on its highest level from 2006-2010 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 effect of the financial crises but have increased again in 2010 by 19 per cent.

Table 3.34. Emissions from ships and aircraft in international traffic bunkered in Norway, 1990-2010. 1000 tonnes, CO<sub>2</sub> in Mtonnes.

| Marine           | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|------------------|------|------|------|------|------|------|------|------|------|------|------|
| CO <sub>2</sub>  | 1.5  | 1.3  | 1.6  | 1.7  | 1.8  | 2.3  | 2.5  | 3.0  | 2.9  | 2.7  | 2.6  |
| CH <sub>4</sub>  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.2  | 0.2  | 0.2  | 0.2  | 0.2  | 0.2  |
| N <sub>2</sub> O | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  | 0.1  |
| NO <sub>x</sub>  | 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 <sub>2</sub>  | 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 |
|------------------|------|------|------|------|------|------|------|------|------|------|
| CO <sub>2</sub>  | 2.6  | 2.1  | 2.1  | 2.0  | 2.3  | 2.3  | 2.1  | 2.1  | 1.8  | 1.4  |
| CH <sub>4</sub>  | 0.2  | 0.1  | 0.1  | 0.1  | 0.2  | 0.2  | 0.2  | 0.2  | 0.1  | 0.1  |
| N <sub>2</sub> O | 0.1  | 0.1  | 0.1  | 0.0  | 0.1  | 0.1  | 0.1  | 0.1  | 0.0  | 0.0  |
| NO <sub>x</sub>  | 47.2 | 37.2 | 36.7 | 35.0 | 39.8 | 39.5 | 35.8 | 33.9 | 26.9 | 19.6 |
| CO               | 2.4  | 1.9  | 1.9  | 1.8  | 2.1  | 2.1  | 1.9  | 1.9  | 1.6  | 1.3  |
| NM VOC           | 2.0  | 1.6  | 1.6  | 1.5  | 1.7  | 1.7  | 1.6  | 1.6  | 1.3  | 1.0  |
| SO <sub>2</sub>  | 12.8 | 7.0  | 8.0  | 7.8  | 8.6  | 5.1  | 5.5  | 6.1  | 4.7  | 4.1  |

| Aviation         | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|------------------|------|------|------|------|------|------|------|------|------|------|------|
| CO <sub>2</sub>  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.6  | 0.7  | 0.8  | 0.8  | 0.9  | 0.9  |
| CH <sub>4</sub>  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| N <sub>2</sub> O | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| NO <sub>x</sub>  | 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 <sub>2</sub>  | 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 |
|------------------|------|------|------|------|------|------|------|------|------|------|
| CO <sub>2</sub>  | 0.8  | 0.7  | 0.7  | 0.8  | 1.1  | 1.2  | 1.2  | 1.2  | 1.1  | 1.3  |
| CH <sub>4</sub>  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| N <sub>2</sub> O | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| NO <sub>x</sub>  | 3.0  | 2.6  | 2.7  | 3.0  | 3.9  | 4.5  | 4.1  | 4.1  | 3.9  | 4.7  |
| CO               | 0.9  | 0.8  | 0.8  | 1.0  | 1.2  | 1.4  | 1.3  | 1.3  | 1.2  | 1.5  |
| NM VOC           | 0.2  | 0.2  | 0.2  | 0.2  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  | 0.3  |
| SO <sub>2</sub>  | 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<sub>x</sub> from international sea traffic in 2010 were about 19.6 ktonnes, which equals 11 per cent of the national Norwegian NO<sub>x</sub> emissions. During the period from 1990 to 2010, NO<sub>x</sub> emissions from international shipping bunkered in Norway decreased by 26 per cent.

NO<sub>x</sub> emissions from international aviation amounted to 4.7 ktonnes in 2010. This is the highest emissions ever, 123 per cent higher than in 1990.

Apart from NO<sub>x</sub> from marine bunkers, emissions of precursors from international aviation and sea transport are small compared to the total national emissions of these gases.

### **3.7.2 CO<sub>2</sub> emissions from biomass**

Emissions are estimated from figures in the energy accounts on use of wood, wood waste and black liquor. According to the guidelines, these CO<sub>2</sub> 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).<sup>5</sup> The rest of the emissions included in the inventory are calculated by Statistics Norway. The calculations are based on emission factors and activity data. The emission factors are collected from different sources, while the activity data used in calculations carried out by Statistics Norway is from official statistics collected by Statistics Norway.

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

The GHG emissions from Industrial processes in 2010 were 13.9 per cent of the total GHG emissions in Norway. The corresponding percentage in 1990 and 2009 were 27.5 and 13.3 per cent respectively. The emissions from this source category decreased by 45.4 per cent from 1990 to 2009 and increased by 9.3 per cent from 2009 to 2010. The decrease from 1990 to 2010 is mainly due to reduced PFC emissions from production of aluminium and SF<sub>6</sub> from production of magnesium. There was a reduction in the PFC emissions by 93.9 per cent even if the production of aluminium in the period 1990-2010 has increased by 26.7 per cent. The reduction in the SF<sub>6</sub> emissions is due to the closing down of production of cast magnesium in 2002, improvements in the GIS-sector and an almost end in the use of SF<sub>6</sub> as tracer gas. In June 2006 also the magnesium recycling foundry was closed down. In addition, N<sub>2</sub>O emissions from nitric acid production have decreased by 82.9 per cent since 1990.

Metal production contributed to 60.8 per cent of the total GHG emissions from Industrial Processes in 2010, mainly from production of ferro alloys and aluminium, and in 1990 the contribution from metal production was 71.9 per cent. Mineral Product and Chemical Industry are the two other main contributing sectors in 2010 with 13.8 and 12.0 per cent, respectively, of the total GHG emissions in this sector.

The Tier 2 key category analysis performed for 1990 and 2010 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, 2C1, 2C2, 2C4 and 2D2 are key categories from Tier 1 key category analysis.

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<sup>5</sup> Former Norwegian Pollution Control Authority.

Table 4.1. Key categories in the sector Industrial Processes.

| IPCC              | Source category  | Gas              | Key category according to tier | Method |
|-------------------|--|------------------|--------------------------------|--------|
| 2A1               | Cement Production  | CO <sub>2</sub>  | Tier 1                         | Tier 2 |
| 2A2               | Lime production  | CO <sub>2</sub>  | Tier 1                         | Tier 2 |
| 2B1               | Ammonia Production                                       | CO <sub>2</sub>  | Tier 1                         | Tier 2 |
| 2B2               | Nitric Acid Production                                   | N <sub>2</sub> O | Tier 2                         | Tier 2 |
| 2B4               | Silicon carbide  | CO <sub>2</sub>  | Tier 2                         | Tier 2 |
| 2C1 <sup>*)</sup> | Iron and Steel Production                                | CO <sub>2</sub>  | Tier 1                         | Tier 2 |
| 2C2               | Ferroalloys Production                                   | CO <sub>2</sub>  | Tier 1                         | Tier 2 |
| 2C3               | Aluminum Production                                      | CO <sub>2</sub>  | Tier 2                         | Tier 2 |
| 2C3               | Aluminum Production                                      | PFC              | Tier 2                         | Tier 2 |
| 2C4               | SF <sub>6</sub> Used in Aluminum and Magnesium Foundries | SF <sub>6</sub>  | Tier 1                         | Tier 2 |
| 2D2               | Food and drink   | CO <sub>2</sub>  | Tier 1                         | Tier 2 |
| 2F                | Consumption of Halocarbons and Sulphur Hexafluoride      | HFCs             | Tier 2                         | Tier 2 |

<sup>\*)</sup> Due to a reallocation after the key category analysis was performed, 2C1 – Iron and Steel Production should be replaced as key by 2B5 Other Chemical Industry

## 4.2 Mineral Products – 2A

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

Production of Mineral Products contributed in 1990 to 1.4 per cent of the total GHG emissions in Norway and this share has increased to 1.9 per cent in 2010. The emissions from the sector increased with 45.0 per cent from 1990-2010 mainly due to increased production of clinker and lime and increased by 1.8 per cent from 2009-2010.

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

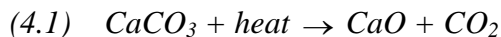
| Mineral products           | CO <sub>2</sub> | Tier   | Key category |
|----------------------------|-----------------|--------|--------------|
| Cement production          | R               | Tier 2 | Yes          |
| Lime production            | R               | Tier 2 | Yes          |
| Limestone and dolomite use | R               | Tier 2 | No           |

R = Figures reported by the plant to Klif

#### 4.2.1 Cement Production – CO<sub>2</sub> – 2A1 (Key Category)

##### 4.2.1.1 Description

Two plants in Norway produce cement. Production of cement gives rise to both non-combustion and combustion emissions of CO<sub>2</sub>. The emission from combustion is reported in Chapter 3 Energy. The non-combustion emissions originate from the raw material calcium carbonate (CaCO<sub>3</sub>). The resulting calcium oxide is heated to form clinker and then crushed to form cement



In 2010, the CO<sub>2</sub> emissions from clinker production accounted for 1.4 per cent of the total national GHG emissions and 10.1 per cent of the GHG emissions in the sector Industrial processes.

From 1990-2010 the CO<sub>2</sub> emissions from clinker production increased by 18.9 per cent and from 2009 to 2010 the CO<sub>2</sub> emission decreased by 10.4 per cent.

CO<sub>2</sub> from clinker production is according to a Tier 1 key category analysis defined as key category due to contribution in level to total GHG emission.

##### 4.2.1.2 Methodological issues

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

##### 4.2.1.3 Activity data

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

##### 4.2.1.4 Emission factors

CO<sub>2</sub>

The emission factors used are plant specific. The factors are dependent on the chemical composition of the clinker i.e. the content of Ca and Mg. The fraction of CaO from non-carbonate sources like ashes is subtracted. The emission factors are calculated particularly for the two Norwegian factories. One plant uses the factor 0.530 tonne CO<sub>2</sub> per tonne clinker (Norcem 2006). The other producers use the emission factor 0.541 tonne CO<sub>2</sub> per tonne clinker as recommended by (SINTEF 1998a). The IPCC default emission factor is 0.5071 tonne CO<sub>2</sub>/tonne clinker. The same emission factors are used for CKD as for clinker production.

##### 4.2.1.5 Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

##### 4.2.1.6 Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.

Statistics Norway occasionally calculate alternative emission figures for CO<sub>2</sub> and compare 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 emission factors used are recommended by SINTEF (1998a) and based on the actual composition of the raw materials used. These emission factors are calculated particularly for the two Norwegian plants and are 0.520 and 0.541 tonne CO<sub>2</sub> per tonne clinker respectively. The IPCC default emission factor is 0.5071 tonne CO<sub>2</sub>/tonne clinker. The calculated emission figures agree quite well with emissions figures reported by the plants.

#### **4.2.1.7 Recalculations**

There has been no recalculation since NIR 2010.

#### **4.2.1.8 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

### **4.2.2 Lime Production – 2A2 (Key category)**

#### **4.2.2.1 Description**

Three plants that produce lime in Norway reported CO<sub>2</sub> emissions from processes to Klif. The GHG emissions from lime production represent 3.3 per cent of the total emission from Industrial processes in 2010 and have increased by 395.9 per cent since 1990. This is due to increased production at existing plants and the establishment of a new plant in 2007 with large production.

CO<sub>2</sub> 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 CO<sub>2</sub> based on actual production volumes of lime and plant specific emission factors for CO<sub>2</sub> 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. The ERT of the 2009 NIR recommended that missing AD should be included in the CRF tables and Norway has since then included these. The ERT of the 2011 NIR asked if there were data available on the types of lime produced in Norway. The production in Norway consists of quicklime and dolomitic lime. In 2010, all lime production was quicklime whereas it accounted for 96% in 2009. The time series consistency for the IEF has improved due to the revised data as described under recalculations.

#### **4.2.2.4 Emission factors**

The plants use emission factors in the range of 0.4254 to 0.437 tonnes CO<sub>2</sub> per tonne limestone and 0.474 tonnes CO<sub>2</sub> 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 III to the 2010 NIR.

#### **4.2.2.7 Recalculations**

For one plant, the reported CO<sub>2</sub> emissions 1990-2007 have been adjusted, partly upwards, partly downwards due to revised data. This results in only minor changes for all years.

#### **4.2.2.8 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

### **4.2.3 Limestone and Dolomite Use – 2A3**

#### **4.2.3.1 Description**

Four plants report emissions from limestone and dolomite use to Klif. One plant neutralizes sulphuric acid waste with limestone and fly ash. This produces CO<sub>2</sub>. The use of fly ash decrease the CO<sub>2</sub> 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. The fourth plant produces glass fibers. The GHG emissions from this source category in 2010 were 0.3 per cent of the total emission from Industrial processes.

Norway has included CO<sub>2</sub> 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.

#### **4.2.3.2 Methodological issues**

The plants report emission figures of CO<sub>2</sub> 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**

An emission factor of 0.45 tonnes CO<sub>2</sub> per tonne sulphuric acid is used by the plant, calculated from the reaction equation. The brick producing plant uses an emission factor of 0.44 tonnes CO<sub>2</sub> per tonne CaCO<sub>3</sub>. The plant producing calcium oxide and magnesium oxide uses emission factors of 0.44 tonnes CO<sub>2</sub> per tonne limestone and 0.46 tonnes CO<sub>2</sub> per tonne dolomite. The plant producing glass fibres uses an emission factor of 0.477 tonnes CO<sub>2</sub> per tonne dolomite.

#### **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 III to the 2010 NIR.

#### **4.2.3.7 Recalculations**

There has been no recalculation since NIR 2010.

#### **4.2.3.8 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

### **4.3 Chemical Industry – 2B**

In the Norwegian inventory, there are 14 different activities included under chemical industry. Nearly all emissions figures from this industry included in the inventory are reported figures from the plants to Klif. Table 4.3 shows the GHGs that are emitted from which industry, tier of methodology and if the source category is key category or not.

The Chemical Industry contributed in 1990 to 6.0 per cent of the total GHG emissions in Norway and this share has decreased to 1.7 per cent in 2010. The emissions from the sector decreased with 70.0 per cent from 1990-2010 mainly due to lower emissions from the

production of nitric acid, ammonia and carbide. The emissions decreased by 6.2 per cent from 2009-2010.

Table 4.3. Chemical industry. Components emitted and included in the Norwegian inventory.

|   | CO <sub>2</sub> | CH <sub>4</sub> | N <sub>2</sub> O | NMVOC | Tier   | Key category |
|---|-----------------|-----------------|------------------|-------|--------|--------------|
| Ammonia                                   | R               | NA              | NA               | NA    | Tier 2 | Yes          |
| Nitric acid                               | NA              | NA              | R                | NA    | Tier 2 | Yes          |
| Silicon carbide                           | R+E             | R/E             | NA               | NA    | Tier 2 | Yes          |
| Calcium carbide                           | R               | NA              | NA               | R     | Tier 1 | No           |
| Methanol                                  | E               | R               | NA               | R     | Tier 2 | No           |
| Plastic                                   | R+E             | R               | NA               | R     | Tier 2 | No           |
| Titanium dioxide production <sup>*)</sup> | 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.

<sup>\*)</sup> Due to a reallocation after the key category analysis was performed, 2C1 – Iron and Steel Production should be replaced as key by 2B5 Other Chemical Industry

#### 4.3.1 Ammonia Production – CO<sub>2</sub> – 2B1 (Key category)

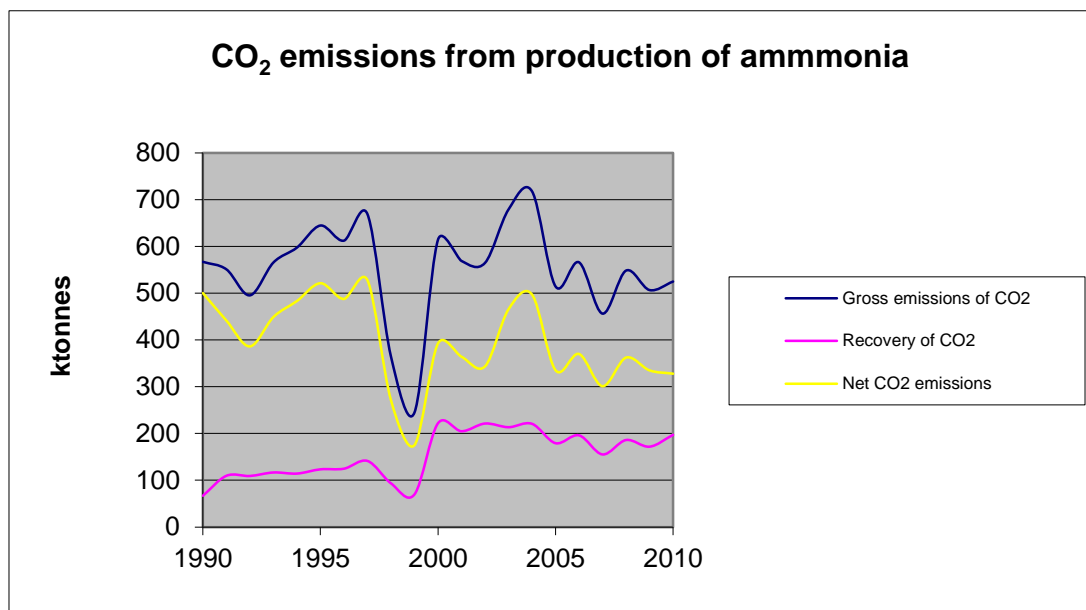
##### 4.3.1.1 Description

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 CO<sub>2</sub> is recovered from the production process.

The net CO<sub>2</sub> emissions from production of ammonia represented 4.7 per cent of the GHG emissions from Industrial processes and 0.7 per cent of the Norwegian emissions in 2010.

The gross CO<sub>2</sub> emissions from the production process were 7.4 per cent lower in 2010 compared to 1990 while the net emissions decreased by 34.4 per cent in the same period. The reduction in the net emissions is due to that the amount of recovered CO<sub>2</sub> increased by about 194.6 per cent. From 2009 to 2010 the gross CO<sub>2</sub> emissions increased by 3.6 per cent, the net emissions decreased by 2.1 per cent while the recovered CO<sub>2</sub> increased by 14.7 per cent. In 2010 197 kilo tonnes CO<sub>2</sub> were captured and sold, see Figure 4.1.

According to the Tier 1 key category analysis ammonia production is defined as key category due to contribution in level and trend.

Figure 4.1. CO<sub>2</sub> emissions from production of ammonia.

Source: Climate and Pollution Agency

#### 4.3.1.2 Methodological issues

The CO<sub>2</sub> emission figures in the Norwegian emission inventory model are based on annually reports from the plant. The plant calculates the emissions by multiplying the amount of each gas used with gas specific emission factor.

The plant has reported consistent figures back to 1990. A part of the CO<sub>2</sub>, which is generated during the production process, is captured and sold to other objectives et cetera soft drinks, and therefore deducted from the emission figures for this source and reported in *2D2 Food and Drink*. Some of the captured CO<sub>2</sub> 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 based on carbon content in the gases consumed.

#### 4.3.1.5 Uncertainties

The amount of gas is measured by using turbine meters and the meters are controlled by the Norwegian Metrology Service. The uncertainty in the measurement of propane and butanes is calculated to  $\pm 0.2$  and ethane  $\pm 0.13$  per cent. The mix of propane/butanes is as average 60 per cent propane and 60% butanes.

#### 4.3.1.6 Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.



The figures reported from the plant are compared to calculations done by Statistics Norway based on total amount of gas consumed and an emission factor on 3 tonne CO<sub>2</sub>/tonne LPG recommended by IPCC (1997b). The calculated emissions figures agree quite well with emissions figures reported by the enterprises.

#### 4.3.1.7 Recalculations

There has been no recalculation since NIR 2008.

#### 4.3.1.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2013.

### 4.3.2 Production of Nitric Acid –N<sub>2</sub>O – 2B2 (Key Category)

#### 4.3.2.1 Description

There are two plants in Norway where nitric acid is produced. Nitric acid is used as a raw material in the manufacture of nitrogenous-based fertilizer. The production of nitric acid (HNO<sub>3</sub>) generates nitrous oxide (N<sub>2</sub>O) and NO<sub>x</sub> as by-products of high temperature catalytic oxidation of ammonia (NH<sub>3</sub>).

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 below.

*Table. 4.4 Production process and default factors for nitric acid production.*

| Production process  | N <sub>2</sub> O Emission Factor (relating to 100 percent pure acid) |
|---|--|
| A. Plants with NSCR <sup>6</sup> (all processes)                          | 2 kg N <sub>2</sub> O/tonne nitric acid ±10%                         |
| B. Plants with process-integrated or tailgas N <sub>2</sub> O destruction | 2.5 kg N <sub>2</sub> O/tonne nitric acid ±10%                       |
| C. Atmospheric pressure plants (low pressure)                             | 5 kg N <sub>2</sub> O/tonne nitric acid ±10%                         |
| D. Medium pressure combustion plants                                      | 7 kg N <sub>2</sub> O/tonne nitric acid ±20%                         |
| E. High pressure plants   | 9 kg N <sub>2</sub> O/tonne nitric acid ±40%                         |

*Source: van Balken (2005).*

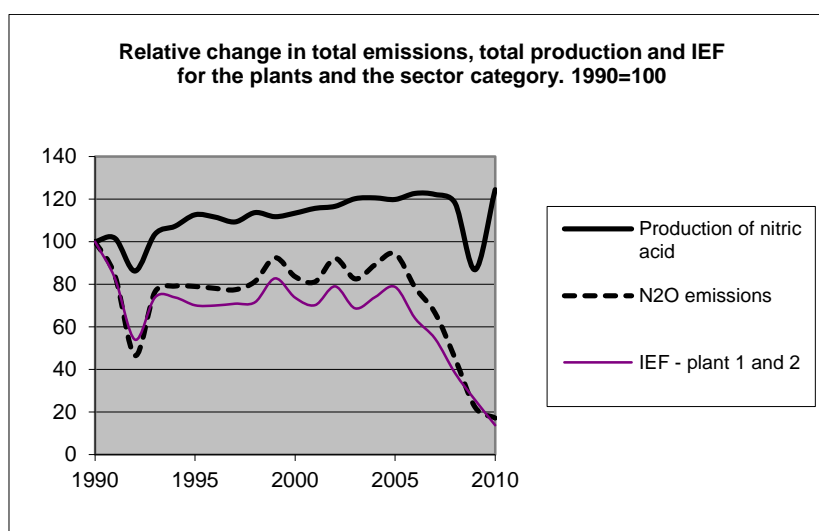
The two plants have together five production lines. Four of the production lines are a mix of technology C and D in table 4.4 and the last one is technology B. One production line was rebuilt in 1991 and in 2006 two lines were equipped with the technology – N<sub>2</sub>O decomposition by extension of 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 4.2 and 4.3 show that the production specific N<sub>2</sub>O 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<sub>2</sub>O emissions from all production lines are from 2008

<sup>6</sup> A Non-Selective Catalytic Reduction (NSCR)

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  $\text{N}_2\text{O}$  emissions from production of nitric acid accounted for 0.7 per cent of the total GHG emissions in 2010, and 4.8 per cent of the GHG emissions in sector Industrial processes. The  $\text{N}_2\text{O}$  emissions have decreased by 82.9 percent from 1990 to 2010 while the production of nitric acid increased by 24.4 percent. Corresponding changes from 2009 to 2010 was a decrease in  $\text{N}_2\text{O}$  emissions by 22.8 per cent and a 43.3 percent increase in production.

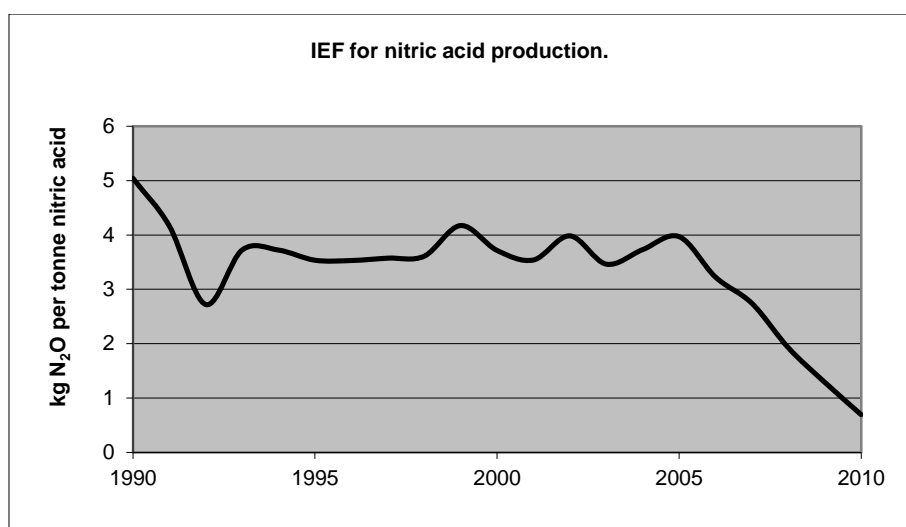
Production of nitric acid is defined as key category both in level and trend according to the Tier 2 key category analysis.

Figure 4.2. Relative change in total emissions, total production and IEF for nitric acid production. 1990=100



Source: Climate and Pollution Agency

Figure 4.3. IEF for nitric acid production. Kg  $\text{N}_2\text{O}$  per tonne nitric acid.



Source: Climate and Pollution Agency

#### 4.3.2.2 Methodological issues

*NO<sub>2</sub>*

The two plants report the emissions of N<sub>2</sub>O to Klif. The N<sub>2</sub>O 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<sub>3</sub> 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  $\pm 7$  (SFT 2000). However, in the 2006 report to Klif one plant reports that the uncertainty in measurement of N<sub>2</sub>O 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 III to the 2010 NIR.

The plants report the production of HNO<sub>3</sub> to Klif. They compare trends in the production data with the trend in N<sub>2</sub>O emission and use this as a quality check.

#### 4.3.2.6 Recalculations

There has been no recalculation since NIR 2009.

#### 4.3.2.7 Planned improvements

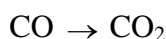
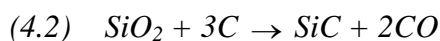
There is no planned activity this year that will improve the data quality for NIR 2013.

### 4.3.3 Silicon Carbide – 2B4 (Key Category)

#### 4.3.3.1 Description

Silicon carbide has been produced at three plants until 2006 when one plant was closed down.

Silicon carbide (SiC) is produced by reduction of quartz (SiO<sub>2</sub>) with petrol coke as a reducing agent.



In the production of silicon carbide, CO<sub>2</sub> and CO is released as a by-product from the reaction between quartz and carbon. Methane (CH<sub>4</sub>) may be emitted from petrol coke during parts of the process and sulphur origin from the petrol coke.

The GHG emissions from production of silicon carbide accounted for 0.1 per cent of the total GHG emissions in 2010, and 1.0 per cent of the GHG emissions in sector Industrial processes. The emissions were reduced by 66.4 per cent in the years 1990- 2010 and increased by 47.1 per cent from 2009 to 2010. The large decrease from 1990 to 2010 is due to reduced production and that one plant was closed down in 2006. The fluctuation in emissions over the years is due to variation in production of crude silicon carbide.

According to the Tier 2 key category analysis carbide production is defined as key category due to change in trend.

#### 4.3.3.2 Methodological issues

Norway changed in NIR 2006 the method for calculating CO<sub>2</sub> from silicon carbide production from the mass balance method described in the Revised 1996 IPCC Guidelines (using input of reducing agents) to an EF-based method (using crude silicon carbide production as activity data). Both methods are regarded as being Tier 2 methods in IPCC 2006. During the review of the initial report in 2007 the reviewer raised question to the change of method but concluded after consideration that the two methods provide very similar results, except for 1990, and that the use of the present method is justified.

CO<sub>2</sub>

Emission figures are reported annually by the three plants to the Klif.

CO<sub>2</sub> from process is calculated based on the following equation:

$$(4.3) \quad CO_2 = \sum Activity\ data * Emission\ factor$$

The three production sites have used amount of produced crude silicon carbide as activity data in the calculation of CO<sub>2</sub> 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 CO<sub>2</sub> is calculated by Statistics Norway based on the emission of CH<sub>4</sub>.

CH<sub>4</sub>

The emission of CH<sub>4</sub> 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 CO<sub>2</sub> and CH<sub>4</sub> are the amount of produced crude silicon carbide. The activity data used by Statistics Norway for the calculation of CO is the consumption of petrol coke as reported to Statistics Norway.

#### 4.3.3.4 Emission factors

CO<sub>2</sub>

All three sites have changed their emission factor to the default factor of 2.62 ton CO<sub>2</sub>/ton crude silicon carbide (IPPC 2006), see Table 4.5.

#### CH<sub>4</sub>

For calculation of methane emissions the plant specific emission factor 4.2 kg CH<sub>4</sub>/tonne crude SiC is used, see Table 4.4. Documentation of the choice and uncertainties of the emission factor is given below.

#### CO

The emission factor is in accordance with the IPCC Guidelines (IPCC 1997b).

Table 4.5. Emission factor for CO<sub>2</sub>, CH<sub>4</sub> and CO used for silicon carbide production.

| Component       | Emission factor                           | Source         |
|-----------------|---|----------------|
| CO <sub>2</sub> | 2.62 kg CO <sub>2</sub> /tonnes crude SiC | IPCC 2006      |
| CH <sub>4</sub> | 4.2 kg CH <sub>4</sub> /tonnes crude SiC  | PS             |
| CO              | 0.4 tonnes CO/tonnes petrol coke          | Rosland (1987) |

#### NMVOC

From 2007 and onwards the emission factor is based on measurements made once a year. The emission factors for 2007 for are 10.906 t NMVOC/kt Sic for Washington Mills and 10.84 t NMVOC/kt Sic for Saint Gobain. For previous years, the emission factor for Saint Gobain is more or less constant whereas the emission factor for Washington Mills varies.

#### 4.3.3.5 Uncertainties

##### CO<sub>2</sub>

Activity data: The three productions sites use the amount of produced crude silicon carbide as activity data. The uncertainty of the activity data given as this production figure is calculated to be ± 3 per cent.

Emission factor: When using the standard emission factor of 2.62 tonne CO<sub>2</sub>/tonnes SiC, the uncertainty range is estimated to be – 16 % to - +7 %. This can be explained due to variations in raw materials as well as process variations, and is based on previous development of site specific emissions factors (SINTEF 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 CO<sub>2</sub>/tonn coke used is not constant. For Washington Mills the factor is in the range 1.07-1.27. For Saint Gobain one has to look at the two plants in Lillesand and Arendal together, because the input and output from them are somewhat mixed together. The factor for them is in the range 0.99-1.24. This implies that the output of SiC will have some variation from batch to batch.

The justification of changing method is that the IEF tonne CO<sub>2</sub> /tonne coke varies over the years due to variation in carbon content in coke and that this variation is larger or in the same order of variation that the production of crude silicon carbide. In addition there is a relatively large difference in the carbon consumption data in the early 1990s due to the use of purchase data as a proxy for carbon consumption. The silicon carbide production data in the early 1990s especially is considered being more accurate than the coke consumption.

Emissions: The total uncertainty of the resulting emissions of CO<sub>2</sub>, based on uncertainties in activity data and emissions factor, is calculated to be in the range of – 20 % to + 10 %.

#### CH<sub>4</sub>

Activity data: The three production sites use the amount of produced crude silicon carbide as activity data. The uncertainty of the activity data given as this production figure is calculated to be ± 3%.

Emission factor:

The emission factor of 4.2 kg CH<sub>4</sub>/tonne SiC is used, and the uncertainty level is estimated to be ± 30%.

The following explains the calculation of emission factor and the uncertainty level:

The production of SiC is a batch process with duration of about 43 hours. The CH<sub>4</sub>-concentration (ppm) is monitored continuously the first 6.5 hours. After this, only control monitoring is carried out. The results show that the concentration of CH<sub>4</sub> is peaking in the first hour of the process, giving a CH<sub>4</sub> concentration 10 – 15 times higher than in the last 36 hours of the process. A typical level of the concentration of CH<sub>4</sub> is given in Figure 4.4 below.

If the CH<sub>4</sub>-concentration is averaged over the total batch time of 43 hours, this will give an emissions factor of 4.2 kg CH<sub>4</sub>/tonne SiC, i.e. 3.5 kg CH<sub>4</sub>/tonne petrol coke.

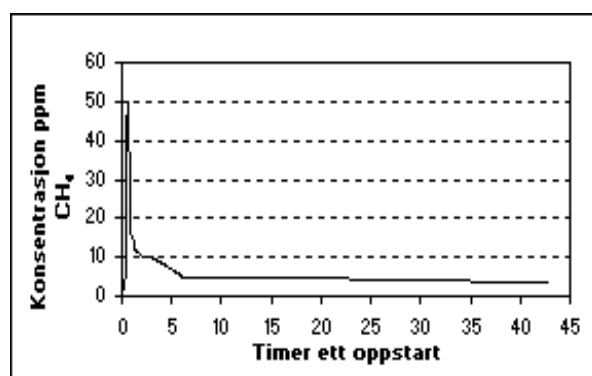


Figure 4.4. Concentration of CH<sub>4</sub> for one batch of SiC.

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  $\pm 5$  per cent.

If these uncertainties are added, the estimate result of total uncertainties for the resulting emissions of CH<sub>4</sub> is  $\pm 30$  per cent.

#### 4.3.3.6 Source 180odel lo 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.

#### 4.3.3.7 Recalculations

There has been no recalculation since NIR 2010.

#### 4.3.3.8 Planned improvements

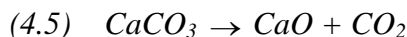
There is no planned activity this year that will improve the data quality for NIR 2013.

### 4.3.4 Production of Calcium Carbide – 2B4

#### 4.3.4.1 Description

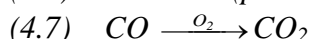
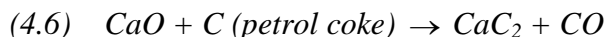
One plant in Norway was producing calcium carbide until 2003. The production of calcium carbide generates CO<sub>2</sub> emissions when limestone is heated and when petrol coke is used as a reducing agent.

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 CO<sub>2</sub> 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 CO<sub>2</sub> has been estimated by (SINTEF 1998e) to be 1.71 tonne/ tonne included 0.02 t CO<sub>2</sub> /t CaC<sub>2</sub> from fuel. In the CRF the emissions from fuels is reported in the Energy chapter. (SINTEF 1998e) conclude that the one reason for the difference between the factors is that the IPCC assumes that all calcium carbonate is calcinated. However, in the production process at the plant they first produced

CaC<sub>2</sub> that gives CO<sub>2</sub> emissions. Some of the CaC<sub>2</sub> was then refined to DIC<sub>2</sub> in a process that consumed CO<sub>2</sub>. This CO<sub>2</sub> gas was collected from one of the first steps of the CaC<sub>2</sub> production. The net consumption of CO<sub>2</sub> in production of DIC<sub>2</sub> is according to SINTEF about 1.3 tonne CO<sub>2</sub> per tonne DIC<sub>2</sub> produced. This implies that the specific CO<sub>2</sub> IEF fluctuates.

#### **4.3.4.5 Uncertainties**

Uncertainty estimates for greenhouse gases are given in Annex II.

#### **4.3.4.6 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.

#### **4.3.4.7 Recalculations**

There has been no recalculation since NIR 2008.

#### **4.3.4.8 Planned improvements**

Since the plant is closed down there is no further planned activity to review historical data.

### **4.3.5 Production of Methanol – 2B5**

#### **4.3.5.1 Description**

One plant in Norway produces methanol. Natural gas and oxygen are used in the production of methanol. The conversion from the raw materials to methanol is done in various steps and on different locations at the plant. CH<sub>4</sub> and NMVOC are emitted during the production process. Emissions from flaring of natural gas by production of methanol are as recommended by the review team reported under 2B5. The CO<sub>2</sub> emissions from energy combustion are included under 1.A.2.C

Indirect emissions of CO<sub>2</sub> are calculated by Statistics Norway based on the emission of CH<sub>4</sub> and NMVOC, see chapter 1.3.3.

#### **4.3.5.2 Methodological issues**

The plant reports emission figures of CH<sub>4</sub> and NMVOC to Klif. The reported emissions are based on measurements.

#### **4.3.5.3 Emission factors**

Emission factors for flare of natural gas are for CO<sub>2</sub>: 2340 tonnes/Sm<sup>3</sup>, for CH<sub>4</sub>: 0.24 tonnes/Sm<sup>3</sup> and for N<sub>2</sub>O: 0.02 tonnes/Sm<sup>3</sup>.

#### **4.3.5.4 Uncertainties**

Uncertainty estimates for greenhouse gases are given in Annex II.

#### **4.3.5.5 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.



#### **4.3.5.6 Recalculations**

There has been no recalculation since NIR 2008.

#### **4.3.5.7 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

### **4.3.6 Production of Plastic 2B5**

#### **4.3.6.1 Description**

Three plants report emissions under this source category. Two of the plants were one plant up to 2001. One of the plants produces ethylene and propylene where the other has vinyl chloride production. Various components are emitted during the production of plastic.

CH<sub>4</sub> and NMVOC emissions are from leakages in the process. Direct CO<sub>2</sub> emission is from combustion and is reported in Chapter 3 Energy.

During the production process of ethylene and vinyl chloride there is an oxide chloride step for production of ethylene chloride followed by cracking to vinyl chloride monomer and hydrochloric acid.

#### **4.3.6.2 Methodological issues**

*CO<sub>2</sub>, CH<sub>4</sub> and NMVOC*

Emission figures are annually reported to Klif. CO<sub>2</sub> from combustion is based on gas specific emissions factors and activity data. CH<sub>4</sub> and NMVOC emissions reported are based on measurements.

Indirect emissions of CO<sub>2</sub> calculated by Statistics Norway are based on the emission of CH<sub>4</sub> and NMVOC.

#### **4.3.6.3 Uncertainties**

It is difficult to measure leakages of CH<sub>4</sub> and NMVOC and therefore the uncertainty is regarded as being large. Uncertainty estimates for greenhouse gases are given in Annex II.

#### **4.3.6.4 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.

#### **4.3.6.5 Recalculations**

For one plant, some CO<sub>2</sub> emissions previously registered as combustion emissions, have now been reallocated to process emissions. This causes an annual rise in the process emissions of 10-15 ktonnes for all years 1990-2008.

#### **4.3.6.6 Planned improvements**

The ERT has noted an unstable and increasing trend from 2006 for the CO<sub>2</sub> emissions from plastic. A preliminary assessment is that the increase may be due to inconsistencies with regards to where emissions from flaring have been allocated. We intend to look into this in time for the submission of the 2013 NIR.

#### **4.3.7 Titanium dioxide production – 2B5**

##### **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 CO<sub>2</sub> are emitted during the production process.

Due to a reallocation after the key category analysis was performed, 2C1 – Iron and Steel Production should be replaced as key by 2B5 Other Chemical Industry. This will be updated in the next NIR submission.

##### **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 CO<sub>2</sub> captured in the products.

##### **4.3.7.3 Emission factors**

Emission factors for flare of natural gas are for CO<sub>2</sub>: 2340 tonnes/Sm<sup>3</sup>, for CH<sub>4</sub> 0.24 tonnes/Sm<sup>3</sup> and for N<sub>2</sub>O: 0.02 tonnes/Sm<sup>3</sup>.

##### **4.3.7.4 Uncertainties**

Uncertainty estimates for greenhouse gases are given in Annex II.

##### **4.3.7.5 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.

##### **4.3.7.6 Recalculations**

As recommended by the ERT, emissions previously reported under *2C1 Pig iron*, have been moved to *2B5 Titanium dioxide production* for the whole time period.

##### **4.3.7.7 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

#### **4.3.8 Production of Explosives – 2B5**

##### **4.3.8.1 Description**

There has been one plant in Norway producing explosives, but the plant was closed down in 2001. Nitric acid was used as a raw material in the manufacture of explosives and in the production of nitric acid NO<sub>x</sub> was emitted.

#### **4.4 Metal Production – 2C**

Metal production in Norway includes plants producing iron and steel, ferroalloys, aluminum, nickel zinc and also magnesium until spring 2006. Production of anodes is also included in

this chapter. Nearly all emissions figures from the production of metals included in the inventory are figures reported annually from the plants to the Klif.

8.4 per cent of total GHG emissions in Norway were from Metal Production in 2010, and the sector contributed with 60.8 per cent of the emissions from Industrial Processes. The largest contributor to the GHG emissions from Metal Production in 2010 is Aluminum production and ferroalloys.

The emissions from Metal Production decreased by 53.9 per cent from 1990-2010 and increased by 16.0 per cent from 2009-2010. The reduction from 1990-2010 was due to decreased PFC and SF<sub>6</sub> that again was due to improvement in technology aluminum production, the close down of a magnesium plant in 2006 and generally lower production volumes. The CO<sub>2</sub> emissions from Metal Production decreased by 0.1 per cent from 1990-2010 and increased by 22.5 percent from 2009-2010.

*Table 4.6. Metal production. Components emitted and included in the Norwegian inventory.*

|                                  | CO <sub>2</sub> | CH <sub>4</sub> | PFCs | SF <sub>6</sub> | Tier     | Key category |
|----------------------------------|-----------------|-----------------|------|-----------------|----------|--------------|
| 2C1 Iron and steel <sup>*)</sup> | R               | NA              | NA   | NA              | Tier 2   | Yes          |
| 2C2 Ferroalloys                  | R               | R               | NA   | NA              | Tier 2/3 | Yes          |
| 2C3 Primary aluminium            | R               | NA              | R    | R               | Tier 2   | Yes          |
| 2C4 Secondary aluminium          | NA              | NA              | NA   | R               | Tier 1   | No           |
| 2C4 Magnesium                    | E               | NA              | NA   | R               | Tier 2   | Yes          |
| 2C5 Nickel                       | R               | NA              | NA   | NA              | Tier 2   | No           |
| 2C5 Anodes                       | R               | NA              | NA   | NA              | Tier 2   | No           |

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

<sup>\*)</sup> Due to a reallocation after the key category analysis was performed, 2C1 – Iron and Steel Production should be replaced as key by 2B5 Other Chemical Industry.

#### **4.4.1 Production of Iron and Steel – CO<sub>2</sub> – 2C1(Key Category)**

##### **4.4.1.1 Description**

Norway includes one plant producing steel in the Norwegian Inventory and the activity data in the CRF is steel produced.

Due to a reallocation after the key category analysis was performed, 2C1 – Iron and Steel Production should be replaced as key by 2B5 Other Chemical Industry. This will be updated in the next NIR submission.

#### **4.4.1.2 Methodological issues**

In the Norwegian GHG Inventory, emission figures of CO<sub>2</sub>, 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. All emission figures are based on calculations.

The total emissions from steel production cover emissions from industrial processes and from combustion. For the years 1998-2001 and 2005-2008 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 CO<sub>2</sub> emissions per ton steel produced in 1998 multiplied with the actual production of steel. For 2002-2004 the same method is used but then we have used the 2005 process emissions per ton steel produced. The emissions from combustion are the total CO<sub>2</sub> emissions reported by the plant minus the estimated emissions from processes.

The process CO<sub>2</sub> 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.

#### **4.4.1.3 Uncertainties**

Uncertainty estimates for greenhouse gases are given in Annex IV.

#### **4.4.1.4 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR. CO<sub>2</sub> emission figures reported to Klif are compared with calculations at Statistics Norway using the amount of reducing agent and emission factors. This method is recommended by IPCC when data from measurements are not available.

Annually reported emission figures are first controlled by the Klif and then Statistics Norway.

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

#### **4.4.1.5 Recalculations**

The reported CO<sub>2</sub> emissions for 2009 have increased by 2 000 tonnes due to revised data. In addition, as recommended by the ERT, emissions previously reported under *2C1 Pig iron*, have been reallocated to *2B5 Titanium dioxide production* for the whole time period.

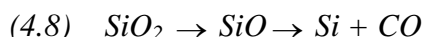
#### **4.4.1.6 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

#### 4.4.2 Production of Ferroalloys – CO<sub>2</sub> – 2C2 (Key Category)

##### 4.4.2.1 Description

There were 12 plants producing ferroalloys in Norway in 2010. One plant closed down in 2001, two plants were closed down during 2003 and two in 2006. The plant that was out of production in 2006 started up again in 2007. Ferrosilicon, silicon metal, ferromanganese and silicon manganese are now produced in Norway. Ferrochromium was produced until the summer in 2001. Ferro silicon with 65 to 96 percent Si and silicon metal with 98-99 percent Si is produced. The raw material for silicon is quartz (SiO<sub>2</sub>). SiO<sub>2</sub> 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<sub>2</sub> and SiO<sub>2</sub> (silica dust).

In ferroalloy production, raw ore, carbon materials and slag forming materials are mixed and heated to high temperatures for reduction and smelting. The carbon materials used are coal, coke and some bio carbon (charcoal and wood). Electric submerged arc furnaces with graphite electrodes or consumable Soederberg electrodes are used. The heat is produced by the electric arcs and by the resistance in the charge materials. The furnaces used in Norway are open, semi-covered or covered.

Several components are emitted from production of ferroalloys. Emission of CO<sub>2</sub> 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<sub>4</sub> 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<sub>2</sub> emissions.

Measurements performed at Norwegian plants producing ferro alloys indicates that in addition to emissions of CO<sub>2</sub> and CH<sub>4</sub> also N<sub>2</sub>O is emitted. The emissions of CH<sub>4</sub> and N<sub>2</sub>O 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<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) from ferroalloy production accounted for 5.1 per cent of the national total GHG emissions in 1990 and 4.0 per cent in 2010. The emissions from production of ferroalloy decreased by 14.9 per cent from 1990 to 2010. From 2009 to 2010 the GHG emissions from ferroalloy production increased by 50.2 per cent.

According to the Tier 1 key category analysis CO<sub>2</sub> emissions from production of ferroalloys are key category due to the large share of total emissions.

##### 4.4.2.2 Methodological issues

###### CO<sub>2</sub>

The methods used in the calculation of CO<sub>2</sub> 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 two different methods for calculating CO<sub>2</sub>-emissions:

1. Mass balance; the emissions for CO<sub>2</sub> is calculated by adding the total input of C in raw materials before subtracting the total amount of C in products, wastes and sold gases (Tier 3)
2. Calculate emission by multiplying the amount of reducing agents in dry weight with country specific emission factors for coal, coke, petrol coke, electrodes, anthracite, limestone and dolomite. (Tier 2)

The two methods are regarded as being consistent and each plant have used the same method for the entire time series.

Indirect emissions of CO<sub>2</sub> are calculated based on the emission of CH<sub>4</sub> and NMVOC.

#### *CH<sub>4</sub> and N<sub>2</sub>O*

The emissions of CH<sub>4</sub> and N<sub>2</sub>O 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 manges, silicon manges and ferrochromium do not emit emissions of CH<sub>4</sub> and N<sub>2</sub>O.

#### *NMVOC*

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

### **4.4.2.3 Activity data**

#### *CO<sub>2</sub>*

Calculation of emissions is based on the consumption of gross reducing agents and electrodes in the production of ferroalloys. The ERT of the 2010 NIR recommended that Norway include in the NIR a table with information on emissions from limestone and dolomite consumption and other AD for ferroalloys production. Norway has chosen to focus on the activity data and table 4.7 shows these for years 2005-2010 (emission factors are provided in table 4.8).

*Table 4.7. Tonnes of various activity data in the ferroalloys production for 2005-2010*

| <b>Activity data</b>   | <b>2005</b> | <b>2006</b> | <b>2007</b> | <b>2008</b> | <b>2009</b> | <b>2010</b> |
|------------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Coal/anthracite        | 380 836     | 257 955     | 308 965     | 334 197     | 210 520     | 360 291     |
| Coke                   | 358 887     | 346 682     | 373 901     | 377 836     | 242 758     | 328 013     |
| Petrol coke            | 44 500      | 31 342      | 37 583      | 41 346      | 31 174      | 48 813      |
| Electrodes             | 21 969      | 5 834       | 3 995       | 5 586       | 4 439       | 7 793       |
| Limestone and dolomite | 42 618      | 54 819      | 28 588      | 168 656     | 96 533      | 123 623     |
| Coke powder            | 0           | 0           | 8 068       | 9 446       | 0           | 9 708       |
| Carbonate ore          | 99 834      | 95 718      | 96 687      | 87 127      | 152 966     | 253 980     |

*Source: Climate and Pollution Agency*

#### *CH<sub>4</sub> and N<sub>2</sub>O*

The gross production of different ferroalloys is used in the calculation.

#### *NMVOC*

The gross amount of reducing agents that are used for the calculation of NMVOC emissions are annually reported to Statistics Norway from each plant.

#### 4.4.2.4 Emission factors

##### *CO<sub>2</sub>*

The carbon content of each raw materials used in the Tier 3 calculation is from carbon certificates from the suppliers. The carbon in each product, CO gas sold et cetera is calculated from the mass of product and carbon content.

In the Tier 2 calculation the emission factors are from SINTEF (1998b, 1998c and 998d) and the factors are listed in Table 4.8.

*Table 4.8. Emission factors from production of ferroalloys. Tonnes CO<sub>2</sub>/tonne reducing agent or electrode.*

|                   | <b>Coal</b> | <b>Coke</b> | <b>Electrodes</b> | <b>Petrol coke</b> | <b>Carbonate ore</b> | <b>Dolomite Limestone</b> |
|-------------------|-------------|-------------|-------------------|--------------------|----------------------|---------------------------|
| Ferro silicon     | 3.08        | 3.36        | 3.36              | --                 | --                   | --                        |
| Silicon metal     | 3.12        | 3.36        | 3.54              | --                 | --                   | --                        |
| Ferro chromium    | --          | 3.22        | 3.51              | --                 | --                   | --                        |
| Silicon manganese | --          | 3.24        | 3.51              | 3.59               | 0.16- 0.35           | 0.43-0.47                 |
| Ferro manganese   | --          | 3.24        | 3.51              | 3.59               | 0.16- 0.35           | 0.43-0.47                 |

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

##### *CH<sub>4</sub> and N<sub>2</sub>O*

Measurements performed at Norwegian plants producing ferro alloys indicate emissions of N<sub>2</sub>O in addition to CH<sub>4</sub>. The emissions of CH<sub>4</sub> and N<sub>2</sub>O 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 CH<sub>4</sub> and N<sub>2</sub>O 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<sub>x</sub> emissions. However, the emissions of CH<sub>4</sub> and N<sub>2</sub>O have also been measured.

Full scale measurements have been performed at different industrial FeSi/Si furnaces. The average CH<sub>4</sub> and N<sub>2</sub>O concentrations in the ferroalloy process are with some exceptions a few ppm. For N<sub>2</sub>O and CH<sub>4</sub> the exception is during spontaneous avalanches in the charge (i.e. collapse of large quantities of colder materials falling into the crater or create cavities) occur

from time to time, see Figure 7 in SINTEF (2004b). In the avalanches the N<sub>2</sub>O emissions goes from around zero to more than 35 ppm. The avalanches are always short in duration. There are also increased N<sub>2</sub>O emissions during blowing phenomenon.

The EF used in the inventory represents the longer-term average N<sub>2</sub>O and CH<sub>4</sub> 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 4.9. 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 4.9. Emission factors for CH<sub>4</sub> and N<sub>2</sub>O from production of ferroalloys. Emission factors in kg per tonne produced ferroalloy.*

| Alloy,<br>charging<br>routines and<br>temperature | Si-met             |                                    |   | FeSi-75%           |                                    |   | FeSi-65%           |                                    |   |
|---|--------------------|------------------------------------|---|--------------------|------------------------------------|---|--------------------|------------------------------------|---|
|   | Batch-<br>charging | Sprinkle-<br>charging <sup>1</sup> | Sprinkle-<br>charging<br>and<br>>750°C <sup>2</sup> | Batch-<br>charging | Sprinkle-<br>charging <sup>1</sup> | Sprinkle-<br>charging<br>and<br>>750°C <sup>2</sup> | Batch-<br>charging | Sprinkle-<br>charging <sup>1</sup> | Sprinkle-<br>charging<br>and<br>>750°C <sup>2</sup> |
| kg CH <sub>4</sub> per<br>tonne metal             | 0.1187<br>M        | 0.0881<br>M                        | 0.1000<br>E   | 0.0890<br>E        | 0.0661<br>E                        | 0.0750<br>E   | 0.0772<br>E        | 0.0573<br>E                        | 0.0650<br>E   |
| kg N <sub>2</sub> O per<br>tonne metal            | 0.0433<br>E        | 0.0214<br>E                        | 0.0252<br>E   | 0.0297<br>E        | 0.0136<br>E                        | 0.0161<br>E   | 0.0117<br>E        | 0.0078<br>E                        | 0.0097<br>E   |

1 Sprinkle-charging is charging intermittently every minute.

2 Temperature in off-gas channel measured where the thermocouple cannot 'see' the combustion in the furnace hood.

M=measurements and E= estimates based un measurements

#### NMVOC

Statistics Norway uses an emission factor of 1.7 kg NMVOC/tonne coal or coke (EPA 1986) in the calculations.

#### 4.4.2.5 Uncertainties

The uncertainty in activity data and emission factors have been calculated to ±5 per cent and ±7 per cent respectively, see Annex II.



#### **4.4.2.6 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR. The reported emissions from the plants were compared with emissions data given in the white book and other relevant data available. In some cases, the emission data were verified by making control calculation based on emission factors and activity data. In all cases, the construction of charts and figures of emissions and activity data helped identifying missing data and possible errors.

All the main producers of ferroalloys in Norway were contacted and asked to supply missing emissions data and activity, and to explain any possible errors identified. The feedback from the companies made it possible to make corrections and filling of gaps in the series of data.

A complete time series from 1990 to 2004 could be established for all three relevant greenhouse gas parameters for most companies. Data from the white book and the reported company data corresponded well.

During the review of the initial report in the 2007 activity data like coal, coke, electrodes, petrol coke and bio carbon were collected from each plant once again and so were emissions of CH<sub>4</sub> and N<sub>2</sub>O based on Efs shown in Table 4.8. 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 an annual quality control (QC) of the emission data on the bases of the consumption of reducing agents they collect in an annual survey and average emission factors.

#### **4.4.2.7 Recalculations**

The reported CO<sub>2</sub> figures for one plant have been marginally adjusted downwards for 2007, and were increased by 10 000 tonnes for 2008 due to revised data.

#### **4.4.2.8 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

### **4.4.3 Production of Primary Aluminium –CO<sub>2</sub> and PFC – 2C3 (Key Category)**

#### **4.4.3.1 Description**

There are seven plants in Norway producing aluminium. Both prebaked anode and the Soederberg production methods are used. In the Soederberg technology, the anodes are baked in the electrolysis oven, while in the prebaked technology the anodes are baked in a separate plant. In general the emissions are larger from the Soederberg technology than from the prebaked technology.

Production of aluminium leads to emission of various components as CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, perfluorocarbons (PFCs), heavy metals and persistent organic pollutants. The emission of CO<sub>2</sub> is due to the electrolysis process during the production of aluminium, while the SO<sub>2</sub> emissions are from the sulphur in the reducing agents used. NO<sub>x</sub> is primary produced by the high temperature oxidation of nitrogen in the air. All plants also report emissions of particles, heavy metals and PAH. Emissions of heavy metals are due to the metal content in the raw materials used and the reducing agents.

There has been a substantial reduction in the total PFC emissions from the seven Norwegian aluminium plants in the period from 1990 to 2010. 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 2010 the specific PFC emissions for prebaked and Soederberg were 0.18 and 0.27 kg CO<sub>2</sub>-equivalent, see Figure 4.5.

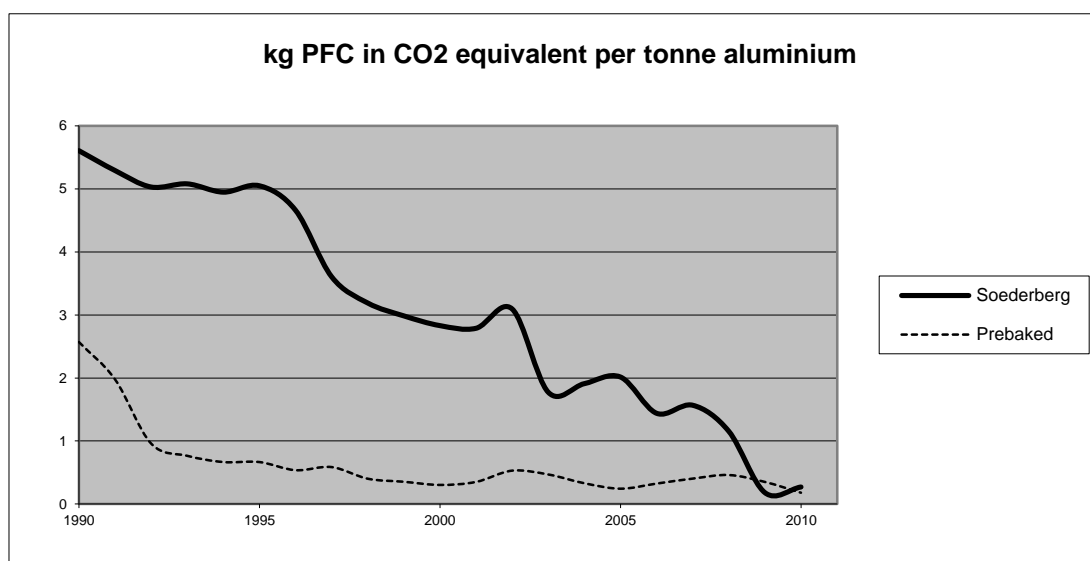
In 1990, 57 per cent of the aluminium production in Norway was produced with prebaked technology and the share of aluminium production from prebaked was increased to 92 per cent in 2010. Two new plants with prebaked technology were established in 2002 and plants using Soederberg technology were closed down in the period 2002-2009.

PFCs emissions from production of aluminium contribute in 1990 to 6.8 per cent of the total GHG emissions in Norway. The share of the totals in 2010 is reduced to 0.4 per cent. Emissions of PFCs are decreased with 93.9 per cent from 1990 to 2010. Between 2009 and 2010 emissions decreased by 45.6 per cent.

The PFC emissions per tonne aluminium produced in Norway was 3.88 kg CO<sub>2</sub>-equivalent in 1990 and 0.19 kg CO<sub>2</sub>-equivalent in 2010. This is a reduction of 95.2 per cent from 1990 to 2010. From 2009 to 2010, the PFC emissions per tonne aluminium produced were reduced by 44.7 per cent.

An increase in production capacity is also included in the modernisation, leading to higher total emissions of CO<sub>2</sub>. The implied emission factor for CO<sub>2</sub> is relatively stable.

PFCs and CO<sub>2</sub> emissions from aluminium production are both key category in level, PFC also in trend both according to the Tier 2 key category analysis.

Figure 4.5. kg PFC in CO<sub>2</sub> equivalent per tonne aluminium

Source: Klif

#### 4.4.3.2 Methodological issues

##### CO<sub>2</sub>

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 CO<sub>2</sub>-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 CO<sub>2</sub> emissions separate for each technology. The following methods are used:

##### CO<sub>2</sub> from Prebake Cells

$$(4.9) \quad Q = A \cdot C \cdot 3.67$$

Where

Q is the total yearly emissions of CO<sub>2</sub>

A is the yearly net consumption of anodes

C is per cent carbon in the anodes

3,67 is the mol-factor CO<sub>2</sub>/C

##### CO<sub>2</sub> 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 CO<sub>2</sub>

S is the yearly consumption of Soederberg paste

K is the share of coke in the Soederberg paste

P is the share of patch in the Soederberg paste

K+P=1

C1 is the fraction of carbon in the coke. Fraction is per cent Carbon/100

C2 is the fraction of carbon in the peach. Fraction is per cent Carbon/100

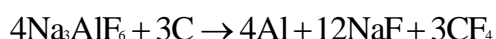
### PFCs

Perfluorinated hydrocarbons (PFCs), e.g. tetrafluoromethane (CF<sub>4</sub>) and hexafluoroethane (C<sub>2</sub>F<sub>6</sub>), are produced during anode effects (AE) in the Prebake and Soederberg cells, when the voltage of the cells increases from the normal 4-5V to 25-40V. During normal operating condition, PFCs are not produced. The fluorine in the PFCs produced during anode effects originates from cryolite. Molten cryolite is necessary as a solvent for alumina in the production process.

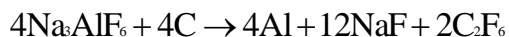
Emissions of PFCs from a pot line (or from smelters) are dependent on the number of anode effects and their intensity and duration. Anode effect characteristics will be different from plant to plant and also depend on the technology used (Prebake or Soederberg).

During electrolysis two per fluorocarbon gases (PFCs), tetrafluormethane (CF<sub>4</sub>) and heksafluorethane (C<sub>2</sub>F<sub>6</sub>), 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 4.10, given as kg CF<sub>4</sub>/tonne Al/anode effect minutes per cellday, is multiplied by the product of anode effect frequency and anode effect duration (in other words, by the number of anode effect minutes per cell day), and this product is finally multiplied by the annual aluminum production figure (tonnes of Al/year). The formula for calculating the PFCs is:

$$\text{kg CF}_4 \text{ per year} = S_{\text{CF}_4} \cdot \text{AEM} \cdot \text{MP}$$

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 :

$S_{\text{CF}_4}$  = “Slope coefficient” for  $\text{CF}_4$ , ( $\text{kg PFC}/\text{t}_{\text{Al}}$ /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  $\text{C}_2\text{F}_6/\text{CF}_4$

Table 4.10. Technology specific slope and overvoltage coefficients for the calculation of PFCs emissions from aluminium production.

| Technology <sup>a</sup> | ”Slope coefficient” <sup>b, c</sup><br>( $\text{kg PFC}/\text{t}_{\text{Al}}$ )/ (anode effect/cell day) |                            | Weight fraction $\text{C}_2\text{F}_6/\text{CF}_4$ |                            |
|-------------------------|--|----------------------------|--|----------------------------|
|                         | $S_{\text{CF}_4}$  | Uncertainty<br>( $\pm\%$ ) | $F_{\text{C}_2\text{F}_6/\text{CF}_4}$             | Uncertainty<br>( $\pm\%$ ) |
| 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  $\text{CF}_4$  and  $\text{C}_2\text{F}_6$ . The mechanisms for producing emissions of PFC are the same as for producing  $\text{CF}_4$  and  $\text{C}_2\text{F}_6$ . The two PFC gases are therefore considered together when PFC emissions are calculated. The  $\text{C}_2\text{F}_6$  emissions are calculated as a fraction of the  $\text{CF}_4$  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 Søderberg 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  $\text{kg CF}_4$  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<sub>6</sub>)*

SF<sub>6</sub> used as cover gas in the aluminium industry is assumed to be inert, and SF<sub>6</sub> emissions are therefore assumed to be equal to consumption. At one plant SF<sub>6</sub> 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<sub>6</sub> 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<sub>4</sub> (the slope coefficients of 0.143 kg CF<sub>4</sub>/tonne Al/anode effect minutes per cell day for CWPB and 0.092 for VSS). The amount of C<sub>2</sub>F<sub>6</sub> is calculated from the Tier 2 values for CF<sub>4</sub>, where the weight fraction of C<sub>2</sub>F<sub>6</sub> to CF<sub>4</sub> is set equal to 0.121 for CWPB and 0.053 for VSS. This change alone increases the calculated CO<sub>2</sub>-equivalent emissions by 10% for our prebake cells, because of the high global warming potential for C<sub>2</sub>F<sub>6</sub>.

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 III to the 2010 NIR.

#### *CO<sub>2</sub>*

It was possible to establish data series of CO<sub>2</sub> from 1990 to 2004 for all plants. There are still some discrepancies between reports of process related CO<sub>2</sub> and energy related CO<sub>2</sub>, especially in the beginning of the 1990s. This is because it was difficult to provide sufficient energy data to calculate the energy related combustions.

The emission figures reported by the plants are also controlled by Statistics Norway. Statistics Norway make their own estimates based on the consumption of reducing agents and production data collected in an annual survey and average emission factors.

#### *Percfluorocarbons (PFCs)*

The emission figures from the aluminium plants are reported to Klif annually. As a quality control, it is checked that the reports are complete. Each figure is compared with similar reports from previous years and also analysed taking technical changes and utilisation of production capacity during the year into account. If errors are found the Klif contacts the plant to discuss the reported data and changes are made if necessary.

Klif has regular 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.

#### **4.4.3.7 Recalculations**

The PFC emissions in 2009 from four plants have been revised due to decimal errors in the figures used in the 2011 submission. The CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emissions reported by three of the plants were in thousand tonnes e.g. 29000 tonnes CF<sub>4</sub> and corrected to 28989 tonnes CF<sub>4</sub>. For the fourth plant the emissions was included in the inventory with two decimals and now is included with three decimals.

#### **4.4.3.8 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

### **4.4.4 Production of Secondary Aluminium – 2C4**

#### **4.4.4.1 Description**

One open mill in Norway is handling secondary aluminium production. For earlier years there have been some emissions of SF<sub>6</sub>.

### **4.4.5 Production of magnesium –SF<sub>6</sub> – 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 CO<sub>2</sub> and CO emissions. During the calcinations of Dolomite (MgCa(CO<sub>3</sub>)<sub>2</sub>) to magnesium oxide, CO<sub>2</sub> 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 CO<sub>2</sub>. SO<sub>2</sub> is emitted due to the sulphur in the reducing agent used.

In the foundry, producing cast magnesium, SF<sub>6</sub> is used as a cover gas to prevent oxidation of magnesium. The Norwegian producers of cast magnesium has assessed whether SF<sub>6</sub> 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 SF<sub>6</sub> used as cover gas is emitted to the air.

SF<sub>6</sub> from magnesium foundries accounted in 1990 for 4.3 per cent of the national total GHG emissions. The emissions have decreased and this is due to improvements in technology and in process management. The primary magnesium production stopped in 2002 and only secondary production is retained and this production has no CO<sub>2</sub> emissions from processes. During 2006 also the production of remelting Mg stopped and there were no emissions from this source in 2007 and 2008.

SF<sub>6</sub> emissions from magnesium foundries are, according to the Tier 1 key category analysis, defined as key category in level and trend.

#### **4.4.5.2 Methodological issues**

##### *CO<sub>2</sub>*

The IPCC (1997b) recommends using the consumption of reducing agent as the activity data for estimating emissions. (SINTEF 1998f), on the other hand, recommends using production volume in the calculations. The Norwegian emission inventory use production data as activity data. The CO<sub>2</sub> emissions are therefore calculated by using annually production volume and the emission factor recommended by (SINTEF 1998f).

##### *SF<sub>6</sub>*

The consumption figures of the cover gas (SF<sub>6</sub>) are used as the emission estimates in accordance with the IPCC Guidelines (IPCC 1997a, 1997b). The SF<sub>6</sub> emissions are reported annually to Klif.

Studies performed by the Norwegian producer have assessed that SF<sub>6</sub> used as cover gas is inert. Therefore the consumption of SF<sub>6</sub> 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 use production volumes as activity data in the calculation of CO<sub>2</sub>. This method is recommended by (SINTEF 1998f). The plant reports the consumption of SF<sub>6</sub> to Klif.

#### **4.4.5.4 Emission factor**

An emission factor of 4.07 tonnes CO<sub>2</sub>/tonnes produced magnesium is used to calculate the annually emissions of CO<sub>2</sub> (SINTEF 1998f).

#### **4.4.5.5 Uncertainties**

The uncertainty in the emissions is assumed to be ± 5 per cent, see Annex II.



#### **4.4.5.6 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 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 CO<sub>2</sub> is emitted. CO<sub>2</sub> is emitted in the production of nickel due to the soda from the production of nickel carbonate and use of coke as a reducing agent.

#### **4.4.6.2 Methodological issues**

CO<sub>2</sub>

Emission figures are annually reported from the plant to the Klif and based on calculation of material balance.

#### **4.4.6.3 Uncertainties**

Uncertainty estimates for greenhouse gases are given in Annex II.

#### **4.4.6.4 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR. There is no source specific QA/QC procedure for this sector. See section 1.6 for the description of the general QA/QC procedure.

#### **4.4.6.5 Recalculations**

There has been no recalculation since NIR 2008.

#### **4.4.6.6 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

### **4.4.7 Manufacture of Anodes – 2C5**

#### **4.4.7.1 Description**

Four plants in Norway produce anodes. Prebaked anodes and coal electrodes are alternatives to the use of coal and coke as reducing agents in the production process for aluminium and

ferroalloys. The anodes and coal electrodes are produced from coal and coke. The production of anodes and coal electrodes leads to emissions of CO<sub>2</sub>.

#### **4.4.7.2 Methodological issues**

The emissions of CO<sub>2</sub> are calculated by each plant and the method is based on the Aluminium Sector Greenhouse Gas Protocol by the International Aluminium Institute (IAI 2005).

#### **4.4.7.3 Uncertainties**

Uncertainty estimates for greenhouse gases are given in Annex II.

#### **4.4.7.4 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.

#### **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 2013.

### **4.5 Other Production – 2D**

#### **4.5.1 Pulp and paper – 2D1**

##### **4.5.1.1 Description**

There are CO<sub>2</sub> emissions from non-combustion from one plant in this sector. The emissions originate from the limestone. Emissions from combustion are included in Chapter 3.

##### **4.5.1.2 Methodological issues**

The CO<sub>2</sub> 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 plant and emission factor. The emissions in the period 1998-2004 are reported in the plant's application for CO<sub>2</sub>-permits within the Norwegian emissions trading scheme. From 2005 and onwards, the plant reports the emissions through the annual reporting under the emissions trading scheme.

##### **4.5.1.3 Activity data**

Activity data is reported by the plant to Klif. The amount of limestone is calculated from purchased amount.

##### **4.5.1.4 Emission factors**

The emission factor used in the calculation is 0.44 CO<sub>2</sub> per tonne limestone.

##### **4.5.1.5 Uncertainties**

No source specific uncertainty is known.

#### **4.5.1.6 Source specific QA/QC and verification**

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.

#### **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 2013.

### **4.5.2 Food and drink – CO<sub>2</sub> – 2D2 (Key category)**

#### **4.5.2.1 Description**

This source category includes NMVOC emissions from production of bread and beer, CO<sub>2</sub> from carbonic acid mainly used in breweries, export of captured CO<sub>2</sub> and CO<sub>2</sub> from production of bio protein.

As mentioned in Section 4.3.1 Ammonia Production, some CO<sub>2</sub> from this production is captured and in Norway mainly used as carbonic acid in carbonated beverages but most of the captured CO<sub>2</sub> 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 2010, about 197 ktonnes CO<sub>2</sub> were sold for national use and export.

CO<sub>2</sub> from food and drink is according to a Tier 1 key category analysis defined as key category due to contribution in level to total GHG emission.

#### **4.5.2.2 Methodological issues**

##### *CO<sub>2</sub>*

The figures are based on the sale statistics from the ammonia producing plant.

##### *NMVOC*

Production of bread and beer (and other similar yeast products) involves fermentation processes that lead to emission of NMVOC (ethanol). Emissions are calculated based on production volumes and emission factors.

##### *Production of Bio Protein CO<sub>2</sub>*

CO<sub>2</sub> emissions from production of bio protein from natural gas are included from the year 2001 when this production started. The bio protein is being used as animal fodder. Emission data reported from the plant to the Klif are included in the national inventory.

#### **4.5.2.3 Activity data**

##### *NMVOC*

Production volumes of bread and beverage are annually reported to Statistics Norway.

#### 4.5.2.4 Emission factors

##### NMVOC

The emission factors in Table 4.11 are taken from (EEA 1996).

Table 4.11. NMVOC emission factors from production of bread and beverage.

|                        | Emission factor | Unit                   |
|------------------------|-----------------|------------------------|
| Production of bread    | 0.003           | tonnes/tonnes produced |
| Production of beverage | 0.2             | kg/1000 litre          |

Source: EEA (1996)

#### 4.5.2.5 Uncertainties

##### NMVOC

The emission factors used is recommended by EEA (1996) and not specific for Norwegian conditions.

#### 4.5.2.6 Source specific QA/QC and verification

##### NMVOC

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III to the 2010 NIR.

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

#### 4.5.2.7 Recalculations

There has been no recalculation since NIR 2008.

#### 4.5.2.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2013.

### 4.6 Consumption of Halocarbons and SF<sub>6</sub>

#### 4.6.1 HFCs and PFCs from Products and Processes – HFC – 2F (Key Category)

##### 4.6.1.1 Description

HFCs and PFCs can be used as substitutes for ozone depleting substances (CFCs and HCFCs) that are being phased out according to the Montreal Protocol. They are used in varied applications, including refrigeration and air conditioning equipment, as well as in foam blowing, fire extinguishers, aerosol propellants and analysing purposes. There is no production of HFCs and PFCs in Norway. However, PFCs are emitted as a by-product during the production of aluminium, see chapter 4.4.3.5. 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 CO<sub>2</sub> equivalents are HFC-134a, HFC-143a and HFC-125. Measured in metric tonnes emissions of the low-GWP HFC-152a are also significant. Due to, i.e., high taxation, the use of PFCs in product-applications is very

low. In January 2003 a tax on import and production of HFC and PFC was introduced. In July 2004 this tax was supplemented with a refund for the destruction of used gas. In 2010 the tax and refund were both 213 NOK (approximately 29 Euro) per tonnes of CO<sub>2</sub>-equivalents. Based on these new realities a project was established to review the emission calculations of HFC and PFC. This work (Statistics Norway (2007b)) was completed in March 2007 and is reflected in this report.

EU regulation (EC) No 842/2006 on certain fluorinated greenhouse gases was included in Norwegian legislation in May 2010.

HFC emissions increased from 0.77 Mtonnes CO<sub>2</sub>-equivalents in 2009 to 0.82 Mtonnes CO<sub>2</sub> equivalents in 2010, and constitute 1.5% of total emissions in Norway.

This sector (2F) is according to the Tier 2 key category analysis defined as key category due to uncertainty in trend.

#### **4.6.1.2 Method**

Actual emissions of HFCs and PFCs are calculated using the Tier 2 methodology. This methodology takes into account the time lag in emissions from long lived sources, such as refrigerators and air-conditioning equipment. The chemicals slowly leak out from seams and ruptures during the lifetime of the equipment. The leakage rate, or emission factor, varies considerably depending on type of equipment.

Potential emissions are calculated employing the Tier 1b methodology, which only considers the import, export and destruction of chemicals in bulk and in products without time lag. The ratio between potential (Tier 1b) and actual emissions (Tier 2) has decreased from about 4:1 in the year 2000 to less than 2:1 in 2010.

#### **4.6.1.3 Activity data**

There is no production of HFC or PFC in Norway. Hence all emissions of these chemicals originate from imported chemicals. 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. Imported and exported amounts of chemicals in all products for the years 1995-1997 were collected through a survey in 1999 (SFT 1999a), and this information was used to estimate imports and exports the years prior to and after the survey. For the source category refrigeration, data on imports from customs statistics were used to update the estimated amounts for the years after 1997.

#### **4.6.1.4 Emission factors**

Leakage rates and product lifetimes used in the calculations are shown in Table 4.12.

Table 4.12. Emission factors for HFCs from products and lifetime of products

| Application category  | Annual emissions during lifetime (per cent of initial charge) | Lifetime of products (years) |
|---|---|------------------------------|
| Refrigeration and air conditioning                                      |   |                              |
| Household refrigerators and freezers                                    | 1   | 15                           |
| Commercial and industrial applications, imported                        | 3.5   | 15                           |
| Refrigerated transport, imported  | 20  | 15                           |
| Air conditioning aggregates and heat pumps, imported                    | 4   | 15                           |
| Water/liquid refrigerating aggregates, water-based heat pumps, imported | 5   | 15                           |
| Stationary equipment produced in Norway                                 | 10  | 15                           |
| Mobile air conditioners   | 10  | 12                           |
| Foam  |   |                              |
| Polyurethane with diffusion barrier                                     | 1   | 40                           |
| Polyurethane without diffusion barrier                                  | 5   | 20                           |
| Extruded polystyrene  | 3   | 30                           |
| Fire extinguishers  | 5   | 15                           |
| Solvents  | 50  | 2                            |
| Aerosol propellants   | 50  | 2                            |

Source: Statistics Norway (2007b)

#### 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  $\pm 50$  per cent for both HFC and PFC.

#### 4.6.1.6 Source specific QA/QC and verification

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

#### 4.6.1.7 Recalculations

There has been no recalculation since NIR 2010.

#### 4.6.1.8 Planned improvements

A project on updating activity data and the calculation model was started in 2011 and is continuing through 2012. The project was initiated as a result of our main data source not

being available from 2010 and onward. Data is however available through the Norwegian Directorate of Custom and Exice, and new routines for collection and revision of data was established in 2011. A first draft for updating activity data for the years 2005-2009 was generated in 2011 by combining the two data sources. In 2012 the calculation model will be moved to a new platform because of the lack of flexibility in the current Excel-based model. Additionally, a small error in the emission factor for HFC-134 and Perfluoropentane (C3F8) was discovered under the centralized review of the 2011 NIR. This does not have consequences for the size of emissions, but will result in a shift in the time series. We intend to reallocate these emissions in the 2013 submission.

#### **4.6.2 Emissions of SF<sub>6</sub> from Products and Processes – 2F**

##### **4.6.2.1 Description**

In mars 2002 a voluntary agreement was signed between the Ministry of Environment and the most important users and producers of GIS. According to this agreement emission from this sector should be reduced by 13 per cent in 2005 and 30 per cent in 2010 with 2000 as base year. For the following up of this agreement, the users (electricity plants and –distributors) and producers (one factory) report yearly to the government. This voluntary agreement terminated successfully in 2010, but a continuation is being discussed.

##### **4.6.2.2 Methodological issues**

The general methodology for estimating SF<sub>6</sub> 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 largely in accordance with the Tier 2 methodology in the IPPC guidelines for emission inventories (IPCC 1997a,b). The calculations take into account imports, exports, recycling, accumulation in bank, technical lifetimes of products, and different rates of leakage from processes, products and production processes. From 2003 and onwards emission estimates reported directly from users and producers, according to the voluntary agreement, are important input.

Emissions from production of GIS (one factory) were included for the first time in 2003. The company has, as part of the voluntary agreement with the Ministry of the Environment, made detailed emission estimates back to 1985. These emissions constitute a significant part of national emissions of SF<sub>6</sub>. In recent years emissions rates have been considerably reduced due to new investments and better routines. The company now performs detailed emission calculations based on accounting of the SF<sub>6</sub> use throughout the whole production chain.

Emissions from a small number of GIS users that are not part of the agreement are calculated with emission factors from Table 4.13. They account for 1-2 per cent of total emissions from GIS use in 2008.

##### **4.6.2.3 Activity data**

Data is collected from direct consultations with importers and exporters of bulk chemicals and products containing SF<sub>6</sub>, and from companies that use SF<sub>6</sub> in various processes.

##### **4.6.2.4 Emission factors**

Leakage rates and product lifetimes used in the calculations are shown in Tables 4.13 and 4.14.

Table 4.13. Yearly rate of leakage of SF<sub>6</sub> from different processes

| Emission source                        | Leakage rate (per cent of input of SF <sub>6</sub> ) |
|--|--|
| 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 4.14 Product lifetimes and leakage rates from products containing SF<sub>6</sub>

| 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                        |
| <b>Other minor sources</b>               | ..                     | ..                       |

Source: SFT (1999d).

#### 4.6.2.5 Source specific QA/QC and verification

During the work on the new methodology in 2004, historical data were recalculated, emission factors from different sources were established and the bank of SF<sub>6</sub> in existing installations was estimated. For GIS, information from the industry, attained through the voluntary agreement with the Ministry of Environment, was important input in this recalculation (Statistics Norway 2007b).



#### 4.6.2.6 Recalculations

For one plant, the reported SF<sub>6</sub> emissions have been revised downwards for 2003 and 2009 due to revised data.

#### 4.6.2.7 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2013.

### 4.6.3 Paraffin wax use – 2G

#### 4.6.3.1 Description

Paraffin waxes are produced from crude oil and used in a number of different applications, including candles, tapers and the like. Combustion of such products results in emissions of fossil CO<sub>2</sub>.

Emissions from the incineration of products containing paraffin wax, such as wax coated boxes, are covered by emissions estimates from waste incineration.

#### 4.6.3.2 Methodological issues

Emissions of CO<sub>2</sub> 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:

$$(4.11) \text{ Emissions} = PC * PF * CC_{Wax} * 44/12$$

Where:

- Emissions = CO<sub>2</sub> emissions from waxes, tonne CO<sub>2</sub>
- PC = total candle consumption, TJ
- PF = fraction of candles made of paraffin waxes
- CC<sub>Wax</sub> = carbon content of paraffin wax (default), tonne C/TJ (Lower Heating Value basis)
- 44/12 = mass ratio of CO<sub>2</sub>/C

Consumption figures on paraffin waxes are multiplied by the default net calorific values (NCV). Net consumption in calorific value is then converted to carbon amount, using the value for carbon content (Lower Heating Value basis) and finally to CO<sub>2</sub> emissions, using the mass ratio of CO<sub>2</sub>/C.

#### 4.6.3.3 Activity data

Statistics Norway collects data on import, export and sold produce of “Candles, tapers and the like (including night lights fitted with a float)”. Using these data, net consumption of paraffin waxes and other candle waxes (including stearin) can be calculated.

#### 4.6.3.4 Emission factors

Parameter values used in the emissions calculations are given in Table 4.15.

Table 4.15 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<br>C/TJ = kg<br>C/GJ | 2006 IPCC  |
| Mass ratio of $CO_2/C$                                   | 3.67   | -                           |            |
| Fraction of paraffin wax (PF)                            | 0.66   | -                           |            |

The assumption of 0.66 as the fraction of all candles being made of paraffin waxes is based on estimates obtained from one major candle and wax importer (estimating ca. 0.5) and one Norwegian candle manufacturer (estimating ca. 0.8). The importer estimated the fraction to be ca. 5 per cent higher in 1990. However, since this possible change is considerably smaller than the difference between the two fraction estimates, we have chosen to set this factor constant for the whole time series. The fraction of paraffin waxes has probably varied during this period, as it, according to the importer, strongly depends on the price relation between paraffin wax and other, non-fossil waxes. However, at present we do not have any basis for incorporating such factor changes.

Furthermore, we assume that practically all of the candle wax is burned during use, so that emissions due to incineration of candle waste are negligible.

#### 4.6.3.5 Uncertainties

According to the 2006 IPCC Guidelines, the default emission factors are highly uncertain. However, the default factor with the highest uncertainty is made redundant in our calculations, due to the level of detail of our activity data.

#### 4.6.3.6 Source specific QA/QC and verification

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

#### 4.6.3.7 Recalculations

There has been no recalculation since NIR 2008.

#### 4.6.3.8 Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2013.

## 5 Solvent and other product use

### 5.1 Overview

This chapter describes emissions from solvents and other products. Use of solvents and products containing solvents result in emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidise to CO<sub>2</sub>.

In addition to solvents emitting NMVOC, there are other products that emit other volatile components. Emissions of N<sub>2</sub>O from anaesthesia procedures and spray cans are included in the Norwegian inventory.

In 2010, the total emissions from solvents and other product use totaled 0,170 million tonnes of CO<sub>2</sub>-equivalents. This represented 0.31 per cent of the total GHG emissions in 2010. The emissions have decreased by 7.3 % compared to 1990 and have increased by 12.7 % from 2009.

### 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 CO<sub>2</sub>, which is included in the total greenhouse gas emissions reported to UNFCCC.

Solvents and other product use are non-key categories.

#### 5.2.2 Method

Our general model is a simplified version of the detailed methodology described in chapter 6 of the EMEP/CORINAIR Guidebook 2007 (EEA 2007). It represents a mass balance *per substance*, where emissions are calculated by multiplying relevant activity data with an emission factor. For better coverage, point sources reported from industries to the 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 Guidelines<sup>7</sup>. 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 CO<sub>2</sub>*

The use of solvents leads to emissions of non-methane volatile organic compounds (NMVOC) which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidise to CO<sub>2</sub>, which is included in the total greenhouse gas emissions reported to UNFCCC (see chapter 1.9.).

### **5.2.3 Activity data**

The data source is the Norwegian Product Register. Any person placing dangerous chemicals on the Norwegian market for professional or private use has a duty of declaration to the Product Register, and import, export and manufacturing is reported annually. The only exception is when the amount of a given product placed on the market by a given importer/producer is less than 100 kg per year.

The information pertained in the data from the Product Register makes it possible to analyse the activity data on a substance level, distributed over product types (given in UCN codes; Product Register 2007), industrial sectors (following standard industrial classification (NACE; Statistics Norway 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

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<sup>7</sup> "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."

chemicals and chemical products” (NACE 24). In order to avoid double counting, NMVOC used as raw materials in this sector are excluded from the emission estimates from the Product Register data.

#### **5.2.4 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)<br>(per cent of total emissions) | Positive (p) | Positive (p)<br>(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<br>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

The indirect emissions of CO<sub>2</sub> have decreased by 8 729 tonnes in 2005, 9 510 tonnes in 2006, 10 234 tonnes in 2007, 10 041 tonnes in 2008 and 8 798 tonnes in 2009. This is due to revised data on use of formic acid used for ensilage means and cosmetics.

#### **5.2.9 Planned improvements**

There is no planned activity this year that will improve the data quality for NIR 2013.

### **5.3 Other product use -3D**

#### **5.3.1 Use of N<sub>2</sub>O in anaesthesia – 3D1**

##### **5.3.1.1 Method**

N<sub>2</sub>O is used in anaesthesia procedures and will lead to emissions of N<sub>2</sub>O. The figures are based on N<sub>2</sub>O data from the two major producers and importers in 2000. These figures are related to the number of births and number of bednights in hospitals for each year to estimate consumption.

##### **5.3.1.2 Activity data**

For this source actual sale of N<sub>2</sub>O 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 N<sub>2</sub>O.

##### **5.3.1.4 Uncertainty**

The figures are uncertain. There may be small importers not included in Statistics Norway's telephone survey with 2000 data, but the emissions are small, so it is believed that the uncertainty is at an acceptable level.

##### **5.3.1.5 Completeness**

A minor consumption from small importers may be missing, but these will probably account for an insignificant fraction of the total N<sub>2</sub>O 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 2013.

### **5.3.2 Use of N<sub>2</sub>O as propellant – 3D4**

N<sub>2</sub>O is used as a propellant in spray boxes and this use will lead to emissions of N<sub>2</sub>O. It is also used in research work, for instance in the food industry and at universities. Small amounts are used at engineering workshops among others for drag-racing. There is no production of N<sub>2</sub>O 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 N<sub>2</sub>O for use as a propellant in Norway. The N<sub>2</sub>O 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 N<sub>2</sub>O 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 2013.



## 6 Agriculture

### 6.1 Overview

About 8 per cent of the total Norwegian emissions of greenhouse gases (GHG) originated from agriculture, in 2010<sup>8</sup>. This corresponds to 4.3 million tonnes CO<sub>2</sub>-eq. The emissions from agriculture are quite stable with emissions in 2010 about 5 percent lower than in 1990<sup>9</sup>, but about 0.2 percent higher than in 2009<sup>10</sup>.

The sectors clearly biggest sources of GHG's were "enteric fermentation" (CH<sub>4</sub>) from domestic animals<sup>11</sup>, contributing with 44 per cent and "agricultural soils" (N<sub>2</sub>O) contributing with 45 percent of the sectors emissions. "Manure management" contributed with about 10 percent<sup>12</sup>. Agriculture contributes particularly to CH<sub>4</sub>, N<sub>2</sub>O and NH<sub>3</sub> emissions. Domestic animals are the major source of CH<sub>4</sub> emissions from agriculture. Both enteric fermentation and manure management contribute to process emissions of CH<sub>4</sub>. Manure management also generates emissions of N<sub>2</sub>O.

Microbiological processes in soil lead to emissions of N<sub>2</sub>O. Three sources of N<sub>2</sub>O are distinguished in the IPCC methodology and are included in the Norwegian inventory:

1. direct emissions from agricultural soils (from use of synthetic fertilisers, animal excreta nitrogen used as fertiliser, biological nitrogen fixation, crop residues, industrial and urban wastes and cultivation of soils with a high organic content)
2. direct soil emissions from animal production (emissions from droppings on pastures)
3. N<sub>2</sub>O emissions indirectly induced by agricultural activities (N losses by volatilisation, leaching and runoff).

There are also some emissions of the greenhouse gases N<sub>2</sub>O and CH<sub>4</sub> arising from the burning of crop residues on the fields.

Animal manure and the use of fertilizer also generate emissions of ammonia (NH<sub>3</sub>). As indicated in Table A1-3 in Annex I of this report, the key category analysis performed in 2012 for the years 1990 and 2010 has revealed that in terms of total level and trend uncertainty the *key categories* in the Agricultural sector are the following:

- Enteric fermentation – CH<sub>4</sub> (4A)
- Direct soil emissions – N<sub>2</sub>O (4D1)
- Animal production - N<sub>2</sub>O (4D2)
- Indirect emissions - N<sub>2</sub>O (4D3)
- Manure management – CH<sub>4</sub><sup>13</sup> and N<sub>2</sub>O (4B)

<sup>8</sup> 4273.40 Ktonnes CO<sub>2</sub>-eq

<sup>9</sup> 4521.32 Ktonnes CO<sub>2</sub>-eq

<sup>10</sup> 4264.44 Ktonnes CO<sub>2</sub>-eq

<sup>11</sup> 1892.13 Ktonnes CO<sub>2</sub>-eq

<sup>12</sup> 444.89 Ktonnes CO<sub>2</sub>-eq

<sup>13</sup> Key category only in Tier 1 key category analysis.

## **6.2 Emissions from enteric fermentation in domestic livestock 4A– CH<sub>4</sub> (Key Category)**

### **6.2.1 Description**

An important end product from the ruminal fermentation is methane (CH<sub>4</sub>). The amount of CH<sub>4</sub> 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 CH<sub>4</sub> 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 CH<sub>4</sub> 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 4.69 % to uncertainty in level and 1.66 % to uncertainty in trend.

Enteric fermentation contributed with 1892.13 Ktonnes CO<sub>2</sub> equivalents in 2010, which is 3.5 per cent of the national GHG emissions.

Enteric fermentation constituted 86 per cent of the overall CH<sub>4</sub> emissions from agriculture and 44 percent of this sector GHG emission. Emissions have been rather stable with minor fluctuations. Emissions decreased by 5.0 percent in the period 1990-2010 and by 0.2 percent in 2009-2010.

### **6.2.2 Methodological issues**

A Tier 2 methodology is used for calculating CH<sub>4</sub> from enteric fermentation for the main emission sources cattle and sheep. The Tier 2 methodology used is described more in detail in Appendix H in Statistics Norway (2011a). The methodology for calculating CH<sub>4</sub> 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 CH<sub>4</sub>/ animal/ year for each kind of animals are used to calculate the emissions.

### **6.2.3 Activity data**

The Tier 2 method of calculation requires subdividing the cattle and sheep populations by animal type, physiological status (dry, lactating or pregnant) live weight and age. Table 6.1 describes the animal categories used for cattle and sheep in the calculations.

For dairy cows, additional information from the Cow Recording System concerning annual milk production and proportion of concentrate in the diet is used (Tine BA annually). The Cow Recording System also supplies annual information about slaughter age and slaughter weight for growing cattle (Moen, pers. Comm., e-mail from Oddvar Moen, Tine Rådgivning, annually). Information about average daily weight gain (ADG), 215odel lo in the calculations for growing cattle, was also taken from the Cow Recording System in 2005 when the Tier 2

model was developed.

*Table 6.1 Categories of cattle and sheep used in the Norwegian calculations of methane emission from enteric fermentation.*

| Categories of cattle and sheep       |
|--------------------------------------|
| Dairy cows                           |
| Beef cows                            |
| Replacement heifers, < one year      |
| Replacement heifers, > one year      |
| Finisher heifers, < one year         |
| Finisher heifers, > one year         |
| Finisher bulls, < one year           |
| Finisher bulls, > one year           |
| Breeding sheep, > one year           |
| Breeding sheep, < one year           |
| Slaughter lamb, < one year. Jan- May |
| Slaughter lamb, < one year. Jun- Dec |

The main source of the livestock statistics is the register of production subsidies. The register covers 90-100 per cent of the animal populations, except for horses and reindeer. The register is used in order to get consistent time series of data. Animals are counted twice a year and the register is updated with these counts. The average number of the two counts is used. In addition to the animals included in the register of production subsidies, an estimate of the number of horses that are not used in farming is obtained from the Norwegian Agricultural Economics Research Institute (NILF). The number of reindeer is obtained from the Norwegian Reindeer Husbandry Administration. For some categories of animals not living a whole year, for instance lambs, lifetime is taken into account to get a yearly average for the number of animals. An expert judgment suggests an average lifetime of 143 days for lambs (UMB, pers. Comm., Expert Judgement by Department of Animal Science, Norwegian University of Life Sciences, Ås 2001). The formula for calculating the average figure for lambs will then be:

$$(6.1) \quad \text{Lambs} * \frac{143}{365}$$

There exist some differences between these numbers and the FAO statistics. The explanation is, that the figures to the FAO are supplied by the Norwegian Agricultural Economics Research Institute (NILF). NILF elaborates an overall calculation for the agricultural sector, which is the basis for the annual negotiations for the economic compensation to the sector. The overall calculation includes a grouping of all agricultural activities, comprising area, number of animals and production data. This method is a little different from the one used by Statistics Norway. Differences include

- Different emphasis on the dates for counting, 31.07 and 31.12

- NILF does not register pigs under 8 weeks, whilst Statistics Norway does.

#### 6.2.4 Emission factors

For cattle and sheep the following basic equation is used to calculate the CH<sub>4</sub> 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 CH<sub>4</sub>/head/yr

GE = gross energy intake, MJ/head/day

Y<sub>m</sub> = CH<sub>4</sub> conversion rate, which is the fraction of gross energy in feed converted to CH<sub>4</sub>.

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 540 days). Further description of the determination of the variables GE and Y<sub>m</sub> for the different animal categories is given in Statistics Norway (2011a) Appendix H.

The emissions from domestic reindeer, deer, ostrich and fur-bearing animals are also included in the Norwegian calculations. For reindeer the emission factor 19.9 kg/animal/year is used. The source of this factor is the Swedish and Finnish emission inventories where it has been developed by a Tier 2 method (Statistics Finland 2009 and Swedish Environmental Protection Agency 2009). Emission factors for deer, ostrich and fur-bearing animals are developed by scaling emission factors for other animals that are assumed most similar with regard to digestive system and feeding. The scaling is done by comparing average weights for the actual animal groups. The emission factor for deer of 52.64 kg/animal/yr has been estimated by scaling the emission factor for dairy cattle and the emission factor 4.97 kg/animal/yr for ostrich by scaling the emission factor for horses. The emission factor for fur-bearing animals is set to 0.10 kg/animal/yr, and has been estimated by scaling the emission factor for pigs.

For the other animal categories the Tier 1 default emission factors for each kind of animal (IPCC 1997b) is used.

*Table 6.2 Emission factors for CH<sub>4</sub> from enteric fermentation and different animal types estimated with the Tier 1 method*

| Animal              | Emission factor<br>(Tonnes/animal/year) |
|---------------------|---|
| Horses              | 0.018                                   |
| Goats               | 0.005                                   |
| Pigs                | 0.0015                                  |
| Hens                | 0.00002                                 |
| Turkeys             | 0.00002                                 |
| Reindeer            | 0.0199                                  |
| Deer                | 0.0526                                  |
| Ostrich             | 0.00497                                 |
| Fur-bearing animals | 0.0001                                  |

*Source: IPCC (1997b) Statistics Finland 2009 and Swedish Environmental Protection Agency 2009 and Agricultural Statistics from Statistics Norway.*

### **6.2.5 Uncertainties**

#### ***Activity data***

The data are considered to be known within  $\pm 5$  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  $\pm 40$  per cent, which is the estimate from (IPCC 2006). An uncertainty estimate of  $\pm 25$  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. 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 2009, the emission factor for reindeer has been revised and changed to a Tier 2 factor for reindeer used by Sweden and Finland.

#### **6.2.8 Recalculations**

There were performed no specific recalculations for this sector.

#### **6.2.9 Planned improvements**

No new improvements are planned before next NIR.

### **6.3 Emissions from manure management – 4B – CH<sub>4</sub>, N<sub>2</sub>O (Key categories)**

#### **6.3.1 Description**

The relevant pollutants emitted from this source category are CH<sub>4</sub> (IPCC 4B (a)), N<sub>2</sub>O (IPCC 4B (b)) and NH<sub>3</sub> (NFR 4B). Emissions from cattle are most important in Norway for all three components.

N<sub>2</sub>O is key category according to Tier 2 key category analysis because of its contributions to level uncertainty. CH<sub>4</sub> is key category only in the Tier 1 key category analysis.

CH<sub>4</sub>-emissions due to manure management amounted to 315 Ktonnes CO<sub>2</sub> equivalents in 2010 whilst N<sub>2</sub>O-emissions amounted to 130 Ktonnes CO<sub>2</sub> equivalents.

Manure management emitted 445 Ktonnes of CO<sub>2</sub> equivalents in 2010, which are approximately 10 per cent of the GHG emissions from agriculture and 0.8 per cent of the Norwegian emissions of GHGs.

Emissions of GHGs from manure management increased by 2.8 % in the period 1990-2010 and decreased by 0.1 % from 2009 to 2010.

Organic material in manure is transformed to CH<sub>4</sub> in an anaerobic environment by microbiological processes. Emissions from cattle (manure) are most important in Norway. The emissions from manure depend on several factors; type of animal, feeding, manure management system and weather conditions (temperature and humidity).

During storage and handling of manure (i.e. before the manure is added to soils), some nitrogen is converted to N<sub>2</sub>O. The amount released depends on the system and duration of manure management. Solid storage and dry lot of manure is the most important source.

Emissions of NH<sub>3</sub> 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 NH<sub>3</sub> 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 17-20 per cent since 1990, and are now close to the IPCC default value of 20 per cent.

### 6.3.2 Methodological issues

#### *CH<sub>4</sub>*

Emissions of methane from manure are estimated using the following equation, in accordance with the IPCC Tier 2 method (IPCC 1997b, a):

$$(6.3) \quad E_i = \frac{N_i \cdot M_i \cdot VS_i \cdot B_{0_i} \cdot MCF_i}{1000} * \rho_{CH4}$$

E: Emissions of methane

N: Population of animals

M: Production of manure (kg/animal/year)

VS: Volatile solids (per cent)<sup>14</sup>

B<sub>0</sub>: Maximum methane-producing capacity (m<sup>3</sup>/kg-VS)

MCF: Methane conversion factor

i: Species

ρ<sub>CH4</sub>: Density methane (0.662 kg/m<sup>3</sup>)

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<sup>14</sup> Volatile solids (VS) are the degradable organic material in livestock manure (IPCC 1997b, a).

Table 6.3 Norwegian factors used to estimate CH<sub>4</sub> from manure management with the IPCC Tier 2 method

|                                | Manure production<br>(kg/animal/day) | VS<br>(per cent) | B <sub>0</sub><br>(m <sup>3</sup> /kg-VS) | MCF<br>(per cent) |
|--------------------------------|--------------------------------------|------------------|---|-------------------|
| Dairy cattle                   | 45                                   | 9.2              | 0.18                                      | 8                 |
| Bulls > 1 year                 | 35                                   | 9.2              | 0.21                                      | 8                 |
| Heifers > 1 year               | 30                                   | 9.2              | 0.21                                      | 8                 |
| Non-dairy cattle < 1 year      | 15                                   | 9.2              | 0.21                                      | 8                 |
| Horses                         | 25.5                                 | 16.4             | 0.21                                      | 8                 |
| Sheep > 1 year                 | 2                                    | 19.5             | 0.19                                      | 5                 |
| Sheep < 1 year                 | 1                                    | 19.5             | 0.19                                      | 5                 |
| Diary goats                    | 1.8                                  | 23               | 0.19                                      | 5                 |
| Other goats                    | 1                                    | 23               | 0.19                                      | 5                 |
| Pigs for breeding              | 9                                    | 9.5              | 0.21                                      | 8                 |
| Pigs for slaughter             | 4.5                                  | 9.5              | 0.21                                      | 8                 |
| Hens                           | 0.16                                 | 15.6             | 0.25                                      | 8                 |
| Chicks bred for laying hens    | 0.085                                | 19.4             | 0.25                                      | 8                 |
| Chicks for slaughter           | 0.085                                | 19.4             | 0.25                                      | 8                 |
| Ducks for breeding             | 0.17                                 | 16               | 0.25                                      | 8                 |
| Ducks for slaughter            | 0.057                                | 16               | 0.25                                      | 8                 |
| Turkey and goose for breeding  | 0.7                                  | 16               | 0.25                                      | 8                 |
| Turkey and goose for slaughter | 0.29                                 | 16               | 0.25                                      | 8                 |
| Mink, males                    | 0.35                                 | 16               | 0.25                                      | 8                 |
| Mink, females                  | 0.7                                  | 16               | 0.25                                      | 8                 |
| Fox, males                     | 0.56                                 | 16               | 0.25                                      | 8                 |
| Fox, females                   | 1.12                                 | 16               | 0.25                                      | 8                 |
| Reindeer                       | 2                                    | 19.5             | 0.19                                      | 2                 |
| Deer                           | 23.7                                 | 9.2              | 0.18                                      | 8                 |
| Ostrich                        | 7.05                                 | 16.4             | 0.21                                      | 8                 |

Source: Agricultural Statistics from Statistics Norway and Norwegian University of Life Sciences.

The factors M, VS, B<sub>0</sub> and MCF are average factors meant to represent the whole country. The factor B<sub>0</sub> represents the maximum potential production of methane under optimum conditions. MCF is a correction of B<sub>0</sub> according to how the manure is handled reflecting Norwegian manure handling practices for each type of animal waste. The factors are



estimated jointly by Statistics Norway and the Norwegian University of Life Sciences (Institute of Chemistry and Biotechnology, Section for Microbiology).

### *N<sub>2</sub>O*

In Norway, all animal excreta that are not deposited during grazing are managed as manure. N<sub>2</sub>O-emissions from manure are estimated in accordance with the IPCC default method (IPCC 1997b), but with Norwegian values for N in excreta from different animals according to Table 6.4. Based on typical Norwegian feedstock ratios, the excretion of nitrogen (N) and phosphorous (P) were calculated by subtracting N and P in growth and products from assimilated N and P. The numbers were in some cases compared to numbers found in balance experiments. Norwegian values are also used for the fraction of total excretion per species for each management system (MS) and for pasture. The fractions are updated every year and are given in Table 6.5. The distributions between different storage systems and pasture used in the estimation of N<sub>2</sub>O emissions are consistent with the distributions used for calculating NH<sub>3</sub> emissions.

Table 6.4 N in excreta from different animals

|   | kg/animal/year <sup>1</sup> |
|---|-----------------------------|
| Dairy cattle  | 82                          |
| Heifer < 1 year                                     | 29                          |
| Bull < 1 year                                       | 24                          |
| Heifer > 1 year                                     | 35                          |
| Bull > 1 year                                       | 35                          |
| Horses  | 50                          |
| Sheep < 1 year                                      | 7.7                         |
| Sheep > 1 year                                      | 11.6                        |
| Goats   | 15.5                        |
| Pigs for breeding                                   | 18.3                        |
| Pigs for slaughtering <sup>2</sup>                  | 4.4                         |
| Hens  | 0.7                         |
| Chicks bred for laying hens <sup>2</sup>            | 0.147                       |
| Chicks for slaughtering <sup>2</sup>                | 0.053                       |
| Ducks, turkeys/ goose for breeding <sup>2</sup>     | 2                           |
| Ducks, turkeys/ goose for slaughtering <sup>2</sup> | 0.34                        |
| Mink  | 4.27                        |
| Foxes   | 9                           |
| Reindeer  | 6                           |
| Deer  | 12                          |
| Ostrich   | 12                          |

<sup>1</sup> Includes pasture<sup>2</sup> 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: Sundstøl and Mroz (1988) and estimations by Statistics Norway.

Table 6.5 Fraction of total excretion per specie for each management system and for pasture 2010

|                  | Anaerobic Lagoon | Liquid system | Solid storage and drylot | Pasture range and paddock | Other manure management systems |
|------------------|------------------|---------------|--------------------------|---------------------------|---------------------------------|
| Dairy cattle     | 0                | 0.75          | 0.06                     | 0.20                      | 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                | 0.26          | 0.29                     | 0.45                      | 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):

$$(6.4) \quad E = \sum_s \left\{ \left[ \sum_i (N_i \cdot Nex_i \cdot MS_{i,s}) \right] \cdot EF_s \right\}$$

E: Emissions of N<sub>2</sub>O-N (kg N<sub>2</sub>O-N/year, N<sub>2</sub>O-N is the amount of nitrogen in the nitrous oxide compound)

N: Population of animals

Nex: Annual average N excretion (kg N/animal/year)

MS: Fraction of total excretion per specie for each management system

EF: N<sub>2</sub>O emission factor (kg N<sub>2</sub>O-N/kg N)

s: Manure management system

i: Species

For liquid system and solid storage and dry lot a correction is made for the NH<sub>3</sub> volatilisation from manure storage.

### NH<sub>3</sub>

Statistics Norway's NH<sub>3</sub> model is used for calculating the emissions of ammonia from manure management. The principle of the model is illustrated in figure 6.1.

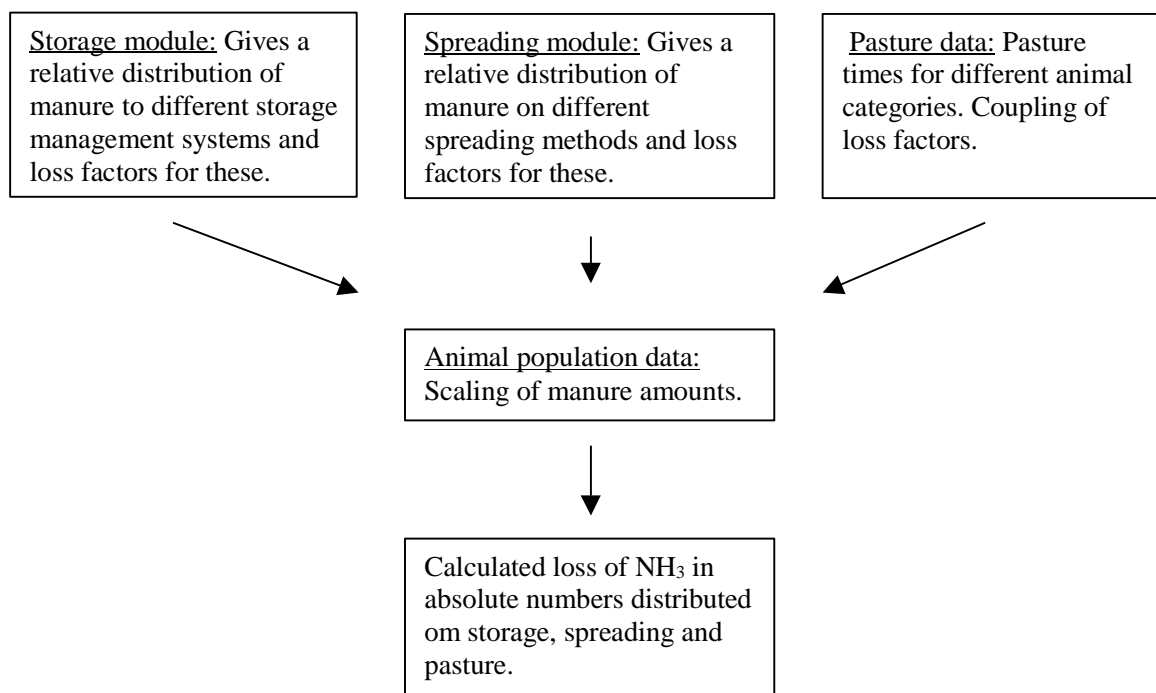


Figure 6.1 The principle of the  $\text{NH}_3$  model

The storage module in the  $\text{NH}_3$  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 6.4).

### 6.3.3 Activity data

#### *$\text{CH}_4$ and $\text{N}_2\text{O}$*

Emissions are estimated from the animal population. How the animal population is estimated is described in Section 6.3.2.

#### *$\text{NH}_3$*

Activity data on storage systems are rare, and the only source practically available is the Sample survey of agriculture and forestry 2003 (Statistics Norway 2004) and Statistics Norway survey of different storage systems in 2000 (Statistics Norway 2001b). Data for storage systems are unavailable for other years. Analyses and estimations of the effects on emissions of the assumed changes in storage systems since 1990 show that the assumed change is of little significance to the emissions. In addition, data on animal populations are used to estimate the amounts of manure. How the animal population is estimated is described in Section 6.2.3.

The manure is distributed to the following storage systems categories:

- Manure cellar for slurry
- Manure pit for slurry
- Indoor built up/deep litter
- Outdoor built up/enclosure
- Storage for solid dung and urine

Each of these categories 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**

##### ***CH<sub>4</sub>***

The calculated average emission factors for different animal types are shown in table 6.6. They are country specific factors which may deviate from the IPCC default values.

## National Inventory Report 2012 - Norway

*Table 6.6 Average CH<sub>4</sub> 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.*

### **N<sub>2</sub>O**

The IPCC default values for N<sub>2</sub>O emission factors from manure management are used. These are consistent with the good practice guidance (IPCC 2000).

*Table 6.7 N<sub>2</sub>O emission factors for manure management per manure management system*

| Manure management system  | Emission factor, kg N <sub>2</sub> O-N/kg N |
|---------------------------|---|
| Liquid system             | 0.001                                       |
| Solid storage and dry lot | 0.02  |
| Pasture range and paddock | 0.02  |

*Source: IPCC (1997b).*

### **NH<sub>3</sub>**

Emission factors vary with production and storage system; in the model there is no variation between regions. The factors used are shown in Table 6.8.

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Table 6.8  $\text{NH}_3$  Emissions factors for various storage systems and productions. Per cent  $\text{NH}_3\text{-N}$  of total N.

|                             | <b>Storage system</b>    |                            |                                |                    |                             |                            |                                  |
|-----------------------------|--------------------------|----------------------------|--------------------------------|--------------------|-----------------------------|----------------------------|----------------------------------|
|                             | 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.



The factors in Table 6.8 are based on data from Denmark, Germany and Netherlands, since measurements of  $\text{NH}_3$ -losses in storage rooms have so far not been carried out in Norway.

The factors are combined with the activity data in the 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  $\text{NH}_3$  emissions from storage of manure and stalled animals, calculated for production and region (Table 6.9). To estimate losses, these emission factors are in turn multiplied with the amount of manure 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.

*Table 6.9 Average emission factors for the manure storage systems used, distributed on type of animal production and region. Per cent of total N*

|                 | South-Eastern<br>Norway | Hedmark<br>Oppland | Rogaland | Western<br>Norway | Trøndelag | Northern<br>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,  $\text{NH}_3$ -model estimations.*

### 6.3.5 Uncertainties

Uncertainties estimates are given in Annex II.

#### 6.3.5.1 Activity data

##### $\text{CH}_4$

The data for the number of animals are considered to be known within  $\pm 5$  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.

##### $\text{N}_2\text{O}$ and $\text{NH}_3$

The data for the number of animals are considered to be known within  $\pm 5$  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  $\pm 15$  per cent. (SFT/Statistics Norway 1999) 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  $\pm 10$  per cent, and the division between storage and pasture, which is considered to be within  $\pm 15$  per cent.

#### **6.3.5.2 Emission factors**

##### *CH<sub>4</sub>*

Norway is using the IPCC default factors (Tier 2 methodology) for the emission of CH<sub>4</sub>, but with some national data. The emission factors are considered to have the uncertainty range  $\pm 25$  per cent (Statistics Norway 2000).

##### *N<sub>2</sub>O*

For the emission of N<sub>2</sub>O 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.

##### *NH<sub>3</sub>*

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 NH<sub>3</sub> model, which has been in use since 2003. The revision of the model is however supposed to have reduced the uncertainty

#### **6.3.6 Completeness**

Major missing emission sources are not likely.

#### **6.3.7 Source specific QA/QC and verification**

In a Nordic project in 2002, the results for emissions of both CH<sub>4</sub> and N<sub>2</sub>O 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 the calculation model for ammonia emissions from the agricultural sector. Data sources used for the recalculations in the revised NH<sub>3</sub> 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).

Statistics Norway's detailed manure survey gives more extended activity data which are better related to emission source categories, for manure management and spreading. New loss factors for different manure management categories are also used in the revised NH<sub>3</sub>-model. These factors are closer connected to specific activities.

#### **6.3.8 Recalculations**

The nitrogen excretion factors for pigs and poultry and the emission factors for NH<sub>3</sub> losses from the manure of sheep and goats in barns have been revised. More information about these recalculations is given in Chapter 9.

#### **6.3.9 Planned improvements**

A project with the aim to update the Norwegian nitrogen excretion factors and the values for manure excreted for the different animal species are ongoing at the Norwegian University of Life Sciences (UMB). The results from the project are planned to be implemented in the 2013 submission.

A project with the aim to revise the Norwegian CH<sub>4</sub> conversion factors (MCF) for the manure storage systems in use is ongoing at the Norwegian University of Life Sciences (UMB). The maximum CH<sub>4</sub> producing capacity (B<sub>0</sub>) is also planned to be revised for cattle manure. The results from the project are planned to be implemented in the 2013 submission.

New information about the use of manure storage systems from the Sample survey of agriculture 2011 performed by Statistics Norway is planned to be implemented in the inventory before the 2013 submission.

## **6.4 Direct and indirect emissions from agricultural soils – 4D – N<sub>2</sub>O (Key Category)**

### **6.4.1 Description**

The greenhouse gases N<sub>2</sub>O and CO<sub>2</sub> are emitted from agricultural soils in Norway. Emissions of CO<sub>2</sub> are discussed section 7.

The emissions of N<sub>2</sub>O in Norway from agricultural soils amounted to 1.93 Mtonnes calculated in CO<sub>2</sub>-equivalents. They accounted for about 63 per cent of the total Norwegian N<sub>2</sub>O emissions in 2010 or about 3.6 per cent of the total Norwegian GHG emissions that year.

The emissions had minor fluctuations in the period 1990-2010. During the period 1990-2010 emissions decreased by 6.5 %. From 2009 to 2010 the emissions increased by 0.6 %.

Three sources of N<sub>2</sub>O 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<sub>2</sub>O emissions indirectly induced by agricultural activities (N losses by volatilization, leaching and runoff).

The use of synthetic fertilisers, animal excreta nitrogen as fertilizer, and droppings on pastures also results in emissions of NH<sub>3</sub>. For the first two sources, the calculated amount of nitrogen that is emitted directly as N<sub>2</sub>O has been corrected for the nitrogen emitted as NH<sub>3</sub>.

Emissions of N<sub>2</sub>O 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: 25.27 % for level in 2010 and 10.18 % for trend (1990-2010).
- 4D2 Animal production: 1.46 % for level in 2010 and 0.77 % for trend (1990-2010).
- 4D3 Indirect emissions: 4.99 % for level in 2010 and 1.14 % for trend (1990-2010).

## 6.4.2 Methodological issues

### 6.4.2.1 Synthetic fertiliser

#### *N<sub>2</sub>O*

The direct emissions of N<sub>2</sub>O from use of synthetic fertiliser are calculated from data on total annual amount of fertiliser sold in Norway and its nitrogen content, corrected for the amount of synthetic fertilizer applied in forest (this in accordance with the comments of the review team in the 2005 review). The resulting amount that is applied on agricultural fields is multiplied with the IPCC default emission factor. The emissions are corrected for NH<sub>3</sub> that volatilises during spreading.

#### *NH<sub>3</sub>*

Statistics Norway's NH<sub>3</sub> model (described section 6.3.2) is used for calculating the emissions of ammonia from the use of synthetic fertilizer. The calculations of NH<sub>3</sub> 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<sub>3</sub> during spreading.

### 6.4.2.2 Manure applied to soils

#### *N<sub>2</sub>O*

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<sub>2</sub>O themselves, but emissions of N<sub>2</sub>O and NH<sub>3</sub> from manure management before manure application on fields are taken into account (see section 6.3.2).

The emission of N<sub>2</sub>O 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<sub>2</sub>O emissions are corrected for NH<sub>3</sub> that volatilises during spreading.

#### *NH<sub>3</sub>*

Statistics Norway's NH<sub>3</sub> model (fig 6.1 in section 6.3.2) is used for calculating emissions of ammonia from spreading of manure on cultivated fields and meadow. A spreading module in the NH<sub>3</sub> model gives the relative distribution of manure spread as fertiliser, distributed on different spreading methods. Total emissions from spreading are estimated by emission factors for the different spreading methods multiplied by the amount of manure. The amount of manure is estimated by the number of animals and manure production factors for each type of animal.

### 6.4.2.3 N<sub>2</sub>O from biological nitrogen fixation

Another source of N<sub>2</sub>O emissions is biological nitrogen fixation. The most important N-fixing crop in Norway is clover. The amount of nitrogen fixed by a crop is very uncertain, and it is difficult to assign a conversion factor for N<sub>2</sub>O 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 N<sub>2</sub>O from crop residues

Concerning re-utilisation of nitrogen from crop residues, there is only limited information. N<sub>2</sub>O 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<sub>DM</sub> for

rapeseed, potato, roots for feed and green fodder, and for  $Frac_N$  for grass, rapeseed and green fodder. Factors from the Austrian National Inventory Report (Umweltbundesamt 2005) have been used for vegetables.

$$(6.5) F_{CR} = \sum_i [Crop_i * (Res / Crop)_i * Frac_{DMi} * Frac_{Ni} * (1 - Frac_{BURNi} - Frac_{REMOVEDi})]$$

$F_{CR}$  = 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

Table 6.10 Factors used for the calculation of the nitrogen content in crop residues returned to soils

|                    | Residue/Crop | $Frac_{DM}$ | $Frac_N$ |
|--------------------|--------------|-------------|----------|
| Grass <sup>1</sup> | 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   |

<sup>1</sup> Including perennial grasses and grass-clover mixtures

Source: IPCC (2000), Swedish Environmental Protection Agency (2005), Umweltbundesamt (2005), Statistics Norway.

#### 6.4.2.5 N<sub>2</sub>O from industrial and urban wastes

No data are available for the amount of N in industrial waste applied as fertilizer, but this source is assumed to be very limited in Norway. Data for the N<sub>2</sub>O 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.

#### 6.4.2.6 N<sub>2</sub>O from cultivation of soils with a high organic content

Large N<sub>2</sub>O 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 N<sub>2</sub>O-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 Skog og landskap (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 Skog og landskap 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 km<sup>2</sup>. After 1995 the area has decreased due to the transition to mineral soil after the peat layer has decomposed and cultivated moors 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 2010, *pers.Comm.*<sup>15</sup>) based on four different estimates for reduction and new cultivation. Four scenarios are developed based on the assumptions of an annual area decline of 1.4 or 1.0 per cent combined with an annual cultivation of new moor of 2 alt. 4 km<sup>2</sup>.

#### 6.4.2.7 Direct soil emissions from animal production (emissions from droppings on pastures)

N<sub>2</sub>O

The fraction of the total amount of animal manure produced that is droppings on pastures is given by national data for the distribution of manure to different storage systems and data for pasture times (Table 6.5). The amount of N deposited during grazing is multiplied with the IPCC default emission factor.

NH<sub>3</sub>

Statistics Norway's NH<sub>3</sub> 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.

<sup>15</sup> Grønlund, A. (2010): Personal information, email from Arne Grønlund 16/8-2010, Ås: Bioforsk.

#### 6.4.2.8 N losses by volatilisation

Atmospheric deposition of nitrogen compounds fertilises soils and surface waters, and enhances biogenic N<sub>2</sub>O formation. Climate and fertiliser type influence the ammonia volatilisation. Deposition of ammonia is assumed to correspond to the amount of NH<sub>3</sub> that volatilises during the spreading of synthetic fertilisers, storage and spreading of manure, and volatilisation from pastures. This amount is obtained from Statistics Norway's ammonia model. The N<sub>2</sub>O emissions are calculated by multiplying the amount of N from deposition with the IPCC default emission factor.

#### 6.4.2.9 N<sub>2</sub>O from leaching and runoff

A considerable amount of fertiliser nitrogen is lost from agricultural soils through leaching and runoff. Fertiliser nitrogen in ground water and surface waters enhances biogenic production of N<sub>2</sub>O as the nitrogen undergoes nitrification and denitrification. The fraction of the fertiliser and manure nitrogen lost to leaching and surface runoff may range from 10 to 80 per cent. The IPCC (IPCC 1997b, a) proposes a default value of 30 per cent, but in the Norwegian inventory a national factor of 18 per cent is used that is believed to give better results under Norwegian conditions. This country specific factor has been calculated based on an estimate of the amount of nitrate leaching for the country on 33 kg N/hectare (Vagstad *et al* 1998), which comes from a runoff model by Jordforsk (Norwegian Centre for Soil and Environmental Research). The figure is an estimated average based on measurements of N-leaching in 12 small watershed areas, and expresses the discharge to nearest surface water recipient. Behind this average figure, there is a huge variation in N-leaching, depending on weather conditions, soil types, farm practices, geographical location etc. Climate data, soil data, agricultural practices etc. are monitored closely in these 12 watershed areas. The areas are chosen so that they together make up a representative selection of Norwegian farming with regard to farming practices, geographical localization and climate and soil conditions. The amount of nitrogen lost to leaching is multiplied with the IPCC default emission factor to calculate the emission of N<sub>2</sub>O.

#### 6.4.3 Activity data

##### N<sub>2</sub>O

The activity data significant for the estimation of direct and indirect emissions of N<sub>2</sub>O from agricultural soils and N<sub>2</sub>O emissions from pastures, and the sources for the activity data are listed in Table 6.11.

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.

Table 6.11 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)  |
| 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> (2008b) and pers. Comm., email from Arne Grønlund 16/8-2010, Ås: Bioforsk   |

 $NH_3$ *-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 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  $\text{NH}_3$  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  $\text{NH}_3$ -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 6.12.

Table 6.12 Parameters included in the estimation of  $NH_3$  emissions from manure

| Parameters (input)   | Sources  |
|--|--|
| Number of animals  | Statistics Norway (applications for productions subsidies)   |
| Nitrogen factors for manure  | Various sources, compiled by Statistics Norway   |
| Area where manure is spread, split on cultivated field and meadow  | Statistics Norway (Sample Surveys of Agriculture, 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   |
| 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 2002) (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  $\text{NH}_3$  emission factors (per cent loss of N) for the different types of fertilisers are shown in table 6.13.

*Table 6.13 Emission factors for  $\text{NH}_3\text{-N}$  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.<sup>16</sup>*

#### *-Animal manure applied to soil and pasture*

Emission factors for spreading of stored manure vary with spreading method, water contents, type and time of treatment of soil, time of year of spreading, cultivation, and region. The basic factors used are shown in Table 6.14.

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 6.14.

<sup>16</sup> Norsk Hydro (1995): Personal information, Kaarstad, Norsk Hydro.

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Table 6.14 Emissions factors for  $NH_3-N$  for various methods of spreading of manure.

Per cent of total N

|                    |                           |                       | Western and northern Norway |        |        | Southern and eastern Norway |        |        |
|--------------------|---------------------------|-----------------------|-----------------------------|--------|--------|-----------------------------|--------|--------|
|                    |                           |                       | Spring                      | Summer | Autumn | Spring                      | Summer | Autumn |
| <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 6.14 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 6.15). 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 6.15 Average  $\text{NH}_3$  emission factors for cultivated fields and meadows after time of spreading and region. 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 | 28.5                 | 33.3   | 28.9            | 33.2   | 21.3     | 34.4   | 10.0           | 28.9   | 30.9      | 34.4   | 11.0            | 33.2   |

Source: Statistics Norway,  $\text{NH}_3$ -model estimations.

The emission factors used for the calculation of the  $\text{NH}_3$  emissions from grazing animals are shown in Table 6.16. These are the same as the emission factors used in Germany (Dämmgen *et. Al.* 2002) and Denmark (Hutchings *et. Al.* 2001).

Table 6.16 Ammonia emission factors from droppings from grazing animals on pasture. Per cent

|                 | N-loss/N applied |
|-----------------|------------------|
| Cattle          | 7.5              |
| Sheep and goats | 4.1              |
| Reindeer        | 4.1              |
| Other animals   | 7.5              |

Source: Dämmgen *et. Al.* (2002), Hutchings *et. Al.* (2001).

## 6.4.5 Uncertainties

### 6.4.5.1 Activity data

There are several types of activity data entering the calculation scheme:

*Sales of nitrogen fertiliser:* The data are based on sales figures during one year (The Norwegian Food Safety Authority). The uncertainty in the sales figures is within  $\pm 5$  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 fertilizer 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  $\pm 15$  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 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  $\text{NH}_3$  emissions:* The data are based on national  $\text{NH}_3$  emission figures. These are within  $\pm 30$  per cent (SFT/Statistics Norway 1999).

*Leakage of nitrogen:* The upper limit for the leakage is the applied nitrogen. The uncertainty is roughly about  $\pm 70$  per cent (SFT/Statistics Norway 1999).

#### **6.4.5.2 Emission factors**

##### *$\text{N}_2\text{O}$*

Uncertainty estimates used for the  $\text{N}_2\text{O}$  emission factors are given in Annex II.

##### *$\text{NH}_3$*

The uncertainty in the estimate of emissions of  $\text{NH}_3$  from use of fertiliser is assessed to be about  $\pm 20$  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,  $\pm 30$  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  $\text{N}_2\text{O}$  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  $\text{NH}_3$  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  $\text{N}_2\text{O}$  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 N<sub>2</sub>O emissions for the whole period.'

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 N<sub>2</sub>O emissions from use of nitrogen fertiliser is based on sales figures for each year. To correct for this there a transfer of fertiliser from 2008 to 2009 was made in the calculations.

#### **6.4.8 Recalculations**

The nitrogen excretion factors for pigs and poultry and the emission factors for NH<sub>3</sub> losses from the manure of sheep and goats in barns have been revised. More information about these recalculations is given in Chapter 9.

#### **6.4.9 Planned improvements**

A project with the aim to update the Norwegian nitrogen excretion factors and the values for manure excreted for the different animal species are ongoing at the Norwegian University of Life Sciences (UMB). The results from the project are planned to be implemented in the 2013 submission.

A project with the aim to revise the Norwegian CH<sub>4</sub> conversion factors (MCF) for the manure storage systems in use is ongoing at the Norwegian University of Life Sciences (UMB). The maximum CH<sub>4</sub> producing capacity (B<sub>0</sub>) is also planned to be revised for cattle manure. The results from the project are planned to be implemented in the 2013 submission.

New information about the use of manure storage systems from the Sample survey of agriculture 2011 performed by Statistics Norway is planned to be implemented in the inventory before the 2013 submission.

The national Frac<sub>LEACH</sub> factor is under revision and the results of the study is planned to be implemented in the 2013 submission.

## 6.5 Emissions from agricultural residue burning (agricultural wastes) – 4F – CH<sub>4</sub>, N<sub>2</sub>O

Burning of agricultural residues gives emissions of standard non-fossil combustion products.

### 6.5.1 Methodological issues

The emissions from the burning of crop residues are calculated in accordance with a Tier 1 approach (EEA 2009):

$$E_{\text{Pollutant}} = AR_{\text{residue\_burnt}} * EF_{\text{Pollutant}}$$

$E_{\text{Pollutant}}$  = emission I of pollutant

$AR_{\text{residue\_burnt}}$  = activity rate (AR), mass of residue burnt (dry matter)

$EF_{\text{Pollutant}}$  = emission factor (EF) for pollutant

### 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 N<sub>2</sub>O from crop residues.

### 6.5.3 Emission factors

Table 6.17. Emission factors for agricultural residue burning.

| Components       | Emission factors |  | Unit        | Source |
|------------------|------------------|--|-------------|--------|
| Greenhouse gases |                  |  |             |        |
| CH <sub>4</sub>  | 2.7              | kg/ tonnes crop residue (d.m.)<br>burned | (IPCC 2006) |        |
| N <sub>2</sub> O | 0.07             | kg/ tonnes crop residue (d.m.)<br>burned | (IPCC 2006) |        |

### 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 CH<sub>4</sub> and N<sub>2</sub>O, 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.

In 2010, the emission factors have been revised and emission factors from the 2006 IPCC guidelines for national greenhouse gas inventories (IPCC 2006) are now used in the inventory.

#### **6.5.7 Recalculations**

The burning of the residues of oilseed has been included in the inventory.

#### **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). The information is mainly based on the report “Emissions and removals of greenhouse gases from land use, land-use change and forestry in Norway” (NIJOS, 2005).

The NIJOS 2005 report discussed carbon stock changes and each category of emissions and removals of CO<sub>2</sub> and other greenhouse gases, the methodological choice, underlying assumptions, availability of data and recommendations for use of data. The NIJOS 2005 report included a chapter entitled “Recommendation for future reporting framework” and a chapter that discussed how data collected for reporting under the UNFCCC could be used for the Kyoto Protocol reporting. These chapters are now covered in “Framework for reporting under Article 3.3 and 3.4 of the Kyoto Protocol” (Anon, 2006b), “Estimates of emissions and removals resulting from activities under Article 3.3 and 3.4 of the Kyoto Protocol” (Anon, 2006a) and “Electing Cropland Management as an Article 3.4 Activity under the Kyoto Protocol. Considerations for Norway” (Rypdal et al, 2006) and in the “National Greenhouse Gas Inventory System in Norway” (see Annex VI).

The whole time-series have been recalculated due to a updating of the activity data provided by the NFI for the entire country due to new data and continuous quality control of the data bases used. CRF-tables for both for LULUCF and KP-LULUCF are updated compared to earlier submitted reports and included in the NIR-submission. The work has been carried out by the Norwegian Forest and Landscape Institute.

### 7.1 Overview of sector

#### 7.1.1 Activity data

In light of the importance of the forest sector and the lack of sources of statistical information that can be used to monitor all land-use transitions on an annual basis, data from the National Forest Inventory (NFI) has been used as the most important source of information to establish total area of forest, cropland, wetlands, settlements and other land and land-use transitions between these. Data from the NFI is also used to calculate net change of carbon stock in living biomass and as input values for modeling changes of carbon stock in dead organic matter and soil.

The data from the NFI are 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 calculated land-use categories for Norway in 1990 and 2010 are shown in Figure 7.1.

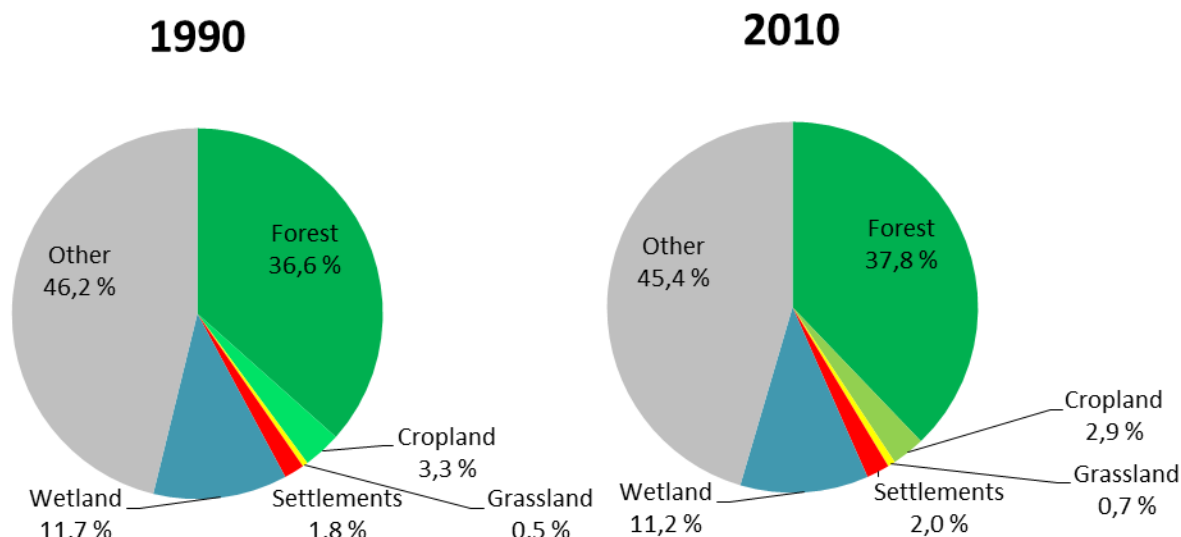


Figure 7.1 Area (%) distribution between the IPCC land-use categories, 1990 and 2010.

Source: The Norwegian Forest and Landscape Institute.

A key finding from these preliminary data is that changes in land-use from 1990 to 2010 are quite small; the area of forest land, grassland and settlements have slightly increased, while the other land-use categories have decreased. The land-use matrix will be recalculated in future greenhouse gas inventories as more information will be available, e.g. from the NFI, maps, old and new aerial photographs. It is planned to use this information to improve the estimates back to 1990. The land use matrix from 1990 to 2010 and from 2009 to 2010 is given in Table 7.4 and Table 7.5.

### 7.1.2 Emissions and removals

In 2010 the net sequestration was calculated at 32 944 Gg CO<sub>2</sub>-equivalents, which would offset 61 per cent of the total greenhouse gas emissions in Norway that year (53 896 Gg CO<sub>2</sub>-equivalents) and 72 percent of the CO<sub>2</sub> emitted. The average annual net sequestration from the LULUCF sector was about 19 643 Gg CO<sub>2</sub>-equivalents for the period 1990–2010.

In 2010 the land-use category forest land remaining forest land was the major contributor to the total amount of sequestration with 35 446 Gg CO<sub>2</sub> (Figure 7.2). Of these, 4 892 Gg CO<sub>2</sub> comes from changes of carbon stock in forest soils, while dead organic matter contributes with 3 480 Gg CO<sub>2</sub> (Figure 7.3). Land converted to forest land contributed with removals of 431 Gg CO<sub>2</sub>. The annual removals from forest land have increased since 1990, and have been fluctuating over the last 8 years. The explanation of the annual variation is provided in a separate paragraph.

All other land-use categories showed net emissions in 2010. In total the emissions were calculated to 2 918 Gg CO<sub>2</sub> (Figure 7.2). Farmed organic soils (mostly for grass production) contributed with CO<sub>2</sub> emissions of 1 606 Gg CO<sub>2</sub>. The uncertainties are, however, large (more than a factor of 2). The estimate has decreased slightly over the years. The CO<sub>2</sub> emissions from agricultural mineral soils are small due to small new areas cleared for agriculture. Erosion control (in particular mandatory spring-till) has contributed to a small sequestration.

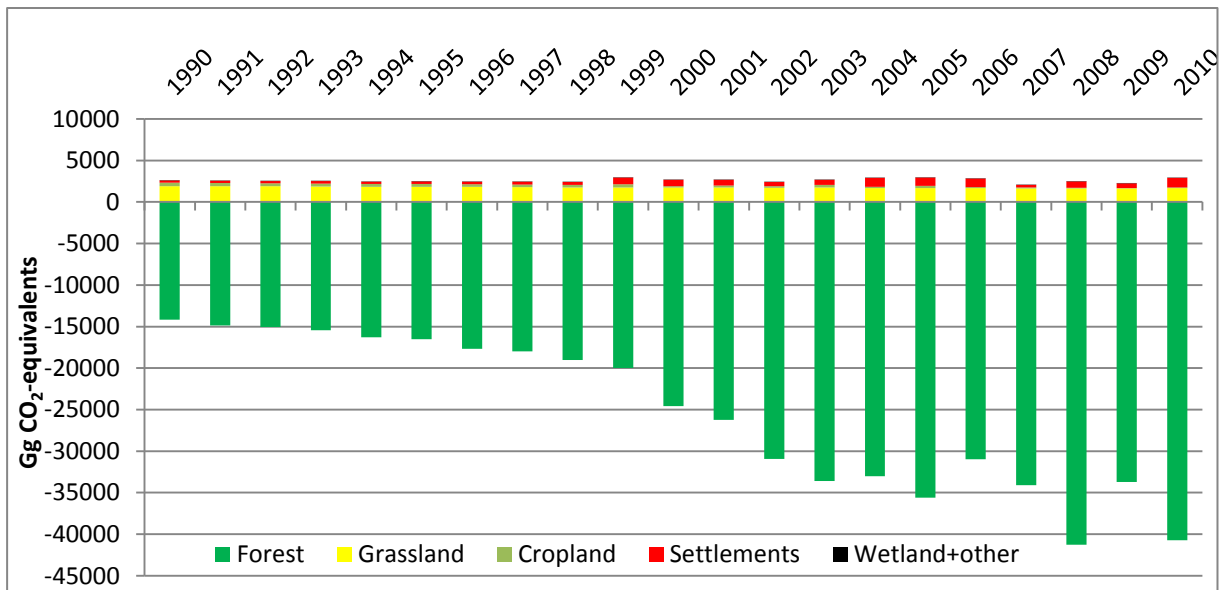


Figure 7.2 Emissions and removals from the LULUCF sector from 1990 to 2010. Gg CO<sub>2</sub>-equivalents. Source: The Norwegian Forest and Landscape Institute.

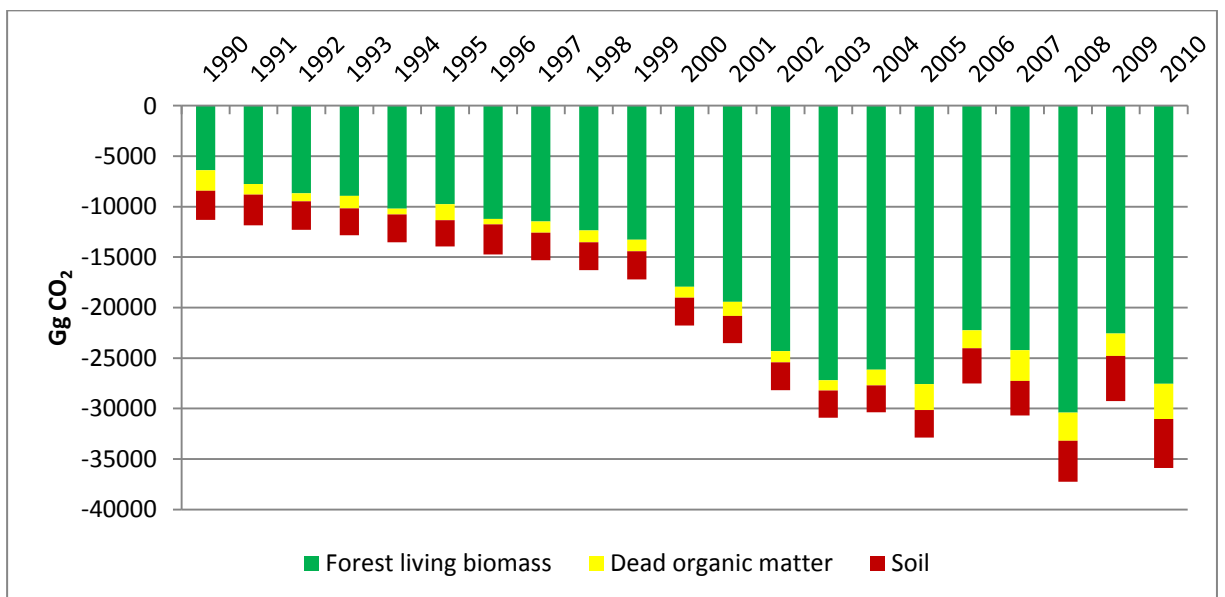


Figure 7.3 Net CO<sub>2</sub> removals on forest land (entire country), dead organic matter and soil (area below the coniferous limit), 1990–2010. Gg. Source: The Norwegian Forest and Landscape Institute.

***Explanation of the annual variation of CO<sub>2</sub> 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 7.4).

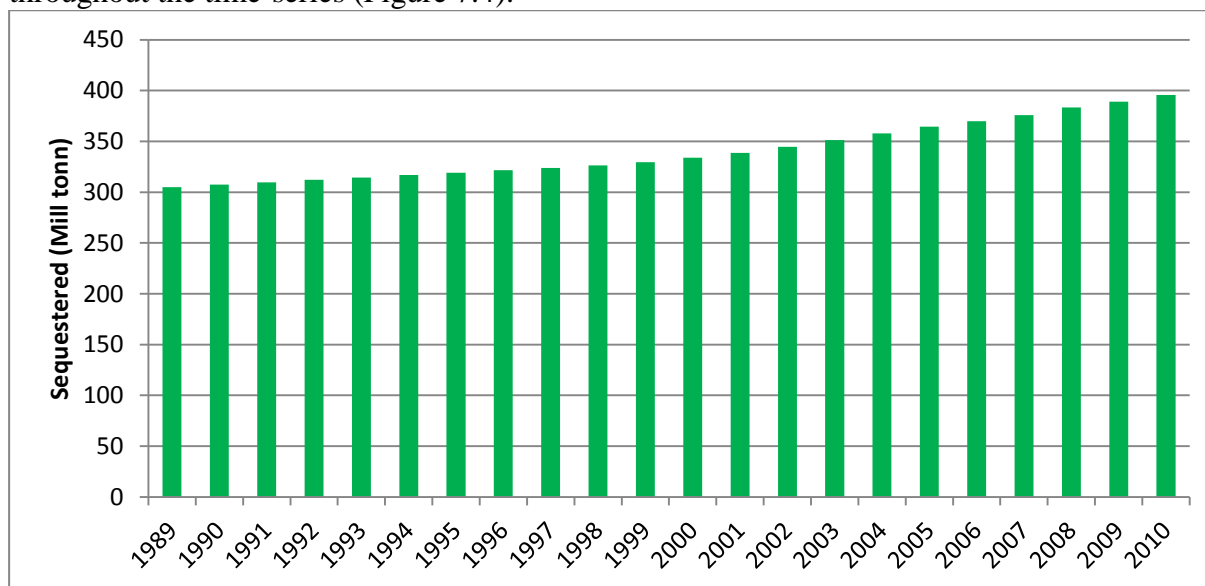


Figure 7.4 Sequestered carbon I in forest living biomass on Forest land remaining forest land, 1990–2010. Million tonnes C.

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 the Second 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, and the low number may influence the future increment growth and hence the net carbon sequestration. Furthermore, the annual drain levels are much lower than the annual increments, causing an accumulation of tree biomass (Figure 7.5).

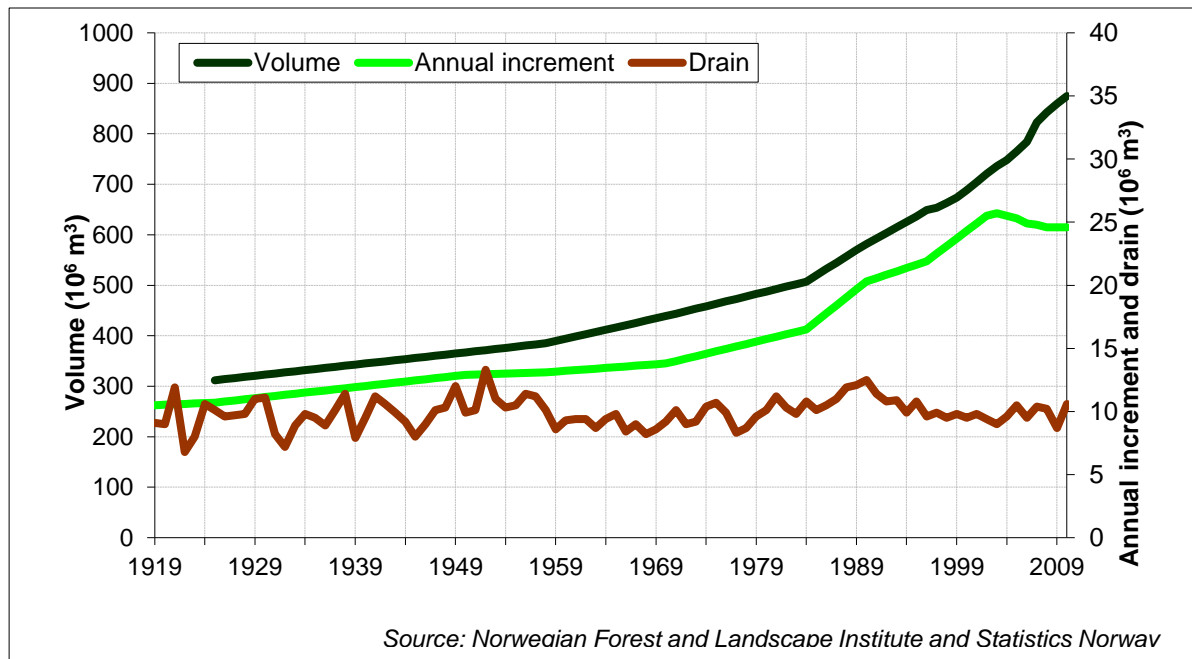


Figure 7.5 Forest drain, annual increment and volume, 1990–2010. The two last years are extrapolated for volume and annual increment.

Source: The Norwegian Forest 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 from 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 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 a correction factor which has been used for every year in this period (a detailed description is given in Chapter 7.2.2).

Values for subsequent years (after 1997) are calculated based on data obtained during the corresponding 5-year cycle; 1998 are based on values obtained from 1994–1998; and so forth until 2010, which are based on values obtained in the period 2006–2010. As 1/5 of the plots are exchanged every year, the estimated net change of removals of  $\text{CO}_2$  in any year is based solely on the changes observed on this 1/5 of the plots, which creates fluctuations from one year to another.

In spite of the systematic grid for the NFI sample plots, we see differences in the amount of carbon sequestered (biomass) in living trees between the selections of plots assessed every year. One group of plots has high values every 5<sup>th</sup> year, while another group of plots has relatively low values every five years. These changes 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 CO<sub>2</sub> removals from the atmosphere caused by the photosynthesis taking place in living biomass. In other words; if there are small changes in the amount of carbon between two subsequent 5-year periods, the estimated net change in removals will be low, and vice versa when large differences between two 5-year periods occur. Then the estimated removals for that year will be larger than the previous year.

The stock change method is also used to calculate the changes in CO<sub>2</sub> sequestered in dead organic matter and soil. The annual fluctuation seen in CO<sub>2</sub> sequestered for dead organic matter and soil are influenced by annual variation in the input data to the Yasso 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.

### **7.1.3 Key categories**

Statistics Norway has carried out the standard key category analysis, both at Tier 1 and Tier 2 levels, for the whole greenhouse gas inventory including source categories from LULUCF (IPCC 2001). Table 7.1 lists the identified LULUCF key categories based on the results from the Tier 2 level analysis. Uncertainties were not determined by a rigid analysis, see Section 7.11.

Compared to earlier submissions, one source has been excluded as key: *5B1 Cropland remaining Cropland – Reduced tillage- Soils*. The change is due to an updating of activity data due to new data and continuous quality control of the data bases used.

Table 7.1 Summary of identified LULUCF key categories.

|  | Source category  | Gas             | Level assessment Tier 2 1990 | Level assessment Tier 2 2010 | Trend assessment Tier 2 1990-2010 | Method (Tier) 2010 |
|--|--|-----------------|------------------------------|------------------------------|-----------------------------------|--------------------|
| <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 <sub>2</sub> | <b>6.37</b>                  | <b>19.86</b>                 | <b>26.79</b>                      | Tier 3             |
| 5A1  | Forest Land remaining Forest Land, Forest inventory area, Dead Biomass   | CO <sub>2</sub> | <b>6.80</b>                  | <b>8.51</b>                  | <b>9.15</b>                       | Tier 3             |
| 5C1  | Grassland remaining Grassland, Histosols, Soils                          | CO <sub>2</sub> | <b>12.49</b>                 | <b>7.85</b>                  | <b>4.90</b>                       | Tier 2*            |
| 5A1  | Forest Land remaining Forest Land, Forest inventory area, Soils, Mineral | CO <sub>2</sub> | <b>5.09</b>                  | <b>6.16</b>                  | <b>6.53</b>                       | Tier 3             |
| 5E2  | Land converted to Settlements, Living biomass                            | CO <sub>2</sub> | <b>0.75</b>                  | <b>2.18</b>                  | <b>2.91</b>                       | Tier 3             |
| 5A1  | Forest Land remaining Forest Land, Forest inventory area, Soils, Organic | CO <sub>2</sub> | <b>2.54</b>                  | <b>1.97</b>                  | <b>1.57</b>                       | Tier 1             |
| 5B1  | Cropland remaining Cropland, Histosols, Soils                            | CO <sub>2</sub> | <b>1.39</b>                  | <b>0.87</b>                  | 0.54                              | Tier 2             |
| 5E2  | Land converted to Settlements, Soils                                     | CO <sub>2</sub> | 0.10                         | 0.65                         | <b>0.93</b>                       | Tier 3             |
| 5A2  | Land converted to Forest Land, Living biomass                            | CO <sub>2</sub> | 0.01                         | 0.58                         | <b>0.89</b>                       | Tier 3             |
| <i>Tier 1 key categories (large contribution to the total emissions):</i>            |  |                 |                              |                              |                                   |                    |
| 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.*

There are some differences between the analysis at Tier 1 and Tier 2 level. All Tier 1 key categories were also keys at Tier 2 level. But, the Tier 1 level analysis does not identify forest drained organic soil and cropland histosols. The reason is that these categories have large uncertainties. The source 5B1 *Cropland remaining Cropland – liming* – is not included in the list of Tier 1, as it has been in previous submissions. This may be due to the reduction of total amount of lime applied over the years, and that this emission is negligible.

For the trend analysis there are small differences between the two Tiers with respect to the LULUCF categories identified. Including LULUCF also influences other key categories identified. However, according to GPG2004 the LULUCF key categories are additional to those identified analyzing the inventory excluding LULUCF. In both analysis, with and without the LULUCF source categories, forest remaining forest (all three pools) are among the top key categories.

## 7.2 Source category description

### 7.2.1 Land use categories, CRF 5A, 5B, 5C, 5D, 5E and 5F

In light of the importance of the forest sector data from the National Forest Inventory are used to establish total area of forest, cropland, wetlands, settlements and other land and land-use transitions between these. The land use categories are in accordance given in IPCC Good practice Guidance (IPCC, 2003).

The rationality of using the NFI as activity data for all land-use categories is as follows: Area figures in Statistics Norway's agricultural statistics are more up to date than any other source, but do not have spatial coverage because of lacks in geo-referencing (although most data are available at the municipality level). This means that the overall data for agricultural areas are



of high quality, but they cannot be used to determine transitions between different land use categories.

**Forest land** is defined according to the Global Forest Resources Assessment (FRA) 2004. Forest land is *land with tree crown cover of more than 10 per cent and area of more than 0.5 ha*. The trees should be able to reach a minimum height of 5 m at maturity *in situ*. No minimum width for Forest land is considered in the Norwegian inventory causing a small discrepancy according to the definition in FRA 2004. Young natural stands and all plantations established for forestry purposes, as well as forest land which are temporarily unstocked as a result of human intervention are included under Forest land. All Forest land is considered managed which includes also recreation areas, protected areas and nature reserves. All forests in Norway are used either for wood harvesting, hunting, picking berries, hiking etc.

**Cropland** is defined for lands where the *soils are regularly cultivated, and where annual or perennial crops are grown*. This category includes temporarily grazed lands that regularly are being cultivated. Cropland also includes areas for meadows and pastures close to the farm.

**Grassland** is identified as *areas utilized for grazing on an annual basis, but which are not mechanically harvested*. More than 50 per cent of the area should be covered with grass. The soil is not cultivated, and may partly be covered with trees, bushes, stumps, rocks etc. Land with tree cover may be classified as grassland if grazing is considered more important than forestry. Meadows and pasture within the farm area are included under cropland, which is consistent with the agricultural statistics. All grassland is considered managed, because grassland left unmanaged will over time be converted to forest or vegetated “other land”.

**Wetlands** are assumed unmanaged and are defined as mires and areas regularly covered or saturated by water for at least some time of the year. A wetland area of about 338 ha is used for peat extraction and assumed managed. Land used for reservoirs (dams) used to hydroelectric power productions are also considered managed wetlands, but is not reported since it is not mandatory (IPCC, 2003).

**Settlements** include all types of built-up land; houses, gardens, villages, towns, cities, parks, golf courses, sport recreation areas, power lines within forests, and cabins areas, industrial areas, gravel pits, mines. All settlements are considered managed.

**Other land** 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.

Management status of the reported land use categories are summarized in Table 7.2, and the National Land cover and Land use categories surveyed by the National Forest Inventory, their correspondence to the UNFCCC/KP Land use categories is given in Table 7.3.

*Table 7.2 Management status of different land use categories. An area is only classified as belonged to one land use category. The predominant national land cover and land use decides to which category.*

| Land use category | Management status                 |
|-------------------|-----------------------------------|
| Forest land       | Managed                           |
| Cropland          | Managed                           |
| Grassland         | Managed                           |
| Wetlands          | Unmanaged or Managed (small area) |
| Settlements       | Managed                           |
| Other land        | Unmanaged                         |

*Table 7.3 National Land cover and Land use categories, their correspondence to the UNFCCC/KP Land use categories.*

| Land cover   | Land use                                      |   |             |                    |                            |   |                           |             |             |
|--|---|---|-------------|--------------------|----------------------------|---|---------------------------|-------------|-------------|
|  | Forestry<br>(no other use or<br>restrictions) | City<br>urban area<br>Settlements of<br>different kinds | Cabin area  | Recreation<br>area | Military<br>training field | Protected<br>Area,<br>Nature<br>Reserve | Roads/Railroad<br>Airport | Power line  | Other       |
| Productive forest land (1)   | Forest  | Settlements   | Settlements | Forest             | Forest                     | Forest                                  | Settlements               | Settlements | Settlements |
| Non-productive forest land (2)   | Forest  | Settlements   | Settlements | Forest             | Forest                     | Forest                                  |                           | Settlements | Settlements |
| Other wooded land,<br>Crown cover 5-10% (3)  | Other   |   | Settlements | Other              | Other                      | Other                                   |                           | Other       |             |
| Wooded mire,<br>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,<br>not regularly cultivated  |   |   |             |                    |                            |   |                           |             | Grassland   |
| Arable land, regularly cultivated  |   |   |             |                    | Cropland                   | Cropland                                |                           |             | Cropland    |
| Other areas, gravel pits,<br>mines, gardens, halting places,<br>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.

#### 7.2.1.1 Consistency in reporting Land use categories – 5A, 5B, 5C, 5D, 5E

The National Forest Inventory (NFI) is a sample plot inventory with the aim of providing data about natural resources and environment for forest land in Norway. The NFI is the only system that can present area changes and current area distribution based on a geo-referenced sample of field plots (NIJOS 2005). The Norwegian Forest and Landscape Institute is responsible for the NFI. Inventory work was started in 1919 with regular inventory cycles. The 10<sup>th</sup> inventory cycle started in 2010 and will be completed in 2014.

The reporting of Land-use categories are based on the re-sampling method with geo-referenced fixed-area circular permanent sample plots utilized by the NFI. These plots are placed in a systematic grid in the entire country (Figure 7.6). The current system with permanent plots was put in place between 1986 and 1993 for areas below the coniferous limit. In 1994 the concept of continuous forest inventory was introduced with 20 per cent of the sample plots located over the entire country inventoried each year. During a 5-year period all plots are assessed with respect to the national land cover and land-use categories, which are

coded into the UNFCCC land-use categories. Hence, the area of these categories is available. For each reporting year the land-use matrix is formed based on the changes in land-use between the consecutive 5-year periods. When a piece of land changes land-use category, it is included in that new land-use category for 20 years.

Up to the 2010 submission, the area of the different land-use categories were based on detailed information from sample plots below the coniferous limit. In order to determine the land use at higher altitudes and in Finnmark County, the NFI conducted a complete forest inventory 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. However, this is a snapshot of the current land use and does not allow for estimation of land-use changes. The plots are planned to be incorporated in the management plan for the future forest inventories.

All areas for the different land-use categories are reported for the entire country in this inventory submission. The land-use reported for 2010 is derived from approximately 26 000 sample plots. The land-use matrix will be recalculated in future greenhouse gas inventories as more information will be available, e.g. from the NFI, maps, old and new aerial photographs. It is planned to use this information to improve the estimates back to 1990 for all new plots included in the system throughout the time-period.

Table 7.4 gives the land-use change from 1990 to 2010 and table 7.5 gives the land-use change from 2009 to 2010. The figures are based on data from the NFI and Norwegian Mapping Authority which provided the figures for the total land area for Norway. A key finding from these data is that the change in land-use from 1990 to 2010 is quite small; the forest-, settlements- and grassland area are increasing and the cropland-, wetland- and other land area are decreasing.

The Land-use change matrix used for the reporting is given in Table 7.6.

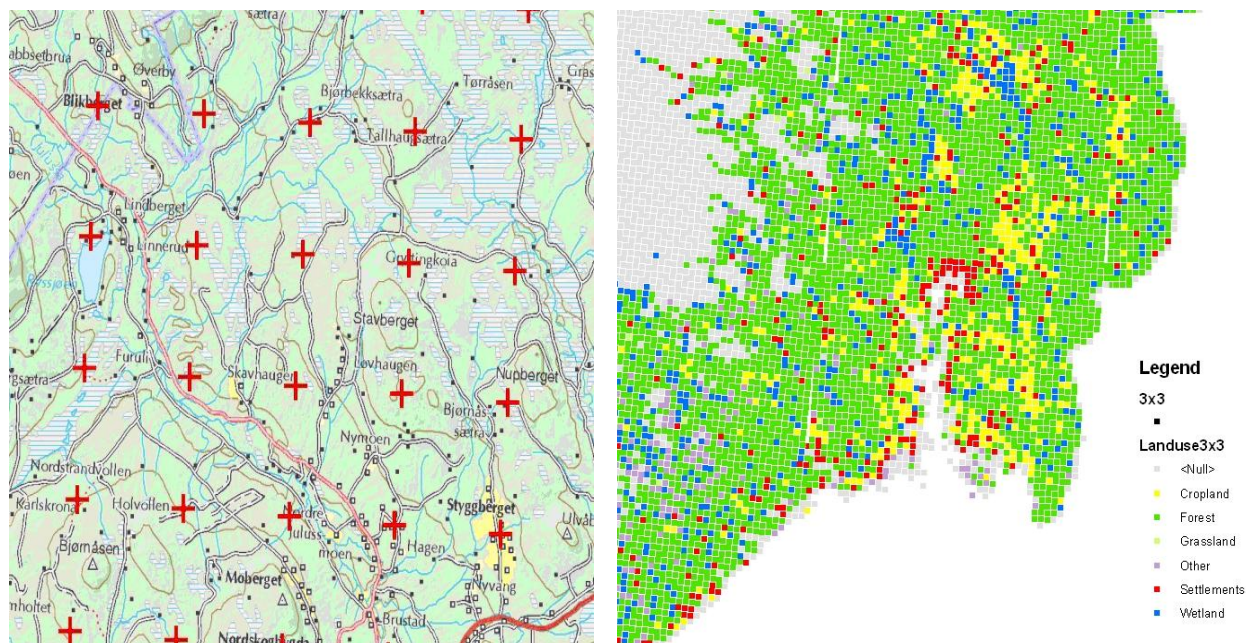


Figure 7.6 The sample plots are covering all relevant land-use. In the example map to the left, plots are placed in the systematic 3x3 km grid, and plots are located on e.g. Forest land, Wetlands and Settlements. To the right we see the distribution of land use-classes in the south eastern part of Norway (below the coniferous tree line).

Table 7.4 Land-use change matrix for IPCC land-use categories from 1990 to 2010. Preliminary values based on data from forested areas assessed by the NFI. Information for other land (e.g. trees less areas at higher elevation) are derived from aerial photos and extracted from maps.

|      |             | 2010           |          |           |          |             |          |           |
|------|-------------|----------------|----------|-----------|----------|-------------|----------|-----------|
|      |             | Land use – kha |          |           |          |             |          |           |
| Year | Land use    | Forest         | Cropland | Grassland | Wetland  | Settlements | Other    | Total     |
| 1990 | Forest      | 11 733.57      | 10.54    | 21.09     | NO       | 69.94       | 3.15     | 11 842.09 |
|      | Cropland    | 43.80          | 893.12   | 69.22     | 2.97     | 58.76       | 9.10     | 1 074.59  |
|      | Grassland   | 14.51          | 11.72    | 106.60    | 3.60     | 4.51        | 11.72    | 152.83    |
|      | Wetland     | 117.34         | 6.67     | 4.96      | 3 613.17 | 5.22        | 40.00    | 3 785.34  |
|      | Settlements | 45.78          | 7.39     | 2.61      | 2.61     | 494.13      | 18.48    | 572.73    |
|      | Other       | 295.97         | 1.08     | 7.66      | NO       | 17.39       | 14631.77 | 14 952.58 |
|      | Total       | 12250.97       | 930.52   | 212.13    | 3622.37  | 649.95      | 14714.22 | 32 380.16 |

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*Table 7.5 Land-use change matrix for IPCC land-use categories from 2009 to 2010. Preliminary values based on data from forested areas assessed by the NFI. Information for other land (e.g. trees less areas at higher elevation) are derived from aerial photos and extracted from maps.*

|      |             | 2010           |          |           |          |             |           |           |
|------|-------------|----------------|----------|-----------|----------|-------------|-----------|-----------|
|      |             | Land use – kha |          |           |          |             |           |           |
| Year | Land use    | Forest         | Cropland | Grassland | Wetland  | Settlements | Other     | Total     |
| 2009 | Forest      | 12 225.20      | 0.90     | 1.80      | 0.00     | 5.59        | 0.00      | 12 233.49 |
|      | Cropland    | 7.12           | 928.26   | 13.07     | 0.00     | 7.84        | 0.54      | 956.83    |
|      | Grassland   | 1.80           | 0.90     | 196.36    | 0.00     | 1.80        | 2.70      | 203.57    |
|      | Wetland     | 3.15           | 0.45     | 0.00      | 3 622.37 | 1.80        | 9.72      | 3 637.49  |
|      | Settlements | 4.60           | 0.00     | 0.00      | 0.00     | 632.65      | 2.07      | 639.32    |
|      | Other       | 9.10           | 0.00     | 0.90      | 0.00     | 0.27        | 14 699.18 | 14 709.46 |
|      | Total       | 12 250.97      | 930.52   | 212.13    | 3 622.37 | 649.95      | 14 714.22 | 32 380.16 |

The national definitions used for the six land-use categories have been consistent since the period 1994–1998 (7<sup>th</sup> NFI). However, in the period 1983–1993 (6<sup>th</sup> NFI) the crown cover percentage for classifying forest was not recorded. Also the category “Grassland” had not been defined in the land-use classification. Because of these missing assessments in the 6<sup>th</sup> NFI, the land-use classes assessed in the 7<sup>th</sup> NFI has been utilized for the corresponding plots in the 6<sup>th</sup> NFI. Consequently, no land-use transfers from “Grassland” were assumed.

*Table 7.6 The land-use change matrix used for the reporting. Land use changes classified under the Kyoto protocol Article 3.3 as Afforestation/Reforestation is denoted with AR, and land-use changes classified as Deforestation is denoted with D. Land use classified for activities under Article 3.4 is denoted Forest Management.*

|             | Forest                           | Cropland                                   | Grassland                                  | Wetlands                                   | Settlements                                | Other                                      |
|-------------|----------------------------------|--|--|--|--|--|
| Forest      | Forest Management<br>D           | Human induced<br>D                         | Human induced<br>D                         | Human induced <sup>1</sup><br>D            | Human induced<br>D                         | Human induced<br>D                         |
| Cropland    | Human induced<br>AR <sup>4</sup> |  | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> |
| Grassland   | Human induced<br>AR <sup>4</sup> | Human induced<br>(negligible) <sup>3</sup> |  | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> |
| Wetlands    | Not human induced <sup>2</sup>   | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> |  | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> |
| Settlements | Human induced<br>AR              | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> |  | Human induced<br>(negligible) <sup>3</sup> |
| Other       | Human induced<br>AR              | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> | Human induced<br>(negligible) <sup>3</sup> |  |

<sup>1</sup> Forest land flooded because of constructed reservoirs

<sup>2</sup>Plot classified as wood mire (crown cover 5–10%) turn in to forest land (crown cover 5–10%) due to natural growth over a time period are regarded as not human induced. A small area of peat extraction is human induced.

<sup>3</sup>The word negligible is used when estimates of emission or removals from changes in soil organic carbon due to land-use change are assumed to not have any significant consequences for the GHG inventory, or no data or methods are available.

<sup>4</sup>Includes agricultural areas which have been abandoned. The abandonment is considered to be an active change in management of those areas.

### 7.2.1.2 Land use changes prior to 1990

According to the Good Practice Guidance (IPCC, 2003), it has been recommended that, when a piece of land changes use, then it is included in that ‘changed status’ for 20 years, with each year 1/20 of the CO<sub>2</sub> and non-CO<sub>2</sub> effects reported. 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 7.7. 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 are underestimated, but the biomass changes are included in the reporting category for “forest land remaining forest land”.

Table 7.7 Estimates of productive forest land 1967–1989 (kha)

| Region | 1967    | 1979               | 1989    |
|--------|---------|--------------------|---------|
| 1      | 4 166.1 | 4 085.3            | 4 288.9 |
| 2      | 689.4   | 770.5              | 894.7   |
| 3      | 1 021.1 | 975.6 <sup>a</sup> | 1 255.2 |
| 4      | 522.1   | 744. <sup>b</sup>  | 514.3   |
| Total  | 6 398.8 | 6 659.8            | 6 953.1 |

<sup>a</sup> Trøndelag only

<sup>b</sup> Includes all of Nordland

### 7.2.1.3 Uncertainties

About 17 000 permanent NFI plots under the coniferous limit in the whole country, except Finnmark, have been used.. With the number of plots, the precision of the estimates (in relative terms) will be high for the common land-use classes. Although the NFI is carried out as a systematic sampling of plots, the formulas for simple random sampling can be used.

The standard error of an area estimate with simple random sampling is:

$$std(\hat{A}_c) = A \sqrt{\frac{p(1-p)}{n}}$$

Where:

$\hat{A}_c$  is the area of a specific land-use category or transfer class,

A is the total area of Norway (32,380,200 ha),

p is the proportion of the land-use class, and

n is the number of sample plots.

In Table 7.8, some examples of standard errors are given for various cases, differentiated on proportion of the land-use category and the number of sample plots used.

*Table 7.8 Examples of standard errors of area estimates, using a certain number (n) of sample plots in the calculations.*

| Proportion of area (p) | Corresponding area | Standard error |     |         |     |         |     |
|------------------------|--------------------|----------------|-----|---------|-----|---------|-----|
|                        |                    | n=5000         |     | n=10000 |     | n=17000 |     |
|                        |                    | (ha)           | (%) | (ha)    | (%) | (ha)    | (%) |
| 0.001                  | 32 380             | 14 474         | 45  | 10 234  | 32  | 7 849   | 24  |
| 0.01                   | 323 802            | 45 563         | 14  | 32 218  | 10  | 24 710  | 8   |
| 0.1                    | 3 238 020          | 137 378        | 4   | 97 141  | 3   | 74 503  | 2   |
| 0.5                    | 16 190 100         | 228 963        | 1   | 161 901 | 1   | 124 172 | 1   |

Table 7.8 shows that the relative errors of the uncommon categories are rather high. On the other hand, once a certain category becomes more frequent, the relative precision of its assessment will be higher. Thus, by using the permanent plots of the NFI as a basis for the area estimation, the uncommon classes will be assessed with low accuracy. The system is sensible to the number of permanent plots. For sparse categories the current number of plots may be considered being close to a minimum. The uncertainties in emission and removal figures are substantially higher for all other land-use classes compared to forest. This is due to lack of data available and all the assumptions needed to be done.

#### **7.2.2 Consistency in reporting carbon stock change in living tree biomass – 5A, 5B, 5C, 5D, 5E**

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 a correction factor which has been used for every year in this period. The formula for the correction factor is:

$$C_t = [(X_t - Y_t) / (\sum_{t=1990}^{1998} X_t - \sum_{t=1990}^{1998} Y_t)] \sum_{t=1990}^{1998} Z_t$$

where:

t = 1990, 1991 .....1998

C<sub>t</sub> = correction factor

X<sub>t</sub> = annual increment in year t

Y<sub>t</sub> = drain in year t

Z<sub>t</sub> = removals of CO<sub>2</sub>

Values for subsequent years (after 1997) are calculated based on data obtained during the corresponding 5-year cycle; 1998 are based on values obtained from 1994–1998; 1999 are based on values obtained from 1995–1999 and so forth until 2010 which are based on values obtained in the period 2006–2010. Hence, 1/5 of the plots are exchanged every year. The change in carbon (biomass) between subsequent 5-years periods creates fluctuations in the estimated net change of removals of CO<sub>2</sub> caused by the living biomass. An explanation of the annual variation is given in Chapter 7.1.2.

The biomass of trees, below and above coniferous limit, with diameter less than 50 mm (small trees) at 1.3 meter height (DBH), trees at higher altitudes and 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 beneath the coniferous limit. Hence, 7 percent of the net change of CO<sub>2</sub> removals of living trees below the coniferous limit each year is included in the estimates. It is assumed that these proportions have remained constant over the last twenty years. The proportion of the annual changes is shown in Figure 7.7.

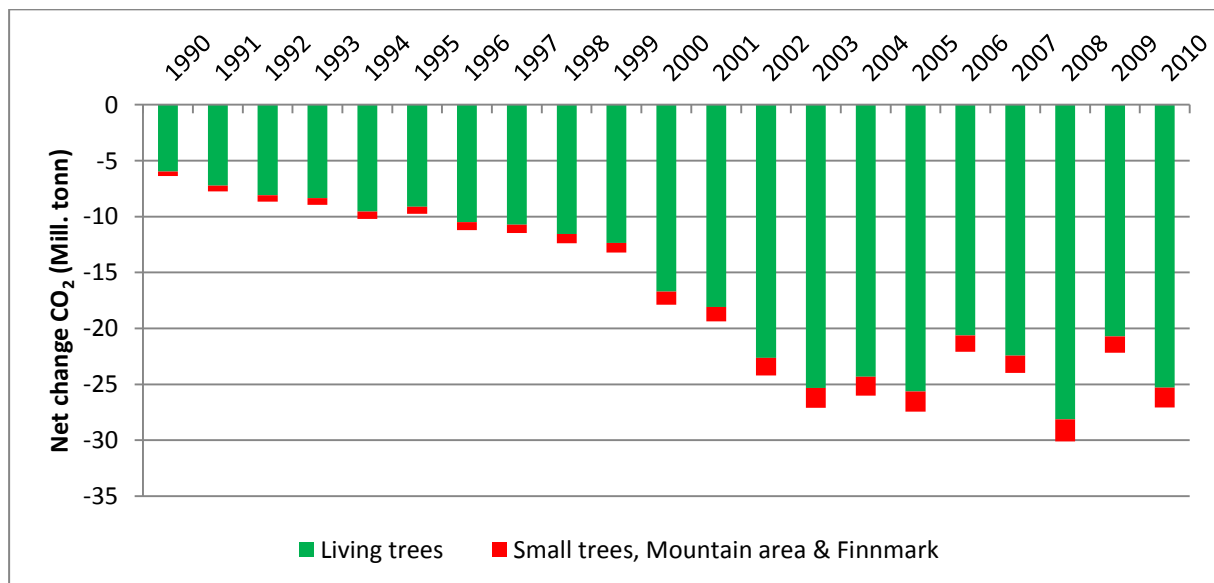


Figure 7.7. Annual net change of CO<sub>2</sub> removals of living trees below the coniferous limit (green), small trees, mountain areas and Finnmark County (red), 1990–2010.



### 7.2.3 Auxiliary data

The data from the NFI have been complemented with other statistical data. The rationale for choosing databases are given in NIJOS 2005.

The data from the NFI are 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.

#### *Horticulture*

Statistics Norway collects data on the area of fruit trees annually (apple, pears, plum, cheery and sweet cherry) which are used to calculate annual changes in carbon stock in living biomass for perennial crops for the greenhouse gas inventory. The statistics are based on information about area and production collected by questionnaires in a sample survey. Active agricultural holdings meeting the minimum of 0.1 ha cultivated area of fruit trees, are included in the statistics. The purpose of the statistics is to present annual statistics covering total area, production yields per area unit and total production for important horticultural crops. The statistics used in the greenhouse gas inventory goes back to 1989. Up to 2005 Statistics Norway worked out area and production statistics for horticultural crops. From 1996 to 2004 the Norwegian Agricultural Authority had the responsibility. From 2005 the statistics are again being worked out by Statistics Norway. Methods and procedures were changed when the Norwegian Agricultural Authority was in charge of the statistics. For 2005 Statistics Norway has kept the same methodology as developed and used by the Norwegian Agricultural Authority. More information can be found at [http://www.ssb.no/vis/hagebruk\\_en/about.html](http://www.ssb.no/vis/hagebruk_en/about.html).

#### *Tillage practice*

Annually agricultural statistics are collected by *Sample surveys of agriculture and forestry*, carried out by Statistics Norway. The samples consist of about 11 500–13 000 units, which are drawn from the Farm register administered by the Norwegian Agricultural Authority. The samples are drawn on the basis of agricultural area in use and productive forest area. The structural variation between different counties is also taken into consideration, and the relative size of the samples differs both by county and by size of holding. The sample surveys of agriculture and forestry provide figures for number of holdings and the size of agricultural area in use. Data concerning soil preparation are collected regularly, likewise information about labour force and working time on holdings. The annual figures on tillage practice are taken from this statistics back to 1989. More information can be found at <http://www.ssb.no/vis/emner/10/04/10/lu/om.html>.

#### *Fertilizers and drainage of forests*

Statistics on *consumption of fertilizers and drainage of forest* are based on silviculture statistics provided by Statistics Norway. The statistics only cover activities financed wholly or partly by the Forest Trust Fund and/or by government subsidies. The silviculture statistics are based on information from the Norwegian Agricultural Authority and their database on the Forest Trust Fund. The figures used in the National Greenhouse Gas Inventory are dated back to 1989. More information can be found at [http://www.ssb.no/english/subjects/10/04/20/skogkultur\\_en/](http://www.ssb.no/english/subjects/10/04/20/skogkultur_en/).

### *Liming of lakes and agricultural soils*

Statistics on *consumption of liming of lakes and agricultural soils* are based on data from the Norwegian Directorate for Nature Management and The Norwegian Food Safety Authority. The statistics are based on reports from commercial suppliers of lime. The figures used in the National Greenhouse Gas Inventory are dated back to 1989. More information can be found at <http://www.dirnat.no/naturmangfold/vann/kalking/> and <http://www.mattilsynet.no/planter/gjodsler/omsetningsstatistikker>.

### *Forest fires*

Statistics on *area burned in forest fires* (numbers of fires, productive and unproductive forests) are available from the Directorate for Civil Protection and Emergency. More information can be found at <http://www.dsb.no/en/Hygiene/English/>.

Area data for *organic soils, peat extraction and others* are based on research projects at Bioforsk.

## **7.3 Forest land 5.A**

### **7.3.1 Forest land remaining forest land – 5A1 (Key Category)**

Forest is the most important land-use category with respect to biomass sequestration in Norway. According to the Tier 2 key category analysis (Section 7.1.3) this category is found to be a key category with respect to sequestration in living biomass, dead biomass, soils (mineral and drained organic) because of uncertainty in level and trend.

#### **7.3.1.1 Methodological issues**

##### ***Change in carbon stock in living biomass***

The IPCCs (2003) stock change method is used. The method implemented corresponds to Tier 3; a combination of national forest inventory data and models to estimate changes in biomass.

##### ***Trees with diameter larger than 50 mm at breast height and below the coniferous tree limit***

The reported carbon refers to the biomass of all living trees with a height of at least 1.3 m. Thus, shrubs and other vegetation, such as herbs are not included in the figures. The biomass of trees with a stem diameter larger than 50 mm measured 1.3 m above the ground (DBH), is individually monitored. It is possible to match the biomass to land use of each tree.

Both above ground and below ground biomass are reported. Above ground biomass is defined as living biomass above stump height (1 per cent of the tree height). The Swedish single tree allometric regression functions developed by Marklund (1988) are applied to data from the NFI for predicting the various tree biomass components; stem, stem bark, living branches, dead branches, needles (not leaves) of Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and birch (*Betula pendula* and *Betula pubescens*). These functions require measurements of a trees diameter and height. These three species (including other coniferous about 1 per cent) constitute about 92 per cent of the standing volume (Larsson and Hylen 2007). Other, broad-leaved species constitute most of the remaining 8 per cent and the birch functions are applied to all broad-leaved species.

Below ground biomass is defined as living biomass below stump height down to a root diameter of 2 mm and are estimated by Petersson and Ståhl's (2006) single tree allometric

regression functions for the same tree species as for above ground living biomass. The living biomass is estimated consistently based on the same monitoring design, by using the same functions for the same tree species from the base year 1990 and onward.

*Trees with diameter less than 50 mm at breast height*

The growing stock of trees with a dbh less than 50 mm at breast height is estimated as a proportion of the volume of total growing stock below the coniferous tree line. This proportion is estimated to 3 per cent and covers all forested areas for the period 2005–2009, except Finnmark County. It is assumed that this proportion has remained constant over the last twenty years, and is therefore incorporated in the net change of carbon stock since 1990 and onwards.

Traditional volume or biomass models have not been developed to predict the stem volumes of trees with dbh less than 50 mm, because the volumes of these trees have usually not been included in the national forest statistics of Norway. The Swedish model by Jonson (1928) has been used to estimate the volume (V). This model expresses the stem volume as a model of dbh only:

$$V = 0.21 \cdot (1 + \text{dbh}^2) + \varepsilon$$

On the basis of the field assessment procedure, the heights of the single small trees are not measured. To assign a height estimate to each value of dbh, a model based on sub-sample tree data from the NFI has been applied (Tomter 1998). The assumption is that the point of the average dbh and height of the smallest measurable trees ( $\geq 50$  mm) and the point  $H = 1.3$  m;  $\text{dbh} = 0$  can be connected by a straight line, thus a linear relationship between H and dbh can be described for the interval  $0 \text{ mm} < \text{dbh} < 50 \text{ mm}$ :

$$\text{Dbh} = 1.4 \cdot H - 1.8 + \varepsilon$$

Trees with a height of less than 1.3 m are not included in the growing stock. The number of small trees is grouped by the main tree species and by the dbh intervals 0–2.4 cm and 2.5–4.9 cm. Thus, the midpoint of each interval has been selected to represent the typical (mean) volume of a tree within a dbh class. Only two diameters (1.25 cm and 3.75 cm) are then required to estimate the volume of the small trees from the model.

*Trees in the mountain birch area and Finnmark County*

During the time-period 2005–2010, the mountain birch areas and Finnmark County were assessed by following the guidelines of the NFI, but with the plots in a less dense systematic grid compared to the rest of the Country. The standing volume in the mountain birch area and in Finnmark County is estimated to 2.7 per cent and 1.3 per cent of the total volume below the coniferous tree line, respectively. It is assumed that this proportion has remained constant over the last twenty years, and is therefore incorporated in the net change of carbon stock since 1990 and onwards.

The volume of the growing stock in these areas is estimated by using traditional national functions (Braastad 1966, Brantseg 1967, Vestjordet 1967, Tomter 1997).

***Change in carbon stock in dead organic matter and in soil***

The dynamic soil model Yasso, as described in detailed by Liski et al. 2005, and for Norwegian conditions by de Wit et al. (2006), are used to calculate changes in carbon stock in dead organic matter and in soil (Figure 7.8). The calculations are hence done according to a Tier 3 method. The current implementation of the Yasso model is not designed for obtaining

estimates of dead organic matter and soil organic carbon for disaggregated areas or land-use classes other than forest land remaining forest land.

The Yasso model describes the accumulation of dead wood and soil organic matter in upland forest soils and is designed to process data derived from forest inventories (Liski et al. 2005). The model requires estimates of litter production as input to the soil and basic weather data. The model has two litter compartments that relate to physical fractions of litter. It has five soil components that differ in their rate of decomposition. A gradual formation of more complex compounds (humification) is possible through limited transfer among soil compartments. The litter and soil compartments can be viewed as “dead wood” and “soil organic matter”. The estimated values of “dead wood” and “soil organic matter” are reported in the CRF tables. With the current parameterization (Liski et al. 2005), the model gives an estimate of the soil organic matter down to the depth of 1 m in the mineral soil. In each time step, fine woody and coarse woody litter input to the soil is first fed into the two litter compartments, whereas non-woody litter (foliage and fine roots) is directly transferred to the soil compartments. Litter is transferred to the soil compartments according to the exposure rates  $a$ . The exposed organic matter is distributed to the soil compartments according to their chemical composition  $c$ . The soil compartments have specific decomposition rates  $k$ . Parts of the decomposed carbon is transferred to a subsequent soil compartment according to transfer rate  $p$ . The possible transfer among soil compartments is shown by the arrows ( $p$ ) in Figure 7.8. Specific parameter values are given in Table 4 in de Wit et al. (2006).

Due to the lack of repeated soil carbon assessments, the initial soil carbon content was calculated assuming a steady state between soil organic matter and litter input at the first year of simulation. It is known (de Wit et al. 2006) that the initial soil C pools influence the following estimates of annual changes. This influence diminishes with time. Thus, to minimize errors due to an unrealistic start value, the steady state was calculated for the first year in a time-series starting in 1960. Simulation output is only used from 1990, thus allowing for an equilibration period of 30 years.

The parameter values used reflect the climate of Southern Finland and Middle Sweden (annual mean temperature of 3.3 C and a May-to-September precipitation deficit of -32 mm). These reference conditions were used in all steps of simulations, hence no annual changes in climate/weather. We assume that the model is relevant for Norwegian conditions.

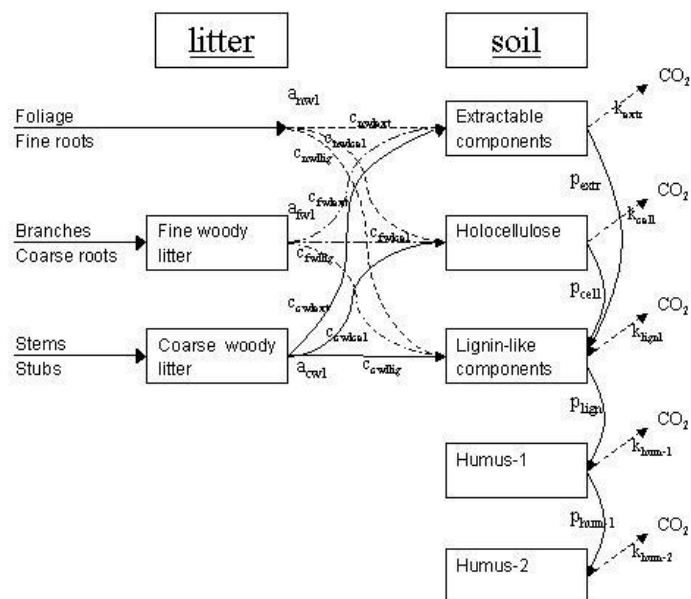


Figure 7.8 Carbon pools and fluxes in soil model Yasso. Values for the parameters are presented in Table 4 in de Wit et al. 2006.

The input values for the Yasso model are estimates of litter/dead wood from standing biomass, natural mortality, harvest residues and, stumps and roots from harvested trees. All data are provided by the NFI and Statistics Norway. From 1994 natural mortality is recorded annually. Earlier estimates are based on periodic registrations of utilizable dead wood. Harvest residues are estimated as 10 per cent of harvested volume (Vestjordet 1968, Bengtson 1975). Dry matter biomass of different litter compartments (foliage, fine roots, branches, coarse roots, stems and stumps) are calculated using biomass expansion factors described for Norway in FAO/ECE (1985), de Wit et al. (2006) and in Lethonen et al. (2004). The functions of Lethonen et al. (2004) for biomass expansion factors are age dependent. The age of different carbon pools are not known, therefore 100 year is used as the mean age for harvested wood and 70 years for growing stock volume and natural mortality volume (expert judgements). Turnover rates (fine roots, foliage) are based on results published in the literature (see Table 3 in de Wit et al. 2006) except for stems and stumps which is based on direct measurements (NFI).

Annual changes in the carbon stock were calculated as the change between successive carbon stock estimates.

The Yasso model is used on areas with mineral soil. For organic soil no estimates were made due to lack of methods and emissions factors. Soils were categorized according to the NFI definition of organic and mineral soil (more than 0.4 m organic layer). The values are given in the CRF-tables. De Wit et al. (2006) calculate a C budget of productive forest in southeast Norway using the model. The estimated soil C density was about 40 per cent of measured soil C density. This study concluded that, in addition to the effect of uncertainty in the start conditions, the underestimation of the soil C-stock may partly be due to overestimation of decomposition rates of recalcitrant organic matter in the soil model and partly due to including only trees as a source of litter (de Wit et al. 2006).

The current application of Yasso does allow separate estimates for soil and dead wood. However, it does not take as input the registration of dead wood in the current inventory (with permanently established plots). It does take as input the registration of dead trees on an annual basis (natural mortality and harvest). For periods earlier than the establishments of the permanent plots the annual natural mortality is based on earlier NFI registrations of standing dead trees. Once a repeated registration of dead wood in the current NFI covers a complete inventory cycle (in 3 years) this information may be used for validation purposes.

**Drained organic soils** used for forest will lead to a substantial loss of C, and abandoning this measure will after some time lead to a slow accumulation of soil C. Due to the general increase in forest we assume no such abandonment. The area of drained organic soil has been drastically reduced since the 1960s (Figure 7.9). This is due to economic conditions and an increased focus on preserving mires. There is no national data on the CO<sub>2</sub> loss from drainage, and hence the method used corresponds to IPCC (2003) Tier 1. The loss is expected to be less than for agriculture soils drained, because of the contribution from forest waste. Due to lack of national emission factor the IPCC default factor for drained organic soils in managed forest (boreal), 0.16 Mg C ha<sup>-1</sup> year<sup>-1</sup>, is used. According to statistics from Statistics Norway, the area of drained organic soils (total accumulated) was 245.4 kha in 2010. The estimated emissions are about 144 Gg CO<sub>2</sub>.

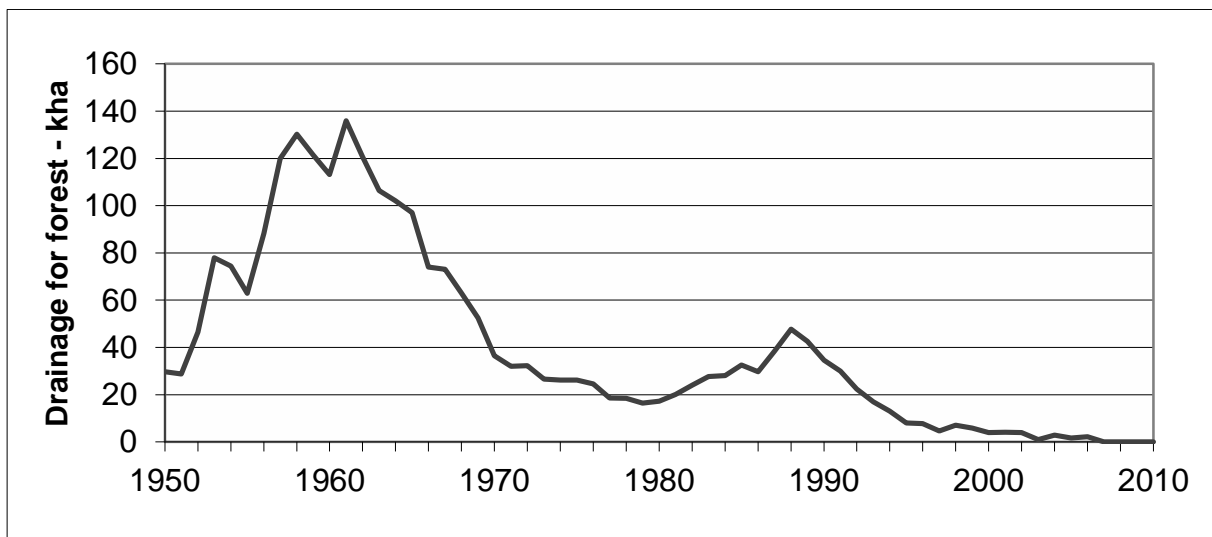


Figure 7.9 Drainage for forest – organic soil. Annually for the time period 1950–2010. Source: Statistics Norway.

### 7.3.2 Land converted to forest land and forest land converted to other land-use categories – 5A2, 5B2, 5C2, 5D2, 5E2, 5F2

We describe the methods and the emission factors together for all land converted to forest land (AR) and forest land converted to other land-use categories (D), because the same activity data and models has been used. All land use changes between the UNFCCC land-use categories are possible in Norway.

Estimates of carbon stock change are provided for living biomass and soil (including litter and other dead organic matter), except for wetlands converted to forest land. We assume that conversion from wetlands to forest land is a gradual process in which wooded mires over time reach the forest definition. These changes are considered not human induced, and hence no carbon stock change is estimated.

### 7.3.2.1 Methodological issues

The method used to estimate area of land converted to and from forest land during the previous 20 years is described in Section 7.2.1.1.

#### *Change in carbon stock in living biomass*

When a stand of trees reaches the predetermined minimum size and crown cover, the stand is measured by the NFI, the living biomass is assessed and the carbon stock change is calculated according to the Tier 3 method described for forest land remaining forest land. For areas subject to AR the annual change in carbon stock is based on the changes in trees under the coniferous tree line established on the land after 31. December 1989. According to the key category analysis, living biomass for land converted to forest land is identified to be a key category according to the Tier 2 trend assessment.

#### *Change in carbon stock in dead organic matter and soils*

The Yasso model used for forest land remaining forest land is not designed for obtaining dead organic matter and soil organic carbon for disaggregated areas of land-use categories. Therefore, the decomposition and soil carbon model Yasso07 was applied for the land converted to forest land (AR) and forest land converted to Settlements and Other land (D). Estimates of carbon stock changes from Yasso07 after land-use change were found to agree with measurements in the HILPE project in Finland. For Forest land converted to Cropland or Grassland emission factors are used (see below). A flow chart of the model is seen in Figure 7.10 (Liski et al. 2009, Tuomi and Liski 2009, Tuomi et al. 2009). The model produced an aggregated estimate of carbon stock change for the total of the litter, dead wood and soil organic matter. It is not possible to obtain separate estimates for these components with the current version of the model, hence the notation keys IE in the CRF-tables.

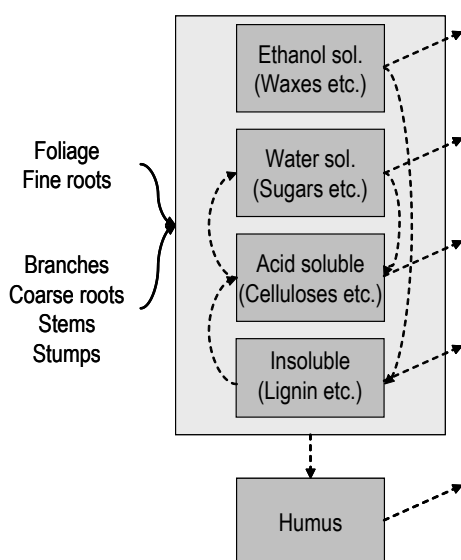


Figure 7.10 Flow chart of Yasso07 soil carbon model. The boxes represent soil carbon compartments and arrows carbon fluxes (Liski et al. 2009, Tuomi and Liski 2009, Tuomi et al. 2009).

[www.ymparisto.fi/syke/yasso](http://www.ymparisto.fi/syke/yasso)

Yasso07 represents processes for mineral soils down to a depth of 1 m. In the current submission all areas have been simulated as mineral soil. Yasso07 is used for conversion to

and from forest land on mineral soil. Soils were categorized according to the NFI definition of organic/mineral soil (more or less than 0.4 m organic layer). Weather data used as input to the model is a mean for areas subjected to AR and D, respectively. Interpolated weather data from the Norwegian Meteorological Institute (mean for 1991–2008<sup>17</sup>) were used for AR-areas (mean annual air temperature 3.88 C°; mean annual precipitation 1286.48 mm; mean amplitude for air temperature 8.19 C°), and for D-areas (mean annual air temperature 4.55 C°; mean annual precipitation 1208.60 mm; mean amplitude for air temperature 8.57 C°).

Conversions to forest land on organic soils are assumed to result in no changes of soil carbon. There is currently no empirical information or estimation methods available. For all Yasso07 simulations the litter input from 1990 to the current year of reporting 2010 was based on the different components (foliage, stem, roots, ..., etc.) of the living tree biomass. These were derived from the total of living tree biomass on areas subject to conversion, by using the proportion of each biomass components as found for all Norwegian forests. The biomass of the tree components was found by using biomass functions by Marklund (1988), and Petersson and Ståhl (2006) (e.g. stem constitute about 43 per cent and coarse roots constitute about 19 per cent of the total biomass). For the areas subject to conversion it was assumed that living tree biomass was equally distributed among the tree species; spruce, pine and birch. Litter production was determined by turnover rates as in de Wit et al. (2006). Natural mortality rates were assessed to 0.4 per cent of the living biomass per year. This mortality rate was equal to or lower than the rate observed for land-use change areas where the NFI registrations were available. In the current application it is assumed that no harvest occurred. Litter quality is described as in the Yasso07 manual.

(<http://www.ymparisto.fi/download.asp?contentid=100355&lan=en>).

Table 7.9 gives an overview of the methods applied for the different conversions and the assumptions associated with the starting value of soil carbon I of the previous land-use classes before conversion. The values are used to start the Yasso07 simulations. For some of the conversions the model was started by running litter input in many time steps (>1000) until the C pools in the model have reached a steady state where input is equal to output (= spin-up). The litter input used for the spin-up varies for each type of conversion. For the conversions from cropland and from grassland to forest land, the amount of litter was gradually increased until the result from the spin-up agreed with the published soil C stock for Norwegian cropland and grassland (references are given below). For the conversion “other to forest land” and from “forest land to other/settlements” the litter input used in the spin-up was found from the living tree biomass on other land and forest land respectively in the period 1993–1997 (inventory 7) on areas that have been subject to conversion after this period.

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<sup>17</sup> Changes in C stocks for litter, dead organic matter and soil on areas subject to conversion to or from forest land were estimated for the first time in 2010 (“Response to the Potential Problems and Further Questions from the ERT formulated in the course of the 2010 review of the greenhouse gas inventories of Norway submitted in 2010”, dated November 8<sup>th</sup> 2010). The methods in the current submission are identical to those used in 2010 only the areas and living tree biomass were updated with 2010 data and only on mineral soil.



*Table 7.9 Methods applied for the different type of land-use change and the assumptions used for the estimation of starting conditions at the time of land-use change in the cases where the model Yasso07 was applied.*

| Type of Land-use change                | Method  |
|--|---|
| AR: Settlements to Forest land         | Yasso07, C pool = 0 at time of change   |
| AR: Cropland to Forest land            | Yasso07, C pool = 152 ton C ha <sup>-1</sup> at time of change; reached by spin-up year 0 with equal input of litter from wheat and barley.   |
| AR: Grassland to Forest land           | Yasso07, C pool = 152 ton C ha <sup>-1</sup> at time of change; reached by spin-up year 0 with input of litter from grass.  |
| AR: Other to Forest land               | Yasso07, C pool at time of change based on spin-up with litter input for land use classes "Other+Wetland" represented by the NFI plots subject to change in the period 1990-2008. Living biomass on "Other" and "Wetlands" areas subject to land use change contained 6.15 tonne C ha <sup>-1</sup> . |
| D: Forest land to Other* / Settlements | Yasso07, C pool at time of change based on spin-up with litter input for LUC "Forest land" represented by the NFI plots subject to change in the period 1990-2008. Living biomass on "Forest land" areas subject to land use change to "Settlement" contained 44.65 tonne C ha <sup>-1</sup> .        |
| D: Forest land to Grassland            | Emission factors  |
| D: Forest land to Cropland             | Emission factors  |

*\*It is assumed that the land-use change from forest to other land has the same starting values as forest land converted to Settlements. Only an accumulated area equivalent to 2 NFI plots has been subject to the conversion "forest to other" and an estimate for this conversion alone would have been highly uncertain. In this submission the estimate is included in the estimates for Forest land converted to Settlements.*

#### *Land converted to forest land*

Using the above described method for running the Yasso07, a mean annual accumulation rate (2007-2008) of 1 ton C ha<sup>-1</sup> was estimated for areas going from "Settlements" to "Forest land". This rate is 2–6 times higher than accumulation rates estimated from a spruce forest chronosequence in southeast Norway (0.16–0.51 tonnes C ha<sup>-1</sup> yr<sup>-1</sup>; Kjønås et al. in prep.). In the simulations it was assumed that all soils under "Settlements" contained no C. A starting point of 0 in the model results in a large accumulation rate. 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. Evaluating the areas under "Settlements" and establishing a starting value for C content in the "Settlement" areas with vegetation is likely to induce a reduction of the total sink in this land-use change category. This is a potential improvement.

AR activities on both "Cropland" and "Grassland" areas induced emissions of C. This is likely to be a consequence of i) high starting values for soil C content of the agricultural land use classes and ii) low litter input in the forest as only litter from living trees are included.

The starting point for soil previously used as Grassland and Cropland are defined by the estimated mean C content in Norway on agricultural mineral soil (Grønlund et al. 2008b). This estimate (15.2 kg C m<sup>-2</sup>) is high compared to the median value for forest soils (12–13 kg C m<sup>-2</sup>, de Wit and Kvindesland 1999). The agricultural soil starting point needs to be qualified

to ensure that a starting point is used that represent the relevant areas and land-use classes. This was not possible for the current estimate, but will be part of the work for future improvements. Furthermore, in the current method two crops are used to establish a start condition for the Cropland soil. This assumption must be checked and improved if necessary to ensure that starting conditions for simulations are valid.

Litter from the ground vegetation in newly afforested and abandoned land is expected to be a significant part of total input to the soil (Kjønaas et al. in prep.). However, up until now there has been no possibility for estimating this input at the national scale. Future improvements will look at the possibility to include ground vegetation litter in the estimation method.

#### *Forest land converted to Cropland or Grassland*

For conversion from forest land to Cropland a general emission factor is used for the entire area. It is assumed that 0.6 tonnes C ha<sup>-1</sup> is lost annually on mineral soils and 8 tonnes C ha<sup>-1</sup> is lost annually on organic soils (Riley and Bakkegård, 2006, Grønlund et al., 2008a). Based on registrations on mineral and organic soil characteristics in the NFI since 1990 and up to the present, of areas subjected to these land-use changes, 10 per cent was characterized by organic soils. Emission on Grassland areas are assumed to be 0 (areas in equilibrium) based on Uhlen (1991) and Grønlund et al. (2008b). These conversions are represented by little area (few sample plots): Cropland 10 544 ha (ca. 10 plots), Grassland 21 089 ha (ca. 21 plots) relative to other conversions.

#### *Planned improvements*

In addition to above mentioned improvements, future submissions will use a higher degree of geographic disaggregation and area specific information on litter quality (tree species) will be applied. This current method is not considered final and is expected to undergo evaluation within the 2014 reporting.

## **7.4 Cropland 5B**

### **7.4.1 Cropland remaining cropland – 5B1 (Key Category)**

About 3 per cent of the total area of Norway is used as cropland. This category is found to be key category with respect to sequestration in soils (histosols) (Tier 2) because of uncertainty in level,

Most of the area for agriculture is used for annual crops which imply that the carbon is not stored over a very long time in aboveground biomass. An exception is horticulture. Carbon stocks in soils can be significant (IPCC, 2003). Land conversion to cropland from forest, grassland or wetlands usually results in a net loss carbon from biomass and soil to the atmosphere (IPCC, 2003). The soil carbon is, however, also affected by management practices (for example ploughing and fertilization) (Singh and Lal, 2004). In addition, Norwegian soils are limed to stabilize the pH. Liming contributes to improving the biomass production and the potential for carbon sequestration.

#### 7.4.1.1 Methodological issues

##### *Change in carbon stock in living biomass*

The annual changes in carbon stocks of cropland remaining cropland can be estimated as the sum of changes in living biomass and soil. The method implemented corresponds to Tier 1 of IPCC (2003).

Changes in living biomass have only been considered for perennial woody crops as in accordance with IPCC (2003). For annual crops, the increase of biomass in crops will equal loss from harvest and mortality the same year, thus there is no net accumulation or loss (IPCC, 2003). The notation key NO has been used in the CRF-tables. Perennial crops are used in horticulture. Statistics Norway collects data on the area of fruit trees (apple, pears, plum, cherry and sweet cherry). In general the area has been decreasing since 1990. There are no national data on their volume and carbon content. IPCC (2003) suggest default parameters for aboveground biomass carbon stock at harvest, biomass accumulation rate and biomass loss for temperate regions (it does not distinguish between vegetation types).

##### *Changes in biomass in existing areas of fruit trees:*

The IPCC default value for biomass accumulation rate is  $2.1 \text{ Mg C ha}^{-1} \text{ year}^{-1}$  (IPCC, 2003). This gives an annual uptake corresponding to only  $19 \text{ Gg CO}_2$  per year. The average age at harvest is somewhat lower than the IPCC default assumption (20–25 years). The average height is around 2 m and one tree occupies about  $10 \text{ m}^2$  according to the Norwegian University of Life Sciences. The “harvest” can then be estimated at around  $6.3 \text{ Gg C ha}^{-1}$ . The net  $\text{CO}_2$  uptake from these areas are reported under cropland remaining cropland – Horticulture (CRF 5.B.1).

##### *Conversion from perennial crops to other land categories:*

Until 2007 the area of fruit trees decreased. In 2007, 2008 and 2009 the area increased for then decreasing again in 2010. There is no statistics indicating directly to what type of land the fruit trees area has been converted to. Therefore, the net emissions of  $\text{CO}_2$  are reported under cropland converted to grassland when the area decrease (CRF 5.C.2.2.). When the area of fruit trees increase, the removals of  $\text{CO}_2$  are reported under grassland converted to cropland (CRF 5.B.2.2). In accordance with IPCC Tier 1 we assume that all carbon is lost at the year of harvest of the tree. The IPCC default value for carbon stock at harvest (temperate region) is  $63 \text{ Mg C/ha}$ . The resulting emissions are very small, see Table 7.10. (There is something wrong in the cells of notation keys for methof and EF used in CRF-table 5.B.2.2. Grassland converted to Cropland. It is not possible to correct the, .The notation keys should be NA for all years, except for 2007, 2008 and 2009. For those years the notation keys should be T1 for method and CS for EF used.)

Table 7.10 CO<sub>2</sub> emissions and removals due to changes in number of fruit trees for agriculture production

|      | Area<br>(kha) | Annual<br>uptake<br>(Gg) | Annual<br>C-loss<br>(Gg) | CO <sub>2</sub><br>emissions<br>(Gg) | CO <sub>2</sub><br>removals<br>(Gg) |
|------|---------------|--------------------------|--------------------------|--------------------------------------|-------------------------------------|
| 1989 | 3.21          |                          |                          |                                      |                                     |
| 1990 | 3.16          | 67.50                    | 3.33                     | 12.2                                 |                                     |
| 1991 | 3.11          | 66.39                    | 3.33                     | 12.2                                 |                                     |
| 1992 | 3.06          | 65.28                    | 3.33                     | 12.2                                 |                                     |
| 1993 | 3.00          | 64.17                    | 3.33                     | 12.2                                 |                                     |
| 1994 | 2.95          | 63.06                    | 3.33                     | 12.2                                 |                                     |
| 1995 | 2.90          | 61.95                    | 3.33                     | 12.2                                 |                                     |
| 1996 | 2.84          | 60.84                    | 3.33                     | 12.2                                 |                                     |
| 1997 | 2.84          | 59.73                    | 3.33                     | 12.2                                 |                                     |
| 1998 | 2.79          | 59.73                    | 0                        | 0                                    |                                     |
| 1999 | 2.72          | 58.62                    | 3.33                     | 12.2                                 |                                     |
| 2000 | 2.61          | 57.08                    | 4.60                     | 16.9                                 |                                     |
| 2001 | 2.59          | 54.83                    | 6.75                     | 24.8                                 |                                     |
| 2002 | 2.39          | 54.46                    | 1.13                     | 4.2                                  |                                     |
| 2003 | 2.36          | 50.09                    | 13.09                    | 48.0                                 |                                     |
| 2004 | 2.30          | 49.53                    | 1.69                     | 6.2                                  |                                     |
| 2005 | 2.23          | 48.39                    | 3.40                     | 12.5                                 |                                     |
| 2006 | 2.24          | 46.77                    | 4.88                     | 17.9                                 |                                     |
| 2007 | 2.32          | 47.13                    | 0                        | 0                                    | 4.0                                 |
| 2008 | 2.35          | 48.62                    | 0                        | 0                                    | 16.4                                |
| 2009 | 2.02          | 49.25                    | 0                        | 0                                    | 6.9                                 |
| 2010 | 3.21          | 42.48                    | 20.32                    | 74.5                                 |                                     |

\*Data for 1990–1998 have been interpolated. The green numbers indicate an update of activity data for that year. Source: Statistics Norway.

### ***Change in carbon stock in dead organic matter***

According to IPCC 2003 the carbon stock change in dead organic matter is not considered for cropland remaining cropland. In this inventory we have chosen to use the notation key NO in the CRF-tables.

### ***Change in carbon stocks in soils***

A country specific methodology has been employed for these calculations. We use a Tier 2 method and national data, taking into account how management practices affect the soil organic carbon which is in accordance with the IPCC (2003).

The IPCC default method takes into account a reference SOC and changes in management practices (tillage and input). IPCC (2003) has proposed default factors for correcting changes caused by management practices and input of organic matter over a 20 year period. Singh and Lal (2004) have considered the effect of ploughing and other management on SOC content in

soils. They conclude that the sequestration rate due to reduced tillage or increased N-application is higher in Norway compared to other countries, possibly due to lower temperatures and consequently lower rates of decomposition.

### *Erosion*

Carbon in Norwegian cropland soils has been studied by Singh and Lal (2001;2004). Singh and Lal (2001) have estimated C loss by *accelerated erosion* of agriculture and pasture land. Erosion leads to less productivity and consequently less biomass returned to soil, and it removes C from the site to somewhere else. On the whole, soil erosion leads to C emissions. In Norway, soil erosion is mainly a problem in south-eastern regions of the country. Based on assumptions on ploughing practices and erosion rates from these, Singh and Lal (2001) have estimated a net erosion rate of 2.2 Mg ha<sup>-1</sup> years<sup>-1</sup> under autumn ploughing. The rate in other areas is 0.44 Mg/ha/years. They assumed 70 per cent autumn plowing and 30 per cent spring stubble, arriving at an average of 1.67 Mg ha<sup>-1</sup> year<sup>-1</sup> for 1999. The grass and pasture erosion rate is 67 kg ha<sup>-1</sup> year<sup>-1</sup>.

In line with Singh and Lal (2001) the following equation has been used to estimate the erosion:

$$SOC\ loss = Area * soil\ loss * sediment\ delivery\ ratio * SOC * Enrichment\ ratio$$

The sediment delivery ratio is assumed to be 10 per cent, and the enrichment ratio is assumed to be 1.35. The mean carbon content of soils varies between regions, 27.3–58.7 g kg<sup>-1</sup>, a value of 40 per cent has been used in the calculations (all these assumptions were taken from Singh and Lal (2001)).

Finally, it is assumed that 20 per cent of the C transported by erosion is released to the atmosphere.

Other factors such as *Residue management, Crop rotations, Cover crops, Fertilizer and organic manure*, may contribute to acceleration or retardation in erosion (Singh and Lal, 2001). According to the discussion in NIJOS (2005) these factors are not accounted for in this report.

### *Tillage practices*

Tillage practices have been changing over the last 10 years aiming at reducing N-leakages and runoff. Farmers are informed and rewarded for reducing the tillage rates in vulnerable areas, in particular autumn tillage (Bye, 2002 and 2005), see Figure 7.11. The fraction of area under autumn tillage was 82 per cent in 1989/2000, which was reduced to 43 per cent in 2001/2002 (based on annual surveys).

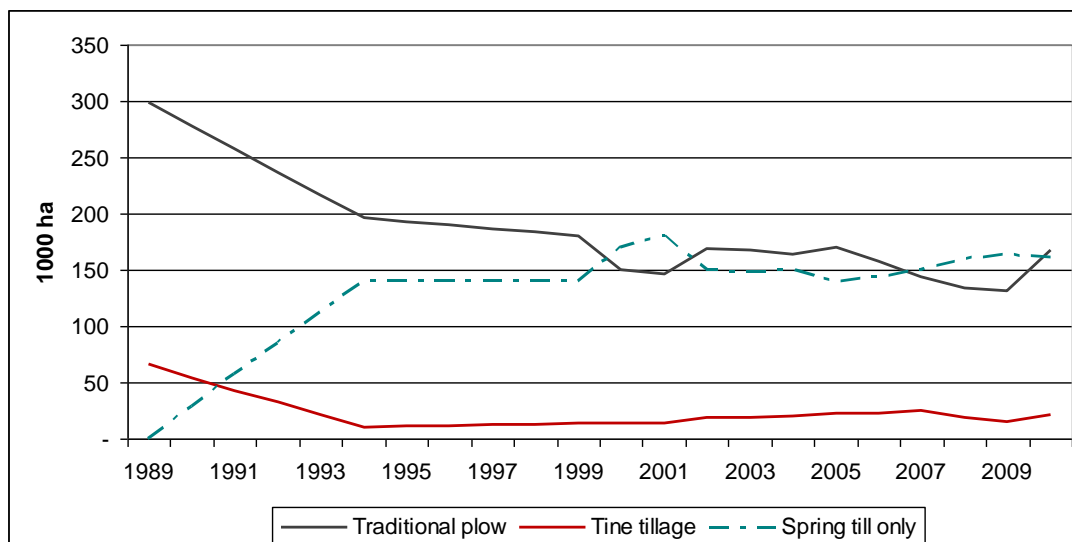


Figure 7.11 Tillage practices 1990-2010. Source: Statistics Norway.

Moving to autumn ploughing to tine has a very similar effect to minimum till. We assume that changes in tillage practices only have affected grain and oil crops (no change for potatoes and vegetables for example). Annual changes in management are taken from Statistics Norway (described in Section 7.2.3). The classes here are autumn till, shallow till, spring till (only) and no till. We have classified spring ploughing only as “minimum till”. Erosion emissions will only be on new (< 25 years) agriculture land, however, the effect of sequestration due to reduced tillage will be on all land where changed tillage is practiced, but the effect of this conversion will be negligible after around 25 years. The IPCC (2003) suggests a time-period of 20 years, but national agriculture experts consider a 25 years horizon as more appropriate for Norway.

The basic erosion factor for agriculture land under traditional till (autumn ploughing) is  $2.2 \text{ Mg ha}^{-1} \text{ year}^{-1}$  (Singh and Lal, 2001). This gives the following calculation:

$$C \text{ loss by erosion (kg C/ha/year)} = \text{Erosion rate} * C \text{ content} * \text{Delivery ratio} * \text{Enrichment ratio}$$

$$\text{Erosion rate} = 2.2 \text{ Mg ha}^{-1} \text{ year}^{-1}$$

$$C \text{ content} = 40 \text{ g kg}^{-1}$$

$$\text{Delivery ratio} = 10 \text{ per cent}$$

$$\text{Enrichment ratio} = 1.35.$$

$$C \text{ loss by erosion} = 12 \text{ kg C ha}^{-1} \text{ year}^{-1}$$

We propose to use the factor ( $12 \text{ kg C ha}^{-1} \text{ year}^{-1}$ ) only for newly cultivated agriculture areas over the last 25 years, because after that period the erosion loss will be negligible. Emissions and removals due to crop rotation have been ignored due to lack of data (NIJOS, 2005).

To estimate the erosion emissions statistics of new agriculture land from Statistics Norway have been used. All of this land is assumed used for grain production (grain area has been rather stable, while other crop production has been reduced). Further it is assumed that half of the new land is under autumn ploughing. In fact, a small amount is also used for grass production (may subtract “surface cultivated” area, around 5 per cent). To estimate the uptake due to reduced tillage we consider all area under no till, reduced till or tine. Because tine was

common previously and the difference between tine and minimum till is small, we subtract the 1979 tine area. After 25 years no more gain in soil organic carbon should be assumed. The results are shown in Table 7.11.

*Table 7.11 Erosion emissions due to ploughing and uptake due to reduced ploughing in Norway\**

|      | <b>25 year old<br/>agriculture<br/>area<br/>(kha)</b> | <b>Erosion<br/>emissions<br/>(Gg)</b> | <b>Area under tine, no till or<br/>minimum till, subtracted 1979<br/>tine area and part of the new<br/>agriculture area (kha)</b> | <b>Carbon<br/>uptake<br/>(Gg)</b> |
|------|---|---------------------------------------|---|-----------------------------------|
| 1990 | 151.6   | 1.50                                  | 0   | 0                                 |
| 1991 | 145.8   | 1.36                                  | 8.410   | 4.2                               |
| 1992 | 139.7   | 1.21                                  | 19.766  | 9.9                               |
| 1993 | 133.2   | 1.08                                  | 31.553  | 15.8                              |
| 1994 | 128.7   | 0.96                                  | 42.924  | 21.5                              |
| 1995 | 124.3   | 0.85                                  | 39.168  | 19.6                              |
| 1996 | 118.8   | 0.81                                  | 41.505  | 20.8                              |
| 1997 | 113.1   | 0.77                                  | 44.012  | 22.0                              |
| 1998 | 106.5   | 0.72                                  | 46.947  | 23.5                              |
| 1999 | 99.1  | 0.66                                  | 50.252  | 25.1                              |
| 2000 | 92.1  | 0.61                                  | 82.754  | 41.4                              |
| 2001 | 85.4  | 0.48                                  | 88.316  | 44.2                              |
| 2002 | 78.1  | 0.42                                  | 65.484  | 32.7                              |
| 2003 | 70.2  | 0.43                                  | 73.197  | 36.6                              |
| 2004 | 71.4  | 0.44                                  | 76.757  | 38.4                              |
| 2005 | 65.0  | 0.39                                  | 69.947  | 35.0                              |
| 2006 | 58.3  | 0.37                                  | 79.970  | 40.0                              |
| 2007 | 51.3  | 0.31                                  | 90.348  | 45.2                              |
| 2008 | 45.1  | 0.25                                  | 95.949  | 48.0                              |
| 2009 | 39.9  | 0.21                                  | 97.727  | 48.9                              |
| 2010 | 37.5  | 0.20                                  | 101.814   | 50.9                              |

\* The green numbers indicate an update of activity data for that year.

Source: Statistics Norway.

For vegetables and potatoes we can assume the same erosion rate as traditional till ( $12 \text{ kg ha}^{-1} \text{ year}^{-1}$ ). The reason is that when harvested roots are taken from the soil, a subsequent carbon loss will occur. The area of vegetables is around 15 118 ha. However, because the area of potatoes has been decreasing in the nineties, we assume that all area of vegetable and potatoes has been agriculture area for more than 25 years, and we assume no erosion loss of carbon.

### *Grassland*

For grassland Singh and Lal (2001) propose a basic erosion rate of  $0.067 \text{ Mg ha}^{-1} \text{ year}^{-1}$  applied to areas which are less than 25 years old. The following equation was used:

*C loss by erosion (kg/ha/year) = Erosion rate \* C content \* Delivery ratio \* Enrichment ratio.*

Erosion rate = 0.067 Mg ha<sup>-1</sup>year<sup>-1</sup>

C content = 40 g kg<sup>-1</sup>

Delivery ratio = 10 per cent

Enrichment ratio = 1.35

This gives an estimate of C loss by erosion equal to 0.36 kg ha<sup>-1</sup>year<sup>-1</sup>.

#### *New area for pastures and meadows*

New area for pastures and meadows are according to Statistics Norway at present around 4 166 ha annually. Assuming the same rate the last 25 years (was in fact higher previously) we get annual emissions that are very small (less than a Gg C). Some if this area may also be drained organic soils (see below).

#### *Cropland on organic soils (histosols)*

There is also a CO<sub>2</sub> loss due to cropland on *organic soils* (histosols). Conversion of wetlands to cropland has decreased over the years, due to changes in the agricultural management. According to IPCC (2003) the accumulated area of organic soils has been multiplied with an emission factor. The default value for cold temperate region is 1.0 Mg C/ha/year.

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 Skog og landskap (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 Skog og landskap 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 km<sup>2</sup>. After 1995 the area has decreased due to the transition to mineral soil after the peat layer has decomposed and cultivated moors 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 2010, pers. Comm.<sup>16</sup>) based on four different estimates for reduction and new cultivation. Four scenarios are developed based on the assumptions of an annual area decline of 1.4 or 1.0 per cent combined with an annual cultivation of new moor of 2 000 alt. 4 000 dekar, respectively 2 and 4 km<sup>2</sup>.

In this submission we have used the same time-series as reported for histosols under the agricultural sector (Chapter 6.4.2.6).

According to Bioforsk (Arne Grønlund, pers. Comm. 2005) the soil database of farmer soil samples (used for advising on liming and fertilization) indicates the following distribution between crop types:

Grass: 86 per cent

Cereals: 9 per cent

Other crops (potatoes, vegetables, green fodder): 5 per cent



As soils samples are likely to be underrepresented on grass compared to cereals and more intensive productions, about 90 per cent of the farmed organic soils are used for grass. In this inventory we assume that 10 per cent of the organic soil area is used for agriculture, the rest for grassland. For a discussion of emission factors, see “grassland remaining grassland” in Section 7.5.1.

Table 7.12 Annual emission of Gg CO<sub>2</sub> from agriculture farmed organic soils (histosols).

|      | Total<br>area<br>kha | Cropland    |                                      | Grassland   |                                      |
|------|----------------------|-------------|--------------------------------------|-------------|--------------------------------------|
|      |                      | Area<br>kha | CO <sub>2</sub><br>emissions<br>(Gg) | Area<br>kha | CO <sub>2</sub><br>emissions<br>(Gg) |
| 1990 | 85.19                | 8.52        | 208.25                               | 76.67       | 1 874.22                             |
| 1991 | 85.19                | 8.52        | 208.25                               | 76.67       | 1 874.24                             |
| 1992 | 85.19                | 8.52        | 208.25                               | 76.67       | 1 874.26                             |
| 1993 | 84.17                | 8.42        | 205.76                               | 75.76       | 1 851.83                             |
| 1994 | 83.17                | 8.32        | 203.31                               | 74.85       | 1 829.75                             |
| 1995 | 82.47                | 8.25        | 201.60                               | 74.23       | 1 814.39                             |
| 1996 | 81.78                | 8.18        | 199.91                               | 73.60       | 1 799.23                             |
| 1997 | 81.10                | 8.11        | 198.25                               | 72.99       | 1 784.25                             |
| 1998 | 80.43                | 8.04        | 196.61                               | 72.39       | 1 769.46                             |
| 1999 | 79.77                | 7.98        | 194.98                               | 71.79       | 1 754.86                             |
| 2000 | 79.11                | 7.91        | 193.38                               | 71.20       | 1 740.43                             |
| 2001 | 78.46                | 7.85        | 191.80                               | 70.62       | 1 726.19                             |
| 2002 | 77.82                | 7.78        | 190.24                               | 70.04       | 1 712.12                             |
| 2003 | 77.19                | 7.72        | 188.69                               | 69.47       | 1 698.23                             |
| 2004 | 76.57                | 7.66        | 187.17                               | 68.91       | 1 684.51                             |
| 2005 | 75.95                | 7.60        | 185.66                               | 68.36       | 1 670.97                             |
| 2006 | 75.34                | 7.53        | 184.18                               | 67.81       | 1 657.59                             |
| 2007 | 74.74                | 7.47        | 182.71                               | 67.27       | 1 644.38                             |
| 2008 | 74.15                | 7.42        | 181.26                               | 66.74       | 1 631.33                             |
| 2009 | 73.57                | 7.36        | 179.83                               | 66.21       | 1 618.44                             |
| 2010 | 72.99                | 7.30        | 178.41                               | 65.69       | 1 605.72                             |

#### 7.4.1.2 Liming of agricultural soils – 5B1 (5IV)

Due mostly to low buffer capacity of soils, Norwegian soils may be limed using limestone (calcium carbonate –  $\text{CaCO}_3$ ). This results in process emissions of  $\text{CO}_2$ . The estimates are based on the lime consumption as reported by “The Norwegian Agricultural Inspection Service”. The emission factor is 0.44 ton  $\text{CO}_2$  per ton calcium carbonate applied (SFT 1990). This emission factor is based on the stoichiometry of the lime applied and is consistent with IPCC (2003). The method is a Tier 1 with a country specific emission factor.

The total emissions (Gg  $\text{CO}_2$ ) from this source are given for the entire time-series in Table 7.13 and the trend is shown in Figure 7.12. National total emissions have been reported yearly from 1990 and onwards, and are contained under the category “5.B.1. Cropland remaining cropland – 5(IV)  $\text{CO}_2$  emissions from agricultural lime application- Limestone  $\text{CaCO}_3$ ” in the CRF-tables.

In the centralized review of the 2009 and 2010 NIR submission, the ERT suggest Norway to explore using a Tier 2 approach, which could be performed by differentiating between different forms of lime and by applying country-specific Efs. This has not been done in the present report due to lack of Efs.

#### 7.4.1.3 Liming of lakes – 5G (5IV)

For several years many lakes in the southern parts of Norway has been limed to reduce the damages from acidification. The total emissions are given for the entire time-series in Table 7.13 and the trend is shown in Figure 7.12.. The amount of calcium carbonate used for liming of lakes was collected from Directorate for Nature Management. The emission factor used is 0.44 ton  $\text{CO}_2$  per ton calcium carbonate applied (SFT, 1990). The emissions are reported under “5G. Other – Liming of lakes – 5(IV)  $\text{CO}_2$  emissions from agricultural lime application – Limestone  $\text{CaCO}_3$ ”.

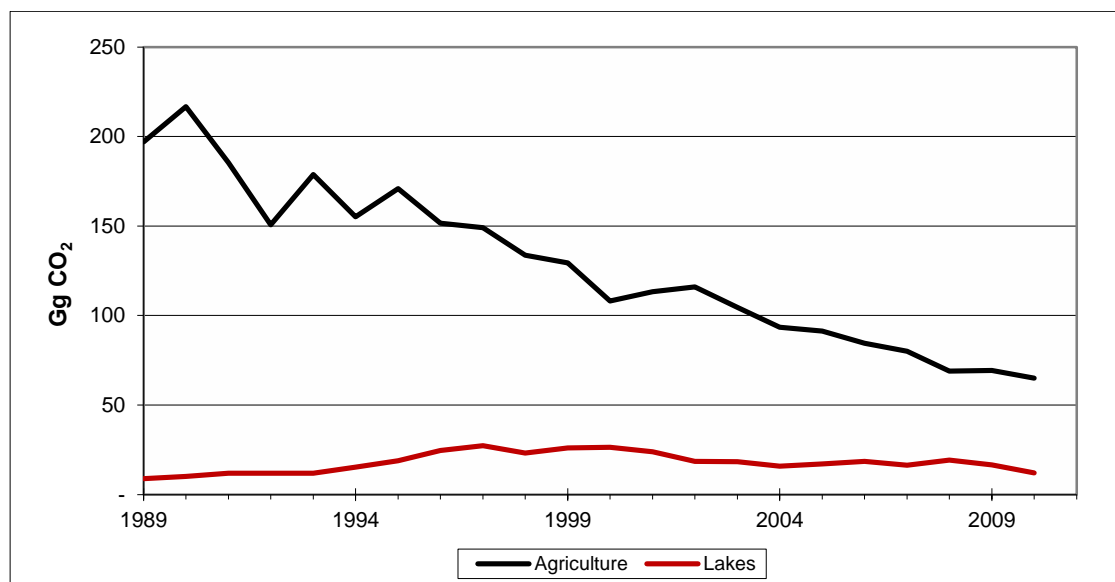


Figure 7.12 Emission of  $\text{CO}_2$  caused by liming of agricultural soils and lakes, 1980–2010.

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*Table 7.13 Amount of lime applied to agricultural area and lakes, and corresponding CO<sub>2</sub> emissions. 1990–2010.*

|      | Agriculture                 |                                | Lakes                       |                                |
|------|-----------------------------|--------------------------------|-----------------------------|--------------------------------|
|      | Amount of lime applied (Mg) | CO <sub>2</sub> emissions (Gg) | Amount of lime applied (Mg) | CO <sub>2</sub> emissions (Gg) |
| 1990 | 492 407                     | 217                            | 23 000                      | 10                             |
| 1991 | 421 163                     | 185                            | 27 000                      | 12                             |
| 1992 | 342 638                     | 151                            | 27 000                      | 12                             |
| 1993 | 406 129                     | 179                            | 27 000                      | 12                             |
| 1994 | 352 415                     | 155                            | 34 869                      | 15                             |
| 1995 | 388 365                     | 171                            | 42 738                      | 19                             |
| 1996 | 344 389                     | 152                            | 55 752                      | 25                             |
| 1997 | 338 898                     | 149                            | 61 856                      | 27                             |
| 1998 | 304 041                     | 134                            | 52 802                      | 23                             |
| 1999 | 294 150                     | 129                            | 59 193                      | 26                             |
| 2000 | 245 884                     | 108                            | 60 076                      | 26                             |
| 2001 | 257 696                     | 113                            | 54 118                      | 24                             |
| 2002 | 263 499                     | 116                            | 42 089                      | 19                             |
| 2003 | 237 631                     | 105                            | 41 833                      | 18                             |
| 2004 | 212 546                     | 94                             | 36 003                      | 16                             |
| 2005 | 207 325                     | 91                             | 38 684                      | 17                             |
| 2006 | 192 030                     | 84                             | 42 258                      | 19                             |
| 2007 | 181 858                     | 80                             | 37 382                      | 16                             |
| 2008 | *156 783                    | 69                             | 43 583                      | 19                             |
| 2009 | 157 706                     | 69                             | 37 830                      | 17                             |
| 2010 | 147 977                     | 65                             | 27 369                      | 12                             |

*\*No data available for 2008. The reported value is an interpolation between 2007 and 2009. The Norwegian Food Safety Authority stopped collecting the amount of lime from shellsand in 2009, this caused the drop in activity data. The green numbers indicate an update of activity data for that year compared to the last submission.*

*Source: Norwegian Food Safety Authority.*

The ERT noted for the 2005 submission that Norway uses the same emission factor as the one applied to cropland, as all lime is assumed to emit CO<sub>2</sub>. The ERT recommended that Norway should provide additional information in the NIR to support the use of the agriculture emission factor for the application of lime to water. Norway response was that it did not see why lime in water should emit less CO<sub>2</sub> than lime in soil. These annual emissions are very minor, thus Norway will continue to use the agriculture emission factor for the application of lime to water.

## **7.4.2 Land converted to cropland – 5B2**

### **7.4.2.1 Methodological issues**

Land conversion to cropland from forest, grassland or wetlands usually results in a net loss carbon from biomass and soils to the atmosphere (IPCC, 2003).

#### ***Change in carbon stock in living biomass***

When forest land is converted to cropland the losses are calculated. Generally, for all other land conversions we assume no changes in carbon stocks in living biomass is not estimated due to lack of data and method. Furthermore, the changes are regarded as negligible. There is one exception when the area of horticulture increases. Then the removals of CO<sub>2</sub> are reported under grassland converted to cropland.

#### ***Change in carbon stock in dead organic matter***

The estimate of carbon stock change in dead organic matter is for forest land converted to cropland included in the estimates of carbon stock change in soil. This is discussed in chapter 7.3.2.1. Due to lack of methods, it is not mandatory to report carbon stock change in dead organic matter for land conversions to cropland, hence the notation key NE in the CRF-reporter.

#### ***Change in carbon stocks in soils***

##### ***Forest land converted to cropland***

The method used for calculating emission from or forest land converted to cropland is described in chapter 7.3.2.1.

##### ***Conversions from all other land use***

Because the basic agriculture erosion factor is based on the one for grassland, we assume no immediate loss when other land-use categories are converted to cropland. Losses are accounted for according to the changes in management (see cropland remaining cropland).

Conversions between wetlands to cropland are negligible. The conversion from wetlands to agriculture land was addressed above, under cropland remaining cropland (cropland on organic soil).

## **7.5 Grassland 5C**

According to the area definitions, grassland also includes pasture. Grasslands are used for harvest and pasture. Parts of the pasture land are in the mountains. Pasture practices have been changing over the last decades, gradually leading to altered vegetation (including expansion of forests and other wooded land).

### **7.5.1 Grassland remaining grassland – 5C1 (Key Category)**

As for cropland, we consider changes in soil carbon. According to the Tier 2 key category analysis this category is identified as key category with respect to changes in carbon stock in soils (histosols) because of uncertainty in level and trend. Changes in management have, however, influenced the vegetation on pastures. Gradually, some of this area will fall under the forest definition.

### 7.5.1.1 Methodological issues

#### *Change in carbon stock in living biomass*

No changes in living biomass are assumed for grassland remaining grassland because the mass of above ground biomass is small and is in a steady state in accordance with IPCC (2003) Tier 1, hence the notation key NO in the CRF tables.

#### *Change in carbon stock in dead organic matter*

No change in dead organic matter is assumed for this category because the mass of aboveground biomass is small and is in a steady state in accordance with IPCC (2003), hence the notation key NO in the CRF tables.

#### *Change in carbon stocks in soils*

As for cropland, we consider changes in carbon stocks in soil. Large amounts of carbon are stored in roots and soils. There have not been any major changes in management of grasslands (apart from pasture) in Norway. Consequently, that would justify ignoring carbon losses or uptake from mineral soils on existing grassland area. For grassland which is harvested (meadow) we have used the erosion factor of Singh and Lal (2001) of  $0.78 \text{ kg C ha}^{-1} \text{ year}^{-1}$ . This factor should, however, only be applied to grassland which is younger than 25 years, see discussion under “cropland remaining cropland” in Section 7.4.1.

There will be a loss of carbon from grassland on *organic soils*. As discussed for cropland, it is assumed that 90 per cent of organic soil used for agriculture production is used for grass production (organic soils are not suited for example for producing grain). The IPCC default emission factor is  $0.25 \text{ Mg C ha}^{-1} \text{ year}^{-1}$  for cold temperate regions. However, according to Norwegian measurements emission can be larger because the age of the organic soils is lower than in Southern Europe. The average subsidence has been estimated by Bioforsk at  $2 \text{ cm year}^{-1(18)}$  which is equivalent to  $20 \text{ Mg C ha}^{-1(19)}$ . Some of this reduction is due to compaction and can be attributed to a sink in the height of the soil layer<sup>(20)</sup>. The soil loss also includes leaching of organic components in the drainage water. Based on measurements the emission losses of  $\text{CO}_2$  from farmed organic soils in Sweden and Finland have been reported to be between 200 and  $1\,000 \text{ g CO}_2\text{-C m}^{-2} \text{ year}^{-1}$  (Final report from the EU Project Greenhouse Gas Emissions for Farmed Organic Soils (GEFOS)). This corresponds to  $2\text{--}10 \text{ Mg ha}^{-1} \text{ year}^{-1}$ . The assumptions on C-losses are also justified because a change in C/N ratio over time is observed. We propose using a loss factor of  $10 \text{ Mg C ha}^{-1} \text{ year}^{-1}$  for high organic matter soil. For mixed organic soils the factor will be lower, we propose using  $5 \text{ Mg C ha}^{-1} \text{ year}^{-1}$  (expert judgement).

Of the total area of histosols given in table 7.12, 90 per cent were assumed used for grass production. Of these we assume one third is highly organic, the rest is mixed. The annual emissions are given in table 7.12.

Given the importance of this estimate compared to other sources and the large difference from the IPCC default value, about  $21 \text{ Gg C year}^{-1}$  ( $78 \text{ Gg CO}_2$ ), it is recommended to further improve the emission factor (measurements, modeling, literature). Other Nordic countries have similar agriculture practices. We will propose to reconsider the Norwegian emission

<sup>18</sup> Meadow. The decrease in layer is larger on field grassland. However, organic soils are rarely used for the purpose.

<sup>19</sup> Assuming a soil density of  $0.2 \text{ kg/l}$ , and 50 per cent C.

<sup>20</sup> Assuming a soil density of  $0.2 \text{ kg/l}$ , and 50 per cent C.

factors in light of results conducted in Sweden and Finland. This is planned to be done within the reporting in 2014.

There is no practice of liming grassland in Norway, hence the notation key NO is used in the CRF-tables.

## **7.5.2 Land converted to grassland – 5C2**

### **7.5.2.1 Methodological issues**

#### ***Change in carbon stock in living biomass***

Carbon stock change in living biomass is calculated for conversion of forest land to grassland (described in Chapter 7.3.2) and when the area of cropland used for horticulture is decreasing. Carbon stock changes for all other land use changes are not estimated, thus the notation key NE is used in the CRF-tables. For cropland converted to grassland this is justified because the IPCC (2003) defaults for aboveground biomass are quite similar for grassland and cropland. (5 Mg carbon ha<sup>-1</sup> for cropland, 8.5 Mg dry matter ha<sup>-1</sup> for grassland (boreal zone) equal to 4.2 Mg C ha<sup>-1</sup> given a carbon content of 0.5) For all other land-use changes to grassland the change in carbon stock for living biomass is regarded as negligible. This is justified because the land area of wetlands, settlements and other land converted to grassland is in average 0.7 kha per year since 1990. In addition, according to IPCC (2003) the implications of converting other land to grassland are uncertain. .

#### ***Change in carbon stock in dead organic matter***

The estimate of carbon stock change in dead organic matter is not estimated for forest land converted to grassland due to lack of data, hence the notation key NE in the CRF tables. This is discussed in chapter 7.3.2.1. 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 dead organic matter is not considered when land is converted to grassland.

#### ***Change in carbon stocks in soils***

The soil organic carbon in grazing land and unmanaged grassland is not known. However, much of the grassland will be in mountain areas where the soil organic carbon can be low.

#### ***Conversion of forest land to grassland***

There are some transitions from forest land to grassland, approximately 1 kha per year since 1990. The Norwegian Forest and Landscape Institute has estimated the mean carbon content in productive forest to 13.6 kg C per m<sup>2</sup> (de Wit, H. A., and S. Kvindesland, 1999). The corresponding mean value for all cultivated mineral soils (both grassland and cropland) has been calculated at 15 kg C per m<sup>2</sup> (Grønlund et al. 2008). These results indicate no large difference in carbon content between forest and cultivated soils. Land with tree cover may be classified as grassland if grazing is considered more important than forest. Thus the carbon stock change in soil is regarded as negligible when forest land is converted to grassland, hence the notation key NE in the CRF tables.

#### ***Conversion of cropland to grassland***

When cropland is converted to grassland the soil organic matter may change due to changes in management, for example ploughing and N-fertilization. The result is expected to be a net uptake. According to Statistics Norway the managed grassland area have increased in the

nineties. Bioforsk confirms that farms with animals (and grass production) have a slightly higher soil organic carbon than those without (NIJOS, 2005). There are no data for grassland outside home fields, but they usually have a lower soil organic carbon. IPCC default Tier 1 method accounts for differences in soil organic carbon in the land use conversion according to changes in management. Assuming that the grassland is nominally managed and the same level of fertilization, also the IPCC (2003) default method indicates no change. We assume the changes in soil organic carbon when cropland is converted to grassland to be negligible, hence the use of notation key NE in the CRF tables. Furthermore, this is a conservative approach since the result of this conversions are expected to be a net uptake

#### *Conversion of wetland to grassland*

See discussion on drained organic soils under “grassland remaining grassland” in Section 7.5.1. The notation key NE is used in the CRF tables.

#### *Conversion of other land to grassland*

Due to lack of data and emission factors, no estimates are given for carbon stock change in soil when other land-use is converted to grassland, hence the notation key NE in the CRF tables.

Due to the sparse soil in the land use category "other land" we assume that the results of these conversions will be a net uptake of CO<sub>2</sub>. Therefore, the approach not to provide estimates for this conversion is regarded as conservative. Furthermore, the area of other land converted to grassland is small and the carbon stock changes are regarded as negligible.

## **7.6 Wetlands 5D**

Most of the wetlands in Norway are unmanaged mires, bogs and fens, as well as lakes and rivers. Managed wetlands include peat extraction and reservoirs (dams).

### **7.6.1 Wetlands remaining wetlands – 5D1**

Wetlands remaining wetlands is only covered in appendix 3a.3 in the Good Practice Guidance (IPCC, 2003). That means that reporting is not mandatory. Consequently, changes in carbon stocks in unmanaged wetlands and reservoirs have not been considered in this report.

#### **7.6.1.1 Methodological issues**

##### *Reservoirs*

At present there exists no readily available water or land-use change statistics related to dams or reservoirs. Reservoirs should be considered in the future due to the many hydroelectric power stations in Norway. Regarding the SINTEF-StatKraft project the preliminary results are classified information according to the Norwegian Water Resources and Energy Directorate. If and when the findings of this project will be declassified is not known at this time.

##### *Peat extraction*

Changes in carbon stocks for peat extraction are estimated with a Tier 1 method based on Swedish emission factors. According to Bioforsk, peat extraction in Norway is between 220 000 and 300 000 m<sup>3</sup> year<sup>-1</sup> (we assume no change in extraction). The extraction is around 5–

10 cm year<sup>-1</sup>. This corresponds to 13 m<sup>2</sup> m<sup>3-1</sup>. The total area harvested is consequently around 338 ha.

The IPCC default method considers only change in soil carbon during peat extraction. Changes in biomass and changes in soil carbon due to other processes associated with extraction (drainage, stockpiling, etc) are assumed to be zero at Tier 1. Extraction is assumed to enhance oxidation, leading to a continuing decrease in soil carbon. Although some of the extraction areas may belong to the temperate zone, we propose using the default emission factor for nutrient poor bogs in the boreal zone. The IPCC emission factor is 0.2 Mg C ha<sup>-1</sup> year<sup>-1</sup>.

We propose using emission factors for Sweden (Uppenberg et al. (2001)). Prior to drainage and extraction the peat land acts as a small carbon sink (62-96 g m<sup>-2</sup> year<sup>-1</sup>). During extraction emissions will be around 10 Mg CO<sub>2</sub> ha<sup>-1</sup> year<sup>-1</sup> (2.7 Mg C ha<sup>-1</sup> year<sup>-1</sup>), somewhat lower after drainage and before extraction. Because the age of the harvested area is not known, we apply the same emission factor for every year.

This gives an annual estimate of 0.9 Gg C or 3.4 Gg CO<sub>2</sub>.

#### *Wooded mire*

Wooded mire according to Norway's national definition will be classified as forest, if the requirements of the international forest definition are met. The rest of wooded mire would be considered "other wooded wetland", and could form a subgroup under "wetlands". The living biomass is, however, negligible compared to forest, and the usefulness of forming such a category would be questionable.

#### *Liming*

Lakes are limed in Norway to stabilize the pH. The methodology is explained in Section 7.4.1.3 (see Table 7.13 and Figure 7.12). The corresponding emissions of CO<sub>2</sub> vary annually.

#### *Other wetlands*

Other wetlands are considered unmanaged, and no emissions and removals are estimated that is in line with IPCC 2003.

### **7.6.2 Land converted to wetlands – 5D2**

No data are available on land converted to managed wetlands. In practice, this is only relevant for reservoirs. Land taken into use for peat extraction would normally be unmanaged wetlands.

Furthermore, conversion of forest land to wetlands is expected to be a slow process, because this involves re-growth of ditches and a steady increase in water level. Additionally, a conversion to the land-use category 'wetlands' requires a reduction in tree cover, otherwise the land would still be considered forest. Clearly, drained forest must have been abandoned for some time in order to return to the land-use category of wetlands.

We assume no loss or uptake of carbon when other land-use is converted to wetlands, because we assume the features of these areas will approach those of wetlands, hence the notation key NO in the CRF tables.



## 7.7 Settlements 5E

### 7.7.1 Settlements remaining settlements – 5E1

Reporting of emissions and removals from this category is not mandatory. There are, furthermore, no data available in Norway to estimate the tree biomass. Changes in carbon stocks for settlements remaining settlements have consequently not been estimated and the notation key NE has been used in the CRF-tables.

### 7.7.2 Land converted to settlements – 5E2 (Key category)

IPCC (2003) suggests a method in which only forest biomass is considered. Thus, all other carbon stock changes when land categories are converted to settlements are not estimated, hence the notation key NE in the CRF-tables. IPCC further suggests as a Tier 1 method that all biomass is lost in the year of conversion.

According to the Tier 2 key category analysis forest land converted to settlements is found to be a key category with respect to losses of living biomass and for soil. It is introduced a new method to calculate carbon stock change for the category forest land converted to settlements.

#### *Change in carbon stock in living biomass*

We assume that all the biomass is lost the year of conversion when forest land is converted to settlements. The emission is calculated following the stock change methods. Due to lack of method carbon stock changes for living biomass have not been estimated for any other land use conversions to settlements (IPCC, 2003), hence the notation key NE in the CRF tables.

#### *Change in carbon stock in dead organic matter*

The estimate of carbon stock change in dead organic matter is for forest land converted to settlements included in the estimates of carbon stock change in soil, hence the notation key IE in the CRF tables. This is discussed in chapter 7.3.2.1. Due to lack of method, carbon stock changes for dead organic matter have not been estimated for any other land conversions to settlements (IPCC, 2003), hence the notation key NE in the CRF tables.

#### *Change in carbon stocks in soils*

When forests are converted to settlements it is reasonable to assume that soils will be disturbed in order to make the surface suitable for building purposes, for instance by leveling the surface and by removing the top soil. As most carbon is in the top soil, it seems reasonable to assume that most soil carbon will be lost in a short time. In this inventory, change in soil carbon has been calculated for forest land converted to settlements according to the method described in Chapter 7.3.2.1. No change in carbon stock in soil has been estimated for any other land-use changes to settlements, due to uncertainty about the methods and in accordance with IPCC (2003), hence the notation key NE in the CRF tables.

## **7.8 Other land 5F**

### **7.8.1 Other land remaining other land – 5F1**

#### **7.8.1.1 Methodological issues**

##### ***Change in carbon stock in living biomass***

It is not mandatory to report carbon stock in living biomass. This is in accordance with IPCC (2003) because this land is considered unmanaged.

##### ***Change in carbon stock in dead organic matter***

It is not mandatory to report carbon stock in dead organic matter. This is in accordance with IPCC (2003), because this land is considered unmanaged.

##### **Change in carbon stocks in soils**

It is not mandatory to report carbon stock in soils. This is in accordance with IPCC (2003) because this land is considered unmanaged.

### **7.8.2 Land converted to other land – 5F2**

#### **7.8.2.1 Methodological issues**

##### ***Change in carbon stock in living biomass***

In the case of conversion from forest land to other land, the carbon stock change in biomass will be reported because the NFI is following all areas over time. Due to the 20 years approach for the land-use transition, there can be reported changes in carbon stock for living tree biomass for land converted to other land. Due to lack of methods and data no estimates for carbon stock changes of living biomass are provided for all other land categories conversions to other land, hence the use of notation key NE in the CRF tables. The carbon stock change is regarded as negligible.

##### ***Change in carbon stock in dead organic matter***

The estimate of carbon stock change in dead organic matter is for forest land converted to other land included in the estimates of carbon stock change in soil, hence the use of notation key IE in the CRF tables. This is discussed in chapter 7.3.2.1. Due to lack of methods and data, no estimates for carbon stock changes of dead organic matter are provided for all other land categories conversions to other land, hence the use of notation key NE in the CRF tables. The carbon stock change is regarded as negligible.

##### ***Change in carbon stocks in soils***

The estimates for carbon stock change in soils when forest land is converted to other land is included in the estimates for forest land converted to settlements, hence the notation keys IE in the CRF tables (explained in Chapter 7.3.2.1). For all other land use conversions to other land we no estimates for carbon stock changes of soil organic matter are provided. This is due to lack of methods and data. The notation key NE is used in the CRF tables. The carbon stock change is regarded as negligible.

## 7.9 Other 5G

### 7.9.1 Liming of agricultural soils and lakes

Emissions of CO<sub>2</sub> from liming of agricultural soils and lakes are included in this category. The descriptions of the methodologies are contained in Section 7.4.1.2 and 7.3.1.3, respectively.

### 7.9.2 Harvested wood products

According to the IPCC default approach, emissions of CO<sub>2</sub> from harvested wood products (HWP) are accounted for in the year of harvest and the country of harvest. All harvested wood is thus assumed to be oxidized to CO<sub>2</sub> in the year of harvesting, and no wood are assumed to be stored in long-lived products. Much of the harvested wood will however be stored for a shorter or longer period of time before it oxidizes. In the 2009 and 2010 submissions, Norway has estimated the net removals from HWP following the stock change approach (SCA) and the revised method. Due to Decision 2/CMP.7 in Durban, the SCA approach can no longer be used after 2015. In this submission Norway has hence started using the *production approach* (PA) and the IPCC HWP method for the reporting of HWP to the UNFCCC. The results are included in annex VII to this report. The results are preliminary and will be recalculated in future submissions. The contribution from HWP is not included in the LULUCF category “5G-Other”.

## 7.10 Emissions of non-CO<sub>2</sub> gases

Changes in forest and other land-use change will influence emissions of other greenhouse gases than CO<sub>2</sub>. Emissions of methane (CH<sub>4</sub>) are caused by fires. Changes in land-use may also change natural emissions, but according to the IPCC methodology these changes are not included in the accounting framework. Emissions of nitrous oxide (N<sub>2</sub>O) are in addition to fires caused by soil organic matter mineralization, nitrogen input and cultivation of organic soils. Indirect emissions are not considered in this sector, but under agriculture. Emissions of N<sub>2</sub>O from land converted to cropland are estimated. According to IPCC (2003) liming of forest and forest management may change N<sub>2</sub>O emissions, but the effect is uncertain. Norwegian forest is, however, not subject to liming. The emissions of non-CO<sub>2</sub> gases are small (non-key) and default parameters and methods have been applied in most circumstances. Norwegian experts, and to some extent Swedish, have been contacted in search for improved information.

Emissions and removals in the Appendices of IPCC (2003) have only partly been included. Methodologies have been presented in NIJOS (2005) for further methodology development, but the corresponding emissions can be reported if national information is available. For the non-CO<sub>2</sub> GHG reservoirs can be a source in Norway, but the corresponding emissions have not been estimated.

### 7.10.1 Forests

N<sub>2</sub>O is produced in soils as a by-product of nitrification and denitrification. Emissions increase due to input of N through fertilization and drainage of wet forest soil (IPCC, 2003). Forest management may also alter the natural methane sink in undisturbed forest soils (IPCC, 2003), but data does currently not allow a quantification of this effect. According to IPCC (2003) fertilizer input is particularly important for this process, but fertilization of forest is of little importance in Norway.

### *N<sub>2</sub>O from fertilization*

Because national emission factors for fertilization of forest soil are unavailable the estimate is based on Tier 1 and default emission factors.

$$N_2O\text{-direct fertiliser} = (F_{Statistics\ Norway} + F_{ON}) * EF_1 * 44/28$$

Where:

$F_{Statistics\ Norway}$  = the amount of synthetic fertilizer applied to forest soil adjusted for volatilization as  $NH_3$  and  $NO_x$ . Gg N.

$F_{ON}$  = the amount of organic fertilizer applied to forest soil adjusted for volatilization as  $NH_3$  and  $NO_x$ . Gg N.

$EF_1$  = Emission factor for emissions from N input, kg  $N_2O$ -N/kg N input.

There are national statistics on the area with fertilizer applied. This area is very small, only 7 km<sup>2</sup> in 2004 and 26 km<sup>2</sup> in 1990 (Statistics Norway, Forestry Statistics). The statistics do not specify whether this is synthetic or organic fertilizer. Furthermore, it does not say anything about the amount applied. Statistics Norway has supplied unpublished data on application on synthetic fertilizer for the period 1995-2005. The average ratio between the amount applied and the area fertilized was used to estimate the amount applied for 1990–1994. It is assumed that organic fertilizer is not applied to forest in Norway. To the extent that it is applied, the associated emissions will be reported under agriculture (this assumption is according to IPCC 2003). The amount of fertilizer applied is given as total weight. The nitrogen content is depending on the type used. According to Statistics Norway, 95 per cent NPK-fertilizer is used on wetlands. On dry land about half is NPK and the rest N-fertilizer. The N-content of these were taken from YARA ([www.hydroagri.com](http://www.hydroagri.com)).

The default emission factor is 1.25 per cent of applied N. There are no national data to improve this. 1 per cent of the N-applied is volatilized as  $NH_3$  (the ammonia model of Statistics Norway).

Table 7.14 Estimated emissions 1990–2010 from fertilization of forest

|                    | Estimate of input of N, Mg |          |                         | Estimate of net amount of N applied, Mg |                 | Estimated emissions N <sub>2</sub> O, Mg |
|--------------------|----------------------------|----------|-------------------------|---|-----------------|--|
|                    | Wetland                    | Dry land |                         |   |                 |  |
| 1990               | 51                         | 177      |                         | 225                                     |                 | 4.4                                      |
| 1991               | 77                         | 271      |                         | 344                                     |                 | 6.8                                      |
| 1992               | 119                        | 210      |                         | 326                                     |                 | 6.4                                      |
| 1993               | 77                         | 150      |                         | 225                                     |                 | 4.4                                      |
| 1994               | 77                         | 140      |                         | 216                                     |                 | 4.2                                      |
| 1995               | 90                         | 138      |                         | 226                                     |                 | 4.4                                      |
| 1996               | 45                         | 179      |                         | 222                                     |                 | 4.4                                      |
| 1997               | 21                         | 200      |                         | 219                                     |                 | 4.3                                      |
| 1998               | 31                         | 216      |                         | 244                                     |                 | 4.8                                      |
| 1999               | 44                         | 183      |                         | 225                                     |                 | 4.4                                      |
| 2000               | 23                         | 124      |                         | 145                                     |                 | 2.8                                      |
| 2001               | 20                         | 100      |                         | 119                                     |                 | 2.3                                      |
| 2002               | 8                          | 155      |                         | 162                                     |                 | 3.2                                      |
| 2003               | 1                          | 71       |                         | 72                                      |                 | 1.4                                      |
| 2004               | 3                          | 71       |                         | 73                                      |                 | 1.4                                      |
| 2005               | 32                         | 61       |                         | 92                                      |                 | 1.8                                      |
| 2006               | 4                          | 38       |                         | 42                                      |                 | 0.8                                      |
| 2007               | 1                          | 68       |                         | 68                                      |                 | 1.3                                      |
| 2008               | 1                          | 88       |                         | 88                                      |                 | 1.7                                      |
| 2009               | 1                          | 94       |                         | 94                                      |                 | 1.8                                      |
| 2010               | 0                          | 61       |                         | 61                                      |                 | 1.2                                      |
| <i>Assumptions</i> |                            |          |                         |   |                 |  |
| Nitrogen content   | 15 %                       | 22.5 %   | Nitrogen volatilization | 1 %                                     | Emission factor | 1.25 %                                   |

Source: Fertilizer consumption Statistics Norway, N-volatilization Statistics Norway, N-content YARA and emission factors IPCC.

The resulting emissions are about 2–4 Mg N<sub>2</sub>O per year, which is very small compared to the emissions from agriculture. The emission factor is highly uncertain. According to IPCC (2003), the range in emission factor can be from 0.25 per cent to 6 per cent. The amount of fertilizer applied to forest should be subtracted from the input to the calculation of emissions from agriculture, because that figure is based on the total fertilizer sale.

#### ***N<sub>2</sub>O from drainage of forest soil***

Drainage of organic soils generates emissions of N<sub>2</sub>O in addition to CO<sub>2</sub>. Drainage will also reduce methane emissions and even generate a sink (IPCC, 2003). However, data are unavailable to estimate this effect (IPCC, 2003) and there are no national data to estimate this. Given that the area drained in Norway currently is low, no estimate is given for methane. This methodology is given in an appendix in IPCC (2003) (for further methodology development).

Because no national data are available, the estimation methodology for N<sub>2</sub>O is based on IPCC (2003). It is assumed that all drainage is related to organic soils.

$$N_2O \text{ emissions} = \text{Area of drained forest soil} * \text{emission factor}$$

The emission factor is taken from IPCC (2003). It is assumed that all soil is nutrient poor, the corresponding emission factor is 0.1 kg N<sub>2</sub>O-N/ha/year (0.6 for nutrient rich). The range of emission factor is from 0.02 to 0.3 which is an indication of the large uncertainty of the estimate. The activity data is the area of drained forest soil provided by Statistic Norway. This is reported in CRF under 5.A.1 *Forest land remaining forest land – 5(II) Non-CO<sub>2</sub> emissions from drainage of soils and wetlands – Organic soil – Area of N<sub>2</sub>O Emissions*.

Table 7.15 shows area drained and N<sub>2</sub>O emissions from drainage of forest soil from 1990 to 2010. About 245 000 ha have been drained accumulated since 1990. It is assumed that there is no rewetting of drained forest soils.

Table 7.15 Area drained and N<sub>2</sub>O emissions from drainage of forest soil, 1990–2010.

| Year | Area drained | Emissions |
|------|--------------|-----------|
| 1990 | 231.8        | 0.04      |
| 1991 | 234.8        | 0.04      |
| 1992 | 237.1        | 0.04      |
| 1993 | 238.8        | 0.04      |
| 1994 | 240.0        | 0.04      |
| 1995 | 240.8        | 0.04      |
| 1996 | 241.6        | 0.04      |
| 1997 | 242.1        | 0.04      |
| 1998 | 242.8        | 0.04      |
| 1999 | 243.4        | 0.04      |
| 2000 | 243.8        | 0.04      |
| 2001 | 244.2        | 0.04      |
| 2002 | 244.6        | 0.04      |
| 2003 | 244.7        | 0.04      |
| 2004 | 244.9        | 0.04      |
| 2005 | 245.1        | 0.04      |
| 2006 | 245.3        | 0.04      |
| 2007 | 245.3        | 0.04      |
| 2008 | 245.3        | 0.04      |
| 2009 | 245.3        | 0.04      |
| 2010 | 245.4        | 0.04      |

\*The green numbers indicate an update of activity data for the respective years

### ***N<sub>2</sub>O and CH<sub>4</sub> from forest fires***

No prescribed burning of forest takes place in Norway and all forest fires are due to accidents in dry periods (wildfires)<sup>21</sup>. According to IPCC (2003) the emissions of CO<sub>2</sub> from fires should be estimated, because the regrowth and subsequent sequestration are taken into account when it takes place. However, both the loss and uptake of CO<sub>2</sub> will be covered by the growing stock

<sup>21</sup> There may be some trials of burning as part of forest management, but this is only performed in small scale and is ignored here.

change based CO<sub>2</sub> calculations. The estimates provided in Table 7.17 are for comparison only and to be able to estimate other pollutants, and will not be used in the CO<sub>2</sub> calculations.

Data on area burned in forest fires are available from the Directorate for Civil Protection and Emergency Planning for 1993–2010 (Table 7.16). For 1990–1992 only data on the number of fires were available and these data were used to estimate the area burned based on the ratio for subsequent years. This method may be very inaccurate because the size of fires is very variable. Because the number of fires was higher in 1990–1992 than later, it is possible that the estimate for the base year is too high.

In accordance with the principles of this report emissions in all forest is reported. The area burned varies considerably from year to year due to natural factors (for example variations in precipitation). Assuming that the carbon content of biomass is 50 per cent, half of the biomass burned will end up as CO<sub>2</sub>. There are no exact data on the amount of biomass burned per area. Normally, only the needles/leaves, parts of the humus and smaller branches are burned. We have assumed that there are 20 m<sup>3</sup> biomass per ha and that the mass of trees burned constitute 25 per cent of this (this is consistent with IPCC (2003)). It is also likely that there is about 1 m<sup>3</sup> dead-wood per ha that will be affected by the fire due to its dryness. It is difficult to assess how much of the humus is burned, and this is much dependent on forest type. There is about 7 500 kg humus per ha, we assume that 10 per cent of this is burned. This factor is, however, very dependent on the vegetation type. Most of the forest fires in Norway take place in pine forest with a very shallow humus layer.

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*Table 7.16 Forest fires in Norway 1990–2010*

| Activity data | Number of fires | Unproductive forest (ha) | Productive forest (ha) | Total area burnt (ha) |
|---------------|-----------------|--------------------------|------------------------|-----------------------|
| 1990          | 578             | 679.6*                   | 256.4*                 | 935.9*                |
| 1991          | 972             | 1 142.8*                 | 431.2*                 | 1 574.0*              |
| 1992          | 892             | 1 048.8*                 | 395.7*                 | 1 444.4*              |
| 1993          | 253             | 135.5                    | 88.3                   | 223.8*                |
| 1994          | 471             | 123.6                    | 108.1                  | 231.7                 |
| 1995          | 181             | 77.6                     | 35.5                   | 113.1                 |
| 1996          | 246             | 169.7                    | 343.8                  | 513.5                 |
| 1997          | 533             | 605.8                    | 260.6                  | 866.4                 |
| 1998          | 99              | 164.7                    | 110.3                  | 275                   |
| 1999          | 148             | 734.0                    | 12.7                   | 86.1                  |
| 2000          | 99              | 142.6                    | 29.3                   | 171.9                 |
| 2001          | 117             | 84.3                     | 5.2                    | 89.5                  |
| 2002          | 213             | 124.7                    | 95.8                   | 220.5                 |
| 2003          | 198             | 905.6                    | 36.8                   | 942.4                 |
| 2004          | 119             | 84.6                     | 32.3                   | 116.9                 |
| 2005          | 122             | 252.7                    | 92.6                   | 345.3                 |
| 2006          | 205             | 3222.6                   | 660.7                  | 3 882.7               |
| 2007          | 65              | 22.2                     | 106.1                  | 128.3                 |
| 2008          | 174             | 1210.2                   | 1963.1                 | 3173.3                |
| 2009          | 109             | 1257.7                   | 70.8                   | 1328.5                |
| 2010          | 62              | 602.8                    | 165.9                  | 768.7                 |

*Source: Directorate for Civil Protection and Emergency Planning*

*\*Area estimated by NIJOS (2005).*



Table 7.17. CO<sub>2</sub> emissions from forest fires, 1990–2010. Gg

| Activity data | Living biomass | Dead wood CO <sub>2</sub> Gg | Humus CO <sub>2</sub> Gg | Total* CO <sub>2</sub> Gg |
|---------------|----------------|------------------------------|--------------------------|---------------------------|
| 1990          | 17.2           | 0.9                          | 1.3                      | 19.3                      |
| 1991          | 28.9           | 1.4                          | 2.2                      | 32.5                      |
| 1992          | 26.5           | 1.3                          | 2.0                      | 29.8                      |
| 1993          | 4.1            | 0.2                          | 0.3                      | 4.6                       |
| 1994          | 4.2            | 0.2                          | 0.3                      | 4.7                       |
| 1995          | 2.1            | 1.0                          | 0.2                      | 2.3                       |
| 1996          | 9.4            | 0.5                          | 0.7                      | 10.6                      |
| 1997          | 15.9           | 0.8                          | 1.2                      | 17.9                      |
| 1998          | 5.0            | 0.3                          | 0.4                      | 5.7                       |
| 1999          | 1.6            | 0.1                          | 0.1                      | 1.8                       |
| 2000          | 3.2            | 0.2                          | 0.2                      | 3.6                       |
| 2001          | 1.6            | 0.1                          | 0.1                      | 1.8                       |
| 2002          | 4.0            | 0.2                          | 0.3                      | 4.5                       |
| 2003          | 17.3           | 0.9                          | 1.3                      | 19.5                      |
| 2004          | 2.1            | 0.1                          | 0.2                      | 2.4                       |
| 2005          | 6.3            | 0.3                          | 0.5                      | 7.1                       |
| 2006          | 71.2           | 3.6                          | 5.3                      | 80.1                      |
| 2007          | 2.4            | 0.1                          | 0.2                      | 2.7                       |
| 2008          | 58.2           | 2.9                          | 4.4                      | 65.5                      |
| 2009          | 24.4           | 1.2                          | 1.8                      | 27.4                      |
| 2010          | 14.1           | 0.7                          | 1.1                      | 15.9                      |

\* These estimates are not included in the CRF due to use of stock change method and to avoid double accounting. Source: The Norwegian forest and Landscape institute.

There are no national data on emission factors for non-CO<sub>2</sub> gases from forest fires. Estimates of non-CO<sub>2</sub> gases emissions are therefore based on the C released as described in IPCC (2003). The following equation are used

$$\text{CH}_4 \text{ emissions} = \text{C} * \text{Emission ratio} * 16/12$$

$$\text{N}_2\text{O emissions} = \text{C} * \text{N/C ratio} * \text{Emission ratio} * 44/28$$

Where C is the carbon released. IPCC (2003) suggests a default N/C ratio of 0.01. The methane emission ratio is 0.012 and for nitrous oxide 0.007.

Table 7.18 gives estimates of CH<sub>4</sub> and N<sub>2</sub>O emissions from forest fires in the period 1990–2010.

Table 7.18. Estimates of CH<sub>4</sub> and N<sub>2</sub>O emissions from forest fire. 1990–2010. Gg

|      | <b>CH<sub>4</sub><br/>Gg</b> | <b>N<sub>2</sub>O<br/>Gg</b> | <b>CO<sub>2</sub>-eqv<br/>Gg</b> |
|------|------------------------------|------------------------------|----------------------------------|
| 1990 | 0.084                        | 0.00058                      | 1.95                             |
| 1991 | 0.142                        | 0.00097                      | 3.28                             |
| 1992 | 0.130                        | 0.00089                      | 3.01                             |
| 1993 | 0.020                        | 0.00014                      | 0.47                             |
| 1994 | 0.021                        | 0.00014                      | 0.48                             |
| 1995 | 0.010                        | 0.00007                      | 0.24                             |
| 1996 | 0.046                        | 0.00031                      | 1.07                             |
| 1997 | 0.078                        | 0.00054                      | 1.80                             |
| 1998 | 0.025                        | 0.00017                      | 0.57                             |
| 1999 | 0.008                        | 0.00005                      | 0.18                             |
| 2000 | 0.015                        | 0.00016                      | 0.36                             |
| 2001 | 0.008                        | 0.00006                      | 0.19                             |
| 2002 | 0.020                        | 0.00014                      | 0.46                             |
| 2003 | 0.085                        | 0.00058                      | 1.96                             |
| 2004 | 0.011                        | 0.00007                      | 0.24                             |
| 2005 | 0.031                        | 0.00020                      | 0.72                             |
| 2006 | 0.349                        | 0.00240                      | 8.08                             |
| 2007 | 0.012                        | 0.00010                      | 0.27                             |
| 2008 | 0.286                        | 0.00200                      | 6.61                             |
| 2009 | 0.120                        | 0.00080                      | 2.77                             |
| 2010 | 0.069                        | 0.00080                      | 1.60                             |

Conversion to forest land from cropland, grassland and settlements does, according to IPCC (2003), not alter the emissions of non-CO<sub>2</sub> greenhouse gases. Exceptions are in cases of fertilization and drainage as addressed above.

### 7.10.2 Cropland

Emissions from on-site and off-site burning of agricultural waste are reported under the agriculture sector and are not addressed here. Emissions from application of fertilizer and cultivation of organic soils are also reported under the agriculture sector. Conversion of forest, grassland, wetlands, settlements and other land to cropland is expected to increase N<sub>2</sub>O emissions. This is due to a mineralization of soil organic matter. Emissions from settlements converted to cropland are reported together with other land converted to cropland.

The methodology based on IPCC (2003) has been used:

*N<sub>2</sub>O-N = Area converted to cropland last 25 years \* N released by mineralization \* Emission factor*

The area converted to cropland the last 25 years are for the time-series 1970-1989 taken from Census of Agricultural 1999 and sample survey of agriculture and forestry 2002 (Statistics

Norway 2003a, 2002b). From 1990 the statistics of different land conversion for mineral soil for each year is taken from the NFI. We are assuming the same emission factor for all land-use categories.

The N released by mineralization is estimated from the C released in mineral soils during conversion to cropland divided by the C:N ratio of soil organic matter (default is 15).

According to Bioforsk the average C:N ratio in Norway is 13.4. The C-loss was based on the erosion loss estimated under “cropland remaining cropland” (Section 7.4.1). The default emission factor from IPCC 2003 is 1.25 per cent.

Table 7.19 gives the accumulated area converted to cropland and related N<sub>2</sub>O emissions from 1990 to 2010. As we can see, the area converted, and hence the emissions of both C and N<sub>2</sub>O have decreased during the period. The entire time-series has been recalculated since last submission.

*Table 7.19 Accumulated area converted to cropland and related N<sub>2</sub>O emissions. 1990–2010. Gg*

|      | <b>Accumulated<br/>area<br/>converted to<br/>cropland<br/>(kha)</b> | <b>Emissions<br/>C Gg</b> | <b>Emissions<br/>N<sub>2</sub>O Gg</b> |
|------|---|---------------------------|--|
| 1990 | 151.6   | 1.50                      | 0.002201                               |
| 1991 | 146.0   | 1.36                      | 0.001991                               |
| 1992 | 140.5   | 1.22                      | 0.001790                               |
| 1993 | 135.0   | 1.09                      | 0.001600                               |
| 1994 | 129.4   | 0.97                      | 0.001419                               |
| 1995 | 123.9   | 0.85                      | 0.001249                               |
| 1996 | 117.4   | 0.80                      | 0.001175                               |
| 1997 | 110.6   | 0.75                      | 0.001100                               |
| 1998 | 102.9   | 0.69                      | 0.001017                               |
| 1999 | 95.3  | 0.64                      | 0.000935                               |
| 2000 | 88.1  | 0.59                      | 0.000858                               |
| 2001 | 82.3  | 0.46                      | 0.000675                               |
| 2002 | 74.7  | 0.40                      | 0.000588                               |
| 2003 | 67.5  | 0.42                      | 0.000612                               |
| 2004 | 60.2  | 0.37                      | 0.000546                               |
| 2005 | 58.9  | 0.36                      | 0.000523                               |
| 2006 | 55.1  | 0.35                      | 0.000512                               |
| 2007 | 48.8  | 0.29                      | 0.000431                               |
| 2008 | 47.8  | 0.27                      | 0.000393                               |
| 2009 | 45.2  | 0.24                      | 0.000354                               |
| 2010 | 44.8  | 0.24                      | 0.000347                               |

*\*The green numbers indicate an update of activity data for the respective years.*

*Source: Statistics Norway and The Norwegian Forest and Landscape Institute.*

### 7.10.3 Grassland

The effect of emissions from mineralization is very uncertain and is not accounted for. Fires in grasslands are ignored; the frequency of such fires is low in Norway. Fertilization of

grassland may also alter the methane sink, but there are currently no data available to account for this.

#### 7.10.4 Wetlands

Norway has many reservoirs due to hydroelectric power production. Flooding may generate emissions of CH<sub>4</sub> and N<sub>2</sub>O. An emission methodology is given in an Appendix of IPCC (2003) for further methodology development. There is an ongoing national project (SINTEF and STATKRAFT) to estimate emissions from reservoirs. Regarding the SINTEF-StatKraft project the preliminary results are classified information according to the Norwegian Water Resources and Energy Directorate. If and when the findings of this project will be declassified is not known at this time.

N<sub>2</sub>O emissions from organic soils managed for peat extraction can be estimated based on Uppenberg et al. (2001). Emission factors after drainage and before extraction range from 0.02–0.1 g/m<sup>2</sup>. The first years after extraction has started (6–7 years) the range is 0.2–1 g/m<sup>2</sup>, later on reduced to 0.01–0.05 g/m<sup>2</sup>. Because the age of the land is not known we propose using a factor of 0.05 g/m<sup>2</sup> for all years.

The area was estimated in Section 7.2.2. This gives us an estimate of 0.2 Gg N<sub>2</sub>O.

According to the same study peat extraction reduces CH<sub>4</sub> emissions (2–40 g/m<sup>2</sup> before drainage and 0.2–4 after). In line with IPCC 2003 this reduction is not accounted for in the calculations.

#### 7.11 Uncertainties

The NIJOS 2005 report identified several large uncertainties in the estimates. The uncertainties are particularly large for emissions of non-CO<sub>2</sub> gases and CO<sub>2</sub> from soil (except forest soil). For these categories of emissions and removals also often the activity data are uncertain. Changes in soil organic carbon are difficult to monitor due to scaling-up problems, lack of time-series and lack of management data. Nevertheless, we are able to conclude that emissions of non-CO<sub>2</sub> gases are small. Also lack of knowledge of the history of a piece of land causes problems. More measurements and more use of models could contribute to reductions in these uncertainties. Uncertainties are also large for other wooded land (tree covered land that does not meet the forest definition) and for Finnmark County which until recently has not been included in the National Forest Inventory. These changes are expected to be small. Also reservoirs should be further investigated due to the importance of dams in Norway (hydroelectric power stations). At the time the preliminary results from ongoing project are classified information, hence estimates for these have not been included in the study. Data are, however, quite certain for stock changes in forest remaining forest which constitute the largest removal of the inventory.

Annex II presents the uncertainty analysis of the Norwegian GHG emission inventory undertaken for the previous NIR submission, with and without inclusion of the LULUCF sector. The uncertainty estimates for many LULUCF categories are not of the same quality as the rest of the inventory. More information about the uncertainty estimates for LULUCF is given in the NIJOS 2005 report. There is an ongoing project with the aim to provide new uncertainty estimates for the LULUCF sector. 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, against 5 per cent and 4 percent without LULUCF in 1990 and 2009, respectively. This is due to the fact that the uncertainty in the LULUCF sector in general is higher than in most

other sectors. The trend uncertainty is 3 percentage points without LULUCF and 7 percentage points when the LULUCF sector is included.

The largest uncertainties are related to N<sub>2</sub>O from fertilizer use and land disturbances, where the uncertainty will be larger than 100 per cent. Also the estimate of CO<sub>2</sub> from farmed organic soils is very uncertain, using the data from Sweden and Finland as an indicator the uncertainty is more than 100 per cent. Also CO<sub>2</sub> from agriculture soils are quite uncertain, by more than 100 per cent. CO<sub>2</sub> from liming is in the other hand well determined as the application is monitored and the emission factor is based on stoichiometry.

## 7.12 Source-specific QA/QC and verification

The Norwegian Forest and Landscape Institute undertakes a control assessment each year to check data quality and ensure consistent methodology in the survey. Furthermore, it completes the QA/QC report as an integrated part of their National system report.

Statistics Norway examines the various statistical data for consistency over time.

The Norwegian Forest and Landscape Institute is in charge of archiving all data from the calculations of emissions and removals from LULUCF. Statistics Norway is in charge of ensuring consistency between LULUCF and non-LULUCF categories and ensures there is no double-counting of emissions or removals between these.

## 7.13 Recalculations

No major changes in methods and EF used compared to the reporting in 2011;

The whole time-series has been recalculated due to;

- updating of activity data, due to new data and continuous quality control of the data bases used.

### 5A1 Forest land remaining forest land

- Compared to the submission of 2011 the whole time-series has been recalculated due to a updating of the activity data.
- The net removals for forest land remaining forest land was 35 446 Gg CO<sub>2</sub> in 2010. When including emissions of CH<sub>4</sub> and N<sub>2</sub>O the net removals were estimated to 35 433 CO<sub>2</sub>-equivalents.

### 5A2 Land converted to forest land

- The whole time-series has been recalculated due to a updating of the activity data
- In 2010 the land-use category land converted to forest land contributed with a total amount of removals of 431 Gg CO<sub>2</sub>. Settlements converted to forest land was the largest contributor with 338 Gg CO<sub>2</sub>. The increase in soil organic carbon on aggregated areas from 1990 constitutes a large part of the removals. See further explanation in section 7.3.2.1 under subtitle “Land converted to forest land”.

### 5B1 Cropland remaining cropland

- The whole time-series of the total area of cropland has been recalculated due to a updating of the activity data.
- The emissions from cropland remaining cropland were 42 Gg CO<sub>2</sub> in 2010.

5B2 Land converted to cropland

- The whole time-series has been recalculated due to a updating of the activity data. Area of organic soil (Histosol) is now in accordance with the area used in the agricultural sector (CRF table 4.D). Emissions from forest land converted to cropland are recorded for the whole time-series. In 2010 there was an emission of 25 Gg CO<sub>2</sub> from land converted to cropland.

5C1 Grassland remaining grassland

- The area of grassland remaining grassland is recalculated for the whole time-series due to a updating of the activity data.
- The emissions from grassland remaining grassland is estimated to be 1 606 Gg of CO<sub>2</sub> in 2010.

5C2 Land converted to grassland

- The whole time-series has been recalculated due to a updating of the activity data and a revision of the methods used to calculate net carbon stock change in living tree biomass.
- An emission of 75 Gg CO<sub>2</sub> was estimated for this category in 2010. This is due to a reduction of living biomass of fruit trees.

5D1 Wetlands remaining wetlands

- The total area of wetlands is recalculated due to a updating of the activity data.
- The emissions from wetlands remaining wetlands are coming from peat extraction. There is assumed no annual changes in this activity and therefore the emissions are equal to 3.4 Gg CO<sub>2</sub> every year in the time-period 1990–2010.

5E2 Land converted to settlements

- The whole time-series has been recalculated due to a updating of the activity data.
- Emissions from forest land converted to settlement were estimated to 1 155 Gg CO<sub>2</sub> in 2010.

5F2 Land converted to other land

- The whole time-series has been recalculated due to a updating of the activity data.
- No emissions or removals of CO<sub>2</sub> were reported for land converted to other land in 2010.

*Table 7.20 Recalculations for the LULUCF-sector in the 2012 submission compared to the 2011 submission. Gg CO<sub>2</sub>- equivalents\**

| <b>Year</b> | <b>Submission<br/>2011</b> | <b>Current<br/>Submission<br/>2012</b> | <b>% change<br/>2011–2012</b> |
|-------------|----------------------------|--|-------------------------------|
| 1990        | -8 556                     | -8 676                                 | 1.4                           |
| 1991        | -9 108                     | -9 253                                 | 1.6                           |
| 1992        | -9 584                     | -9 730                                 | 1.5                           |
| 1993        | -10 101                    | -10 273                                | 1.7                           |
| 1994        | -10 850                    | -11 048                                | 1.8                           |
| 1995        | -11 211                    | -11 432                                | 2.0                           |
| 1996        | -12 006                    | -12 241                                | 2.0                           |
| 1997        | -12 564                    | -12 817                                | 2.0                           |
| 1998        | -13 279                    | -13 845                                | 4.3                           |
| 1999        | -13 849                    | -14 207                                | 2.6                           |
| 2000        | -18 530                    | -19 070                                | 2.9                           |
| 2001        | -20 397                    | -20 786                                | 1.9                           |
| 2002        | -25 060                    | -25 746                                | 2.7                           |
| 2003        | -27 849                    | -28 204                                | 1.3                           |
| 2004        | -27 182                    | -27 447                                | 1.0                           |
| 2005        | -29 613                    | -29 890                                | 1.0                           |
| 2006        | -24 238                    | -24 645                                | 1.7                           |
| 2007        | -28280                     | -28 578                                | 1.1                           |
| 2008        | -34303                     | -34 694                                | 1.1                           |
| 2009        | -25329                     | -26 985                                | 6.5                           |
| 2010        |                            | -32 944                                |                               |

## 7.14 Planned improvements

In order to meet the reporting requirements of LULUCF the Norwegian National Forest Inventory (NFI) system has expanded its coverage beyond areas conventionally considered to be productive forest area (below the coniferous tree limit). There are now in place permanent plots covering the entire country. All plots are assessed according to the NFI manual. At the time being, there is a time-series from 1989 until 2010 covering all areas below the coniferous tree limit and a status quo of the current land-use and the standing living biomass on the areas of higher altitudes and in Finnmark County. The preliminary results for these additional areas are planned to be further improved. It is planned that all newly installed plots will be included in the NFI's consecutive 5 year re-sampling cycles, and hence information will be included in the land-use change matrix and in the stock change method as the data becomes available.

The development of new and improved methods for reliable back-casting of biomass and land-use classes is currently taking place. The aims are to adjust the land-use classification to be better aligned with the LULUCF classification, establishing a reliable 1990-status for the

entire country, and improved estimates for the annual change in living biomass from 1990 up to today. The methods will include information extracted from ortophotoes that are made available through a web-based service starting in 2007 ([www.norgebilder.no](http://www.norgebilder.no)), old aerial photographs, maps and land use classification and forest data coming from the consecutive NFI cycles. The plan is to include updated time-series for the entire country in the 2014 report.

It is planned to improve the estimates of net change in soil organic carbon for mineral soils at forest land remaining forest land, land converted to forest land and forest land converted to other land-use categories. It is planned to use the Yasso07 model for these calculations. Furthermore, it is planned to update all required input values covering the entire country when they are available from the NFI and research projects, and at latest for the reporting in 2014. The plans also include validation of output estimates.

In 2010 the NFI started a survey of dead wood on the ground at all inventory plots in the entire country. The results will be used in the inventory consecutively when available.

Within 2013 it is planned to evaluate the methods used for assessing emissions and removals for cropland and grassland.



## 8 Waste

### 8.1 Overview

This sector includes emissions from landfills (6A), wastewater handling (6B) and small scale waste incineration (6C). Waste incineration from plants with energy utilization is accounted for under 1A (Energy combustion). Waste incineration included here are emissions of other greenhouse gases than CO<sub>2</sub> from methane flared at landfills and combustion of hospital waste in hospital incinerators until 2005 and cremations.

The emissions of greenhouse gases from the waste sector were decreased by 31.4 per cent (0.572 million ton CO<sub>2</sub> eq.) from 1990 to 2010. The reduction were due to decreased CH<sub>4</sub> emissions from landfills 35.8 per cent (0.602 million ton CO<sub>2</sub> eq.) while the source category Domestic and Commercial Wastewater increased their emissions by 0.030 million ton CO<sub>2</sub> eq.

Solid waste disposal on land (i.e. in landfills) is the main emission category within the waste sector, accounting for in 2010 about 87 per cent of the sector's total emissions. Wastewater handling in domestic and commercial sector accounts for approximately 13 per cent of the sectors emission in 2010. 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 2010.

### 8.2 Managed Waste Disposal on Land – CH<sub>4</sub> – 6A1 (Key Category)

#### 8.2.1 Description

CH<sub>4</sub> and non-fossil CO<sub>2</sub> are emitted during biological decomposition of waste. This transformation of organic matter takes place in several steps. During the first weeks or months, decomposition is aerobic, and the main decomposition product is CO<sub>2</sub>. When there is no more oxygen left, the decomposition becomes anaerobic, and methane emissions start to increase. After a year or so, CH<sub>4</sub> 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 slightly 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 degradable organic waste to landfills and due to that this will result in further reduction of methane emissions. The tax was in 2011 280 NOK per ton waste deposit. However, there is a possibility of exemption from the prohibition of depositing waste at landfills in a short period and for waste landfilled with an exemption the tax is 463 NOK per ton waste deposited.

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 2010 83 landfills had system in operation for extraction of methane and 19.4 kilo tonnes of methane were recovered. This is 9 per cent lower than in 2009. 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 33 per cent from 1995 to 2010 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 landfilling of July 1 st 2009 there has been a strong decrease in waste depositing. There are given many permits for disposal for one year extra, some extended out 2010, and a few within 2011. The amount of waste generated in 2010 was 2.7 per cent higher than in 2009. 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 CH<sub>4</sub> from solid waste disposal are key category in level in 1990 and 2010 and trend due to uncertainty in AD and EF.

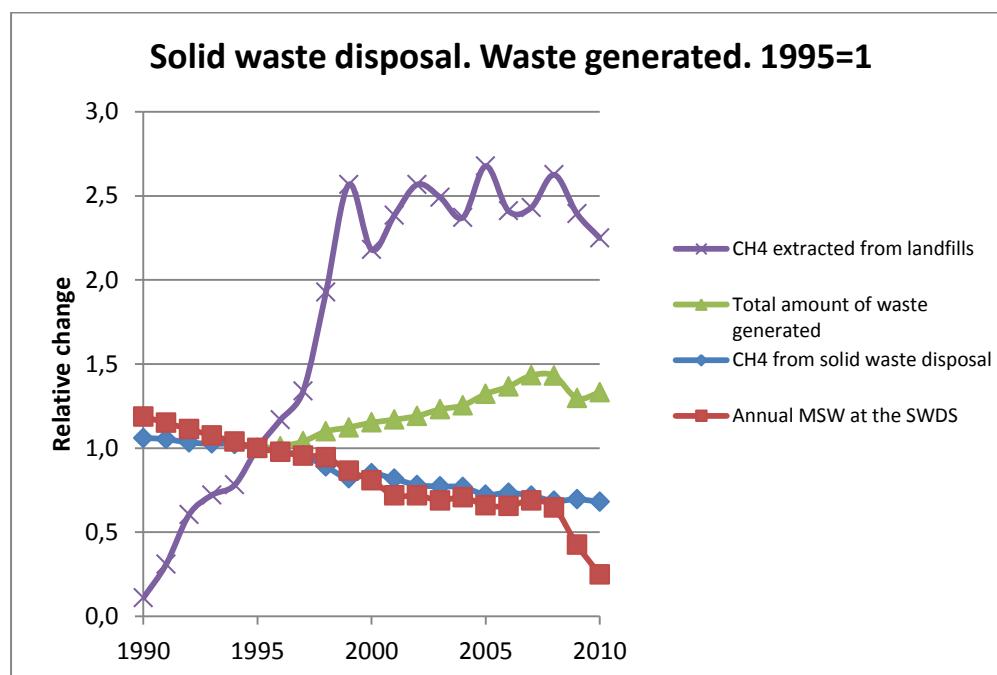


Figure 8.1. Relative change in emissions of methane from solid waste disposal, annual MSW at the SWDS, methane extracted from landfills and total amount of waste generated in Norway.

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 landfiling, 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  $DDOC_{mass}$  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  $DDOC_{mass}$  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 landfiling, 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<sub>m</sub> 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

$$(8.9) \quad CH_4 \text{ emitted in year } T = (\sum CH_4_{prod}(T)) - R(T) * (1 - OX)$$

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 <sub>f</sub>       | : Fraction of DOC dissimilating, anaerobic conditions                                    |
| DDOC                   | : Dissimilatable Organic Carbon, anaerobic conditions                                    |
| DDOC <sub>md</sub>     | : DDOC mass landfilled   |
| DDOC <sub>ml</sub>     | : DDOC mass left not dissimilated from DDOC <sub>m</sub> landfilled, year of landfilling |
| DDOC <sub>ma</sub>     | : DDOC mass left not dissimilated at end of year   |
| DDOC <sub>ma(ly)</sub> | : DDOC mass accumulated from last year   |
| DDOC <sub>mdi</sub>    | : DDOC mass dissimilated from DDOC <sub>m</sub> landfilled, year of landfilling          |
| DDOC <sub>mdiss</sub>  | : DDOC mass dissimilated in calculation year   |
| CH <sub>4</sub> prod   | : CH <sub>4</sub> produced   |
| F                      | : Fraction of CH <sub>4</sub> by volume in generated landfill gas                        |
| 16/12                  | : Conversion factor from C to CH <sub>4</sub>  |

R(T) : Recovered CH<sub>4</sub> 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, 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 exceptions:

- Wood content in sludge deposited at industrial sites is added to the amount of deposited wood from the waste accounts.
- Textiles are supposed to consist of 50 per cent plastic (SFT 2005b). The plastic fraction of deposited textiles is therefore subtracted from the amount of deposited textiles and added to deposited plastic.

- The material category “Other” is supposed to contain 13 per cent of biodegradable waste, which is added to the amount of paper.

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    |
| $t_{1/2}$ (half life time)                   | 3,7 years     | 11,6 years  | 23,1 years  | 11,6 years  |
| DOC  | 0.150 Mg/Mg   | 0.400 Mg/Mg | 0.400 Mg/Mg | 0.400 Mg/Mg |
| DOC <sub>f</sub> (Part of DOC dissimilating) | 0.5           | 0.5         | 0.5         | 0.5         |
| Ox. Methane oxidized in top layer            | 0.1           | 0.1         | 0.1         | 0.1         |
| F. Part of methane in generated landfill gas | 0.5           | 0.5         | 0.5         | 0.5         |

*Source: SFT (2005b) and Statistics Norway (2006).*

#### **8.2.5 Uncertainties**

The amount of different waste materials is considered to be known within  $\pm 20$  per cent. The emission factors used are considered to have the uncertainty range  $\pm 30$  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*

- Correction of error. A significant amount of mixed waste, 30 000 tonnes in 1990 increasing to 180 000 tonnes in 2008, have been included in the inventory. The amount is allocated to all waste fractions in the same way as mixed waste from households.
- Revised activity data and correction of error. A sample survey on waste from manufacturing industries has been carried out for 2008. This has led to updated figures for 2008. In addition figures for 2003 have been corrected. Waste from manufacturing industries has been updated for all years since 2000 due to interpolation.
- Revised activity data. Reported figures on disposed waste in Statistics Norway's waste statistics have replaced estimates for 2009. New waste statistics shows a somewhat different trend than the preliminary estimates indicated. Since July 2009 it has been prohibited to dispose organic matter at landfills in Norway.

These changes have led to increased emissions of methane for all years after 1990. The emissions rose from 0.1 per cent in 1990 to 1 per cent for 2008 and 0.9 percent for 2009.

#### **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 Norway does not separately report emissions from unauthorized/unmanaged SWDSs.

## 8.4 Wastewater handling – N<sub>2</sub>O – 6B (Key category)

### 8.4.1 Description

Emissions of CH<sub>4</sub> and N<sub>2</sub>O from Wastewater handling has been relative stable during the 1990 to 2006, with a small increase for CH<sub>4</sub>. The emission trend for this period is described in Section 2.3.

According to the Tier 2 key category analysis emissions of N<sub>2</sub>O from wastewater handling are key category in level in 1990 and 2010.

### 8.4.2 Methodological issue

#### CH<sub>4</sub>

Emissions of methane from domestic and commercial waste water have been calculated. Emissions from water consumption in food processing industries (breweries, dairies and slaughterhouses) are included for all years since 1990. Emissions of methane from industries with their own waste water treatment plants are small, because the plants are mainly. CH<sub>4</sub> from domestic sludge is calculated together with the waste water emissions.

Emissions of methane from domestic waste water are calculated according to the IPCC default methodology:

$$(8.10) \quad E_i = N_i * D * B_0 * MCF$$

E: Emissions of methane

N: Population in Norway

D: Organic load in biochemical oxygen demand (kg BOD/1000 persons/year)

B<sub>0</sub>: Maximum methane-producing capacity (kg CH<sub>4</sub>/kg DC)

MCF: Methane conversion factor

i: Year

Emissions of methane from water consumption in each food processing industries are calculated using the same equation as for domestic water, except that for COD is estimated based on water consumption multiplied with mg COD/l wastewater.

$$(8.11) \quad E_i = W_i * COD_i * B_0 * MCF$$



- E: Emissions of methane  
 W: Water consumption/economic turnover (million NOK)  
 COD: Organic load in chemical oxygen demand (kg COD/unit wastewater)  
 B<sub>0</sub>: Maximum methane-producing capacity (kg CH<sub>4</sub>/kg DC)  
 MCF: Methane conversion factor  
 i: Industry

## N<sub>2</sub>O

For this source emissions of nitrous oxide from domestic and commercial wastewater have been calculated. Until this year only N<sub>2</sub>O 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 N<sub>2</sub>O emissions from human sewage, which is not treated in sewage treatment plants. Emissions of N<sub>2</sub>O from industries with their own waste water treatment plants are not estimated.

N<sub>2</sub>O 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 N<sub>2</sub>O 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 N<sub>2</sub>O 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 N<sub>2</sub>O emissions are estimated like this:

N<sub>2</sub>O 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 N<sub>2</sub>O 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<sub>2</sub>O-N/kg sewage-N produced. Conversion factor of N<sub>2</sub>O-N to N<sub>2</sub>O is 1.57.

N<sub>2</sub>O 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 N<sub>2</sub>O. 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 N<sub>2</sub>O-N.

For the part of the population that is not connected to large treatment plants, the N<sub>2</sub>O 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 N<sub>2</sub>O 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 <sub>2</sub> O <sub>(s)</sub> : | N <sub>2</sub> O emissions from human sewage (kg N <sub>2</sub> O –N/ yr)                 |
| Protein:                          | annual per capita protein intake (kg/person/yr)   |
| NR <sub>PEOPLE</sub> :            | Number of people not connected to treatment plants  |
| EF <sub>6</sub> :                 | emissions factor (default 0.01 (0.002-0.12) kg N <sub>2</sub> O –N/kg sewage- N produced) |
| Frac <sub>NPR</sub> :             | Fraction of nitrogen in protein (default = 0.16 kg N/kg protein).                         |

The N<sub>2</sub>O from sewage sludge applied on fields is included under Chapter 6, Agriculture.

#### 8.4.3 Activity data

##### CH<sub>4</sub>

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 released into domestic sewer systems. Emissions of methane from industries with their own wastewater treatment plants are small, because the plants are mainly aerobic or the methane gas is being recovered.

As recommended by the review team Norway has estimated emissions of CH<sub>4</sub> 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).

##### N<sub>2</sub>O

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](http://www.ssb.no/avlut_en/about.html)). These figures are used for estimating N<sub>2</sub>O 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](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. 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

##### *CH<sub>4</sub>*

The IPCC emission factor for  $B_0$  of 0.6 kg  $CH_4$ /kg DC is used. The methane conversion factor (MCF) is, according to good practice, given by the fraction of BOD that will ultimately degrade anaerobically. Country-specific MCF factors are estimated by Statistics Norway for the years 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". 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.

Emissions from water consumption in food processing industries are calculated using the average MCF-factor (0.01) for wastewater. The IPCC emission factor for  $B_0$  of 0.6 kg  $CH_4$ /kg DC is used. The COD factors for the different groups are taken from IPPC 2006 and some are average factors made by Statistics Norway. Based on the water consumption and Gross values from industry in 2004 we know the water consumption per economic turnover. The same factor is used for all years for the different products, see table 8.2. The table also 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 8.2. The developed water consumption coefficients and chemical oxygen demand in m<sup>3</sup>/million NOK and mg/l.

|  | m <sup>3</sup> /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<sub>2</sub>O

For the part of the population and the part of the industry that are connected to large treatment plants the N<sub>2</sub>O 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<sub>2</sub>O-N/kg sewage-N produced. The conversion factor of N<sub>2</sub>O-N to N<sub>2</sub>O is 1.57. N<sub>2</sub>O 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<sub>2</sub>O (country-specific EF). The amount of N removed at the plant is multiplied with 0.02 and then multiplied with the factor of 1.57 for conversion of N-removed to N<sub>2</sub>O-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<sub>6</sub> of 0.01kg N<sub>2</sub>O/kg sewage-N produced is used, and the fraction of nitrogen in protein, Frac<sub>NPR</sub>, is 0.16 kg N/kg protein.

Protein is annual per capita protein intake (kg/person/year).

A report from the Directorate for Health and Social Affairs estimates the amount of daily per capita protein intake for Norway for 1997 (Johansson and Solvoll, 1999). There has not been done any other survey like this, where the daily per capita protein intake for Norway has been estimated.

In 1997 the daily per capita protein intake for Norway was 86 gram, which gives 31.39 kilo per year. For the years 1990, 1995, 2000, 2003, 2004 and 2005 the Directorate for Health and Social Affairs has made estimations of the potential protein intake for the population (Directorate for Health and Social Affairs 2006).

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.<sup>22</sup>). This is shown in the Table 8.3.

*Table 8.3. Potential protein intake, and estimated protein intake, in g/person/day, kg/person/year, for the years 1990-2009.*

| Year              | Potential protein intake g/per/day | kg/per year | Index 1997 =100 | Estimated protein intake kg/per/year |
|-------------------|------------------------------------|-------------|-----------------|--------------------------------------|
| 1990              | <b>94</b>                          | 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              | <b>93</b>                          | 33.9        | 99.1            | 31.1                                 |
| 1996              | 93.4                               | 34.1        | 99.6            | 31.3                                 |
| 1997              | 93.8                               | 34.24       | 100             | <b>31.39</b>                         |
| 1998              | 94.2                               | 34.4        | 100.4           | 31.5                                 |
| 1999              | 94.6                               | 34.5        | 100.9           | 31.7                                 |
| 2000              | <b>95</b>                          | 34.7        | 101.3           | 31.8                                 |
| 2001              | 96                                 | 35.0        | 102.3           | 32.1                                 |
| 2002              | 97                                 | 35.4        | 103.4           | 32.5                                 |
| 2003              | <b>98</b>                          | 35.8        | 104.5           | 32.8                                 |
| 2004              | <b>101</b>                         | 36.9        | 108.07          | 33.9                                 |
| 2005              | 100                                | 36.5        | 107.0           | 33.6                                 |
| 2006              | 102                                | 37.2        | 109.1           | 34.2                                 |
| 2007              | 112                                | 40.9        | 119.8           | 37.6                                 |
| 2008 <sup>1</sup> | 112                                | 40.9        | 119.8           | 37.6                                 |
| 2009 <sup>1</sup> | 112                                | 40.9        | 119.8           | 37.6                                 |

Numbers in bold in column 2 are from the Directorate for Health and Social Affairs, 2006 (2006)

<sup>1</sup>Estimates 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.

<sup>22</sup> Johansson, L. (2005): Personal information by telephone, Directorate for Health and Social Affairs.

#### **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 B2 Domestic and commercial wastewater*

- Correction of error. Due to the use of wrong emission factors, previously calculated CH<sub>4</sub> emissions were somewhat too low in 2008 and too high in 2009. Insignificant changes
- Revised data. The number of inhabitant connected to small treatment plants for the years 2008-2009 have been replaced with the average of the population at the beginning of the year and the end of the same year when calculating CH<sub>4</sub> emissions from waste water handling. Insignificant changes in emissions.

#### **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 – CO<sub>2</sub> – 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. 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.

### 8.5.2 Methodological issues

Emissions from flaring of landfill gas by landfills are estimated. However, CO<sub>2</sub> emissions from flaring of landfills are not included in the inventory, as these are considered as being of biogenic origin. The emissions are estimated by multiplying the amount of gas flared with the emission factors shown in Table 8.2.

Emissions from 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. 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.

#### *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 number of cremated bodies is taken from the death statistics at Statistics Norway (Statistical Yearbook).

#### 8.5.4 Emission factors

Table 8.4. Emission factors for flare, cremation and hospital waste incineration.

| Component        | Flare Landfill<br>gas<br>kg/tonnes | Cremation<br>Tonnes/body | Hospital waste<br>Tonnes/tonnes |
|------------------|------------------------------------|--------------------------|---------------------------------|
| CO <sub>2</sub>  | 0                                  | 0                        | 0.3                             |
| CH <sub>4</sub>  | 0.37 <sup>1</sup>                  | 0.00001176               | 0.00023                         |
| N <sub>2</sub> O | 0.0015 <sup>1</sup>                | 0.0000147                | 0.000035                        |

Source: <sup>1)</sup> 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  $\pm 30$  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 2012 been recalculated for the entire time series 1990-2009 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, as far as possible, consistent through the whole time series.

The driving force for making improvements in the emission inventory is to meet the reporting requirements in the UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 18/CP. In addition, it is important for decision makers and others to have accurate emission estimates as basis for making decisions of what measures to introduce to reduce emissions.

The most important recalculations for greenhouse gases in the 2012 submission are

1. Revised activity data for waste deposited on landfills have caused increased emission of CH<sub>4</sub> for the whole time series in *6A Solid waste disposal on land*. The impact of the changes has led to increased emissions of total CH<sub>4</sub> from less than 0.1 per cent in the first years till about 1 per cent in the last years in the period.
2. Revised factors in the calculation of N<sub>2</sub>O emissions in several agricultural groups have caused increased emissions for all years.
3. A reallocation of use of refinery gas between *1A1b Petroleum refining* and *1B2c 2ii Flaring of gas* has caused changes for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O for all years in these groups.
4. Emissions previously reported under *2C1 Pig iron*, have been moved to *2B5 Titanium dioxide production* for the whole time period.

### 9.2 Specific description of the recalculations

#### 9.2.1 Energy

Most of the recalculations have been performed for 2009, because the energy figures for 2009 used in the previous inventory 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. In the following, *reported emissions* are defined as 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.

*1A 1a Public electricity and heat production*

- Revised data. Reported N<sub>2</sub>O emissions from one district heating plant in 2008 has been somewhat increased. For two plants, reported figures for 2009 replaces previously used 2008 figures. There is a minor change in the reported N<sub>2</sub>O figure for 2009 for another plant. For yet another plant the figure on use of fuel oil in 2009 has been marginally reduced, causing corresponding emission reductions.
- Revised data. Figures on use of wood waste at one district heating plant have been somewhat adjusted for 2006-2009, causing marginal emission changes.
- Revised data. A minor reduction in use of light fuel oil in 2008 causes marginal emission reductions. This reduction should have been reflected in an increase in another sector, in order to include total sales in the energy statistics and emission calculations. Unfortunately, this transfer has not taken place, which means that total CO<sub>2</sub> emissions in 2008 are approximately 4 500 tonnes too small. The error will be corrected in the 2013 submission.
- New method. As one pulp and paper producing plant also produces electricity, the use of factor calculations of emissions instead of reported figures for CH<sub>4</sub> and N<sub>2</sub>O as described under 1A2d, also cause emission changes for all years in 1A1a.

*1A 1b Petroleum refining*

- Reallocation. Previously, the same key for distribution between flaring and energy utilisation of refinery gas was used for all years in the whole period 1990-2009. Now plant and year specific figures have been used instead. This causes a reallocation of emissions between 1A1b and 1B2c, but there is no change in total emissions. The reallocation causes higher emissions for 1A1b in 1991, 1995 and 2003-2009, whereas the emissions have been reduced in 1990, 1992-1994, and 1996-2002. Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are affected by the change.
- Correction of error. The removal of a previous double counting for CO<sub>2</sub> and CH<sub>4</sub> in 2008 and 2009 has counteracted the emission increase caused by the reallocation mentioned above, and caused an overall reduction in CO<sub>2</sub> emissions for 2008 and a reduced increase for CH<sub>4</sub> in 2008 and for both CO<sub>2</sub> and CH<sub>4</sub> in 2009. The removal of a previous double counting for CO<sub>2</sub> and CH<sub>4</sub> in 2008 and 2009 has, in addition to the reallocation mentioned above, caused a further reduction in CO<sub>2</sub> and CH<sub>4</sub> emissions for these years.

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

- Reallocation/revised data. Part of the 2008 CO<sub>2</sub> figure for one plant, previously registered as emission from venting, has been reallocated to combustion. At the same time, parts of the CH<sub>4</sub> figures 2007-2009 for the same plant, previously registered as combustion emissions, have been reallocated to 1B2aiii. There are also changes in total CH<sub>4</sub> figures for this plant.
- Correction of error: CO<sub>2</sub> and CH<sub>4</sub> for 1A1C (Manufacture of solid fuels and other energy industries) and 1A3D (National navigation) in 2005. In the previous submission, emissions from drilling at moveable offshore installations were reallocated from 1A3D to 1A1C. In that operation, a mistake was made for certain components in 2005. This mistake has now been corrected. Total emissions for the two sectors were reduced.

- Reallocation: As part of the correction mentioned above, an amount of fuel oil was reallocated from 1A3D (National navigation) to 1A1C (Manufacture of solid fuels and other energy industries) in 2005. All components are affected. Total emissions for N<sub>2</sub>O for the two sectors were unchanged, whereas for CO<sub>2</sub> and CH<sub>4</sub> there was an additional correction as mentioned above.

*1A 2 c Chemicals*

- Revised data. Reported figures on CH<sub>4</sub> from one plant have been adjusted downwards for 2005-2007.
- Reallocation. CO<sub>2</sub> figures for one plant, previously registered as combustion emissions, have now been split between combustion and process. This causes an annual reduction in the size of 10-15 ktonnes for all years 1990-2008.

*1A 2 d Pulp and paper*

- New method. Previously, reported emissions for CH<sub>4</sub> and N<sub>2</sub>O from two plants and CH<sub>4</sub> from another plant were used in the inventory. They have now been replaced by factor estimations based on registered use of different energy commodities for all years 1990-2009.
- Revised data. A revised reported CH<sub>4</sub> figure for one plant in 2008 has caused an emission reduction.

*1A 2 f Other*

- Revised data. For two rock wool producing plants, there are minor changes in reported CO<sub>2</sub> figures for 2005-2008.

*1A 3a Civil aviation*

- Correction of error. For 2007-2009, the key for distribution of jet fuel between airplanes and helicopters were, due to an error, previously not updated. The correction of this error has led to a minor shift between LTO and cruise, as the distribution between airplanes and helicopters in these groups differs. For CH<sub>4</sub>, also the emission factors vary between the two groups, causing a minor reduction in overall emissions from civil aviation.

*1A 3 b i-iii Road transport*

- Revised data. The consumption of auto diesel includes a certain amount of biodiesel. The emission factor for CO<sub>2</sub> is reduced to account for this effect. Due to revised figures on total sales of auto diesel for the year 2009, the emission factor for CO<sub>2</sub> has been upwards adjusted.
- Revised data. The consumption of gasoline includes a certain amount of bioethanol, but until 2010 the amount has been insignificant. However, while gathering bioethanol data also information on 2008-2009 was obtained. The emission factor for CO<sub>2</sub> is reduced by ca. 0.1% to account for this effect.

*1A 3d National navigation*

- Correction of error. Due to the use of a wrong figure for marine gas oil in ships used in oil and gas extraction in 2007 (32 300 tonnes too low), emissions from this source have increased by (per cent increase): CO<sub>2</sub> 4.7, CH<sub>4</sub> 1.4, N<sub>2</sub>O 1.3.
- Correction of error: CO<sub>2</sub> and CH<sub>4</sub> for 1A1C (Manufacture of solid fuels and

other energy industries) and 1A3D (National navigation) in 2005. In the previous submission, emissions from drilling at moveable offshore installations were reallocated from 1A3D to 1A1C. In that operation, a mistake was made for certain components in 2005. This mistake has now been corrected. Total emissions for the two sectors were reduced.

- Reallocation: As part of the correction mentioned above, an amount of fuel oil was reallocated from 1A3D (National navigation) to 1A1C (Manufacture of solid fuels and other energy industries) in 2005. All components are affected. Total emissions for N<sub>2</sub>O for the two sectors were unchanged, whereas for CO<sub>2</sub> and CH<sub>4</sub> there was an additional correction as mentioned above.

*1A 3 eii Other mobile sources and machinery*

- Revised data. A small rise in 2008 emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, due to the inclusion of a minor auto diesel figure for one plant.
- Reallocation. Due to a reallocation of auto diesel 2000-2009 between forestry and other mobile sources and machinery, there is a small increase of emissions of all components these years. The reallocation is due to an error in the estimation of diesel use in forestry, which has given too high figures for the years in question. As total use is defined as equal to total sales, the amounts subtracted from forestry have been transferred to 1A3eii.

*1 A 4 a Commercial / Institutional: Stationary*

- Correction of error. 1.6 ktonnes of coal coke has been removed from this category in 2009. However, because of higher use of other energy goods, there is still an overall emission increase in 1A4a.

*1A 4 b Residential*

- Revised activity data. For the years 2005-2009 the amount of wood burned in private households has been revised due to a new weighting of figures from the survey used to calculate wood consumption. This has led to increased emissions of all components included in the national inventory, included CH<sub>4</sub>, for 2007-2009 and reduced emissions 2005-2006.

*1A 4 c Agriculture/Forestry/Fishing*

- Reallocation. Due to a reallocation of auto diesel 2000-2009 between forestry and other mobile sources and machinery, there is a small decrease in emissions of all components these years. The reallocation is due an error in the estimation of diesel use in forestry, which has given too high figures for the years in question.

*1 B 2 a iii Oil exploration, production, transport*

- Revised data. CH<sub>4</sub> emissions have been increased by 391 tonnes in 2009 due to a revised reported figure on loading of oil at one plant on shore.
- Reallocation/revised data. Parts of CH<sub>4</sub> figures 2007-2009 for one plant, previously registered as combustion emissions, have been reallocated to 1B2aiii. There are also changes in total CH<sub>4</sub> emissions for this plant.

*1B 2a v Distribution of oil products*

- Revised data. Due to revised figures in the sales statistics for petroleum products, indirect emissions of CO<sub>2</sub> from petrol distribution in 2006-2009

have been somewhat altered. The figures for 2006 and 2007 have increased by 1 tonne, emissions in 2008 have been reduced by 20 tonnes and the figures for 2009 are 199 tonnes higher.

*1B 2b Natural gas – gas distribution*

- Revised data. Revised figures on use of natural gas caused a minor decrease in CH<sub>4</sub> emissions in 2008 and an increase in 2009.

*1B 2c1iii Venting combined*

- Revised data. New reported figures for two oil and gas extraction fields have increased the CH<sub>4</sub> emissions in 2009 by 444 tonnes. Indirect CO<sub>2</sub> emissions from CH<sub>4</sub> and NMVOC have increased by 4478 tonnes.
- New data. CO<sub>2</sub> emissions in 2007 have risen by 70 500 tonnes, due to the inclusion of a previously not registered figure for one plant.
- Reallocation. A part of the previously registered CO<sub>2</sub> figure for one plant has been reallocated to combustion.

*1B 2c2ii Flaring of gas*

- Reallocation. As mentioned above in 1A 1b the same key for distribution between flaring and energy utilisation of refinery gas previously has been used for all years in the whole period 1990-2009. Now plant and year specific figures have been used instead. This causes a reallocation of emissions between 1A1b and 1B2c, but there is no change in total emissions. The reallocation causes lower emissions for 1B2c in 1991, 1995 and 2003-2009, whereas the emissions have been increased in 1990, 1992-1994, and 1996-2002. Emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O are affected by the change.
- Correction of error. The removal of a previous double counting for CO<sub>2</sub> and CH<sub>4</sub> in 2008 and 2009 has, in addition to the reallocation mentioned above, caused a further reduction in CO<sub>2</sub> and CH<sub>4</sub> emissions for these years.
- Reallocation/revised data. Parts of the CH<sub>4</sub> figures 2007-2009 for one plant, previously registered as emissions from flaring, have been reallocated to process. There are also changes in total CH<sub>4</sub> figures for this plant.

**9.2.2 Industrial processes**

*2 A 2 Lime production*

- Revised data. For one plant, the reported CO<sub>2</sub> emissions 1990-2007 have been adjusted, partly upwards, partly downwards. Only minor changes for all years.

*2 B5 Plastic*

- Reallocation. CO<sub>2</sub> figures for one plant, previously registered as combustion emissions, have now been split between combustion and process. This causes an annual rise in the size of 10-15 ktonnes for all years 1990-2008.

*2 B5 Titanium dioxide production*

- Reallocation. As recommended by the ERT, emissions previously reported under *2C1 Pig iron*, have been moved to *2B5 Titanium dioxide production* for the whole time period.

*2 C 1 Iron and steel production*

- Revised data. For one plant, the reported CO<sub>2</sub> figure for 2009 has been increased by 2 000 tonnes.
- Reallocation. As recommended by the ERT, emissions previously reported under *2C1 Pig iron*, have been moved to *2B5 Titanium dioxide production* for the whole time period.

#### *2 C 2 Ferroalloys production*

- Revised data. For one plant, the reported CO<sub>2</sub> figures have been marginally adjusted downwards for 2007 and increased by 10 000 tonnes for 2008.

#### 2 C 3 Aluminium productions

- Revised data. PFC emissions in 2009 from four plants have been revised due to decimal errors in the figures used in the 2011 submission. The CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emissions reported by three of the plants were in thousand tonnes e.g. 29000 tonnes CF<sub>4</sub> and corrected to 28 989 tonne CF<sub>4</sub>. For the fourth plant the emissions was included in the inventory with two decimals and now is included with three decimals.

#### *2 F 8 Electrical equipment*

- Revised data. For one plant, the reported SF<sub>6</sub> emission has been revised downwards for 2003 and 2009.

### **9.2.3 Solvents and other product use**

#### *3A, 3B, 3C, 3D Solvent losses*

- Revised data on use of formic acid used for ensilage means and cosmetics. Indirect emissions of CO<sub>2</sub> have decreased by 8 729 tonnes in 2005, 9 510 tonnes in 2006, 10 234 tonnes in 2007, 10 041 tonnes in 2008 and 8 798 tonnes in 2009.

### **9.2.4 Agriculture**

#### *4B11\_Liquid systems and 4B12\_Solid storage and dry lot*

- The factors for the production of N in faeces and urine of slaughter pigs and poultry have been corrected. Estimated N excretion factors per slaughtered animal were previously linked to stalls (places). Since the number of slaughtered animals exceeds the number of stalls manifolds, the corrections have increased the estimated production of N in manure, and have consequently led to a minor increase in the estimated emissions of NH<sub>3</sub> and N<sub>2</sub>O from the manure of slaughter hogs and poultry. Approximately 70 per cent of the produced manure from pigs and poultry is linked to liquid systems, while the rest is disposed in solid storage and dry lot.
- Emission factors for NH<sub>3</sub> losses from the manure of sheep and goats stalled in barns have been corrected. These factors were previously set equal to the factors of pigs, but have been changed so that they correspond to the factors of other ruminants. These factors are lower, which in turn has led to reduced NH<sub>3</sub> emissions. The remaining N-pool in the manure has consequently increased correspondingly, which in turn has led to a slight increase in N<sub>2</sub>O emissions. Slightly less than 50 per cent of the manure produced in barns from sheep and is linked to liquid systems, while the rest is disposed in solid storage and dry lot.

The total effect of the revised nitrogen excretion factors for pigs and poultry and the revised emission factors for  $\text{NH}_3$  losses from the manure of sheep and goats in barns are an increase in the  $\text{N}_2\text{O}$  emissions from the category 4D Manure managements for the whole time series (386-517 tonnes  $\text{N}_2\text{O}$ ).

#### *4D1.2\_ Animal Manure Applied to Soils*

- As explained in the paragraph above, corrections in the use of N-excretion factor for hogs and poultry and  $\text{NH}_3$  losses from sheep and goats in barns have led to a higher estimate of N in the remaining manure. Consequently, the estimated amount of N in manure applied to soils has also increased for the whole time series. Total effect of the recalculations was increased emissions for the whole time series (72-143 tonnes  $\text{N}_2\text{O}$ ).

#### *4D3.1\_ Atmospheric Deposition*

- The corrections of the factors for  $\text{NH}_3$  losses from the manure of sheep and goats in barns have reduced the estimated  $\text{NH}_3$  losses. Consequently, the subsequent depositions of  $\text{NH}_3$ , and thereby the  $\text{N}_2\text{O}$  emissions from these depositions had also a minor decrease. The higher N amount in the manure spread due to revised N excretion factors for slaughter pigs and poultry has reduced the decrease.

#### *4D3.2\_ Nitrogen Leaching and Run-off*

- Increased application of N in manure to the soils due to revised N excretion factors for slaughter pigs and poultry (see the previous paragraphs) increases the  $\text{N}_2\text{O}$  emissions from leaching and runoff for the whole time series (26-51 tonnes  $\text{N}_2\text{O}$ ).

#### *4F Burning of crop residues*

- Burning of crop residues in the fields are in general the residues of grain and oilseed. The residues of oil seed have been omitted in the calculations previously, but were included in 2012. This has led to a minor increase for the whole time series in the estimated emissions from this source, compared to previous estimations.

### **9.2.5 Waste**

#### *6 A Solid waste disposal on land*

- Correction of error. A significant amount of mixed waste, 30 000 tonnes in 1990 increasing to 180 000 tonnes in 2008, have been included in the inventory. The amount is allocated to all waste fractions in the same way as mixed waste from households.
- Revised activity data and correction of error. A sample survey on waste from manufacturing industries has been carried out for 2008. This has led to updated figures for 2008. In addition figures for 2003 have been corrected. Waste from manufacturing industries has been updated for all years since 2000 due to interpolation.
- Revised activity data. Reported figures on disposed waste in Statistics Norway's waste statistics have replaced estimates for 2009. New waste statistics shows a somewhat different trend than the preliminary estimates indicated. Since July 2009 it has been prohibited to dispose organic matter at landfills in Norway.

These changes have led to increased emissions of methane for all years after 1990. The emissions rose from 0.1 per cent in 1990 to 1 per cent for 2008 and 0.9 per cent for 2009.

*6 B2 Domestic and commercial wastewater*

- Correction of error. Due to the use of wrong emission factors, previously calculated CH<sub>4</sub> emissions were somewhat too low in 2008 and too high in 2009. Insignificant changes
- Revised data. The number of inhabitant connected to small treatment plants for the years 2008-2009 have been replaced with the average of the population at the beginning of the year and the end of the same year when calculating CH<sub>4</sub> emissions from waste water handling. Insignificant changes in emissions.

**9.2.6 Land-Use, Land-Use Change and Forestry**

No major changes in methods and Efs used compared to the reporting in 2011.

The whole time-series has been recalculated due to;

- Updating of activity data, due to new data and continuous quality control of the data bases used.

*5A1 Forest land remaining forest land*

- Compared to the submission of 2011 the whole time-series has been recalculated due to a updating of the activity data.
- The net removals for forest land remaining forest land was 35 446 Gg CO<sub>2</sub> in 2010. When including emissions of CH<sub>4</sub> and N<sub>2</sub>O the net removals were estimated to 35 433 CO<sub>2</sub>-equivalents.

*5A2 Land converted to forest land*

- The whole time-series has been recalculated due to a updating of the activity data.
- In 2010 the land-use category land converted to forest land contributed with a total amount of removals of 431 Gg CO<sub>2</sub>. Settlements converted to forest land were the largest contributor with 338 Gg CO<sub>2</sub>. The increase in soil organic carbon aggregated areas from 1990 constitutes a large part of the removals. See further explanation in section 7.3.2.1 under subtitle "Land converted to forest land".

*5B1 Cropland remaining cropland*

- The whole time-series has of the total area of cropland has been recalculated due to a updating of the activity data.
- The emissions from cropland remaining cropland were 42 Gg CO<sub>2</sub> in 2010.



*5B2 Land converted to cropland*

- The whole time-series has been recalculated due to a updating of the activity data. Area of organic soil (Histosol) is now in accordance with the area used in the agricultural sector (CRF table 4.D).
- Emissions from forest land converted to cropland are recorded for the whole time-series. In 2010 there was an emission of 25 Gg CO<sub>2</sub> from land converted to cropland.

*5C1 Grassland remaining grassland*

- The area of grassland remaining grassland is recalculated for the whole time-series due to a updating of the activity data.
- The emissions from grassland remaining grassland are estimated to be 1 606 Gg CO<sub>2</sub> in 2010.

*5C2 Land converted to grassland*

- The whole time-series has been recalculated due to a updating of the activity data.
- An emission of 75 Gg CO<sub>2</sub> was estimated for this category in 2010. This is due to a reduction of living biomass of fruit trees.

*5D1 Wetlands remaining wetlands*

- The total area of wetlands is recalculated due to a updating of the activity data.
- The emissions from wetlands remaining wetlands are coming from peat extraction. There is assumed no annual changes in this activity and therefore the emissions are equal to 3.4 Gg CO<sub>2</sub> every year in the time-period 1990–2010.

*5E2 Land converted to settlements*

- The whole time series has been recalculated due to a updating of the activity data.
- Emissions from forest land converted to settlements were estimated to 1 155 Gg CO<sub>2</sub> in 2010.

*5F2 Land converted to other land*

- The whole time series has been recalculated due to a updating of the activity data.
- No emissions or removals of CO<sub>2</sub> were reported for land converted to other land in 2010.

*Table 9.2 Recalculations in the 2012 submission compared to the 2011 submission for the LULUCF-sector. Gg CO<sub>2</sub>-equivalents*

| <b>Year</b> | <b>Submission<br/>2011</b> | <b>Current<br/>Submission<br/>2012</b> | <b>%<br/>change<br/>2011–<br/>2012</b> |
|-------------|----------------------------|--|--|
| 1990        | -8 556                     | -8 676                                 | 1.4                                    |
| 1991        | -9 108                     | -9 253                                 | 1.6                                    |
| 1992        | -9 584                     | -9 730                                 | 1.5                                    |
| 1993        | -10 101                    | -10 273                                | 1.7                                    |
| 1994        | -10 850                    | -11 048                                | 1.8                                    |
| 1995        | -11 211                    | -11 432                                | 2.0                                    |
| 1996        | -12 006                    | -12 241                                | 2.0                                    |
| 1997        | -12 564                    | -12 817                                | 2.0                                    |
| 1998        | -13 279                    | -13 845                                | 4.3                                    |
| 1999        | -13 849                    | -14 207                                | 2.6                                    |
| 2000        | -18 530                    | -19 070                                | 2.9                                    |
| 2001        | -20 397                    | -20 786                                | 1.9                                    |
| 2002        | -25 060                    | -25 746                                | 2.7                                    |
| 2003        | -27 849                    | -28 204                                | 1.3                                    |
| 2004        | -27 182                    | -27 447                                | 1.0                                    |
| 2005        | -29 613                    | -29 890                                | 1.0                                    |
| 2006        | -24 238                    | -24 645                                | 1.7                                    |
| 2007        | -28280                     | -28 578                                | 1.1                                    |
| 2008        | -34303                     | -34 694                                | 1.1                                    |
| 2009        | -25329                     | -26 985                                | 6.5                                    |

### **9.3 Implications of the recalculations for the greenhouse gases**

#### **9.3.1 Implications for emissions levels**

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Table 9.3 shows the effects of recalculations on the emission figures for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O 1990-2008. Table 9.4 shows the effect on recalculations on the emission figures for HFCs, PFCs and SF<sub>6</sub> 1990-2008.

*Table 9.3 Recalculations in 2012 submission to the UNFCCC compared to the 2011 submission. CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. Tonnes CO<sub>2</sub>-equivalents.*

|      | CO <sub>2</sub>    |                    |                   | CH <sub>4</sub>    |                    |                   | N <sub>2</sub> O   |                    |                   |
|------|--------------------|--------------------|-------------------|--------------------|--------------------|-------------------|--------------------|--------------------|-------------------|
|      | 2011<br>submission | 2012<br>submission | Difference<br>(%) | 2011<br>submission | 2012<br>submission | Difference<br>(%) | 2011<br>submission | 2012<br>submission | Difference<br>(%) |
| 1990 | 34802.9            | 34797.9            | 0.0               | 4665.6             | 4666.9             | 0.0               | 4728.7             | 4759.4             | 0.6               |
| 1991 | 33349.5            | 33342.3            | 0.0               | 4707.1             | 4708.7             | 0.0               | 4581.8             | 4613.3             | 0.7               |
| 1992 | 34157.9            | 34152.0            | 0.0               | 4762.2             | 4764.5             | 0.0               | 4015.8             | 4049.9             | 0.8               |
| 1993 | 35798.1            | 35797.9            | 0.0               | 4824.3             | 4827.5             | 0.1               | 4232.7             | 4266.4             | 0.8               |
| 1994 | 37705.4            | 37705.5            | 0.0               | 4891.8             | 4895.6             | 0.1               | 4323.8             | 4358.0             | 0.8               |
| 1995 | 37777.1            | 37777.3            | 0.0               | 4864.1             | 4868.8             | 0.1               | 4378.4             | 4414.8             | 0.8               |
| 1996 | 41023.7            | 41023.6            | 0.0               | 4872.6             | 4878.1             | 0.1               | 4417.5             | 4457.5             | 0.9               |
| 1997 | 41130.6            | 41130.6            | 0.0               | 4886.9             | 4893.4             | 0.1               | 4416.0             | 4457.1             | 0.9               |
| 1998 | 41306.5            | 41311.2            | 0.0               | 4749.5             | 4756.4             | 0.1               | 4454.1             | 4494.1             | 0.9               |
| 1999 | 42154.3            | 42145.0            | 0.0               | 4596.6             | 4605.2             | 0.2               | 4655.2             | 4696.1             | 0.9               |
| 2000 | 41740.0            | 41742.9            | 0.0               | 4722.9             | 4733.4             | 0.2               | 4433.3             | 4475.3             | 0.9               |
| 2001 | 43109.1            | 43109.3            | 0.0               | 4726.2             | 4740.3             | 0.3               | 4337.3             | 4379.6             | 1.0               |
| 2002 | 42248.1            | 42245.0            | 0.0               | 4553.0             | 4571.3             | 0.4               | 4521.5             | 4566.8             | 1.0               |
| 2003 | 43603.5            | 43601.6            | 0.0               | 4642.9             | 4666.2             | 0.5               | 4360.9             | 4405.8             | 1.0               |
| 2004 | 44043.1            | 44041.0            | 0.0               | 4617.0             | 4646.4             | 0.6               | 4511.0             | 4566.4             | 1.2               |
| 2005 | 43281.3            | 43052.0            | -0.5              | 4424.6             | 4460.3             | 0.8               | 4575.6             | 4630.5             | 1.2               |
| 2006 | 43511.0            | 43505.3            | 0.0               | 4282.7             | 4325.5             | 1.0               | 4222.1             | 4288.6             | 1.6               |
| 2007 | 45298.8            | 45472.4            | 0.4               | 4423.3             | 4470.3             | 1.1               | 4057.4             | 4116.4             | 1.5               |
| 2008 | 44417.8            | 44370.3            | -0.1              | 4296.9             | 4351.4             | 1.3               | 3571.1             | 3636.8             | 1.8               |
| 2009 | 42842.7            | 42893.7            | 0.1               | 4259.6             | 4324.3             | 1.5               | 3038.9             | 3106.6             | 2.2               |

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*Table 9.4. Recalculations in 2012 to the UNFCCC submission compared to the 2011 submission. HFCs, PFCs and SF<sub>6</sub>. Ktonnes CO<sub>2</sub>-equivalents.*

|      | HFCs            |                 |                | PFCs            |                 |                | SF <sub>6</sub> |                 |                |
|------|-----------------|-----------------|----------------|-----------------|-----------------|----------------|-----------------|-----------------|----------------|
|      | 2011 submission | 2012 submission | Difference (%) | 2011 submission | 2012 submission | Difference (%) | 2011 submission | 2012 submission | Difference (%) |
| 1990 | 0.02            | 0.02            | 0.00           | 3370.40         | 3370.40         | 0.00           | 2199.78         | 2199.78         | 0.00           |
| 1991 | 0.11            | 0.11            | 0.00           | 2992.92         | 2992.92         | 0.00           | 2079.15         | 2079.15         | 0.00           |
| 1992 | 0.34            | 0.34            | 0.00           | 2286.92         | 2286.92         | 0.00           | 705.03          | 705.03          | 0.00           |
| 1993 | 2.42            | 2.42            | 0.00           | 2297.72         | 2297.72         | 0.00           | 737.71          | 737.71          | 0.00           |
| 1994 | 9.20            | 9.20            | 0.00           | 2032.47         | 2032.47         | 0.00           | 877.98          | 877.98          | 0.00           |
| 1995 | 25.82           | 25.82           | 0.00           | 2007.74         | 2007.74         | 0.00           | 607.79          | 607.79          | 0.00           |
| 1996 | 52.24           | 52.24           | 0.00           | 1829.08         | 1829.08         | 0.00           | 574.10          | 574.10          | 0.00           |
| 1997 | 86.52           | 86.52           | 0.00           | 1632.94         | 1632.94         | 0.00           | 579.86          | 579.86          | 0.00           |
| 1998 | 129.82          | 129.82          | 0.00           | 1485.53         | 1485.53         | 0.00           | 726.74          | 726.74          | 0.00           |
| 1999 | 180.56          | 180.56          | 0.00           | 1388.46         | 1388.46         | 0.00           | 873.96          | 873.96          | 0.00           |
| 2000 | 238.36          | 238.36          | 0.00           | 1317.90         | 1317.90         | 0.00           | 934.42          | 934.42          | 0.00           |
| 2001 | 303.71          | 303.71          | 0.00           | 1328.63         | 1328.63         | 0.00           | 791.20          | 791.20          | 0.00           |
| 2002 | 362.68          | 362.68          | 0.00           | 1437.60         | 1437.60         | 0.00           | 238.30          | 238.30          | 0.00           |
| 2003 | 402.84          | 402.84          | 0.00           | 909.10          | 909.10          | 0.00           | 234.86          | 227.86          | -2.98          |
| 2004 | 439.42          | 439.42          | 0.00           | 879.94          | 879.94          | 0.00           | 276.05          | 276.05          | 0.00           |
| 2005 | 481.80          | 481.80          | 0.00           | 828.65          | 828.65          | 0.00           | 312.03          | 312.03          | 0.00           |
| 2006 | 520.24          | 520.24          | 0.00           | 742.50          | 742.50          | 0.00           | 212.09          | 212.09          | 0.00           |
| 2007 | 565.00          | 565.00          | 0.00           | 820.91          | 820.91          | 0.00           | 76.24           | 76.24           | 0.00           |
| 2008 | 623.92          | 623.92          | 0.00           | 772.74          | 772.74          | 0.00           | 65.40           | 65.40           | 0.00           |
| 2009 | 707.68          | 707.70          | 0.00           | 379.16          | 376.76          | -0.63          | 64.47           | 61.46           | -4.67          |

*Table 9.5. Trends in emissions 1990-2009. 2012 submission compared to 2011 submission. GHG. Per cent change 1990-2009.*

|                 | Total GHG | CO <sub>2</sub> | CH <sub>4</sub> | N <sub>2</sub> O | PFCs   | SF <sub>6</sub> | HFCs      |
|-----------------|-----------|-----------------|-----------------|------------------|--------|-----------------|-----------|
| 2012 submission | 3.37      | 23.27           | -7.34           | -34.73           | -88.82 | -97.21          | 3 861 203 |
| 2011 submission | 3.06      | 23.10           | -8.70           | -35.74           | -88.75 | -97.07          | 3 861 171 |

### 9.3.2 Implications for emission trends

In this submission compared to the 2011 submission, CO<sub>2</sub> emissions have decreased by 0.5 per cent in 2005, mainly because of the correction of a previous error in 1A3d. In 2007, CO<sub>2</sub> emissions have risen by 0.4 per cent, once again because of a corrected error in 1A3d. Revised figures on emissions from landfills have most impact on the emission increase for CH<sub>4</sub>. There is a growing rise in total emissions during the period, from 0.0 per cent in 1990 to 1.5 per cent in 2009. New calculations for some agricultural sources have caused a growing rise in N<sub>2</sub>O emissions in the period, from 0.6 per cent in 1990 to 2.2 per cent in 2009. The emission trend for total greenhouse gas emissions from 1990 to 2009 shows a somewhat larger increase in the 2012 submission compared with the 2011 submission, mainly because of reduced decreases in emissions of CH<sub>4</sub> and N<sub>2</sub>O in the period, but also a larger growth in CO<sub>2</sub> emissions. For HFCs, PFCs and SF<sub>6</sub> there are only marginal differences between the emissions in the 2011 and 2012 submissions.

## **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 in this chapter is provided in accordance with Decision 15/CP.10 (FCCC/CP/2004/10/Add.2) and Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol. The information provided is also in accordance with the instructions in Decision 16/CMP.1 and with the requirements from paragraphs 5–9 in Decision 15/CMP.1. Collection of activity data and calculations are carried out in line with the Good Practice Guidance for Land use, Land-use Change and Forestry (2003).

When reporting emissions and removals for the activities under Article 3.3 and 3.4 of the Kyoto Protocol, Norway is using parts of the activity data and methods used when reporting emissions and removals for Forest land and land-use changes to and from forest land under the UNFCCC, see chapter 7.

Norway has chosen commitment-period accounting.

##### 11.1.1 Definition of forest and other criteria

**Forest land** is defined according to the Global Forest Resources Assessment (FRA) 2004. Forest land is land with tree crown cover of more than 10 per cent and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. No minimum width for Forest land is considered in the Norwegian inventory causing a small discrepancy according to the definition in FRA 2004. Young natural stands and all plantations established for forestry purposes, as well as forest land which are temporarily unstocked as a result of human intervention are included under Forest land.

*Table 11.1 Parameters for defining Forest land*

| Parameter           | Range     | Selected value |
|---------------------|-----------|----------------|
| Minimum land area   | 0.05–1 ha | 0.5 ha         |
| Minimum crown cover | 10–30%    | >10%           |
| Minimum height      | 2–5 m     | 5 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 for 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.

Practically all forest in Norway will be used 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.

#### **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 National Forest Inventory (NFI) of Norway provides data for land use, land-use change and forestry for the greenhouse gas reporting related to Article 3.3 and Article 3.4.

The information about the areas subjected to Afforestation/Reforestation (**AR**) and Deforestation (**D**) is based on the NFI, which has been carried out continuously since 1986 and up to present. Land use obtained between 1986 and 1993 serves as the baseline for the land use and biomass by 31.12.1989. Because no data from permanent sample plots exists before 1986 and relatively small changes has been detected in total forest land, we have chosen not to take into account changes that may have occurred prior to 1990. This implies that stock changes in land converted to forest are underestimated, but the biomass changes are included in the reporting category for “forest land remaining forest land”. All land-use changes to and from forest taken place after 31.12.1989 are considered human induced, except wetlands to forest land.

**AR** activities refer to the conversion of non-forested land to a forested state and are reported together (IPCC 2003, section 4.2.5.1) and **D** refers to the conversion of forested land to a non-forested state (IPCC 2003, section 4.2.5.1).

All Forest land is considered managed which includes also recreation areas, protected areas and nature reserves. All forests are used either for wood harvesting, hunting, picking berries, hiking etc., and are therefore subjected to Forest Management (**FM**).

#### **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 is based on a selection of the NFI plots used to report under the convention. The data for all areas under the coniferous tree line in a 3x3 km grid are used to estimate area subjected to ARD activities back to 1990. Each plot covers a circular area of 250 m<sup>2</sup> and represents approximately 0.9 kha. Since 1986 all plots are classified according to a national land cover and land use classification system, which is further converted consistently to the UNFCCC Land-use categories. AR activities are accounted as long as the forest definition is met and deforestation is recorded when land-use change has occurred.

Areas above the coniferous tree line and in Finnmark County are not included in the estimates for areas subjected to ARD. At current time there is no time-series of land-use change in these areas. The plan is to include these areas and the corresponding changes in carbon stock in the 2014 report for KP-LULUCF. Information from the NFI, maps, old and new aerial photos are planned to be used to establish land use of each new plot in the base year 1990. The estimates

of net carbon stock change in living biomass for these areas is included in the reported estimates for areas subjected to the activity Forest Management under Article 3.4.

Further description is given in section 7.3 and 7.2 in this report.

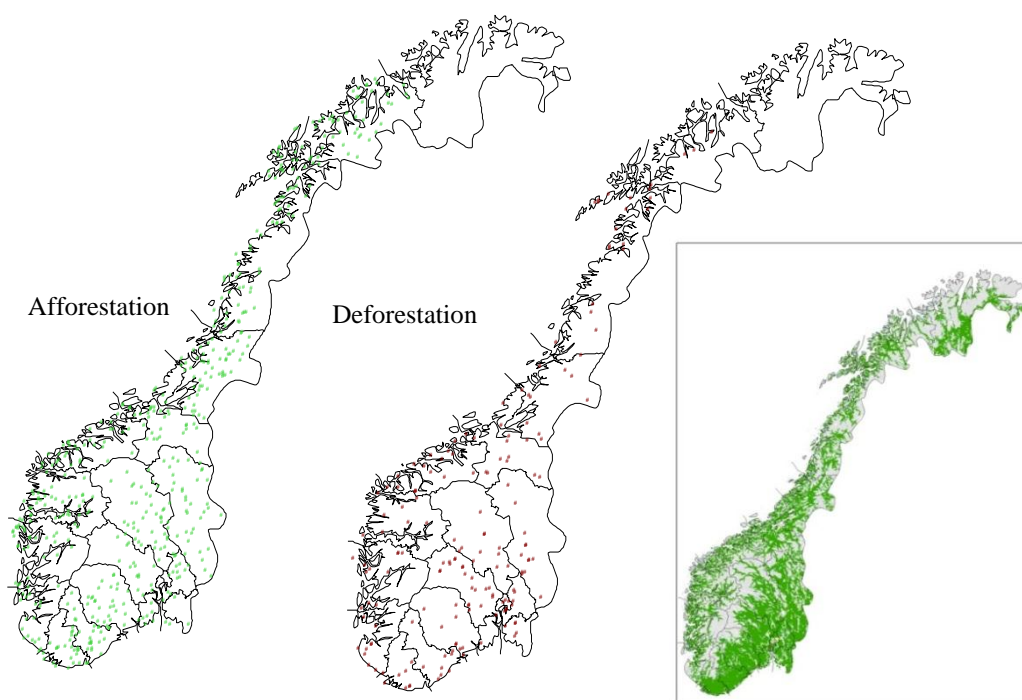
### 11.2.2 Methodology used to develop the land transition matrix

The land-use transition 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. The 20 years approach has been used for the land-use transition classes.

Further description is given in section 7.2 in this report.

### 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 permanent 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 (in country review) upon request. For further details, see Section 11.2.1.



*Figure 11.1 The locations of sample plots reported under Afforestation/Reforestation and Deforestation (1990–2010), and the green area in the small map shows the area of Forest Management in Norway.*



## 11.3 Activity specific Information

### 11.3.1 Methods for carbon stock change and GHG emission and removal estimates

#### 11.3.1.1 Description of the methodologies and the underlying assumptions used

##### *Carbon stock changes in living biomass*

The calculations of carbon stock changes in living biomass are based on data obtained from the NFI. The reported carbon refers to the biomass of all living trees with a height of at least 1.3 m. Thus, small trees, shrubs and other vegetation, such as herbs are not included in the figures for areas subject to activities under Article 3.3. The biomass of trees with a stem diameter larger than 50 mm measured 1.3 m above the ground is individually monitored. Swedish single tree allometric regression functions developed for Norway spruce, Scots pine and birch are applied to estimate the biomass (Marklund 1988, Petersson and Ståhl 2006). It is possible to match the biomass to land use for each tree.

The estimates reported for areas subject to Forest Management under Article 3.4 are calculated by using the activity data and methods for forest land remaining forest land described in 7.2.1.1 and 7.3.1. The same method as described above for Article 3.3 is used to calculate carbon stock change in living biomass for Forest Management. In addition, the estimate for Forest Management also includes carbon stock for small trees, mountain birch areas and forests in Finnmark County. This is further described in chapter 7.3.1.1.

Norway has selected to use the stock change method to estimate emissions and removals for forest land remaining forest land, land converted to forest land and forest land converted to other land-use categories, and hence for land subject to ARD activities. Fixed emission factors ( $\text{Mg CO}_2\text{ha}^{-1}$ ) are therefore not used in the current submission.

Further description is given in section 7.3 Forest land in this report.

##### *Change in carbon stock in dead organic matter and in soil*

The dynamic soil model Yasso as described in detail by Liski et al. (2005), and for Norwegian conditions by de Wit et al. (2006), is used to calculate changes in carbon stock in dead organic matter and in soil for Forest Management. The calculations are hence done according to a Tier 3 method. The current implementation of the Yasso model is not designed for obtaining estimates of dead organic matter and soil organic carbon for disaggregated areas or land-use categories other than forest land remaining forest land. Therefore, we have applied the soil carbon model Yasso07 for the land converted to forest land (AR) and forest land converted to Settlements and Other land (D) (Liski et al 2009). For Forest land converted to Cropland or Grassland emission factors are used. The model produced an aggregated estimate of carbon stock change for the total of the litter, dead wood and soil organic matter. It is not possible to obtain separate estimates for these components with the current version of the model.

Further description is given in Chapter 7.3.1 and 7.3.2.

#### 11.3.1.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

With the current system it is not possible to obtain separate estimates for net carbon stock change for litter, dead wood and soil for areas subjected to ARD. The model Yasso07 produced an aggregate estimate for carbon stock change for the total of litter, dead wood and soil organic matter. The aggregated value is reported under soil for areas subject to ARD

activities. Therefore, the notation key IE is used for the carbon pools litter and dead wood in NIR 1.

During the centralized review in 2010, Norway provided (in the answer to the Saturday paper) preliminary estimates for carbon stock changes in dead wood for areas subjected to ARD. The material and methods used was based on data of dead wood observed on the permanent NFI plots. Further description can be found in the paper “The Responses to the Potential Problems and Further Questions from the ERT formulated in the course of the 2010 review of the greenhouse gas inventories of Norway submitted in 2010: KP-LULUCF“, which is available on request. The dataset used for areas subjected to AR was small as it covers only one year out of the five year cycle (2010-2014). The preliminary results indicate that dead wood represents a sink ( $12.09 \text{ Gg carbon year}^{-1}$ ) on areas subjected to AR. Norway assumes that all carbon in dead wood is released at the time of deforestation, and hence dead wood became a source of  $\text{CO}_2$  emission ( $10.61 \text{ Gg carbon year}^{-1}$ ). The estimate of carbon in dead wood is an average value based on the amount of dead wood on forest land prior to deforestation, hence the value is fixed for all years. These estimates cannot at the moment be used to verify or demonstrate that dead wood in afforestation/reforestation (AR) and deforestation (D) areas are not a net source or a sink of anthropogenic greenhouse gas emissions, because the uncertainty in these estimates is very high. This will, however, be improved when the current NFI cycle is completed after 5 years in 2014. Since Norway are providing aggregated estimates for carbon stock change for the total of litter, dead wood and soil organic matter based on the Yasso07 model, the preliminary estimates of removals and emission for dead wood on areas subjected to ARD are not included in the inventory in order to avoid double accounting.

Controlled biomass burning does not occur on land subjected to ARD and FM activities. The reported emission for biomass burning is in accordance with wild fires. It is not possible to assign the wild fire statistics to land subject to ARD activities. Therefore, the emissions are reported as IE and included under FM (**R in NIR 1**).  $\text{CO}_2$  emissions from biomass burning caused by wildfires are included under changes in carbon stock (**IE in NIR 1**). This is due to the use of the stock change method.

Middle aged or older forest stands on mineral soils are sometimes fertilized to increase the forest production. All fertilization is therefore assumed to occur on Forest land remaining Forest land and reported as IE for AR in NIR 1. Furthermore, the available statistics on applied amount of fertilizers is not designed for obtaining estimates of emission for disaggregated areas subjected to AR activities.

Within current agricultural practice, lime is applied almost exclusively on cropland. Lime is applied on agricultural soil but not on forest soils. Furthermore, the available statistics of applied amount of lime is not designed for obtaining estimates of emission for disaggregated areas. Thus, all lime has been reported as occurring in cropland remaining cropland (**IE in NIR 1**).

### **11.3.1.3 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.

### **11.3.1.4 Changes in data and methods since the previous submission (recalculations)**

The activity data has been updated. All given estimates are carried out in accordance to the IPCC Good practice guidance for LULUCF (2003). The same method as used in the 2011

submission, to estimate carbon stock change in soil for areas subject to ARD activities is applied.

#### **11.3.1.5 Uncertainty estimates**

Uncertainty estimates for Article 3.3 and 3.4 are required according to Marrakesh Accords. Norway is not able to provide uncertainty estimates for Article 3.3 and 3.4 for this inventory. The Norwegian Forest and Landscape Institute started a project 01.09.2011, that has as the goal to provide uncertainty estimates both for Article 3.3 and 3.4. The uncertainty estimates used in the Key category analysis for the LULUCF sector are mainly based on Expert judgments. The plan is to provide preliminary estimates at the latest in 2013 and the final estimates in the submission of 2014.

#### **11.3.1.6 Information on other methodological issues**

The methods used to estimate emissions and removals from ARD activities are of the same tier method as those used for the UNFCCC reporting.

#### **11.3.1.7 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 will cover the period of consideration. The permanent plots were installed from 1986 until 1993. From 1994 and onwards the plots have been surveyed continuously in a five year cycle. By assessing the national land cover- and land use class for all the plots the NFI records directly land-use changes to and from forest. Since 1994 all the ARD activities are considered to be human induced.

#### **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 forest land which are temporarily unstocked as a result of human intervention, are included under Forest land and not treated as deforestation. The NFI teams assess land cover and land use according to national criteria (see Table 7.3 in section 7.2 Source category descriptions – NIR 2012) that are defined in the field instruction<sup>23</sup>. They are also trained to distinguish between forest management operations and land-use change. The basic steps or a decision tree to explain how this is done are planned to be included in future annual submissions, at least when the reporting for the commitment period is due in 2014.

#### **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.

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<sup>23</sup> Landsskogtakseringens feltinstruks 2010,  
[http://www.skogoglandskap.no/publikasjon/landsskogtakseringens\\_feltinstruks\\_2010](http://www.skogoglandskap.no/publikasjon/landsskogtakseringens_feltinstruks_2010)

## **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**

All forests in Norway are subjected to FM. Hence, all land-use change to and from Forest land occurred after 1990 are human-induced. The permanent NFI plots were installed from 1986 until 1993. From 1994 and onwards the plots have been surveyed continuously in a five year cycle. By assessing the national land cover- and land use class for all plots the NFI records directly land use changes to and from forests (see Table 7.3 in section 7.2 Source category descriptions – NIR 2012).

### **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 relating to Forest Management:**

For the purpose of the reporting under the Kyoto Protocol the definition of forest is in accordance with the definition in item 11.1.1 above.

Practically all forest in Norway will be used 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.

## **11.6 Other information**

### **11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4.**

Information in NIR 3 is provided for FM in this submission. A description of the key categories can however be seen in Section 7.1.3 in NIR 2012. According to the level assessment analysis Land converted to Settlements – living biomass is a key category and according to the trend assessment Land converted to forest land – living biomass is a Key category.

## **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 2011 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\_2012\_1\_12-54-24 15-2-2012.xls.

### **12.2 Summary of information reported in the SEF tables**

There were 270,075,620 AAUs in Norway's national registry at the end of the year 2011. Of these units, 197,478,782 units were held in Party holding accounts; 18,785,282 units in entity holding accounts; 32,966 units in other cancellation accounts and 53,778,590 units in the retirement account.

There were 747,944 ERUs in the registry at the end of 2011. The Party holding accounts held 95,123 ERUs; the entity holding accounts held 309,303 ERUs and the retirement account held 343,518 ERUs.

There were 9,057,797 CERs in the registry at the end of 2011. 2,284,852 CERs were held in Party holding accounts; 2,942,117 CERs were held in entity holding accounts; 60,305 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 2011 corresponded to 279,881,361 tonnes of CO<sub>2</sub> eq. Norway's assigned amount is 250,576,797 tonnes of CO<sub>2</sub> eq.

### 12.3 Discrepancies and notifications

| Annual Submission Item  | Reporting information   |
|---|---|
| 15/CMP.1 annex I.E paragraph 12:<br>List of discrepant transactions             | No discrepant transactions occurred in 2011.  |
| 15/CMP.1 annex I.E paragraph 13 & 14:<br>List of CDM notifications              | No CDM notifications occurred in 2011.  |
| 15/CMP.1 annex I.E paragraph 15:<br>List of non-replacements                    | No non-replacements occurred in 2011.   |
| 15/CMP.1 annex I.E paragraph 16:<br>List of invalid units                       | No invalid units exist as at 31 December 2011.  |
| 15/CMP.1 annex I.E paragraph 17<br>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](http://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 Regulation<sup>24</sup>) 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 2011.

Holding and transaction information of units (Paragraph 47)

*General remarks*

<sup>24</sup> 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

Holding and transaction information is provided on a holding type level due to more 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 2011

*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 2011.

*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 CO<sub>2</sub> equivalents. 90 percent of the assigned amount is 225,519,117 tonnes CO<sub>2</sub> equivalents. The inventory for the year 2008, submitted in 2010, is the most recently reviewed inventory for Norway (FCCC/ARR/2010/NOR). The total emissions in 2008 amounted to 53,705,780 tonnes CO<sub>2</sub> equivalents. (The emission estimate of 54,407,796 tonnes CO<sub>2</sub> equivalents in Norway's re-submission in November 2010 is incorrect, as communicated by the Climate and Pollution Agency to the UNFCCC secretariat). Five times 53,705,780 tonnes CO<sub>2</sub> equivalents amounts to 268,528,900 tonnes CO<sub>2</sub> 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 2008. Therefore, the commitment period reserve is 225,519,117 tonnes CO<sub>2</sub> equivalents.

## **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:

- New routines for input data control were completed and implemented. Reported emissions, emission factors and activity data for the latest inventory year are routinely compared to those of the previous inventory year. In addition, implied emissions factors are calculated for emissions from stationary combustion at point sources and are compared to previous inventory year.
- A reorganisation at Statistics Norway that merges the emission inventory group with the energy statistics.
- The Climate and Pollution Agency has started to build up a physical and electronic library with the most important methodology reports. More details are found in Annex V.



## 14 Information on changes in national registry

The table below provides high level descriptions of significant changes implemented in the Norwegian registry in 2011. A clear statement is given for items where no changes occurred. Detailed information on items where changes have occurred is attached in annex VIII.<sup>25</sup>

| Reporting Item   | Reported information   |
|--|--|
| 15/CMP.1 annex II.E paragraph 32.(a): Change of name or contact                                | No change in the name or contact information of the registry administrator occurred during the reported period   |
| 15/CMP.1 annex II.E paragraph 32.(b) : Change of cooperation arrangement                       | No change of cooperation arrangement occurred during the reported period   |
| 15/CMP.1 annex II.E paragraph 32.(c) : Change to database or the capacity of national registry | No change to the database or to the capacity of the national registry occurred during the reported period  |
| 15/CMP.1 annex II.E paragraph 32.(d) : Change of conformance to technical standards            | No change in the registry's conformance to technical standards occurred for the reported period.   |
| 15/CMP.1 annex II.E paragraph 32.(e): Change of discrepancies procedures                       | <p>The NO registry deployed version 5.2 of the Greta Registry software (hereafter denoted v5.2) in June 2011. V5.2 implemented a change to the message flow for external transfers. The new message flow introduces an additional step that marks the transaction and unit blocks as proposed in the acquiring registry until the acquiring registry has confirmed acceptance of the unit blocks and the ITL has completed the transaction.</p> <p>This additional step ensures that the NO registry cannot transfer units received by external transfer until the ITL have completed the transaction. The new message flow will thereby reduce the risk of discrepant transactions occurring in the NO registry.</p> <p>Please consult the v.5.2 release notes (ETR 5.2 Release Notes_1.0) and v5.2 test report (SFW V5.2 Test Report_1.0) for further details. The documents are attached in annex VIII.</p> |

<sup>25</sup> 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.

| Reporting Item   | Reported information   |
|--|--|
| 15/CMP.1 annex II.E paragraph 32.(f): Change of security                               | <p>As reported in the 2011 NIR submission, the NO registry introduced a mandatory two-man rule for all existing and new accounts. By January 2011 all accounts had an additional account representative (AAR). The role of the AAR is to approve or reject any transaction proposals made by the primary (PAR) or secondary (SAR) account representative. In effect, this two-man rule means that all transactions need approval from two authorized users in order to be proposed to the ITL and CITL.</p> <p>The NO registry imposed mandatory security requirements on the users in addition to other recommended security measures. The requirements and recommendations are stated in section 4 in the User Agreement:</p> <p><a href="http://www.kvoteregister.no/docs/Terms%20and%20conditions.pdf">http://www.kvoteregister.no/docs/Terms%20and%20conditions.pdf</a></p> <p>In addition, the Greta registry version 5.2 introduced several security enhancement options. The NO registry implemented the following enhancements:</p> <ul style="list-style-type: none"> <li>• Dual approval of registry administrator transactions.</li> <li>• User logon audit trail</li> <li>• Generic error on logon failure</li> </ul> <p>More details on the security enhancements options are given in v5.2 release notes and v5.2 test report attached in annex VIII.</p> |
| 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                      | No change of the registry Internet address occurred during the reporting period.   |
| 15/CMP.1 annex II.E paragraph 32.(i): Change of data integrity measures                | No change of data integrity measures occurred during the reporting period.   |
| 15/CMP.1 annex II.E paragraph 32.(j) : Change of test results                          | Deployment of v5.2 did not necessitate any changes of test results. Please consult the v5.2 test report (SFW V5.2 Test Report_1.0) for details of the testing conducted on this version. The document is attached in annex VIII.   |

National Inventory Report 2012 - Norway

| Reporting Item  | Reported information  |
|---|---|
| Previous Annual Review recommendations, ref FCCC/ARR/2009/NOR | There are no recommendations related to registry operations in the review report FCCC/ARR/2010/NOR. No notices or recommendations are stated in section 1.2 Summary of Findings of the SIAR Part 2 Report IAR/2010/NOR/2/1. |

## **15 Information on minimization of adverse impacts in accordance with Article 3. Paragraph 14**

Norway approaches the report on activities under Article 3.14 from the perspective of being a major exporter of fossil fuels, although we recognize that this is only one aspect of the potential social, environmental and economic impacts of mitigation.

Norway is well aware that taxation of fossil fuels, as well as other policies and measures that influence demand of these, has implications for price and thus has implications for the revenue earned by exporters. This is one of the reasons why Norway emphasizes the need to devise cost-effective policies, thereby minimizing such impacts. The final consequences are, however, uncertain and will generally also depend on policies implemented by the producers.

Norway's share of global consumption is so small that it is unlikely to significantly affect these markets. Cost efficiency across all emission sources and sinks has guided the development of policies and measures since Norway started to implement measures to mitigate climate change two decades ago, and is applied when implementing its commitments under Article 3.1 of the Kyoto Protocol.

### Market prices and externalities:

In its economic, energy and environmental policies Norway strives to have a market-based approach where prices reflect costs, including for externalities. The reflection of the costs of externalities with respect to emissions of greenhouse gases is undertaken through levies and the establishment of an emissions trading scheme. 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).

Further, both the trading scheme and the levies are designed so that the international price of emissions for units under the Clean Development Mechanism and the European trading scheme is reflected in the domestic cost of emissions. The state has also established a purchase programme which acquires the necessary number of Kyoto units to comply with the commitments under Article 3.1, as well as the unilateral target of reducing emissions by 10 percentage points more than its Kyoto commitments (see NC 5 chapter 4.3.1.9). This programme, the design of the levy and of the emissions trading system contributes to a cost-effective balance between domestic measures and use of the Kyoto mechanisms.

### Unsafe and unsound technologies:

Norway does not subsidize environmentally unsound and unsafe technologies, and hence phasing out subsidies is not applicable. Norway is also a member of The Friends of Fossil Fuel Subsidy Reform group.

### 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 newly 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 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 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 CO<sub>2</sub> capture (Technology Centre Mongstad, please view NC 5 chapter 4.3.9).

*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](http://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.

As of 2011, Norway is primarily working with eight countries; Angola, Bolivia, Ghana, Mozambique, Sudan, South-Sudan, Timor-Leste and Uganda, while 16 countries receive limited assistance. These are Afghanistan, Bangladesh, Ecuador, Iraq, Ivory Coast, Kenya, Lebanon, Mauretania, Nicaragua, Nigeria, the Palestinian Territory, São Tomé and Príncipe, South Africa, Tanzania, Vietnam and Zambia.

The OfD initiative was launched in 2005. 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. 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.

Key implementing agencies include the Norwegian Petroleum Directorate, Petrad (International programme for petroleum management and administration), the Climate and Pollution Agency, the Directorate for Nature Management and the Petroleum Safety Authority. 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.

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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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