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Greenhouse Gas Emissions 1990-2016, 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 2018 National Inventory Report (NIR). The NIR and the associated Common Reporting Format (CRF) tables have been prepared in accordance with the revised UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 24/CP.19. The methodologies used in the calculation of emissions are consistent with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. The structure of this report is consistent with the UNFCCC guidelines for inventory reporting.

This National Inventory Report 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 under the Kyoto Protocol. Chapter 12 includes information on Kyoto units, chapter 13 includes information on changes in national systems, chapter 14 includes information on changes in national registries and chapter 15 includes information on minimization of adverse impacts.

The Norwegian Environment Agency, a directorate under the Norwegian Ministry of Climate and Environment, is responsible for the reporting. Statistics Norway has been the principle contributor while the Norwegian Institute of Bioeconomy Research is responsible for chapters 6 and 11 and all information regarding Land Use, Land Use Change and Forestry.

Oslo, April 13th, 2018.

Audun Rosland

Director, Department of Climate

Norwegian Environment Agency

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National Inventory Report 2018

E.S. Executive Summary

E.S.1. Background information on greenhouse gas (GHG) inventories and climate change

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) 2018 for the period 1990-2016.

The report and the associated Common Reporting Format (CRF) tables have been prepared in accordance with the revised UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 24/CP.19. The methodologies used in the calculation of emissions are consistent with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. As recommended by the IPCC Guidelines, country specific methods have been used where appropriate.

Emissions of the following greenhouse gases are covered in this report: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). Norway does not have any emissions of nitrogen trifluoride (NF_3) to report. In addition, the inventory includes calculations of emissions of the precursors NOx, NMVOC, and CO, as well as for SO_2. Indirect CO_2 emissions originating from the fossil part of CH_4 and NMVOC are calculated and reported.

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

In 2016, the total emissions of greenhouse gases in Norway amounted to 53.2 million tonnes CO_2 equivalents, without emissions and removals from Land-Use, Land-Use Change and Forestry (LULUCF). From 1990 to 2016, the total emissions increased by 3.0 per cent. Norway has experienced economic growth since 1990, with only minor setbacks in the early 1990s. The economic growth partly explains the general growth in CO_2 emissions since 1990. In addition, the offshore petroleum sector has expanded significantly during the past 20 years.

The total GHG emissions, without LULUCF, decreased by 1.2 per cent between 2015 and 2016. In 2016, CO_2 contributed to 82.7 per cent of the total emission figures, while methane and nitrous oxide contributed to 9.5 and 4.7 per cent, respectively. PFCs, HFCs and SF_6 together accounted for 3.0 per cent of the total GHG emissions.

In 2016, the total net removal from the LULUCF sector was 24.4 million tonnes CO_2 equivalents.The land-use category forest land was the main contributor to the total amount of sequestration with 28.8 million tonnes of CO_2. The net greenhouse gas emissions, including all sources and sinks, were 28.9 million tonnes CO_2 equivalents in 2016, a decrease of 30.1 per cent from the net figure in 1990.

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

Figure E.S. 1 shows the overall trend in the total emissions by gas for the period 1990-2016. The proportion of CO_2 emissions of the national total greenhouse gas emissions has increased from about 69 per cent in 1990 to almost 83 per cent in 2016. The increased proportion of CO_2 relative to other gases is due to growth in the CO_2 emissions during this period, as well as a reduction in emissions of N_2O, PFCs and SF_6 gases because of implemented environmental measures and/or technological improvements and closures of industrial plants.

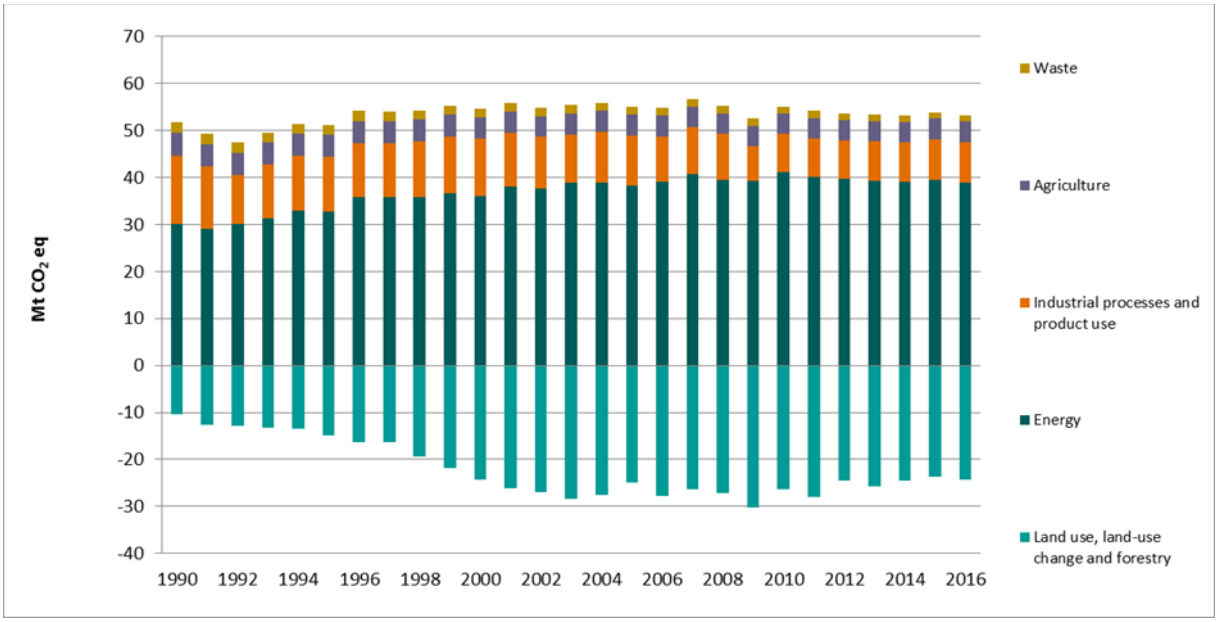


Figure E.S. 1 Total emissions of greenhouse gases by sources and removals from LULUCF in Norway, 1990-2016 (Mtonnes CO_2 equivalents).
Source: Statistics Norway/Norwegian Environment Agency/Norwegian Institute of Bioeconomy Research

Table E.S. 1 Emissions of greenhouse gases in Norway during the period 1990-2016. Units: CO_2 in Mtonnes (Mt), CH_4 and N_2O in ktonnes (kt) and other gases in tonnes (t).

Gas	CO_2	CH_4	N_2O	PFC			SF_6	HFC								
				CF_4	C_2F_6	C_3F_8		23	32	125	134a	143a	152a	227ea	134	143
Year	Mt	kt	kt	t			t	t								
1990	35.7	231.5	14.1	467.4	36.2	NO	92.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
1995	38.5	234.6	12.8	283.3	18.1	NO	25.4	0.0	0.4	5.2	38.6	4.1	1.3	0.0	0.0	0.0
2000	42.2	226.9	13.1	186.4	11.6	NO	39.1	0.1	2.0	34.8	90.5	28.7	7.0	0.2	0.0	0.0
2005	43.6	218.0	14.0	116.7	7.6	NO	13.0	0.1	6.1	57.2	139.4	44.8	26.8	1.0	0.8	1.1
2006	43.9	212.9	12.9	102.1	8.6	NO	8.8	0.1	7.9	63.2	158.5	48.0	30.1	0.9	0.8	1.9
2007	45.9	217.7	12.3	111.7	10.3	NO	3.1	0.1	10.0	64.4	184.9	46.6	31.7	1.1	0.7	1.6
2008	44.9	211.9	10.8	104.7	10.0	NO	2.6	0.1	12.5	68.9	218.5	52.0	30.5	0.8	2.7	1.4
2009	43.2	213.4	9.0	49.8	5.8	NO	2.4	0.1	15.9	73.9	245.1	50.4	30.7	0.9	2.2	1.3
2010	45.8	214.1	8.7	27.3	3.0	0.01	3.0	0.1	19.8	94.2	280.2	69.3	34.6	0.7	2.0	1.1
2011	45.0	207.9	8.7	29.9	3.4	0.01	2.4	0.2	22.6	99.0	305.9	65.0	34.5	2.1	1.8	1.0
2012	44.6	206.3	8.7	22.9	2.6	0.01	2.3	0.5	25.5	99.0	339.5	60.6	35.0	1.9	1.7	0.9
2013	44.3	207.4	8.6	20.6	2.3	0.00	2.5	0.4	31.1	97.3	364.4	57.4	34.6	1.2	1.5	0.8
2014	44.0	210.8	8.6	20.3	2.4	0.00	2.2	0.3	34.6	103.8	362.0	69.4	36.6	0.9	1.4	0.8
2015	44.7	206.5	8.7	16.7	1.9	NO	3.1	0.3	39.5	111.7	346.3	66.9	37.8	1.1	1.3	0.7
2016	44.0	203.2	8.5	21.2	2.4	NO	2.8	0.3	42.4	119.3	381.7	78.0	39.5	4.0	1.2	0.6

Source: Statistics Norway/Norwegian Environment Agency

Table E.S. 2 Emissions in million tonnes CO_2 equivalents in 1990, 2015, 2016 and changes (per cent) between 1990-2016 and 2015-2016 (without LULUCF).

Year	CO_2	CH_4	N_2O	PFCs	SF_6	HFCs	Total
1990	35.7	5.8	4.2	3.9	2.1	0.0	51.7
2015	44.7	5.2	2.6	0.1	0.1	1.2	53.9
2016	44.0	5.1	2.5	0.2	0.1	1.4	53.2
Changes 1990-2016	23.3 %	-12.3 %	-40.2 %	-95.2 %	-97.0 %	3106145.2 %	3.0 %
Changes 2015-2016	-1.4 %	-1.6 %	-3.0 %	27.2 %	-8.8 %	10.6 %	-1.2 %

Source: Statistics Norway/Norwegian Environment Agency

About 45 per cent of the methane emissions in 2016 originated from agriculture, and 20 per cent originated from landfills. The total methane emissions decreased by 1.6 per cent from 2015 to 2016.

In 2016, agriculture and nitric acid production contributed to 74 per cent and 12 per cent of the total N_2O emissions, respectively. Due to technical improvements in production of nitric acid, and despite the increased production, the total emissions of N_2O have decreased by 40 per cent since 1990.

The PFC emissions increased by 27 per cent from 2015 to 2016, and the emissions have, in total, been reduced by 95 per cent since 1990. PFC emissions originate primarily from the production of aluminium, where technical measures have been undertaken to reduce them. CO_2 emissions from aluminum production have increased since 1990 due to increased production levels.

SF_6 emissions have been reduced by 97 per cent from 1990 to 2016, mainly because of technological improvements and the closure of a magnesium production plant and a magnesium recycling foundry.

HFC emissions decreased by 5.2 per cent in 2016 compared to 2015. Emissions in 1990 were insignificant and then increased significantly from mid-1990s until 2002. The increase in HFCs emissions has been moderated by the introduction of a tax on HFCs in 2003.

The net removal from the LULUCF sector was 24.4 million tonnes CO_2-equivalents in 2016. Since 1990, there has been an increase in carbon stored in living biomass, dead organic matter and in soils in Norway, increasing net sequestration of CO_2 by 133 per cent since 1990. The increase in carbon stored is a result of an active forest management policy over the last 60 to 70 years. The annual harvest rate 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 IPCC sectors' share of the total greenhouse gas emissions in Norway in 2016.

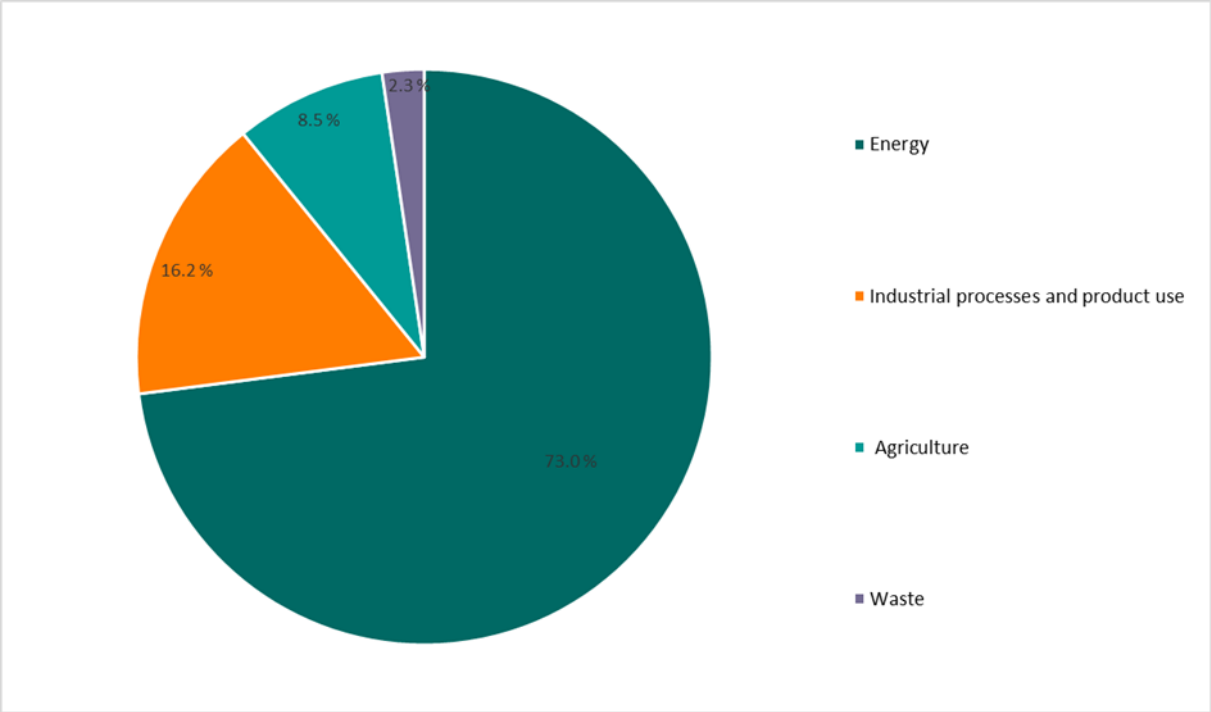


Figure E.S. 2 Emissions by IPCC sector in 2016, excluding LULUCF.
Source: Statistics Norway/Norwegian Environment Agency

The most important sector in Norway, with regards to the emissions of greenhouse gases (GHG), is the energy sector, accounting for 73.0 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 2016 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.

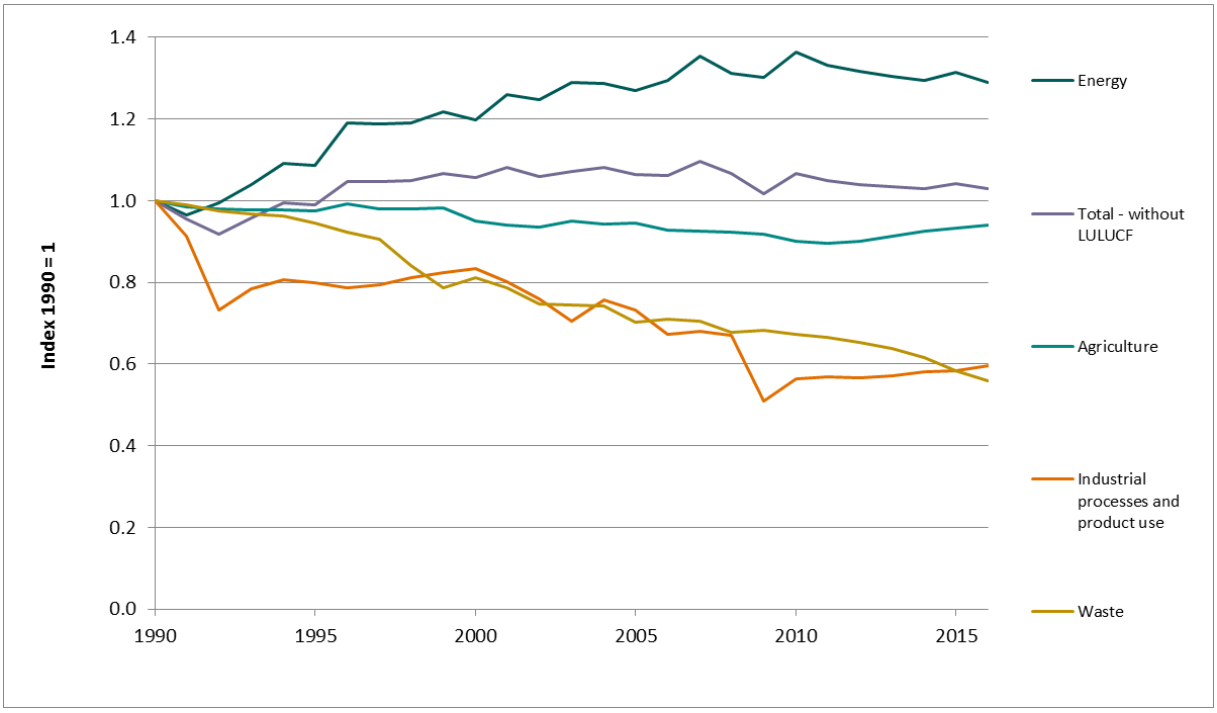


Figure E.S. 3 Changes in GHG emissions, relative to 1990, by IPCC sector 1990-2016. Index 1990 = 1.
Source: Statistics Norway/Norwegian Environment Agency

From 1990 to 2016, the increase in the emissions from the energy sector amounted to 29 per cent, mainly due to higher activity in the offshore and transport sectors. The energy sector's emissions decreased by 1.9 per cent from 2015 to 2016. Between 1990 and 2016, there have been temporary emission reductions in e.g. 1991, 1995, 2000, 2002 and 2005 and again in 2008 and 2009, when the energy sector emissions decreased due to lower economic activity.

Emissions from Transport showed an overall increase of 25.3 per cent from 1990 to 2016, with a decrease of 2.8 per cent from 2015 to 2016. The share of transport in the total GHG emissions has increased from 19.9 per cent in 1990 to 24.2 per cent in 2016. Road transportation accounts for 77.1 per cent of emissions from the transport sub-sector, while emissions from navigation and civil aviation accounts for 13.2 and 9.3 per cent, respectively. Due to the fact that most railways are electrified in Norway, emissions of GHG from this source are insignificant

Industrial processes and other product use sector contributed to almost 16 per cent of the total national emissions of greenhouse gases in 2016. Production of metals and chemicals are the main sources of process-related industrial emissions of both CO_2 and other greenhouse gases such as N_2O (fertilizer production) and PFCs (aluminium production). Between 1990 and 2016, emissions from industrial processes experienced an overall decrease by 40 per cent. This is mainly due to reduced PFC emissions from the production of aluminium and SF_6 from the production of magnesium.

The agricultural sector contributed in 2016 to 8.5 per cent to the total emissions of greenhouse gases, corresponding to 4.5 million tonnes CO_2 equivalents. Emissions from agriculture increased by 1 per cent between 2015 and 2016 and decreased by 6 per cent between 1990 and 2016. The dominant sources of GHGs are agricultural soils (N_2O) and enteric fermentation (CH_4) from domestic animals. These sources contributed to about 37 and 51 per cent to the sector's emissions, respectively.

The waste sector contributed to 2 per cent of total Norwegian greenhouse gas emissions in 2016. GHG emissions from the waste sector were relatively stable during the 1990s. From 1998, the emissions declined, and in 2016, they were 44 per cent lower than in 1990. Total waste volumes have increased significantly over the period, but this has been offset by increased recycling and incineration of waste as well as increased flaring of methane from landfills. Several measures introduced in the 1990s have resulted in smaller amounts of waste disposed at disposal sites**.** With a few exceptions, it was then prohibited to dispose easy degradable organic waste at landfills in Norway. In 1999, a tax was introduced on waste delivered to final disposal sites. From July 1 2009, it was banned to deposit biodegradable waste to landfills. This will result in further reduction of methane emissions.

E.S.4 Other information (precursors and SO_2)

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

The overall NO_x emissions have decreased by approximately 24 per cent from 1990 to 2016, primarily because of stricter emission regulations directed towards road traffic, which counteracted increased emissions from oil and gas production and from navigation. From 2015 to 2016, the total NO_x emissions decreased by 1.9 per cent.

NMVOC emissions 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 decreased by 62 per cent from 2001 to 2016, and were, in 2016, 49 per cent lower than in 1990. From 2015 to 2016, NMVOC emissions decreased by 2.9 per cent.

Over the period 1990-2016, emissions of CO decreased by 54 per cent. This is primarily explained by the implementation of new emissions standards for motor vehicles.

Emissions of SO_2 were reduced by 70 per cent from 1990 to 2016. This can mainly be explained by a reduction in sulphur content of all oil products and lower process emissions from ferroalloys and aluminium productions, as well as refineries.

Part I: Annual Inventory Submission

1 Introduction

1.1 Background information on GHG inventories and climate change

The 1992 United Nation Framework Convention on Climate Change (UNFCCC) was ratified by Norway on 9 July 1993 and entered into force on 21 March 1994. One of the commitments of the Convention is that Parties are required to report their national inventories of anthropogenic emissions by sources and removals by sinks of the greenhouse gases CO_2, CH_4, N_2O as well as fluorinated greenhouse gases not controlled by the Montreal Protocol (HFCs, PFCs, NF_3 and SF_6), 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. The National Inventory Report 2018 together with the associated Common Reporting Format (CRF) tables are Norway's contribution to the 2018 round of reporting and it covers emissions and removals for the period 1990-2016.

The 2018 NIR contains supplementary information required under Article 7, paragraph 1 of the Kyoto Protocol:

- 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.

The national inventory report is prepared in accordance with the revised UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 24/CP.19. The methodologies used in the calculation of emissions and removals are consistent with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

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

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

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

Norway has examined whether there are activities that would result in emissions of trinitrogenfluoride (NF_3) and our assessment is that here are no emissions of NF_3 in Norway.

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

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

The report also contains calculations of emissions of the precursors and indirect greenhouse gases NO_x, NMVOC, CO and SO_2, which should be included according to the reporting guidelines. However, we have in this submission not included detailed descriptions of the calculation methodologies for these gases. This information is available in the report *Informative Inventory Report (IIR) 2018. Norway* (Norwegian Environment Agency 2018).

Since the introduction of annual technical reviews of the national inventories by independent experts in 2000, Norway has undergone many desk/centralized/in-country reviews. The recommendations from these reviews have resulted in many improvements to the inventory. For the latest implemented improvements and planned improvements, see chapter 10.

1.2 A description of the national inventory arrangements

1.2.1 Institutional, legal and procedural arrangements

The Norwegian CO_2 emission inventory has been produced for more than three decades, and was gradually expanded with other emission components. It started as a collaboration between Statistics Norway and the Norwegian Environment Agency, and the reporting to the UNFCCC has evolved based on this greenhouse gas emission inventory. The Norwegian Environment Agency, Statistics Norway and the Norwegian Institute of Bioeconomy Research (NIBIO) are the institutions in the national greenhouse gas inventory system in Norway. Statistics Norway is responsible for the calculation of emissions from the Energy, IPPU, Agriculture and Waste source categories. The Norwegian Institute of Bioeconomy Research is responsible for the calculations of emission and removals from Land Use, Land-Use Change and Forestry (LULUCF).

The Norwegian Environment Agency was appointed as the national entity through the budget proposition to the Norwegian parliament (Stortinget) for 2006. These institutional arrangements have been continued for the second commitment period of the Kyoto Protocol, as described in the budget proposition to the Norwegian parliament in 2015 (Prop. 1S (2014-2015).

To ensure that the institutions comply with their responsibilities, Statistics Norway and NIBIO have signed agreements with Norwegian Environment 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.

1.2.2 Overview of inventory planning, preparation and management

The Norwegian Environment Agency, Statistics Norway, and the Norwegian Institute of Bioeconomy Research are the institutions of the national greenhouse gas inventory system, and 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 section 1.2.3, section 1.3 and Annex V. An overview of institutional responsibilities and cooperation is shown in Figure 1.1.

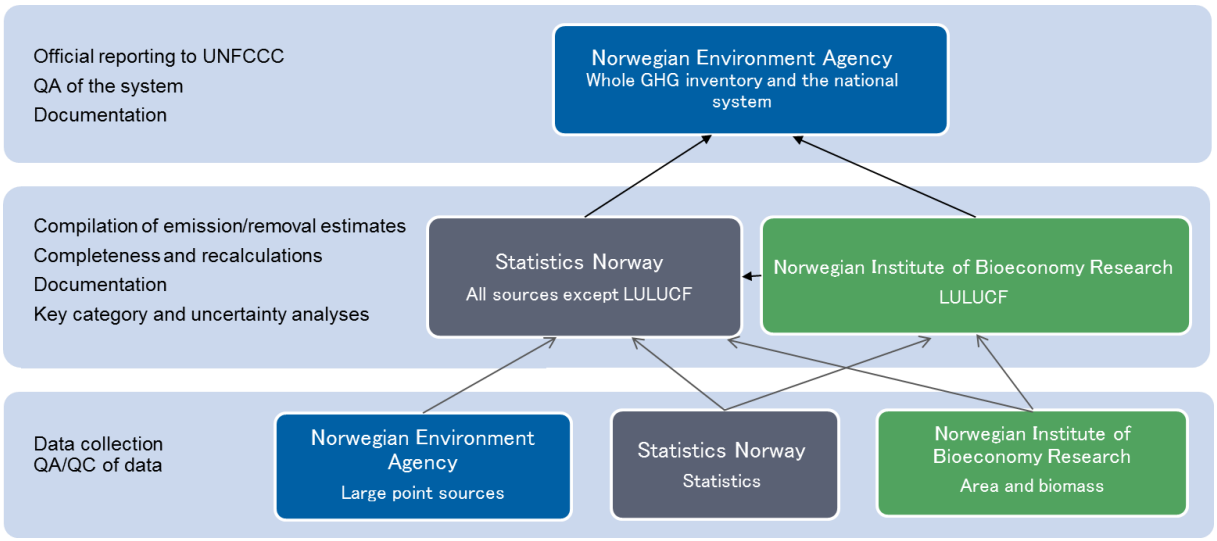


Figure 1.1 Overview of institutional responsibilities and cooperation

1.2.3 Quality assurance, quality control and verification

1.2.3.1 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 has implemented a formal quality assurance/quality control plan. The detailed description of this is found in Annex V. All three institutions annually prepare a QA/QC report, according to the plan. These reports document to what extent the QA/QC procedures have been followed. These reports are available to the expert review teams (ERT).

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

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

The established QA/QC procedures include the following:

- The Norwegian Environment Agency is the national entity designated to be responsible for the reporting of the national inventory of greenhouse gases to the UNFCCC. This includes coordination of the QA/QC procedures;
- Statistics Norway and the Norwegian Institute of Bioeconomy Research are responsible for the quality control system with regard to technical activities of the emission inventory preparation in their respective institutions;

- General inventory level QC procedures, as listed in table 6.1 in chapter 6 of the 2006 IPCC Guidelines (IPCC 2000), are performed every year;
- Source category-specific QC procedures are performed for key categories and some non-key categories with regard to emission factors, activity data and uncertainty estimates.

1.2.3.2 QA Procedures

According to the IPCC Good practice guidance, good practice for QA procedures requires an objective review to assess the quality of the inventory and to identify areas where improvements should be made. Furthermore, it is good practice to use QA reviewers that have not been involved in preparing the inventory. In Norway, the Norwegian Environment Agency is responsible for reviewing the inventory with regard to quality and areas for improvement.

Norway has performed several studies comparing inventories from different countries (Kvingedal et al. 2000). Annex V gives more information concerning the quality assurance of emission data in the Norwegian emission inventory.

1.2.3.3 General QC procedures

The Norwegian emission inventory is produced in several steps. Statistics with preliminary emission estimates are published by Statistics Norway 4-5 months after the end of the inventory year. These data are based on preliminary statistics and indicators and data that have been subjected to a less thorough quality control. The more final emission statistics, which forms the basis for the emission inventory reported to the UNFCCC (for all source categories except LULUCF) is produced about one year after the inventory year. At this stage, final statistics are available for almost all emission sources. Recalculations of the inventory are performed annually to ensure that methodological changes and refinements are implemented for the whole time series. In itself, this stepwise procedure is a part of the QA/QC procedure since all differences in data are recorded and verified.

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

In the following, the procedures listed in table 6.1 in chapter 6 of the 2006 IPCC Guidelines (IPCC 2000) are described, as well as how these checks are performed for the Norwegian greenhouse gas emission inventory.

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

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

Check for transcription errors in data input and references

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

Check that emissions are calculated correctly

When possible, estimates based on different methodologies are compared. An important example is the metal production sector, where CO_2 estimates reported by the plants are compared with estimates based on the Good Practice methodology corrected for national circumstances. In this case, both production based and reducing agent based calculations are performed to verify the reported value. The Norwegian Environment Agency and Statistics Norway control and verify emission data reported to the Norwegian Environment Agency by industrial enterprises, registered in the database Forurensning. First, the Norwegian Environment Agency checks the data received from these plants, and if errors are discovered, they may then ask the plants responsible to submit new data. Subsequently, Statistics Norway makes, where possible, occasional comparable emission calculations based on activity data sampled in official statistics, and deviations are explained through contact with the plants. Regarding more detailed information about the QC of data reported by industrial plants, see Annex V and VIII.

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

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

Check the integrity of database files

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

Check for consistency in data between source categories

Activity data and other parameters that are common to several source categories should be evaluated for consistency. An example is recovery of landfill gas. A fraction of this gas is flared, and emissions are reported in the Waste source category. Another fraction is recovered for energy purposes, and this gas is an input to the energy balance with emissions reported in the Energy source

category. Consistency checks ensure that the amount landfill gas subtracted from source category 5A (Managed waste disposal on land), equals the amount added to source category 1A (Energy combustion) and source category 5C (Waste incineration) (the amount of gas flared).

Consistency is also checked for activity data that is used in both the Agriculture and LULUCF sectors. This is the case for the area of organic soils on croplands and grasslands, which is used to estimate CO_2 emissions in the LULUCF sector (source categories 4.B and 4.C) and N_2O emissions in the agriculture sector (source category 3D16). Within agriculture (source categories 3A, 3B and 3D), the same activity data on animal numbers and characteristics is used as far as possible.

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

Statistics Norway has established automated procedures to check that inventory data fed into the model does not deviate too much from the estimates for earlier years, and that the calculations within the model are correctly made. Checks are also made that emissions data are correctly transcribed between different intermediate products. The model is constructed so that it gives error messages if factors are lacking, which makes it quite robust to miscalculations.

Check that uncertainties in emissions and removals are estimated correctly

An approach 2 uncertainty analysis for greenhouse gases is undertaken annually, see further information in section 1.6.2 and Annex II.

Undertake review of internal documentation

For some sources, expert judgements dating some years back are used with regard to activity data/emission factors. In most of the cases these judgements have not been reviewed since then, and may not be properly documented, which may be a weakness of the inventory. The procedures have improved the last few years, and the requirements for internal documentation to support estimates are now quite strict; all expert judgements and assumptions made by the Statistics Norway staff should be documented. This should increase reproducibility of emissions and uncertainty estimates. In 2011, work was begun to go through all emission factors, digitally register those that have sufficient documentation, and flag those that do not, for future revision.

Check of changes due to recalculations

Emission time series are recalculated every year to ensure time series consistency. The recalculated emission data for a year are compared with the corresponding estimates from the year before. For example, CO_2 data calculated for 1990 in 2017 are compared with the 1990 CO_2 data calculated in 2016. The intention is to explain all major differences as far as possible. Changes may be due to revisions in energy data, new plants, correction of former errors and new emission methodologies.

Undertake completeness checks

Estimates are reported for all source categories and for all years to the best of our knowledge with the exception of a few known data gaps, which are listed in section 1.7. There may, of course, exist sources of greenhouse gases which are not covered. However, emissions from potentially additional sources are likely to be very small or negligible. During the implementation of the 2006 IPCC Guidelines, a systematic evaluation of all potential new sources was performed.

Compare estimates to previous estimates

Internal checks of time series for all emission sources are performed every year when an emission calculation for a new year is implemented. It is examined whether any detected inconsistencies are due to data and/or methodology changes. For example, in 2017 Statistics Norway/the Norwegian Environment Agency calculated emission data for 2016 for the first time. These data were compared with the 2015 estimates for detection of any considerable deviations. There may be large deviations that are correct, caused for instance by the shutdown of large industrial plants or the launch of new ones.

1.2.3.4 Source category-specific QC procedures

Statistics Norway and the Norwegian Environment Agency have carried out several studies on specific emission sources, e.g. emissions from road, sea, and air transport, emissions from landfills as well as emissions of HFCs and SF_6. These projects are repeated in regular intervals when new information is available. During the studies, emission factors have been assessed and amended in order to represent the best estimates for national circumstances, and a rational for the choice of emission factor is provided. The emission factors are often compared with factors from literature. Furthermore, activity data have been closely examined and quality controlled, as have the uncertainty estimates.

The QC procedures with regard to emission data, activity data and uncertainty estimates for the different emission sources are described in the QA/QC-chapters of the relevant source-categories. The source category-specific analyses have primarily been performed for key categories on a case-by-case basis, which is described as being good practice. The QC procedures are described Annex V: "National Greenhouse Gas Inventory System in Norway" and Annex VIII: "QA/QC performed for GHG emissions from industrial point sources included in the national GHG inventory".

1.2.3.5 Verification studies

In general, the final inventory data provided by Statistics Norway and the Norwegian Institute of Bioeconomy Research are checked and verified by Norwegian Environment Agency. Some verification studies, which have been performed previously, are briefly described in the following.

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 (Kvingedal et al. 2000). The main goals of that work were to investigate the possibility of using statistical data as indicators for comparing emission estimates between countries on a general basis, and to test the method on the Norwegian national emission estimates. In the report, Norwegian emission data were 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 were corrected. We do realize that this method of verification only considers consistency and completeness 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 compared emissions of greenhouse gases from the agricultural sector in the national emission inventories with the emissions derived from the IPCC default methodology and the IPCC default factors.

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

From 2005 and especially from 2008, Norway's use of plant specific data has been strengthened by the availability of data from the EU ETS. The Norwegian Environment Agency conducted the verification of the annual reports up until the inventory year 2012. Since then, verification has been performed by an accredited third party. As a data source, the EU ETS provides better quality data, and these data are checked against the emissions reported under the regular permits and the reports submitted as part of the voluntary agreement. More details are found in Annex VIII.

In 2009, a new model for calculating the emissions of NMVOC from the use of solvents and other product uses was developed. The emission factors were evaluated and revised through a cooperation project between the Nordic countries. The results from the new model were compared against the similar results in Sweden and the United Kingdom; see Holmengen and Kittilsen (2009) for more details.

In 2011, the Norwegian University of Life Sciences (NMBU) published a comparison of the methodologies used for calculating CH_4 emissions from manure management in Sweden, Finland, Denmark and Norway (Morken & Hoem 2011).

In a project in 2012 at the Norwegian University of Life Sciences (NMBU) that updated the Norwegian nitrogen excretion factors and the values for manure excreted for different animal species, comparisons were made with the corresponding factors used in Sweden, Denmark and Finland and with IPCC default factors as a verification of the Norwegian factors (Karlengen et al. 2012). Comparisons were also made of the emission factors used for calculating enteric methane. In 2015, the equations for calculating emissions from enteric fermentation were evaluated and updated.

In 2015, IEFs for many of the IPPU source categories have been compared with what other Annex I countries have reported using a tool developed by the UNFCCC.[1]

[1] http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php

1.2.3.6 Quality assurance and quality control (QA/QC) and verification for the LULUCF sector

The Norwegian Institute of Bioeconomy Research (NIBIO) implements the QA/QC plan described for the National Greenhouse Gas Inventory System in Annex V. A LULUCF-specific plan for QA/QC was developed internally at NIBIO. The LULUCF-specific plan has two objectives: 1) to ensure that emission estimates and data contributing to the inventory are of high quality, and 2) to facilitate an assessment of the inventory in terms of quality and completeness. These objectives are in accordance with chapter 6 of the 2006 IPPC guidelines for quality assurance and quality control.

The QA/QC plan for the LULUCF sector is based on the general Tier 1 QC procedures and includes two check lists (one for the source-category compiler and one for the LULUCF inventory compiler), an annual timeframe of the outlined QC activities, and a target for when to elicit QA reviews. In general, QA is initiated if a new method or model is implemented.

Internal structures at NIBIO have changed slightly every year with regard to the LULUCF reporting. Existing QC procedures are evaluated and improved upon each year in order to ensure that the methods and calculations used are subjected to an internal QC prior to reporting. The CRF tables go through internal QC by more than one person before the database is submitted to the national focal point. Furthermore, after the overall compilation of estimates from all sectors, there is an exchange of CRF tables from the focal point to NIBIO, and an additional QC is performed. Improving the QA/QC procedures is an ongoing process that will be further improved in future submissions.

1.2.3.7 Confidentiality issues

In general, the data contained in the Norwegian emission inventory are available to the public, both emission estimates, activity data and emission factors. Data that are confidential according to the Statistics Act are replaced by non-confidential data collected by the Norwegian Environment Agency for most sources. Confidentiality is still an issue for some of the data collected by Statistics Norway when there are few entities reporting for a source category. In order to comply with confidentiality issues, emission estimates for these sources are aggregated. This is especially prominent in source category 2F, where emissions from 2F2-5 are aggregated in category 2F6 due to confidentiality.

1.2.4 Changes in the national inventory arrangements since previous submission

Statistics Norway, one of the three parts in the Norwegian National System, is undergoing a reorganization of staff and work areas between its two offices/locations; Oslo and Kongsvinger. The experts compiling the emission inventory for all sectors except LULUCF, have up to now been located in Oslo. This group of experts will through 2018 be replaced by a new staff located in Kongsvinger. The long term goal of this relocation is to improve data quality by increasing the contact and collaboration between the departments producing the input (activity) data and the inventory compilers.

1.3 Inventory preparation, data collection, processing and storage

The institutions in the national inventory system; the Norwegian Environment Agency, Statistics Norway, and the Norwegian Institute of Bioeconomy Research, have agreed on a “milestone” production plan. This production plan reflects national publishing obligations etc. The plan is described in Annex V (Norway’s National System) and is supplemented by internal production plans in each of the three institutions.

The three 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 compiling of the data used in the models that produce emission estimates for the source categories Energy, IPPU, Agriculture and Waste. Statistics Norway also operates these models. The Norwegian Environment 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 Institute of Bioeconomy Research is responsible for the estimated emissions from the LULUCF sectors, collects almost all data and calculates the emissions.

The collected data are subjected to the Quality Assessment and Quality Control (QA/QC) routines described in section 0 and Annex V, 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 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 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 Norwegian Environment Agency has established a library with the most important methodology reports.

1.4 Brief general description of methodologies (including tiers used) 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 2016. Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants" (Statistics Norway 2016a). From 2017 onwards, Statistics Norway updates the methodology descriptions for energy, industry, agriculture and waste in the NIR, and no longer publishes a separate report. Information on the methods and framework for the production of data and the emission estimates for the LULUCF sector are described in Chapter 6 of the NIR.

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

The emission estimation methodologies are being improved continuously. Statistics Norway and the Norwegian Environment Agency have carried out several studies on specific emission sources. Often, such projects are connected to an evaluation of emission reduction measures. An important consequence of Statistics Norway's work is increased 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.

Several emission sources – e.g. road traffic, agriculture, air traffic and solvents – are covered by more detailed side 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).

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

For emissions from *combustion*, the activity data is use of energy products. In the Norwegian energy accounts, the use of energy products 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). This makes it possible to match activity data with relevant emission factors. 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 technical 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 within 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), while on the other hand, 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 Norwegian Environment Agency). When such measured data are available, they are usually considered to give better representation of the actual emission, and the estimated values are replaced by the measured ones:

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

where A_{PS} and E_{PS} are the activity and the measured emissions at the point sources, respectively. Emissions from 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 Norwegian Environment Agency from the plants, and some may be obtained from current reports and investigations. The emissions are fitted into the general model using the parameters industry, technical 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 basis data in the energy balance/accounts, and is almost identical to that used in the national accounts, which is aggregated from the European NACE classification (Statistics Norway 2008). 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 Institute of Bioeconomy Research is in charge of estimating emissions and removals from Land use, Land-Use Change and Forestry (LULUCF) where most of the categories have area statistics as activity data. A software based calculation system that primarily uses the data analysis software R, was developed for the implementation of the IPCC good practice guidance for the LULUCF sector. The system uses input data from different sources and creates final output datasets. These final datasets include all the data needed for the tables in the common reporting format (CRF) for both the Climate Convention and the Kyoto Protocol.

The National Forest Inventory (NFI) database contains data on areas for all land uses and land-use conversions as well as carbon stocks in living biomass. The NFI is used to estimate total areas of forest land, cropland, grassland, wetlands, settlements, other land, and land-use transitions between these categories. The data from the NFI are complemented with other data (e.g. timber harvest, horticulture, crop types, fertilizer use, drainage of forest soil, 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 (interpenetrating panel design). Up until 2010 the estimates were based on detailed information from sample plots in lowlands outside Finnmark county. Since 2010 the NFI has been expanded to include mountainous areas and Finnmark county in order to monitor the land use, land-use changes, and forestry activities in the whole country. All areas were included for the first time in the estimates for the LULUCF sector in the 2012 submission. Area estimates have been bridged in a consistent manner.

The estimates of carbon stocks and their changes in living biomass are based on single tree measurements of trees larger than 50 mm at 1.3 m height (DBH) on sample plots within forest and other wooded land. Biomass is calculated using single tree allometric biomass models developed in Sweden for Norway spruce and Scots pine (Marklund 1988; Petersson & Ståhl 2006) and Norwegian models for birch (Smith 2016; Smith 2014). These models provide biomass estimates for various tree biomass components: stem, bark, living branches, dead branches, foliage, stumps, and roots. These components are used to calculate above- and belowground biomass.

The dynamic soil model Yasso07 is used to calculate changes in carbon stock in dead organic matter and in soil for forest land remaining forest land (Tuomi et al. 2009; 2011b). Estimates are made for individual NFI plots for the entire time-series. The Yasso07 model provides an aggregated estimate of carbon stock change for the total of litter, dead wood, and soil organic matter. All data used as input to the models is provided by the NFI. Auxiliary data used for estimation of C emissions from cropland, grassland, wetlands, and settlements were provided by Statistics Norway, Norwegian Meteorological Institute, as well as other data sources at the Norwegian Institute of Bioeconomy Research.

1.4.4 Data sources

The data sources used in the Norwegian inventory 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 national emission factors are highly uncertain or lacking (e.g. N_2O from agriculture, CH_4 and N_2O from stationary combustion, CH_4 and N_2O road transport) or when the source is insignificant in relation to other sources.

Aggregated results from the side models: The operation of the side models in the inventory 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 Norwegian Environment Agency by the plants' responsible (based on measurements or calculations at the plants).

1.5 Brief description of 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 Approach 2 method. A description of the methodology as well as background tables and the results from the analyses is presented in Annex 1. In this chapter a summary of the 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 Approach 2 level if available. The advantage of using an Approach 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 Approach 1 and Approach 2.

The Approach 2 and Approach 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. In addition we have also included a category identified on qualitiative criteria. Altogether there are 47 key categories. Key categories in the Land use, land use change and forestry sector (LULUCF) were identified in separate analyses and are summarized in Table 1.2.

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

The Approach 1 analysis included in the NIR uses a different aggregation level for some source categories than in the Approach 1 analysis generated in the CRF reporter.

Note that the key category and uncertainty analyses were performed before the data were finalized, and the background data differ slightly from data elsewhere in the NIR. This might have affected which categories are above and below the cutoff limit for key categories.

Table 1.1 Summary of identified emission key categories. Excluding LULUCF.

IPCC Category Code	IPCC Category	Greenhouse gas	Identification criteria[1]	Method
1A1,1A2,1A4	Stationary combustion, Solid Fuels	CO_2	L1 T1	Tier 2
1A1,1A2,1A4	Stationary combustion, Biomass	CH_4	L2	Tier 2
1A1,1A2,1A4	Stationary combustion, Gaseous Fuels	CO_2	L1 T1 L2 T2	Tier 2
1A1,1A2,1A4	Stationary combustion, Gaseous Fuels	CH_4	L2 T2	Tier 2
1A1,1A2,1A4	Stationary combustion, Liquid Fuels	CO_2	L1 T1 L2 T2	Tier 2
1A1,1A2,1A4	Stationary combustion, Other Fuels	CO_2	L1 T1 L2 T2	Tier 2
1A3a	Civil Aviation	CO_2	L1 T1 L2 T2	Tier 2
1A3b	Road Transportation	CO_2	L1 T1 L2 T2	Tier 1a
1A3d	Navigation	CO_2	L1 T1 L2 T2	Tier 2
1A3d	Navigation	CH_4	T1 L2 T2	Tier 2
1A4	Other Sectors, mobile combustion	CO_2	L1 T1 L2 T2	Tier 2

IPCC Category Code	IPCC Category	Greenhouse gas	Identification criteria[1]				Method
1A5b	Mobile	CO_2	L1	T1			Tier 2
1B1a	Coal Mining	CH_4		T1	L2	T2	Tier 1
1B2a	Oil (incl. oil refineries, gasoline distribution)	CO_2	L1	T1	L2	T2	Tier 2
1B2a	Oil (incl. oil refineries, gasoline distribution)	CH_4	L1		L2		Tier 2
1B2b	Natural Gas	CH_4				T2	Tier 2
1B2c	Venting and Flaring	CO_2	L1	T1	L2	T2	Tier 2
1B2c	Venting and Flaring	CH_4	L1	T1	L2	T2	Tier 2
1C	CO_2 Transport and storage	CO_2	Q				CS (Tier 2)
2A1	Cement Production	CO_2	L1				Tier 3
2A2	Lime Production	CO_2	L1	T1			Tier 2
2B1	Ammonia Production	CO_2	L1	T1			Tier 2
2B2	Nitric Acid Production	N_2O	L1	T1	L2	T2	Tier 2
2B5	Carbide Production	CO_2	L1	T1		T2	Tier 2
2B6	Titanium dioxide production	CO_2	L1				Tier 2
2B8	Petrochemical and carbon black production	CO2	L1	T1			Tier 2
2C2	Ferroalloys production	CO_2	L1		L2		Tier 2/3
2C3	Aluminium production	CO_2	L1	T1	L2	T2	Tier 2/3
2C3	Aluminium production	PFCs	L1	T1	L2	T2	Tier 2
2C4	Magnesium production	SF_6	L1				Tier 2
2D1	Lubricant use	CO_2		T1			Tier 2
2F	Product uses as substitutes for ODS	HFCs	L1	T1	L2	T2	Tier 2
3A	Enteric Fermentation	CH_4	L1	T1	L2	T2	Tier 1/2
3B1	Manure management - Cattle	CH_4	L1				Tier 2
3B	Manure Management	N_2O	L1		L2		Tier 1/2
3Da1	Direct emissions from managed soils -Inorganic N fertilizers	N_2O	L1		L2	T2	Tier 1
3Da2	Direct emissions from managed soils - Organic N fertilizer	N_2O	L1		L2	T2	Tier 1
3Da3	Direct emissions from managed soils - Urine and dung deposited by grazing animals	N_2O	L1		L2		Tier 1
3Da4	Direct emissions from managed soils - Crop residues	N_2O			L2	T2	Tier 1
3Da6	Direct emissions from managed soils - Cultivation of organic soils	N_2O	L1		L2		Tier 1
3Db1	Indirect emissions from managed soils - Atmospheric deposition	N_2O			L2		Tier 1
3Db2	Indirect emissions from managed soils - Nitrogen leaching and run-off	N_2O			L2		Tier 1
3G	Liming	CO_2	L1	T1			Tier 1
5A1a	Managed Waste Disposal sites. Anaerobic.	CH_4	L1	T1	L2	T2	Tier 2
5B	Biological treatment of Solid Waste	CH_4				T2	Tier 1
5B	Biological treatment of Solid Waste	N_2O				T2	Tier 1
5D	Wastewater treatment and discharge	CH_4			L2	T2	Tier 1

[1] *"L" refers to level and "T" to trend analyses. Numbers refer to approaches. "Q" refers to qualitative criteria.*

The approach 2 analysis on level and trend (excluding LULUCF) for 2016 does not include any additions or removals of categories.

The Approach 1 trend analysis identified three new sources: CO_2 from ammonia production (2B1), CO_2 from Petrochemical and carbon black production (2B8), and N_2O from Biological treatment of solid waste (5B).

Emission of CO_2 from Food and beverages industry (2H2) is no longer a key source in any of the analyses. This category was new on the list last year.

From the LULUCF analyses, 30 key categories were identified by both the Approach 1 and Approach 2 level analyses (Table 1.2). The sources that became key categories this year were dead organic matter on cropland, grassland, and settlements converted to forest land and living biomass on grassland remaining grassland. The sources no longer classified as key categories this year are living biomass on cropland converted to forest land and mineral soils on grassland remaining grassland.

Table 1.2 Summary of identified LULUCF key categories.

IPCC Category Code	IPCC Category	Greenhouse gas	Identification criteria[1]	Method
4(II)Crop	Cropland - drained organic soil - Organic soil CC + LC	CH_4	L2	Tier 1
4(II)Forest	Forest land drained organic soils - Drained organic soil	CH_4	L2	Tier 1
4(II)Forest	Forest rem forest- drained organic soils (SSB) - Drained organic soil	N_2O	L1 T1 L2 T2	Tier 1
4(III)	Direct N2O from N mineralization/immobilization - Mineralization/immobilization	N_2O	L2 T2	Tier 1
4.A.1	Forest remaining forest - Litter + dead wood + Mineral soil	CO_2	L1 T1 L2 T2	Tier 3
4.A.1	Forest remaining forest - Living biomass	CO_2	L1 T1 L2 T2	Tier 3
4.A.1	Forest remaining forest, drained organic soils - Organic soil	CO_2	L1 T1 L2 T2	Tier 1
4.A.2.1	Cropland to Forest - DOM	CO_2	L2 T2	Tier 2
4.A.2.2	Grassland to Forest - DOM	CO_2	T1 L2 T2	Tier 2
4.A.2.2	Grassland to Forest - Living biomass	CO_2	T2	Tier 3
4.A.2.2	Grassland to Forest - Mineral soil	CO_2	T1 L2 T2	Tier 2
4.A.2.4	Settlements to Forest - DOM	CO_2	L1 T1 L2 T2	Tier 2
4.B.1	Cropland remaining cropland - Organic soil	CO_2	L1 T1 L2 T2	Tier 1
4.B.2.1	Forest to Cropland - DOM	CO_2	L1 T1 L2 T2	Tier 2
4.B.2.1	Forest to Cropland - Living biomass	CO_2	L2 T2	Tier 3
4.B.2.1	Forest to Cropland - Mineral soil	CO_2	T2	Tier 2
4.B.2.1	Forest to Cropland - Organic soil	CO_2	L2 T2	Tier 1
4.B.2.3	Wetland to Cropland - Organic soil	CO_2	L2	Tier 1
4.C.1	Grassland remaining grassland – Living biomass	CO_2	L2	Tier 2
4.C.2.1	Forest to Grassland - DOM	CO_2	L1 T1 L2 T2	Tier 2
4.C.2.1	Forest to Grassland - Living biomass	CO_2	L2 T2	Tier 3
4.C.2.1	Forest to Grassland - Mineral soil	CO_2	L1 T1 L2 T2	Tier 2
4.D.1	Wetland Peat extraction - on+off-site - Organic soil	CO_2	L2	Tier 1 & Tier 2
4.E.1	Settlements remaining settlements - Organic soil	CO_2	L1 L2	Tier 1
4.E.2.1	Forest to Settlement - DOM	CO_2	L1 T1 L2 T2	Tier 2
4.E.2.1	Forest to Settlement - Living biomass	CO_2	L1 T1 L2 T2	Tier 3
4.E.2.1	Forest to Settlement - Mineral soil	CO_2	T1 L2 T2	Tier 2
4.E.2.1	Forest to Settlement - Organic soil	CO_2	L1 L2	Tier 1
4.E.2.2	Cropland to Settlement - Mineral soil	CO_2	T2	Tier 2
4.G	Harvested wood Products - HWP	CO_2	L1 T1 L2 T2	Tier 2

[1] *"L" refers to level and "T" to trend analyses. Numbers refer to approaches.*

1.6 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals

1.6.1 Approach 1 uncertainty analysis

The uncertainties in the emission levels for 2016 have been investigated by an approach 1 analysis. The results are given in Table 1.3 and Table 1.4. Note that the figures may differ slightly from data elsewhere in the NIR because the uncertainty analysis was performed before the data were finalized.

Table 1.3 Approach 1 uncertainties in emission levels. Each gas and total GWP weighted emissions. Excluding the LULUCF sector. 2016.

2016	**μ (mean)**	**Uncertainty 2σ (per cent of mean)**
Total	53.3 mill. tonnes	3
CO_2	44.1 mill. tonnes	3
CH_4	5.1 mill. tonnes	15
N_2O	2.5 mill. tonnes	31
HFC	1.4 mill. tonnes	54
PFC	186 ktonnes	22
SF_6	64 ktonnes	45

Table 1.4 Approach 1 uncertainties in emission levels. Each gas and total GWP weighted emissions. Including the LULUCF sector. 2016.

2016	**μ (mean)**	**Uncertainty 2σ (per cent of mean)**
Total	28.9 mill. tonnes	15
CO_2	19.1 mill. tonnes	22
CH_4	5.2 mill. tonnes	15
N_2O	2.9 mill. tonnes	28
HFC	1.4 mill. tonnes	54
PFC	186 ktonnes	22
SF_6	64 ktonnes	45

1.6.2 Approach 2 uncertainty analysis

The uncertainty in the Norwegian greenhouse gas emission inventory has been investigated by an approach 2 analysis and the results are given in Table 1.5 to Table 1.8. The approach 2 analysis is also further described in Annex II.

The uncertainty in the Norwegian emission inventory was initially 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, based on approach 2 analyses, and the last report investigated the uncertainty in the emission estimates of long-range air

pollutants. The analysis of greenhouse gases was repeated in Statistics Norway (2010a) and more thoroughly in (Flugsrud & Hoem 2011). The report *Uncertainties in the Norwegian Greenhouse Gas Emission Inventory* (Rypdal & Zhang 2000) includes more detailed documentation of the analysis method used in all analyses. Both approach 1 and 2 uncertainty analyses are now performed annually.

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 Approach 2 method, as described in the IPCC guidelines (IPCC 2006). Analyses have been made both excluding and including the sector LULUCF (Land Use, Land-Use Change and Forestry).

Table 6.2 from the IPCC good practice guidance is included in Annex II as Table AII-4. Column G in Table 6.2 is estimated as uncertainty for source category divided by total GHG emissions.

1.6.2.1 Uncertainty in emission levels

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

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

1990	**μ (mean)**	**Fraction of total emissions**	**Uncertainty 2σ (per cent of mean)**
Total	51.7 mill. tonnes	1	4
CO_2	35.7 mill. tonnes	0.69	3
CH_4	5.8 mill. tonnes	0.11	16
N_2O	4.2 mill. tonnes	0.08	27
HFC	44 tonnes	0.00	50
PFC	3.9 mill. tonnes	0.08	20
SF_6	2.1 mill. tonnes	0.04	1
2016	**μ (mean)**	**Fraction of total emissions**	**Uncertainty 2σ (per cent of mean)**
Total	53.3 mill. tonnes	1	3
CO_2	44.1 mill. tonnes	0.83	3
CH_4	5.1 mill. tonnes	0.10	13
N_2O	2.5 mill. tonnes	0.05	42
HFC	1.4 mill. tonnes	0.03	50
PFC	186 ktonnes	0.00	20
SF_6	64 ktonnes	0.00	42

Table 1.6 Uncertainties in emission levels. Each gas and total GWP weighted emissions. Including the LULUCF sector.

1990	**μ (mean)**	**Fraction of total emissions**	**Uncertainty 2σ (per cent of mean)**
Total	41.3 mill. tonnes	1	7
CO_2	24.9 mill. tonnes	0.60	8
CH_4	5,9 mill. tonnes	0.14	16
N_2O	4.5 mill. tonnes	0.11	25
HFC	44 tonnes	0.00	50
PFC	3.9 mill. tonnes	0.09	20
SF_6	2.1 mill. tonnes	0.05	2
2016	**μ (mean)**	**Fraction of total emissions**	**Uncertainty 2σ (per cent of mean)**
Total	28.9 mill. tonnes	1	15
CO_2	19.1 mill. tonnes	0.66	21
CH_4	5.2 mill. tonnes	0.18	13
N_2O	2.9 mill. tonnes	0.10	38
HFC	1.4 mill. tonnes	0.05	49
PFC	186 ktonnes	0.01	20
SF_6	64 ktonnes	0.00	42

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_2 is known with an uncertainty of 3 per cent of the mean. The total uncertainty level was 3 per cent of the mean in 2016. There have been major changes in uncertainty level for the different emission components between the two years. The highest uncertainty change between 1990 and 2015 is in the uncertainty estimates for the SF_6 emissions, which has increased from 1 to 42 per cent of the mean. However, the SF_6 emissions are strongly reduced because magnesium production was closed down. The figures for the emission of SF_6 from magnesium production was quite well known, but now a larger part of the SF_6 emissions comes from sources with higher uncertainty. For N_2O there is also a considerable increase in the uncertainty between the years. One reason for the change can be found in that N_2O from the production of synthetic fertilizer with a quite low uncertainty contributes to a smaller part of the total N_2O emissions in 2016 than in 1990. For the other gases there are only smaller changes in the uncertainty from 1990 to 2015.

By including the LULUCF sector the results from the analysis show a total uncertainty of 7 per cent of the mean in 1990 and 15 per cent in 2016. This is due to the fact that the uncertainty in the LULUCF sector in general is higher than in most other sectors.

1.6.2.2 Uncertainty in emission trend

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

Table 1.7 Uncertainty of emission trends. 1990-2016. Excluding the LULUCF sector.

	Per cent change ((μ2015-μ1990)*100/μ1990)	**Uncertainty (2*σ*100/μ1990)**
Total	3	3
CO_2	23	3
CH_4	-12	11
N_2O	-40	3
HFC[1]	..	..
PFC	-95	19
SF_6	-97	1

Table 1.8 Uncertainty of emission trends. 1990-2016. Including the LULUCF sector.

	Per cent change ((μ2015-μ1990)*100/μ1990)	**Uncertainty (2*σ*100/μ1990)**
Total	-30	7
CO_2	-23	10
CH_4	-12	11
N_2O	-36	3
HFC[1]	..	..
PFC	-95	19
SF_6	-97	1

[1] The base year emissions of HFCs are so close to zero that figures for per cent change and uncertainty are meaningless.

The result shows that the increase in the total GHG emissions from 1990 to 2016 is 3 per cent, with an uncertainty in the trend of ± 3 percentage points, when the LULUCF sector is not included. This means that the 2016 emissions are likely between 0 and 6 per cent above the 1990 emissions (a 95 percent confidence interval).

With the sector LULUCF included in the calculations there has been a decrease in the total emissions figures on -30 per cent, with a trend uncertainty of ±7 percentage points.

1.7 General assessment of 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 1.2.3.6.

The inventory includes emissions on the archipelago Svalbard as well as on mainland Norway. In particular, emissions from coal mining on Svalbard is included.

The revised UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 24/CP.19 specifies that a Party may consider that a disproportionate amount of effort would be required to collect data for a gas from a specific category that would be insignificant in terms of the overall level and trend in national emissions and in such cases use the notation key NE. The Party should in the NIR provide justifications for exclusion in terms of the likely level of emissions. An emission should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions (specified in a footnote to total GHG emissions without LULUCF for the latest reported inventory year) and does not exceed 500 kt CO_2-equivalents. The total national aggregate of estimated emissions for all gases and categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions.

Norway has used the emissions for 2016 as reported in this NIR as the basis for national total GHG emissions. The national total GHG emissions without LULUCF in 2016 is reported to be 53 242 518 tonnes CO_2-equivalents. The threshold for an individual emission to be considered insignificant is therefore 26 621 tonnes CO_2-equivalents while the total threshold to be considered insignificant is 53 243 tonnes CO_2-equivalents.

The emissions (excluding LULUCF) that Norway has considered as insignificant and their likely level of emissions are presented in Table 1.9. The individual emissions excluded are all below the individual threshold and the total emissions excluded are also below the total threshold. Table 1.10 provide information on emissions reported as NE for the LULUCF-sector.

Table 1.9. Emissions considered insignificant and reported as NE (excluding LULUCF).

CRF code	Description of emission source	Gases	Likely level of emissions (tonnes CO_2-equivalents)
3A4, 3B4	Other animals: Enteric fermentation and manure management	CH_4, N_2O	See chapter 6.2. Includes ostrich, llama, etc. Emissions from ostrich were reported in previous submissions, and were less than 500 t CO_2-eq when population was highest. Other animals have smaller populations.
3D	Agricultural soils	CH_4	No methodology, see note to CRF Table3s2.
5C2	Open burning of waste	CO_2, CH_4, N_2O	Order of 1200 t CO_2-eq. by estimate from 1999.
5D2	Wastewater treatment: Industrial wastewater	N_2O	Unknown.
	Total		Estimated emissions less than 2000 t CO_2-eq.

Source: Statistics Norway and Norwegian Environment Agency

For the LULUCF sector the notation key NE was used to report the following sources, either because they were non-mandatory or considered negligible.

Table 1.10. Emissions reported as NE for LULUCF.

CRF code	Description of emission source	Gases	Explanation
4D1	Wetlands – flooded land remaining flooded land	CO_2	It is not mandatory because there is no default method for estimating carbon stock changes for this source.
4D2	Wetlands – land converted to peat extraction	CO_2	Emissions from organic soils are not estimated because they are considered a negligible source.
4(II)	Emissions from drainage and rewetting	CO_2, CH_4 and N_2O	It is not mandatory to estimate emissions from rewetting organic or mineral soils.
4(V)	Biomass burning – controlled burning- forest land remaining forest land land converted to forest land	CH_4 and N_2O	We assume emission from controlled forest fires are negligible because very few fire drills are performed and a consistent time-series is not available.
4(V)	Biomass burning- wildfires – grassland	CH_4 and N_2O	We assume emission from wildfires on grasslands are negligible because these very rarely occur.

Source: Norwegian Institute for Bioeconomy Research

2 Trends in Greenhouse Gas Emissions

2.1 Description and interpretation of emission trends for aggregated GHG emissions

In 2016, total greenhouse gas (GHG) emissions in Norway were 53.2 million tonnes of carbon dioxide equivalents, which is a decrease of 0.6 million tonnes compared to 2015[2]. Between 1990 and 2016, the total GHG emissions increased by approximately 1.5 million tonnes, equivalent to an increase of 3.0 per cent. Emissions reached their peak at 56.7 million tonnes in 2007.

The net GHG emissions, including all sources and sinks, are 28.9 million tonnes of CO_2 equivalents in 2016. The total emissions distribution among the main IPCC sectors from 1990 to 2016 is illustrated in Figure 2.1.

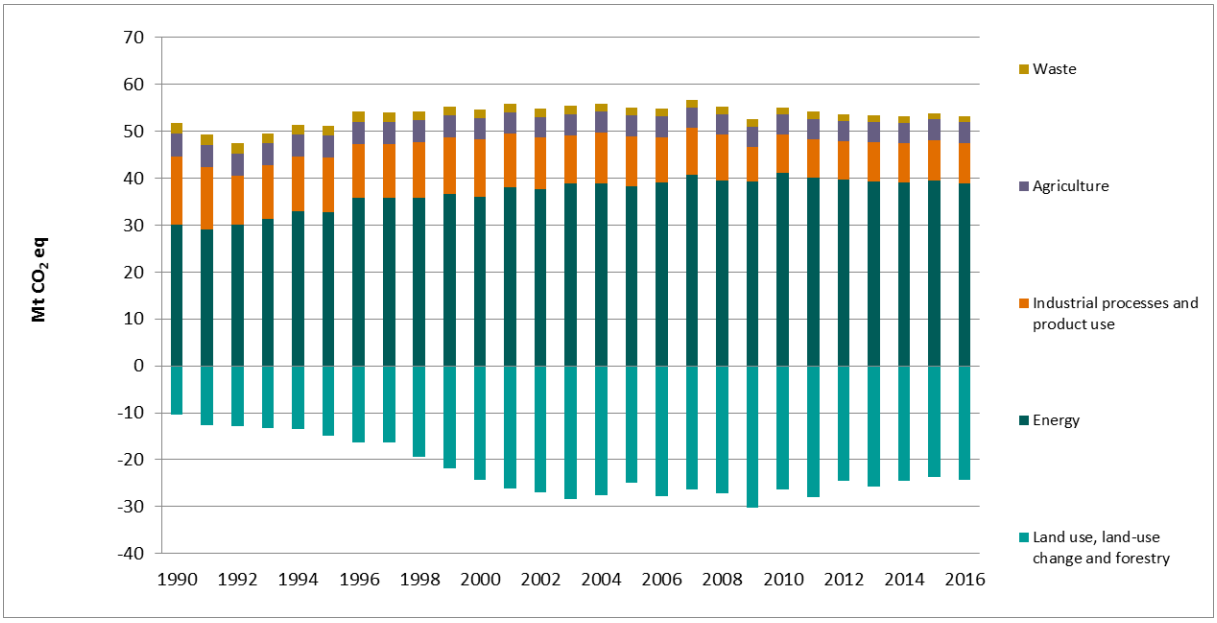


Figure 2.1. Total emissions of greenhouse gases by sources and removals from LULUCF in Norway, 1990-2016 (Mtonnes CO_2 equivalents). Source: Statistics Norway/Norwegian Environment Agency/Norwegian Institute of Bioeconomy Research

Table 2.1 presents the total emissions including indirect CO_2 emissions[3] and the distribution among the main CRF sectors from 1990 to 2016. Total indirect CO_2 emissions and net removal from LULUCF are also presented in this table.

[2] In this NIR, if not specified otherwise, total emission figures include indirect CO_2 emissions but not emissions and removals from land use, land-use change and forestry (LULUCF).

[3] Non-CO_2, carbon-containing gases (methane (CH4), CO or NMVOC) will eventually be oxidised to CO_2 in the atmosphere. The CO_2 emissions formed are termed "indirect CO_2 emissions".

Table 2.1. Total emissions of greenhouse gases by sources and removals in Norway 1990-2016. Million tonnes of CO_2 equivalents.

Year	Energy	Industrial processes and product use	Agriculture	LULUCF	Waste	Total with indirect CO_2 and without LULUCF	Total with indirect CO_2 and with LULUCF	Indirect CO_2 emissions
1990	30.1	14.5	4.8	-10.4	2.2	51.7	41.3	0.6
1995	32.7	11.6	4.7	-14.9	2.1	51.1	36.2	0.9
2000	36.1	12.1	4.6	-24.2	1.8	54.6	30.4	1.0
2005	38.3	10.6	4.5	-24.8	1.6	55.0	30.2	0.5
2006	39.0	9.7	4.5	-27.9	1.6	54.8	26.9	0.5
2007	40.8	9.9	4.4	-26.4	1.6	56.7	30.3	0.5
2008	39.5	9.7	4.4	-27.3	1.5	55.2	27.9	0.4
2009	39.2	7.4	4.4	-30.3	1.5	52.6	22.3	0.3
2010	41.1	8.2	4.3	-26.4	1.5	55.1	28.7	0.3
2011	40.1	8.3	4.3	-28.0	1.5	54.2	26.2	0.3
2012	39.7	8.2	4.3	-24.5	1.5	53.7	29.2	0.3
2013	39.3	8.3	4.4	-25.8	1.4	53.4	27.6	0.3
2014	39.0	8.4	4.4	-24.6	1.4	53.2	28.7	0.4
2015	39.6	8.5	4.5	-23.8	1.3	53.9	30.1	0.4
2016	38.8	8.6	4.5	-24.4	1.3	53.2	28.9	0.3

Source: Statistics Norway/Norwegian Environment Agency/Norwegian Institute of Bioeconomy Research

Figure 2.2 illustrates the yearly evolution of GHG emissions from the IPCC sectors (not including LULUCF) in percentage change, relative to 1990.

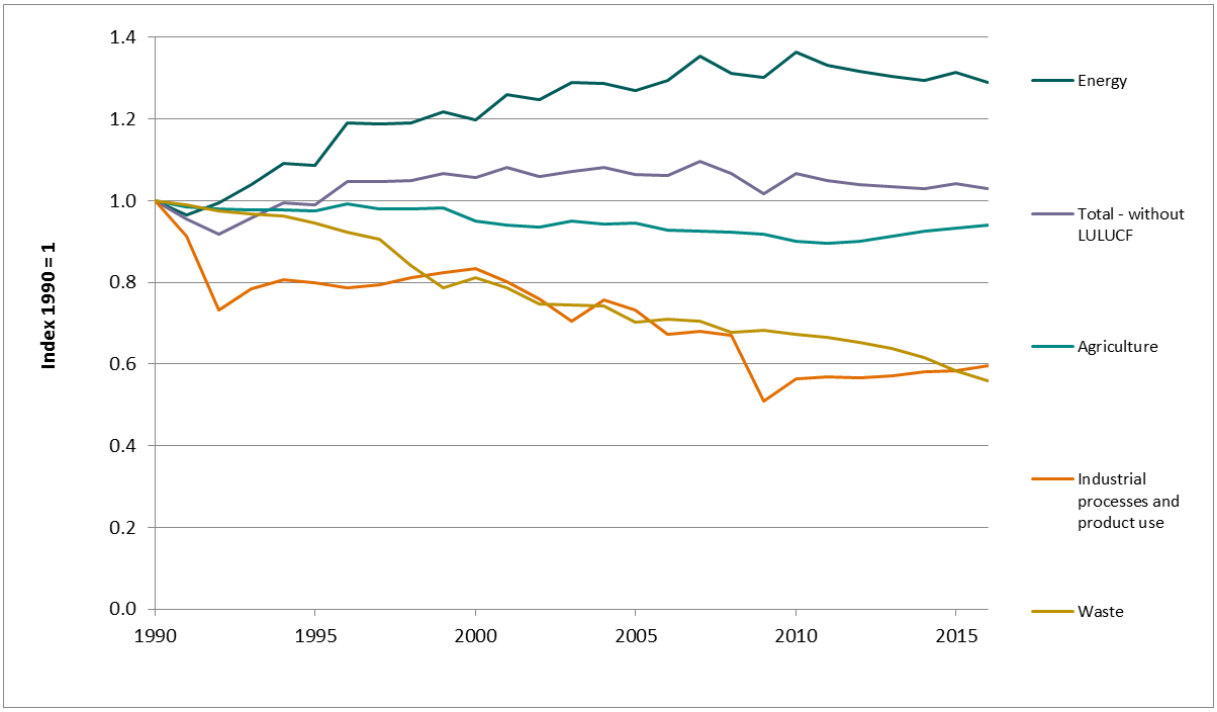


Figure 2.2. Changes in emissions of greenhouse gases, relative to 1990, illustrated by UNFCCC source categories, 1990-2016. Index 1990 = 1. Source: Statistics Norway/Norwegian Environment Agency

Norway has experienced economic growth since 1990, generating a general growth in emissions. In addition, the offshore petroleum sector has expanded significantly for the past 20 years. This has resulted in higher CO_2 emissions from energy use, both in energy industries and transport. Looking at the overall trend from 1990 to 2016, emissions increased by 3.0 per cent.

The downward trend in GHG emissions from the industry sector can be explained, in the early 1990's, by the implementation of policies and measures in the metal industry, resulting in less emission intensive production methods and later in the 2000's by close-downs and production reductions mainly in the metal industry as well.

Emissions from agriculture have decreased by 6.0 per cent since 1990 due to reductions of activity in the agriculture sectors.

The downward trend in GHG emissions from the waste sector is due to reductions of waste amounts disposed at disposal sites.

In the next two chapters, emission trends are explained both by sectors and by gas for the period 1990-2016.

2.2 Description and interpretation of emission trends by sector

Figure 2.3 illustrates the 2016 distribution of Norwegian GHG emissions by IPCC classification of sources. The energy sector is by far the most important source of emissions, contributing to 73.5 per cent of the national GHG emissions.

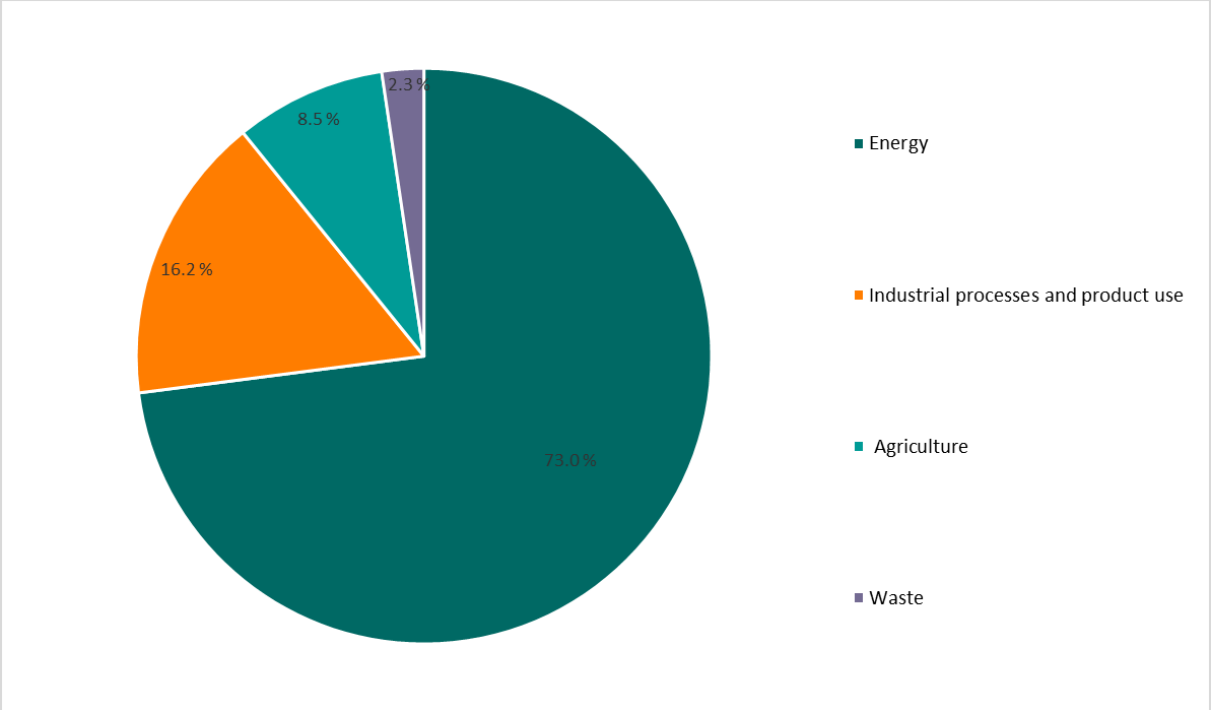


Figure 2.3. Distribution of GHG emissions in Norway in 2016 by sector, excluding LULUCF.
Source: Statistics Norway/Norwegian Environment Agency

Figure 2.4 displays GHG emissions trends by sectors between 1990 and 2016. The Energy sector is divided into its five main sub-sectors: fuel combustion in energy industries, fuel combustion in manufacturing industries and construction, fuel combustion in transport, fuel combustion in other sectors[4], and fugitive emissions from fuels.

While emissions have decreased for most of the sectors, emissions from energy industries and transport have significantly increased since 1990.

[4] Includes CRF key categories 1A4 (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 1A5 (fuel used in stationary and mobile military activities).

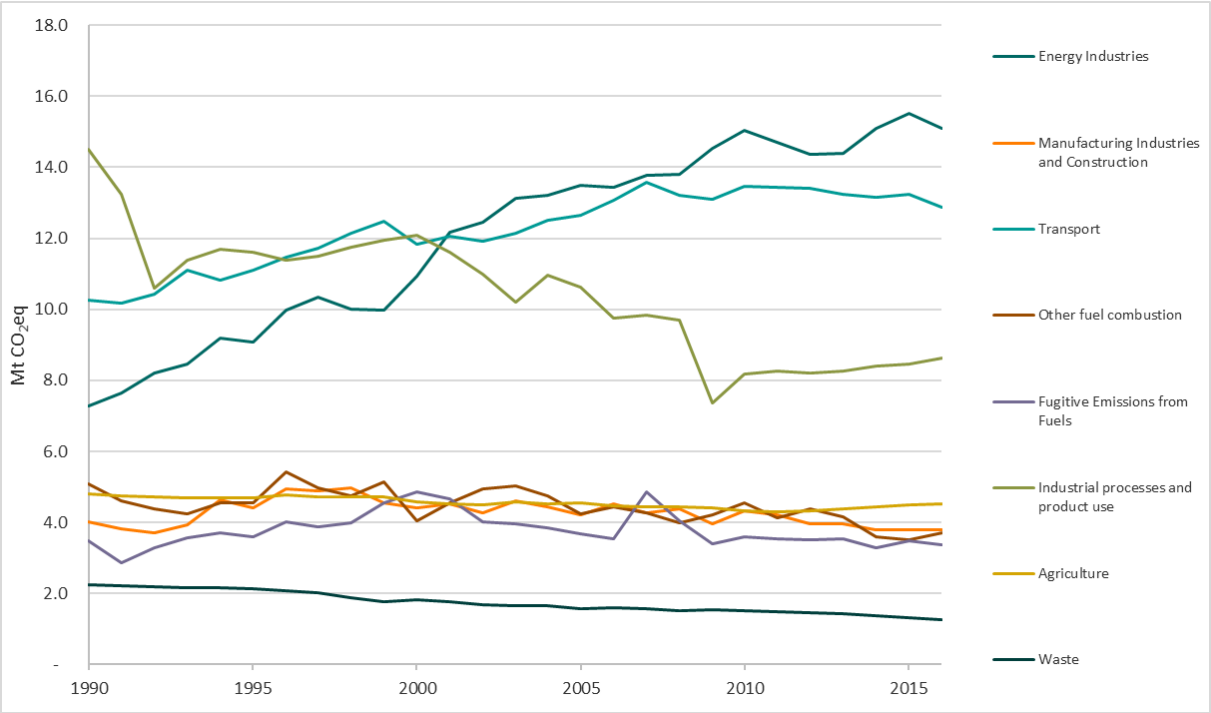


Figure 2.4. Development of emissions of all GHG (Mtonnes CO_2 eq.) from the different sectors, excluding LULUCF, 1990-2016. Source: Statistics Norway/Norwegian Environment Agency

2.2.1 Energy

Figure 2.5 displays the distribution of GHG emissions in 2016 by the main sub-sectors within the energy sector.

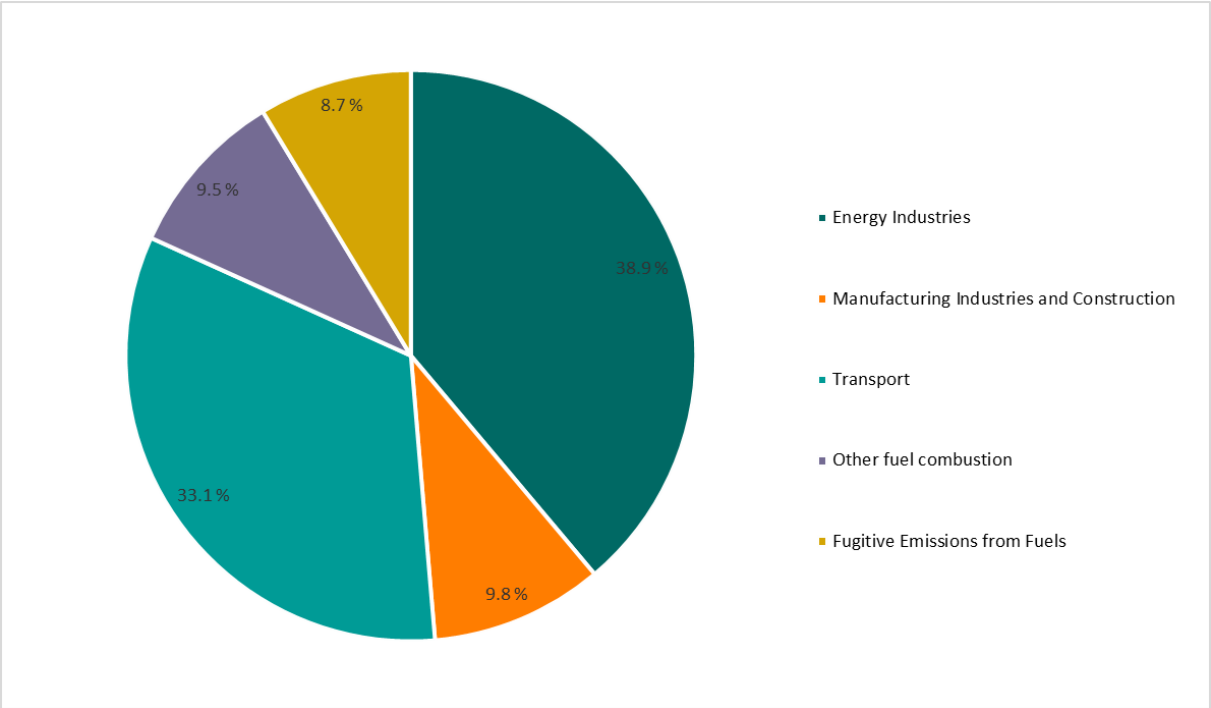


Figure 2.5. Greenhouse gas emissions in 2016 from the energy sector distributed among the different source categories. Source: Statistics Norway/Norwegian Environment Agency

The major sources of emissions within the energy sector are energy industries and transport, contributed to 38.9 per cent and 33.1 per cent of emissions from the energy sector in 2016, respectively. The remaining emissions are nearly equally shared between the sub-sectors: energy use in manufacturing industries and construction (CRF 1A2), other fuel combustion (CRF 1A4 and 1A5) and fugitive emissions from fuels (CRF 1B).

The Norwegian electricity production is dominated by hydroelectric power. Thus, emissions from energy industries origin almost completely from fuel combustion in oil and gas extraction and related activities. Electricity is normally used in manufacturing processes and for heating purposes.

The total emissions of GHG from the energy sector over the period 1990-2016 are listed in Table 2.2.

Table 2.2. Total emissions of greenhouse gases (Mtonnes CO_2-eq.) from the energy sector in Norway, 1990-2016. CO_2 transport and storage is presented in ktonnes CO_2-eq

Year	Energy Industries	Energy in Manufacturing Industries and Construction	Transport	Other fuel combustion	Fugitive Emissions from Fuels	CO2 transport and storage	Total
1990	7.3	4.0	10.3	5.1	3.5	0.0	30.1
1995	9.1	4.4	11.1	4.6	3.6	0.0	32.7
2000	10.9	4.4	11.8	4.0	4.9	9.3	36.1
2005	13.5	4.2	12.7	4.3	3.7	7.2	38.3
2006	13.4	4.5	13.1	4.4	3.5	3.5	39.0
2007	13.8	4.3	13.6	4.3	4.9	77.9	40.8
2008	13.8	4.4	13.2	4.0	4.1	109.0	39.5
2009	14.5	4.0	13.1	4.2	3.4	56.4	39.2
2010	15.0	4.3	13.5	4.6	3.6	96.8	41.1
2011	14.7	4.2	13.4	4.1	3.5	91.2	40.1
2012	14.4	4.0	13.4	4.4	3.5	62.9	39.7
2013	14.4	4.0	13.2	4.2	3.5	33.5	39.3
2014	15.1	3.8	13.2	3.6	3.3	44.0	39.0
2015	15.5	3.8	13.2	3.5	3.5	42.0	39.6
2016	15.1	3.8	12.9	3.7	3.4	10.6	38.8

Source: Statistics Norway/Norwegian Environment Agency

Emission changes from 1990 to 2016, relative to 1990, presented for various sub-sectors within the energy sector, are illustrated in Figure 2.6.

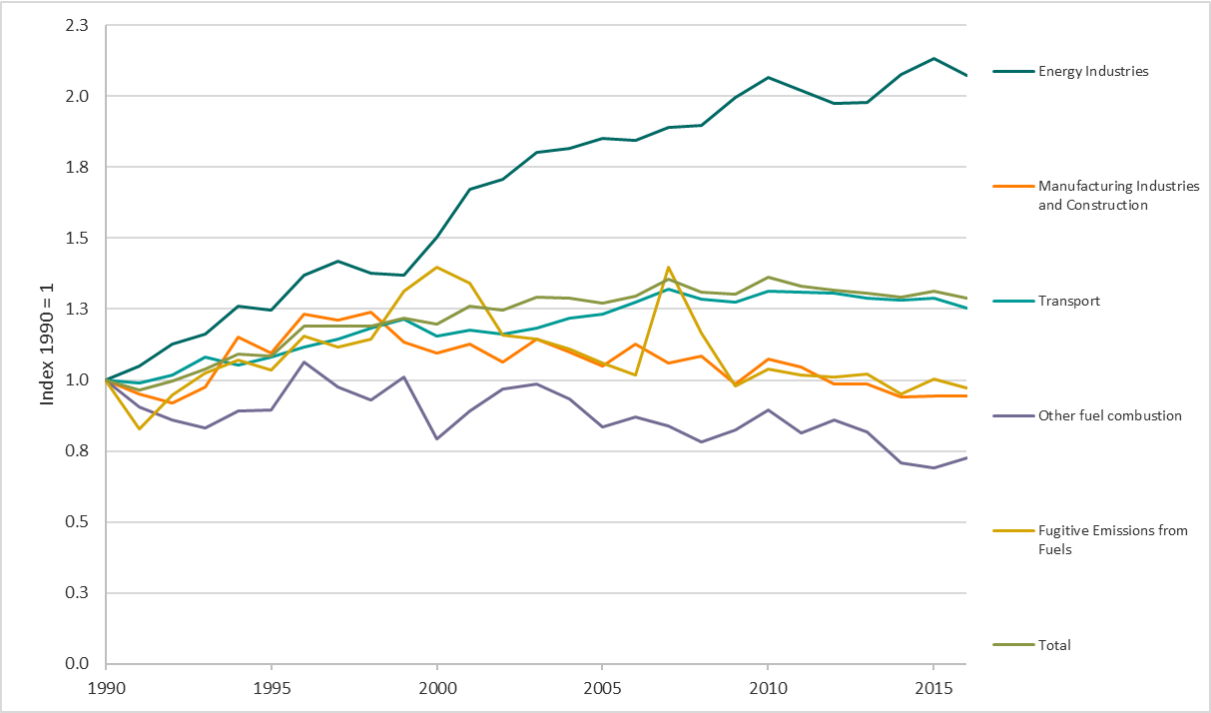


Figure 2.6. Changes in emissions of greenhouse gases, relative to 1990, for the various sub-sectors within the energy sector, 1990-2016. Index 1990 = 1. Source: Statistics Norway/Norwegian Environment Agency

The GHG emissions from the energy sector increased by 28.9 per cent from 1990 to 2016, primarily due to increased activity in oil and gas extraction and transport, specifically road transportation.

Emissions from energy were reduced between 2008 and 2009, mainly because of the world economic recession. Since 2010, the energy sector's emissions decreases except for 2015. From 2015 to 2016, emissions decreased by 1.9 per cent.

Emissions from fuel combustion in **Energy Industries** were 107.3 per cent higher in 2016 than in 1990. They decreased by 2.8 per cent from 2015 to 2016. The main emission source in the Energy Industries sub-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 2016, emissions from energy use in offshore oil and gas extraction contributed to almost 23.7 per cent of the national GHG emissions. In 1990, the corresponding contribution was 11.4 per cent. The growth can be explained by the increase of oil and gas production and the increase of energy demand in extraction, due to aging of oil fields and transition from oil to gas.

Electricity production is largely dominated by hydroelectric generation. Between 1990 and 2016, 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[5] originate to a large extent from the production of raw materials and semi-manufactured goods, e.g. alloys, petrochemicals, paper and minerals.

[5] 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.

Emissions from **Manufacturing Industries and Construction** have remained relatively stable since 1990, with a small decrease of 0.2 Mtonnes CO_2eq from 1990 to 2016. Between 2015 and 2016, emissions have been stable.

Emissions from **Transport** showed an overall increase of 25.3 per cent from 1990 to 2016, with a decrease of 2.8 per cent from 2015 to 2016. The highest emissions from transport since 1990 was 13.5 million tonnes in 2007. The share of transport in the total GHG emissions has increased from 19.9 per cent in 1990 to 24.2 per cent in 2016. Road transportation accounts for 77.1 per cent of emissions from the transport sub-sector, while emissions from navigation and civil aviation accounts for 13.2 and 9.3 per cent, respectively. Due to the fact that most railways are electrified in Norway, emissions of GHG from this source are insignificant.

GHG emissions from road transportation increased by 27.7 per cent from 1990 to 2016 and contributed to 18.6 per cent of the national GHG emissions in 2016. This trend is mainly due to the increase of activity in goods transport, as a response to higher economic activity. From 2015 to 2016, emissions decreased by 3.7 per cent. In addition to a reduced activity, the decreased emissions observed since 2007 could for the first years after be explained by the switch from petrol to diesel driven personal cars, due to the implementation of a CO_2 differentiated tax in 2007. However, in the later years a blending requirement of biofuels have increased consumption of bio diesel and bio ethanol and hence reduced CO_2 emissions. In addition, the sales of electric vehicles have gradually increased since 2011, and added up to 16% of personal cars and 2% of light duty vehicles in 2016, due to economic incentives.

Navigation contributed to the national total GHG emissions by 3.2 per cent in 2016. Emissions from navigation increased mainly in the 1990s, due to an increase of activity related to the oil and gas extraction sector. Since the year 2000, the emissions have been reduced, giving a total reduction of 0.7 per cent in the period 1990-2016.

Civil aviation contributed to 2.2 per cent of the national GHG emissions in 2016. Emissions from civil aviation have increased by 74.4 per cent since 1990, but the substitution of older planes by new and more energy efficient planes has played an important role to limit the emission growth. The average annual growth in emissions during the period 1990-2016 was 2.3 per cent. The growth in emissions from civil domestic aviation was substantially higher in the 1990s than it has been after. Indeed, between 1990 and 1999, the average annual growth rate is 6.2 per cent while between 1999 and 2016 is only 0.3 per cent.

GHG emission trends from the main transport modes are illustrated in Figure 2.7 and Table 2.3.

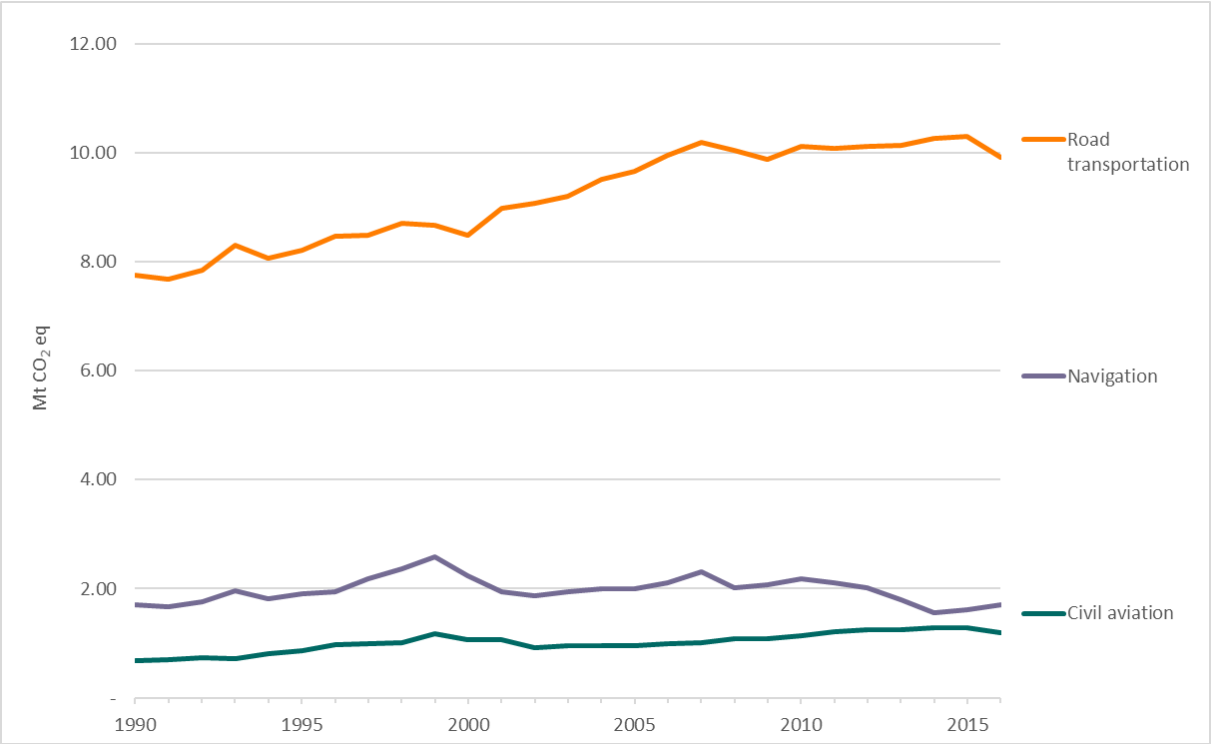


Figure 2.7. Emissions in million tonnes CO_2 equivalents from the most important modes of transport, 1990-2016. Source: Statistics Norway/Norwegian Environment Agency

Table 2.3. Total emissions of greenhouse gases from the transport sector in Norway, 1990-2016. Million tonnes CO_2 equivalents.

Year	Civil Aviation	Road transportation	Railways	Navigation	Total Transport
1990	0.69	7.76	0.11	1.71	10.27
1995	0.87	8.21	0.12	1.90	11.10
2000	1.07	8.48	0.05	2.24	11.85
2005	0.95	9.65	0.05	2.01	12.65
2006	0.99	9.95	0.05	2.10	13.08
2007	1.01	10.19	0.05	2.32	13.56
2008	1.09	10.05	0.05	2.01	13.20
2009	1.09	9.88	0.05	2.07	13.09
2010	1.14	10.11	0.04	2.18	13.48
2011	1.22	10.07	0.04	2.10	13.43
2012	1.24	10.11	0.05	2.01	13.41
2013	1.25	10.13	0.05	1.80	13.23
2014	1.29	10.26	0.05	1.56	13.16
2015	1.28	10.29	0.05	1.61	13.23
2016	1.20	9.91	0.05	1.70	12.86

Source: Statistics Norway/Norwegian Environment Agency

The sub-sector "**Other fuel combustion**" (Table 2.2) includes, in particular, fuel combustion in agriculture, forestry and fisheries, residential sector and commercial/institutional sectors (CRF key categories 1A4). The total emissions from CRF sector 1A4 were 3.5 million tonnes of CO_2 equivalents

in 2016. Emissions decreased by 25.4 per cent from 1990 to 2016, and increased by 5.1 per cent from 2015 to 2016.

In 2016, GHG emissions from residential sources (stationary and mobile) accounted for 17.6 per cent of emissions from the "other fuel combustion" sub-sector. Emissions from the residential subsector have been reduced by 62.7 per cent since 1990, mainly due to the electrification of heating infrastructures. However, new technologies and occasional electricity shortages have at times reversed this trend.

Emissions from stationary combustion in the residential subsector are climate-dependent. Indeed, mild winter can lead to relatively lower consumption of fuels and thus reduced emissions. Whereas dry and cold winter can lead to relatively higher emissions. Since 1990, emissions from stationary combustion in the residential sector have decreased by 73.0 per cent, mainly due to decrased energy consumption.

Emissions from commercial/institutional sources (mobile and stationary) have increased by 38.8 per cent since 1990. Emissions from commercial/institutional stationary sources decreased by 39.3 per cent from 1990 to 2016, whereas emissions from mobile sources were multiplied by more than 10 between 1990 and 2016.

The sub-sector "**Fugitive emissions from fuels"** in Table 2.2 refers to emissions from oil and gas activities such as flaring of natural gas, leakages and venting of methane. Indirect CO_2 emissions from NMVOC emitted during the loading and unloading of oil tankers are also accounted for in this sub-sector. Fugitive emissions from fuels contributed to 6.3 per cent of the national GHG emissions in 2016 and to 8.7 per cent of the GHG emissions within the energy sector. Fugitive emissions from fuels have decreased by 2.9 per cent since 1990. Between 2015 and 2016, emissions increased by 3.1 per cent.

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.

2.2.2 Industrial processes and product use

The industrial processes and other product use (IPPU) sector accounted for 16.2 per cent of the national GHG emissions in 2016. The emissions from this sector decreased by 40.5 per cent from 1990 to 2016. Emissions increased by 1.9 per cent between 2015 and 2016.

Metal Industry is the main source of emissions within the IPPU sector in the period 1990-2016. It contributed indeed to 55.7 per cent of the GHG emissions from the IPPU sector in 2016. The other main contributing sources in 2016 were Product uses as substitutes for ODS, Chemical Industry and Mineral Industry. They contributed to 15.8, 12.5 and 11.3 per cent of the GHG emissions from the IPPU sector, respectively.

Figure 2.8 shows the variations in the contribution to GHG emissions from 1990 to 2016 of the different IPPU sub-sectors. Table 2.4 provides figures for the total GHG emissions from the IPPU sector for the same period.

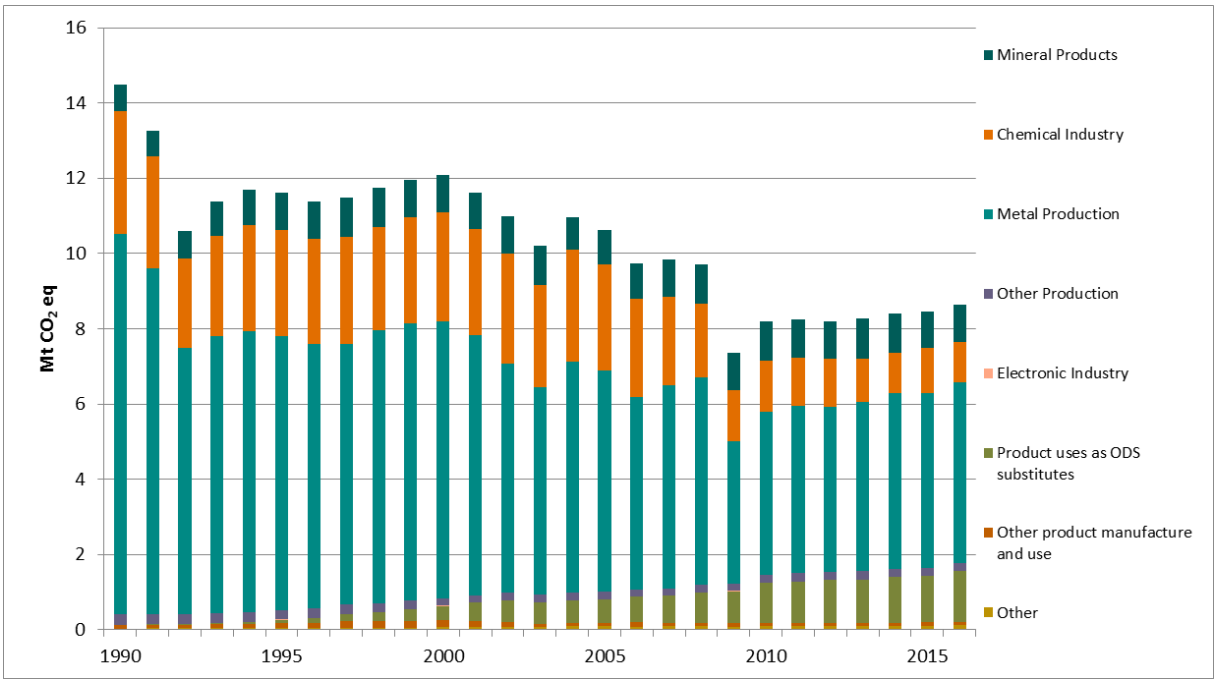


Figure 2.8. Total greenhouse gas emissions (Mtonnes CO_2-eq.) in the IPPU sub-sector in Norway, 1990-2016[6]. Source: Statistics Norway/Norwegian Environment Agency

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 then emitted as process related gases.

9.0 per cent of national GHG emissions came from **Metal industry** in 2016, whose emissions decreased by 3.5 per cent from 2015 to 2016.

. The largest contributors to the GHG emissions from Metal Production in 2016 are productions of ferroalloys and aluminium. Emissions from those productions constituted more than 97 per cent of emissions from Metal industry in 2016. The large decrease in emissions in 2009 reflects low production levels of ferroalloys, due to lower economic activity and economic recession

In 1990, PFCs emissions from aluminium production contributed to 7.5 per cent of the national GHG emissions, while in 2016, it has been reduced to 0.3 per cent. Emissions of PFCs have decreased by 95.2 per cent since 1990 and, between 2015 and 2016, emissions increased by 27.2 per cent.

Since 2010, production of ferroalloys has been the most important source of GHG emissions within the metal production category. The GHG emissions from ferroalloys production amounted to 2.6 million tonnes of CO_2 equivalents in 2016 and accounted for 4.9 per cent of the national total GHG emissions. Emissions from production of ferroalloys increased by 2.2 per cent from 1990 to 2016 with a 4 per cent increase from 2015. The large increase in emissions from 2009 to 2010 (50.2 per

[6] Under Other production, Norway reports the two source categories: pulp and paper and food and drink.

cent) is due to a low production level in 2009. The production level in 2009 is also lower than 2008 and reflects the lower economic activity due to the economic recession.

Table 2.4. Total greenhouse gas emissions (Mtonnes CO_2-eq.) from the IPPU sub-sectors in Norway, 1990-2016.

Year	Mineral industry	Chemical Industry	Metal industry	Non-energy products from fuels and solvent use	Electronics Industry	Product uses as ODS substitutes	Other product manufacture and use	Other	Total
1990	0.7	3.3	10.1	0.3	0.0	0.0	0.1	0.0	14.5
1995	1.0	2.8	7.3	0.2	0.0	0.1	0.1	0.0	11.6
2000	1.0	2.9	7.4	0.2	0.0	0.4	0.2	0.1	12.1
2005	0.9	2.8	5.9	0.2	0.0	0.6	0.1	0.1	10.6
2006	1.0	2.6	5.1	0.2	0.0	0.7	0.1	0.1	9.7
2007	1.0	2.3	5.4	0.2	0.0	0.7	0.1	0.1	9.9
2008	1.0	2.0	5.5	0.2	0.0	0.8	0.1	0.1	9.7
2009	1.0	1.3	3.8	0.2	0.0	0.9	0.1	0.1	7.4
2010	1.0	1.4	4.3	0.2	0.0	1.1	0.1	0.1	8.2
2011	1.0	1.3	4.4	0.2	0.0	1.1	0.1	0.1	8.3
2012	1.0	1.3	4.4	0.2	0.0	1.1	0.1	0.1	8.2
2013	1.1	1.2	4.5	0.2	0.0	1.2	0.1	0.1	8.3
2014	1.1	1.1	4.7	0.2	0.0	1.2	0.1	0.1	8.4
2015	1.0	1.2	4.6	0.2	0.0	1.2	0.1	0.1	8.5
2016	1.0	1.1	4.8	0.2	0.0	1.4	0.1	0.1	8.6

Source: Statistics Norway/Norwegian Environment Agency

In 1990, SF_6 from magnesium foundries accounted for 4.0 per cent of the national total GHG emissions. Emissions decreased until the closure of all plants in 2007. Reductions in SF_6 emissions over the period are, in the early 90s, mainly due to improvements in the production processes, in 2002, due to the closing down of production of cast magnesium and in 2006, due to the closing down of secondary magnesium production.

Emissions from **Mineral Industry** were 1.0 million tonnes in 2016, which accounted for 1.8 per cent of the national GHG emissions. Emissions increased by 33.5 per cent from 1990 to 2016, mainly due to the increase of clinker and lime production in more recent years. Emissions from this sub-sector decreased by 1.6 per cent from 2015 to 2016.

In 2016, the CO_2 process emissions from cement production were 1.3 per cent of the national GHG emissions. They have increased by 7.9 per cent since 1990, due to increased production of clinker. Emissions increased by 1.9 per cent from 2015 to 2016.

The Chemical Industry includes primarily N_2O from nitric acid production and CO_2 from production of ammonia and carbides. The GHG emissions from this sub-sector amounted to 1.1 million tonnes of CO_2 equivalents in 2016, which represented 2.0 per cent of the national GHG emissions. Emissions have decreased by 66.9 per cent since 1990, mainly due to the reduction of emissions from the production of nitric acid, ammonia and carbides. Emissions have decreased by 10.4 per cent since 2015 mainly due to the increase of ammonia production.

2.2.3 Agriculture

In 2016, 8.5 per cent of the national GHG emissions originated from agriculture, corresponding to 4.5 million tonnes of CO_2 equivalents. Emissions from agriculture have decreased by 6.0 per cent since 1990 and increased by 0.6 per cent since 2015.

The largest sources of GHGs within the agriculture sector are “enteric fermentation” (CH_4) and “agricultural soils” (N_2O). In 2016, these sub-sectors represented 51.0 per cent and 37.4 per cent of the agriculture sector, respectively, while “manure management” represented 9.7 per cent.

The main driver behind the emission trend in agriculture are the development in the number of animals for the significant animal groups. The main reasons for the decreasing trend in GHG emissions are the reduction of nitrogen content in the synthetic fertilizers used, use of more concentrate and more effective milk production which led to reduction of the number of diary cows.

Enteric fermentation contributed to 2.3 million tonnes of CO_2 equivalents in 2016, corresponding to 4.3 per cent of the national GHG emissions. This sub-sector constituted 90.2 per cent of the overall CH_4 emissions from agriculture for the period 1990-2016.

The emissions of N_2O from **agricultural soils** amounted to 1.7 million tonnes of CO_2 equivalents in 2016. This accounted for 67.0 per cent of the national N_2O emissions in 2016 and 3.2 per cent of the national GHG emissions.

In 2016, emissions CH_4 and emissions of N_2O from **manure management** amounted to 0.2 million and 0.3 million tonnes of CO_2 equivalents, respectively. This accounted for 0.8 per cent of the Norwegian GHG emissions.

Table 2.5. Greenhouse gas emissions (Mtonnes CO_2-eq.) from the agricultural sub-sectors in Norway, 1990-2016. Urea application is in ktonnes CO_2-eq.

Year	Enteric Fermentation	Manure Management	Agricultural Soils	Field burning of agricultural residues	Liming	Urea application	Total
1990	2.42	0.40	1.72	0.04	0.23	0.55	4.81
1995	2.37	0.40	1.70	0.02	0.19	0.55	4.68
2000	2.34	0.39	1.70	0.01	0.14	0.11	4.57
2005	2.32	0.40	1.70	0.01	0.11	0.10	4.54
2006	2.27	0.40	1.68	0.01	0.10	0.12	4.46
2007	2.25	0.40	1.69	0.01	0.10	1.17	4.45
2008	2.25	0.40	1.68	0.01	0.09	0.89	4.43
2009	2.28	0.41	1.62	0.00	0.09	1.35	4.41
2010	2.26	0.42	1.57	0.00	0.08	0.32	4.34
2011	2.21	0.41	1.62	0.00	0.08	0.33	4.31
2012	2.21	0.41	1.62	0.00	0.08	0.23	4.33
2013	2.23	0.43	1.64	0.00	0.08	0.16	4.39
2014	2.24	0.43	1.68	0.00	0.09	0.16	4.45
2015	2.27	0.43	1.70	0.00	0.09	0.22	4.49
2016	2.30	0.44	1.69	0.00	0.08	0.19	4.52

Source: Statistics Norway/Norwegian Environment Agency

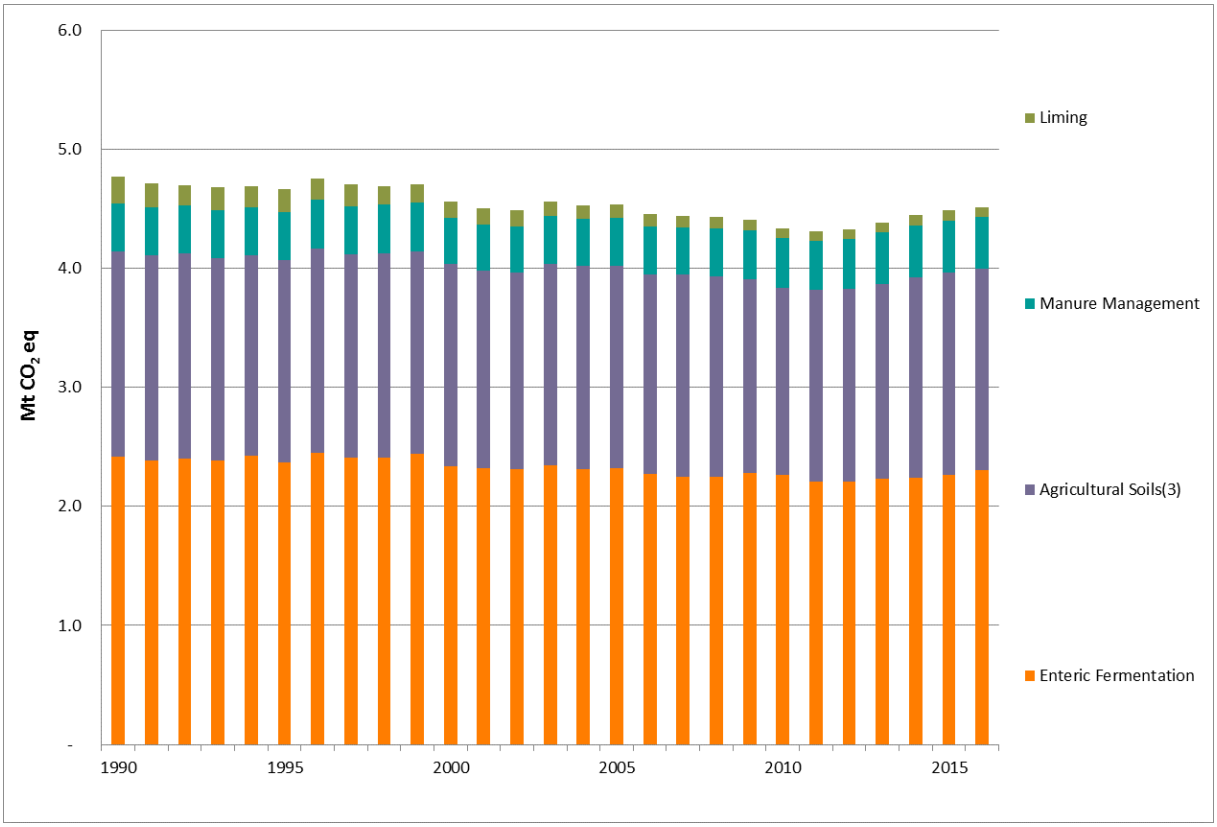


Figure 2.9. Total greenhouse gas emissions (Mtonnes CO_2-eq.) in the agriculture sub-sectors in Norway, 1990-2016. Source: Statistics Norway/Norwegian Environment Agency

2.2.4 Land Use, Land-Use Change and Forestry (LULUCF) and KP-LULUCF

The LULUCF sector differs from the other sectors in that it can function as both a source of atmospheric emissions and a sink of emissions through the removal of atmospheric CO_2. The balance of the two is net emissions or removals in the LULUCF sector.

In 2016, the net removal in the LULUCF sector was 24.4 million tonnes CO_2 equivalents, which correspond to almost half of the national GHG emissions that year. The average annual net sequestration from the LULUCF sector has been 22.2 million tonnes CO_2 equivalents per year for the period 1990-2016.

The calculated changes in carbon depend upon several factors such as growing conditions, harvest levels, management practices and land use changes.

The area distribution of the land-use categories for Norway in 1990 and 2016 is illustrated in Figure 2.10. The figure shows that the net changes in land-area distribution in Norway from 1990 to 2016 have been relatively small; only the area of settlements has increased slightly, while the other land-use categories have decreased. Details on gross changes between the respective categories may be found in the land transition matrix, Table 6.2 in the LULUCF chapter.

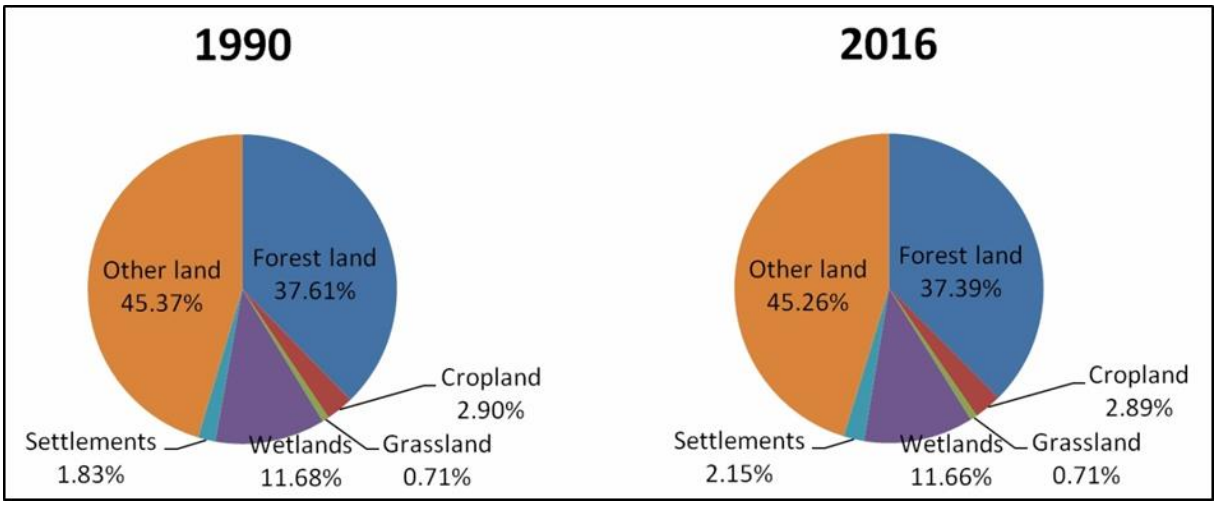


Figure 2.10 Area (%) distribution between the IPCC land-use categories, 1990 and 2016.
Source: The Norwegian Norwegian Institute of Bioeconomy Research

Figure 2.11 illustrates net emissions and removals of CO_2-eq by land use-category. As can be seen, all land-use categories other than forest land showed net emissions in 2016. In total, the emissions were calculated to about 4.5 million tonnes of CO_2 equivalents, of which the main emissions came from the land-use categories cropland and settlements. Emissions from settlements increased by more than three times from 1990 to 2016, and are, in 2016, responsible for the largest emissions from the LULUCF sector, with 2.1 million tonnes of CO_2 equivalents.

Forest land was the major contributor to the net sequestration of CO_2 in the sector. In 2016, the total net removals from forest land were 28.8 million tonnes of CO_2. Within this category, land converted to forest land contributed with 0.52 million tonnes of CO_2.

The figure clearly shows that the net removals from forest land has increased from 1990 to 2016. During this time period, the total net sequestration of CO_2 from forest land increased by 143 per cent. The explanation for this growth is an increase in standing volume and gross increment, while

the amount of CO_2 emissions due to harvesting and natural losses has been quite stable. The 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. These areas are now at their most productive age and contribute to the increase in living biomass and hence the carbon stock.

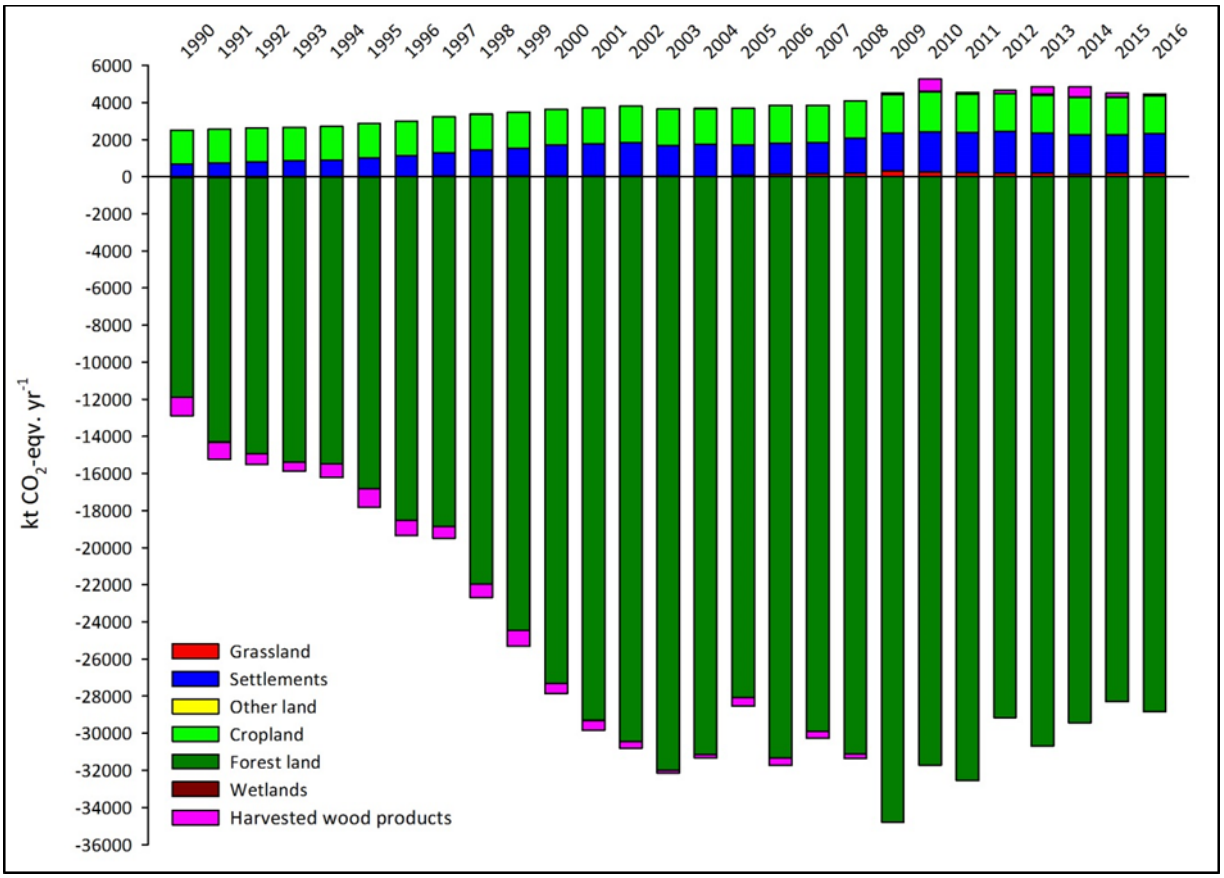


Figure 2.11 Net CO_2 emissions and removals (kt CO_2-equivalents per year) from the LULUCF sector by land-use category (forest land, cropland, grassland, wetlands, settlements, other land, and harvested wood products) from 1990 to 2016, including emissions of N_2O and and CH_4.
Source: Norwegian Institute of Bioeconomy Research

In chapter 11, supplementary information on Norway's commitment to report on and account for emissions and removals from Land Use, Land-Use Change and Forestry under the Kyoto Protocol (KP-LULUCF) is provided. All emissions and removals are estimated according to the 2013 Kyoto Protocol supplement (IPCC 2014a).

Reporting on activities under Article 3.3 (Afforestation/reforestation and Deforestation) and forest management (Article 3.4) is mandatory for all Parties under the Kyoto Protocol. In addition, any activity elected in the first commitment period (2008-2012) is mandatory in the second commitment period (2013-2020). For the second commitment period, Norway has also elected the voluntary activities Cropland Management and Grazing Land Management in the accounting under Article 3.4.

Areas where afforestation and reforestation and deforestation activities have occurred in Norway are small compared to the area of forest management. As illustrated in Table 2.6, estimated C sequestration for the activity forest management is substantial, whereas net emissions occur from

deforestation, cropland and grazing land management. In addition, C sequestration from afforestation/reforestation is estimated.

Table 2.6. CO_2, N_2O and CH_4 emissions (kt CO_2 eq yr^{-1}) and CO_2 removals of all pools for Article 3.3 and 3.4 under the Kyoto Protocol for the base year (1990) and for each of the first four years of the second commitment period.

	Net emissions (kt CO_2–eq yr^{-1})				
Year	**Afforestation/ reforestation**	**Deforestation**	**Forest management**	**Cropland management**	**Grazing land management**
1990			-12 890.88	1 782.49	-77.35
2013	-569.52	2 367.59	-29 934.63	1 759.48	7.20
2014	-557.23	2 249.09	-28 626.29	1 771.05	3.97
2015	-542.97	2 250.70	-27 797.83	1 773.47	1.53
2016	-519.18	2 325.99	-28 396.13	1 769.89	0.37

Source: Norwegian Institute of Bioeconomy Research

The accounting of emissions and removals from LULUCF towards Norway's commitment under the Kyoto protocol will be in accordance with Decision 2/CMP.7. The final quantity of emissions and removals for each year of the commitment period to be accounted towards Norway's commitment will be determined at the end of the commitment period, i.e. in 2022, when emissions and removals for the year 2020 have been reported. Until the year of accounting, emissions and removals from the Kyoto Protocol activities may be recalculated due to changes in activity data and/or methodology.

Preliminary accounting quantities from land use, land-use change and forestry for the first four years of the second commitment period under the Kyoto Protocol indicate that Norway will have a net emission of about 0.1 million tonnes of CO_2- equivalents in total for these four years. The preliminary accounting quantities from the activities, calculated according to Decision 2/CMP.7, comprise emissions (million tonnes of CO_2-equivalents) of 9.2 from deforestation and 0.3 from grazing land management; and removals of 2.2 from afforestation and reforestation, 7.2 from forest management and 0.05 from cropland management.

2.2.5 Waste

The waste sector, with emissions of 1.3 million tonnes of CO_2 equivalents in 2016, accounted for 2.3 per cent of the national GHG emissions.

This sector includes emissions from landfills (CH_4), wastewater handling (CH_4 and N_2O), biological treatment of solid waste and small-scale waste incineration (CO_2 and CH_4). Waste incineration with utilization of energy is included in the Energy sector.

Solid waste disposal on land (landfills) is the main sub-sector within the waste sector. It accounted for 83.2 per cent of the sector's total emissions in 2016. Whereas wastewater handling accounted for 11.5 per cent and biological treatment of solid waste for 5.4 per cent. Small-scale waste incineration accounted for 0.01 per cent.

GHG emissions from the waste sector have generally decreased since 1990. In 2016, emissions were 44.2 per cent lower than in 1990 and 4.6 per cent lower than in 2015. The total amount of waste

generated increased by almost 60 per cent from 1995 to 2015, but due to the increase in material recycling and a ban against disposing biodegradable waste to landfills, methane emissions have decreased.

The distribution of the waste emissions by sub-sector is presented in Figure 2.12 and Table 2.7.

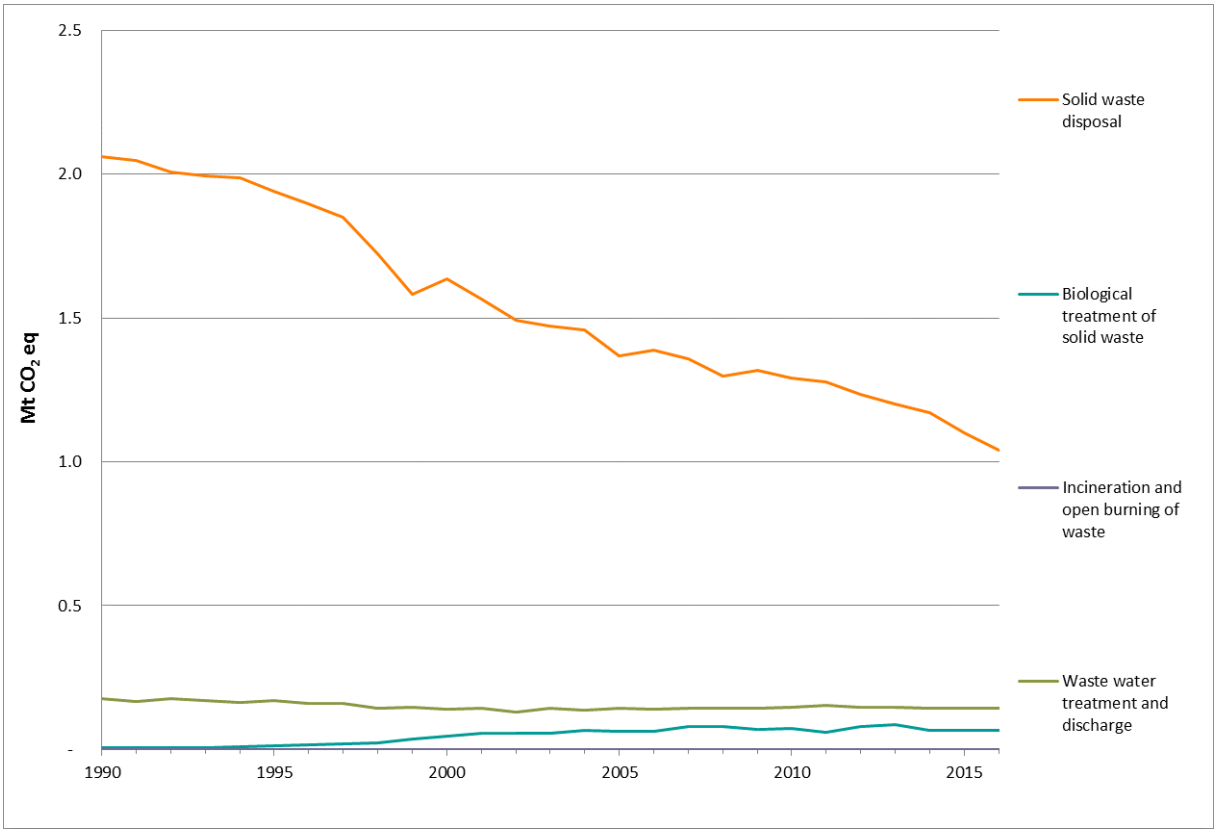


Figure 2.12. Total emissions of greenhouse gases (Mtonnes CO_2-eq.) in Norway from the waste sub-sectors, 1990-2016. Source: Statistics Norway/Norwegian Environment Agency

Table 2.7 shows the decrease of methane emissions (landfills) since 1990. The reduction is due to a smaller amount of waste disposed at disposal sites. With a few exceptions, it was then prohibited to dispose easy degradable organic waste at landfills in Norway. In 1999, a tax was introduced on waste delivered to final disposal sites. Since July 2009, it is banned to deposit biodegradable waste to landfills. This results in further reduction of methane emissions.

Table 2.7. Emissions (Mtonnes CO_2-eq.) from the waste sub-sector in Norway, 1990-2016. Incineration and open burning of waste is presented in ktonnes CO_2-eq.

Year	Solid waste disposal	Biological treatment of solid waste	Incineration and open burning of waste	Waste water treatment and discharge	Total
1990	2.06	0.01	0.21	0.18	2.24
1995	1.94	0.01	0.21	0.17	2.12
2000	1.63	0.05	0.20	0.14	1.82
2005	1.37	0.06	0.14	0.14	1.57
2006	1.39	0.06	0.08	0.14	1.59
2007	1.36	0.08	0.10	0.14	1.58
2008	1.30	0.08	0.12	0.14	1.52
2009	1.32	0.07	0.10	0.14	1.53
2010	1.29	0.07	0.09	0.15	1.51
2011	1.28	0.06	0.08	0.15	1.49
2012	1.23	0.08	0.07	0.15	1.46
2013	1.20	0.09	0.07	0.15	1.43
2014	1.17	0.07	0.06	0.14	1.38
2015	1.10	0.07	0.07	0.14	1.31
2016	1.04	0.07	0.07	0.14	1.25

Source: Statistics Norway/Norwegian Environment Agency

2.3 Description and interpretation of emission trends by gas

As shown in Figure 2.13, CO_2 is by far the largest contributor to the total GHG emissions, followed by CH_4, N_2O, and then the fluorinated gases PFCs, SF_6 and HFCs. In 2016, the relative contributions to the national total from the different gases were: CO_2 82.7 per cent, CH_4 9.5 per cent, N_2O 4.7 per cent and fluorocarbons (PFCs, SF_6 and HFCs) 3.0 per cent. While the relative share of the gases has been quite stable since 2010, the relative share of CO_2 has increased by approximately 1 per cent each year during the period 2005-2010, from 79.1 per cent in 2005 up to 83.1 per cent in 2010.

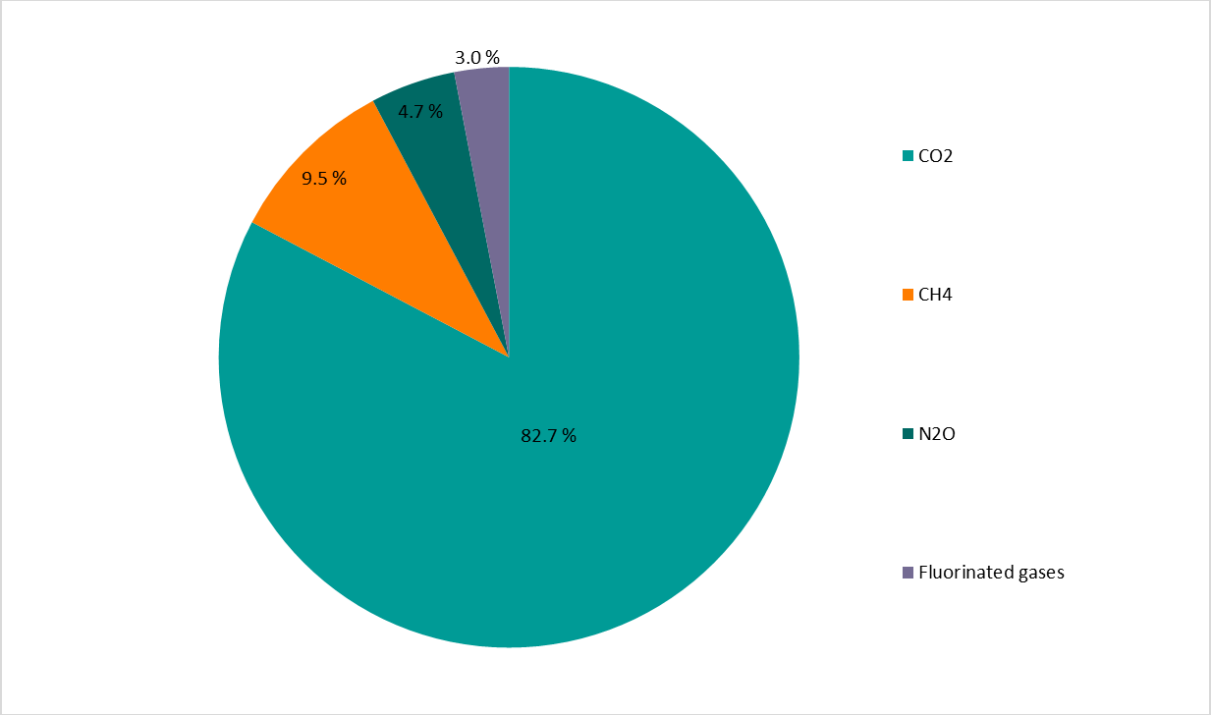


Figure 2.13. Distribution of emissions of greenhouse gases in Norway by gas, 2016.
Source: Statistics Norway/Norwegian Environment Agency

Table 2.8 presents emission figures for all greenhouse gases, expressed in absolute emission figures and total CO_2 equivalents.

Table 2.8. Emissions of greenhouse gases in Norway, 1990-2016. Units: CO_2 and CO_2 eq. in Mtonnes (Mt), CH_4 and N_2O in ktonnes (kt) and other gases in tonnes (t).

Gas	CO_2	CH_4	N_2O	PFC			SF_6	HFC								
				CF_4	C_2F_6	C_3F_8		23	32	125	134a	143a	152a	227ea	134	143
Year	Mt	kt	kt	T			t	T								
1990	35.7	231.5	14.1	467.4	36.2	NO	92.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
1995	38.5	234.6	12.8	283.3	18.1	NO	25.4	0.0	0.4	5.2	38.6	4.1	1.3	0.0	0.0	0.0
2000	42.2	226.9	13.1	186.4	11.6	NO	39.1	0.1	2.0	34.8	90.5	28.7	7.0	0.2	0.0	0.0
2005	43.6	218.0	14.0	116.7	7.6	NO	13.0	0.1	6.1	57.2	139.4	44.8	26.8	1.0	0.8	1.1
2006	43.9	212.9	12.9	102.1	8.6	NO	8.8	0.1	7.9	63.2	158.5	48.0	30.1	0.9	0.8	1.9
2007	45.9	217.7	12.3	111.7	10.3	NO	3.1	0.1	10.0	64.4	184.9	46.6	31.7	1.1	0.7	1.6
2008	44.9	211.9	10.8	104.7	10.0	NO	2.6	0.1	12.5	68.9	218.5	52.0	30.5	0.8	2.7	1.4
2009	43.2	213.4	9.0	49.8	5.8	NO	2.4	0.1	15.9	73.9	245.1	50.4	30.7	0.9	2.2	1.3
2010	45.8	214.1	8.7	27.3	3.0	0.01	3.0	0.1	19.8	94.2	280.2	69.3	34.6	0.7	2.0	1.1
2011	45.0	207.9	8.7	29.9	3.4	0.01	2.4	0.2	22.6	99.0	305.9	65.0	34.5	2.1	1.8	1.0
2012	44.6	206.3	8.7	22.9	2.6	0.01	2.3	0.5	25.5	99.0	339.5	60.6	35.0	1.9	1.7	0.9
2013	44.3	207.4	8.6	20.6	2.3	0.00	2.5	0.4	31.1	97.3	364.4	57.4	34.6	1.2	1.5	0.8
2014	44.0	210.8	8.6	20.3	2.4	0.00	2.2	0.3	34.6	103.8	362.0	69.4	36.6	0.9	1.4	0.8
2015	44.7	206.5	8.7	16.7	1.9	NO	3.1	0.3	39.5	111.7	346.3	66.9	37.8	1.1	1.3	0.7
2016	44.0	203.2	8.5	21.2	2.4	NO	2.8	0.3	42.4	119.3	381.7	78.0	39.5	4.0	1.2	0.6

Source: Statistics Norway/Norwegian Environment Agency

Table 2.9 presents the emissions in million tonnes per greenhouse gas and the changes in per cent for each greenhouse gas for the period 1990–2016, and for 2015-2016.

Table 2.9. Emissions in Mtonnes CO_2 equivalents and changes in per cent for each greenhouse gas.

Year	CO_2	CH_4	N_2O	PFCs	SF_6	HFCs	Total
1990	35.7	5.8	4.2	3.9	2.1	0.0	51.7
2015	44.7	5.2	2.6	0.1	0.1	1.2	53.9
2016	44.0	5.1	2.5	0.2	0.1	1.4	53.2
Changes 1990-2016	23.3 %	-12.3 %	-40.2 %	-95.2 %	-97.0 %	3106145.2 %	3.0 %
Changes 2015-2016	-1.4 %	-1.6 %	-3.0 %	27.2 %	-8.8 %	10.6 %	-1.2 %

Source: Statistics Norway/Norwegian Environment Agency

As presented in Table 2.8 and Table 2.9, CO_2 emissions increased significantly from 1990 to 2016 with 8.3 million tonnes CO2 eqivalents. Emissions of CH_4 and N_2O decreased by 0.7 and 1.7 million tonnes CO2equivalents, respectively. During the same period, PFCs and SF_6 emissions significantly decreased with 3.7 and 2.0 million tonnes CO2 equivalents, respectively, while HFCs has increased from almost 0 to 1.4 million tonnes CO_2 equivalents.

The fluorocarbons constituted a larger fraction of the GHG emission total in the early 1990s than in 2016, while CO_2 represented a smaller share in 1990 than in 2016.

The Figure 2.14 illustrates the changes in per cent for the different greenhouse gases for the period 1990 to 2016.

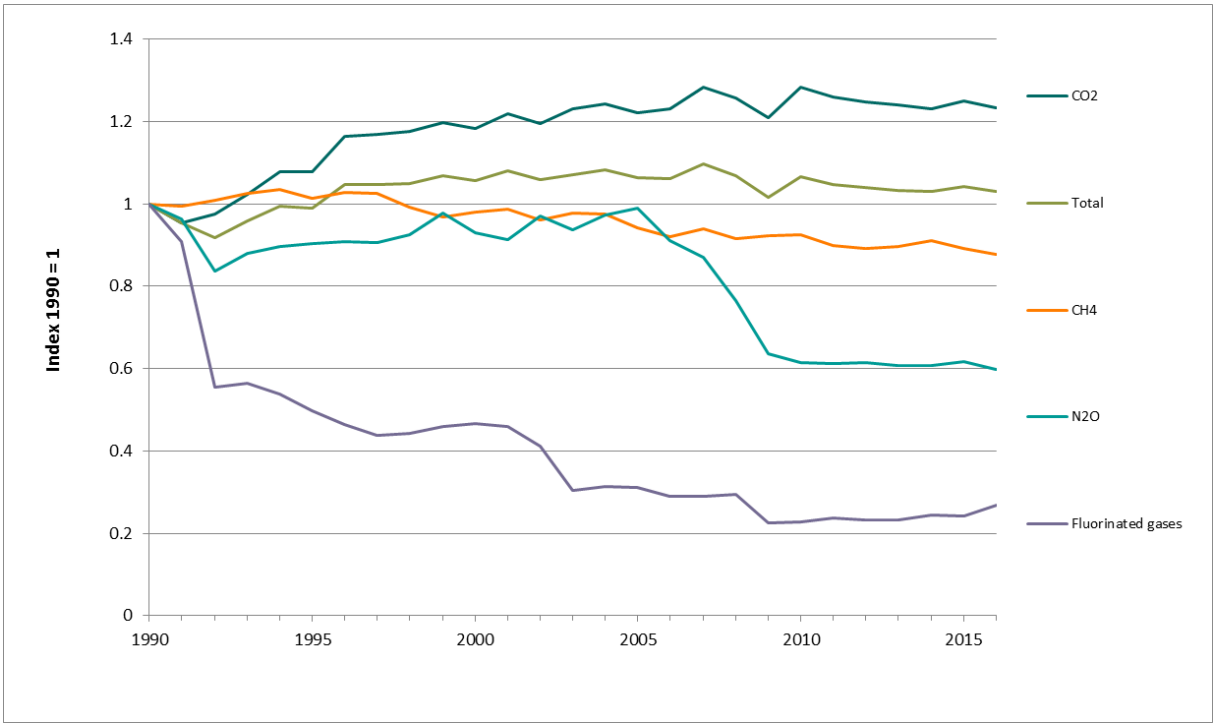


Figure 2.14. Changes in emissions of greenhouse gases, relative to 1990, by gas, 1990-2016. Index 1990 = 1. Source: Statistics Norway/Norwegian Environment Agency

Figure 2.14 shows that the overall increasing total emission trend of CO_2 has been weakened by decreased emissions of fluorinated gases due to SF_6 and PFCs emissions reduction.

2.3.1 Carbon dioxide (CO_2)

The Norwegian CO_2 emissions originate primarily from energy industries, transport and industrial processes.. Since generation of electricity is almost exclusively hydroelectric, emissions from stationary combustion are dominated by industrial sources and internal energy use.

The distribution of CO_2 emissions among various categories is shown in Figure 2.15.

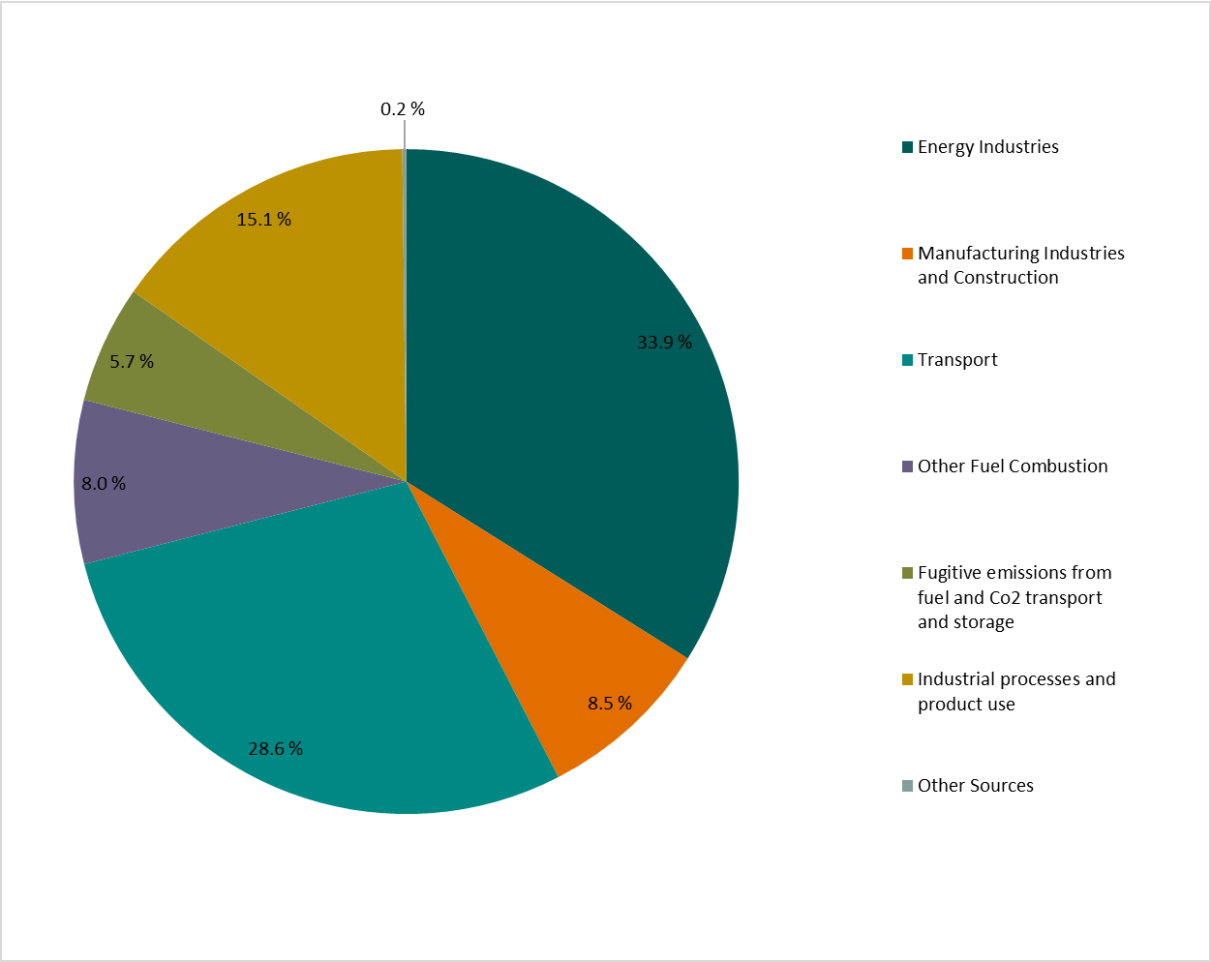


Figure 2.15. Distribution of CO_2 emissions in Norway by various source categories in 2016.
Source: Statistics Norway/Norwegian Environment Agency

Table 2.10 lists CO_2 emissions from each source category for the period 1990-2016. The changes in emissions from 1990 to 2016 relative to 1990 are displayed in Figure 2.16.

Table 2.10. CO_2 emissions (million tonnes) from different source categories, 1990-2016.

Year	Energy Industries	Manufacturing Industries and Construction	Transport	Other Fuel Combustion	Fugitive emissions from fuel and CO_2 transport and storage	Industrial processes and product use	Other sources	Total
1990	7.2	4.0	10.1	4.9	2.9	6.4	0.2	35.7
1995	9.0	4.4	10.9	4.3	2.8	6.9	0.2	38.5
2000	10.9	4.4	11.7	3.8	3.9	7.5	0.1	42.2
2005	13.4	4.2	12.5	4.0	2.7	6.7	0.1	43.6
2006	13.3	4.5	13.0	4.2	2.6	6.3	0.1	43.9
2007	13.6	4.2	13.4	4.0	3.9	6.6	0.1	45.9
2008	13.7	4.3	13.0	3.7	3.2	6.9	0.1	44.9
2009	14.4	3.9	12.9	3.9	2.5	5.4	0.1	43.2
2010	14.9	4.3	13.3	4.3	2.8	6.3	0.1	45.8
2011	14.6	4.1	13.2	3.9	2.7	6.3	0.1	45.0
2012	14.2	3.9	13.2	4.1	2.7	6.3	0.1	44.6
2013	14.3	3.9	13.0	3.9	2.7	6.4	0.1	44.3
2014	15.0	3.7	12.9	3.4	2.4	6.5	0.1	44.0
2015	15.4	3.7	12.9	3.3	2.6	6.6	0.1	44.7
2016	14.9	3.7	12.6	3.5	2.5	6.7	0.1	44.0

Source: Statistics Norway/Norwegian Environment Agency

Since 1990, the total emissions of CO_2 have increased by 23.3 per cent, or by 8.3 million tonnes. The increases of natural gas use in gas turbines in the oil and gas extraction industry have been the most important contributor to the overall CO_2 increase.

In 2016, the total Norwegian emissions of CO_2 were 44.0 million tonnes. It has decreased by 1.4 per cent or 0.6 million tonnes since 2015.

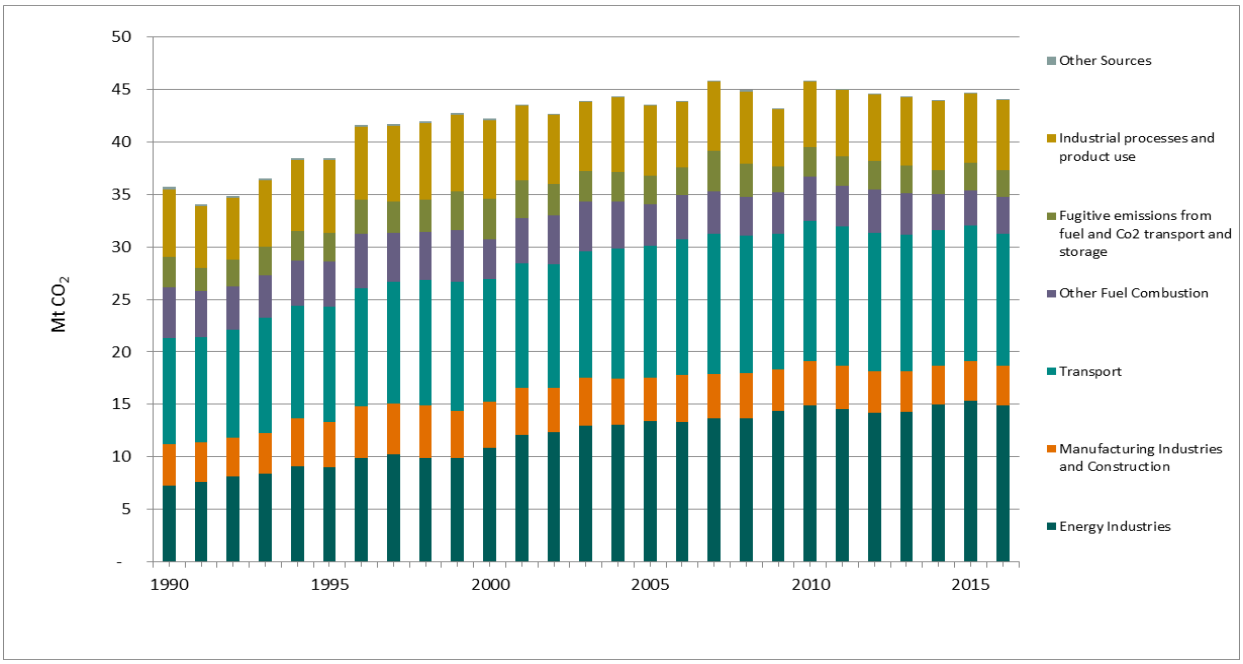


Figure 2.16. CO_2 emissions (Mtonnes) in Norway, 1990-2016.
Source: Statistics Norway/Norwegian Environment Agency

CO_2 emissions from energy indutries have increased by 107 per cent since 1990 as a result of large increases in production volume of oil and gas and the export of natural gas in pipelines. In 2016, emissions from energy industries decreased by 0.4 million tonnes or 2.7 per cent compared to 2015.

CO_2 emissions from transport have increased by 24.5 per cent since 1990. CO_2 emissions from this sector is dominated by road transportation which acounted for 78 per cent of the CO_2 emissions in 2016. CO_2 emissions from road transportation increased with 28.6 per cent between 1990 and 2016 although emissions from personal cars powered by gasoline decreased by 56.7 per cent during this period.

CO_2 emissions from industrial processes have increased by 4.0 per cent since 1990, and contributed to 15.1 per cent of total CO_2 emissions in 2016. Metal production accounted for 69.3 per cent of the CO_2 emissions from industrial processes in 2016.

2.3.2 Methane (CH_4)

In 2016, 50.6 per cent of methane emissions originated from agriculture, 26.5 per cent from the energy sector and 22.5 per cent originated from the waste sector. Methane emissions are dominated by releases from enteric fermentation in the agriculture sector, by fugitive emissions from oil and gas extraction in the energy sector and by landfills in the waste sector.

Figure 2.17 illustrates the distribution of Norwegian CH_4 emissions in 2016.

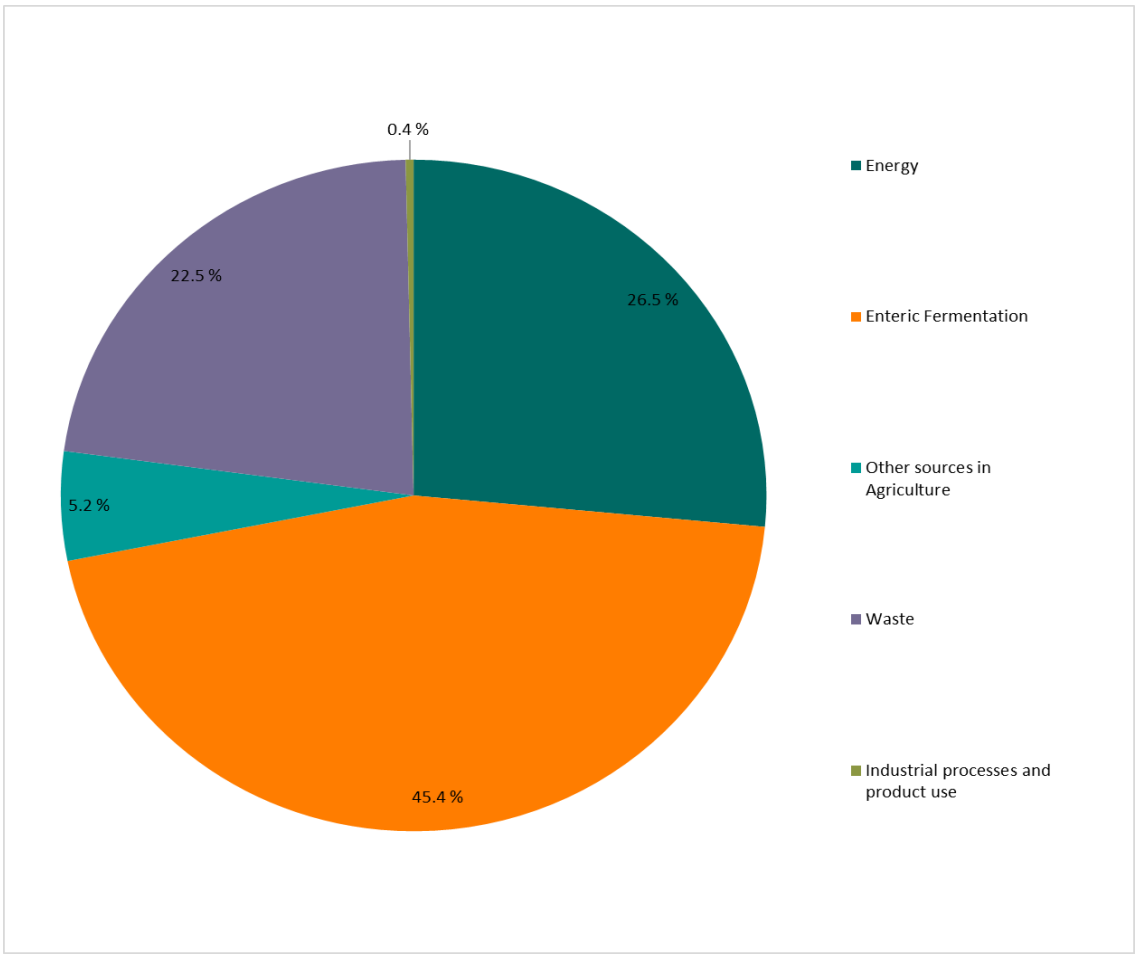


Figure 2.17. Distribution of Norwegian CH_4 emissions by major sources in 2016.
Source: Statistics Norway/Norwegian Environment Agency

The methane figures from 1990 to 2016, distributed among the different categories are displayed in Table 2.11.

Table 2.11. Emissions of CH_4 (ktonnes) in Norway, 1990-2016.

Years	Energy	Enteric fermentation	Other sources in Agriculture	Waste	Other Sources	Total
1990	36	97	11	87	0	232
1995	47	95	10	82	0	235
2000	53	94	10	70	1	227
2005	56	93	10	59	1	218
2006	52	91	10	60	1	213
2007	58	90	10	59	1	218
2008	55	90	10	57	1	212
2009	54	91	10	57	1	213
2010	57	91	10	56	1	214
2011	54	88	10	56	1	208
2012	53	88	10	54	1	206
2013	54	89	10	53	1	207
2014	59	90	11	51	1	211
2015	56	91	11	48	1	207
2016	54	92	11	46	1	203

Source: Statistics Norway/Norwegian Environment Agency

The total methane emissions decreased by 1.6 per cent from 2015 to 2016. Since 1990, CH_4 emissions have decreased by 12.3 per cent. Table 2.11 and Figure 2.18 show that this decrease is primarily due to the decrease of emissions from waste treatment, which more than compensated the growth in the energy sector, specially in the oil and gas industry.

The waste volumes have grown during the period 1990-2016, but this effect has been more than offset by the increase of recycling, incineration of waste and burning of methane from landfills.

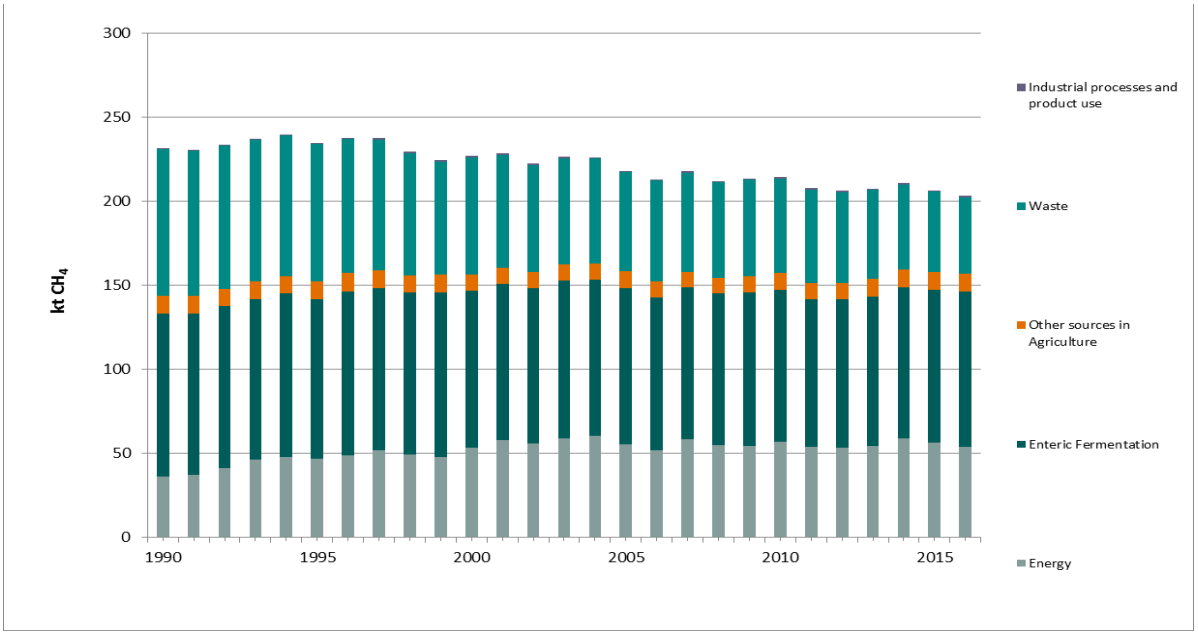


Figure 2.18. CH_4 emissions (ktonnes) for major Norwegian sources, 1990-2016.
Source: Statistics Norway/Norwegian Environment Agency

2.3.3 Nitrous oxide (N_2O)

Figure 2.19 shows that, in 2016, 74.0 per cent of the Norwegian N_2O emissions are of agricultural origin, agricultural soils being the most prominent contributor within the agriculture sector. Industrial prosesses is the second contributor, with 13.3 per cent. Nitric acid production is the main source of N_2O emissions within industrial processes accounted for more than 90 per cent of the sector.

The energy sector accounted for 8.4 per cent and the waste sector for 4.3 per cent. Emissions are dominated by road transport in the energy sector and by waste water treatment and discharge in the waste sector.

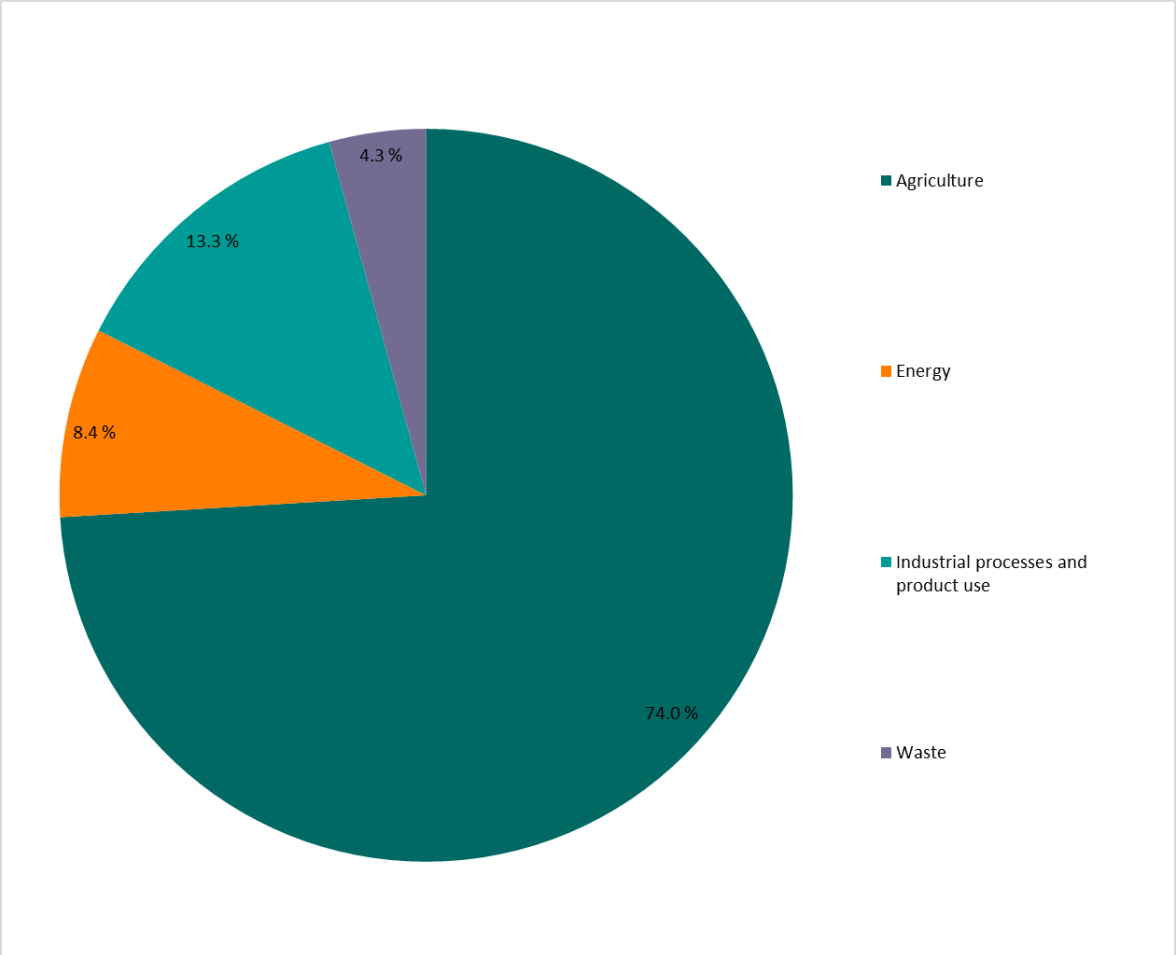


Figure 2.19. Distribution of Norwegian N_2O emissions by major sources in 2016.
Source: Statistics Norway/Norwegian Environment Agency

Reductions of emissions during the period 1990-2016 are mainly due to decreased emisisons from nitric acid production. Changes in the production processes of nitric acid led to the decrease of N_2O emissions, first in the beginning of the 1990s, and then since 2006. Technological improvements in the production process have significally brought the emissions down during the last ten years.

During the period 1990–2016 the total N_2O emissions decreased by 40.2 per cent. From 2015 to 2016, emissions decreased by 3.0 per cent. Details are presented in Table 2.12 and Figure 2.20.

Table 2.12. Emissions of N_2O (ktonnes) in Norway by major sources, 1990-2016.

Years	Agriculture	Energy	Industrial processes and product use	Other Sources	Total
1990	6.3	0.6	7.0	0.2	14.1
1995	6.2	0.6	5.7	0.2	12.8
2000	6.2	0.7	6.0	0.3	13.1
2005	6.3	0.6	6.8	0.3	14.0
2006	6.2	0.6	5.7	0.3	12.9
2007	6.2	0.7	5.0	0.4	12.3
2008	6.2	0.6	3.6	0.4	10.8
2009	6.0	0.6	2.0	0.4	9.0
2010	5.9	0.7	1.8	0.4	8.7
2011	6.0	0.7	1.6	0.3	8.7
2012	6.0	0.7	1.6	0.4	8.7
2013	6.1	0.7	1.4	0.4	8.6
2014	6.2	0.7	1.3	0.4	8.6
2015	6.3	0.7	1.4	0.4	8.7
2016	6.3	0.7	1.1	0.4	8.5

Source: Statistics Norway/Norwegian Environment Agency

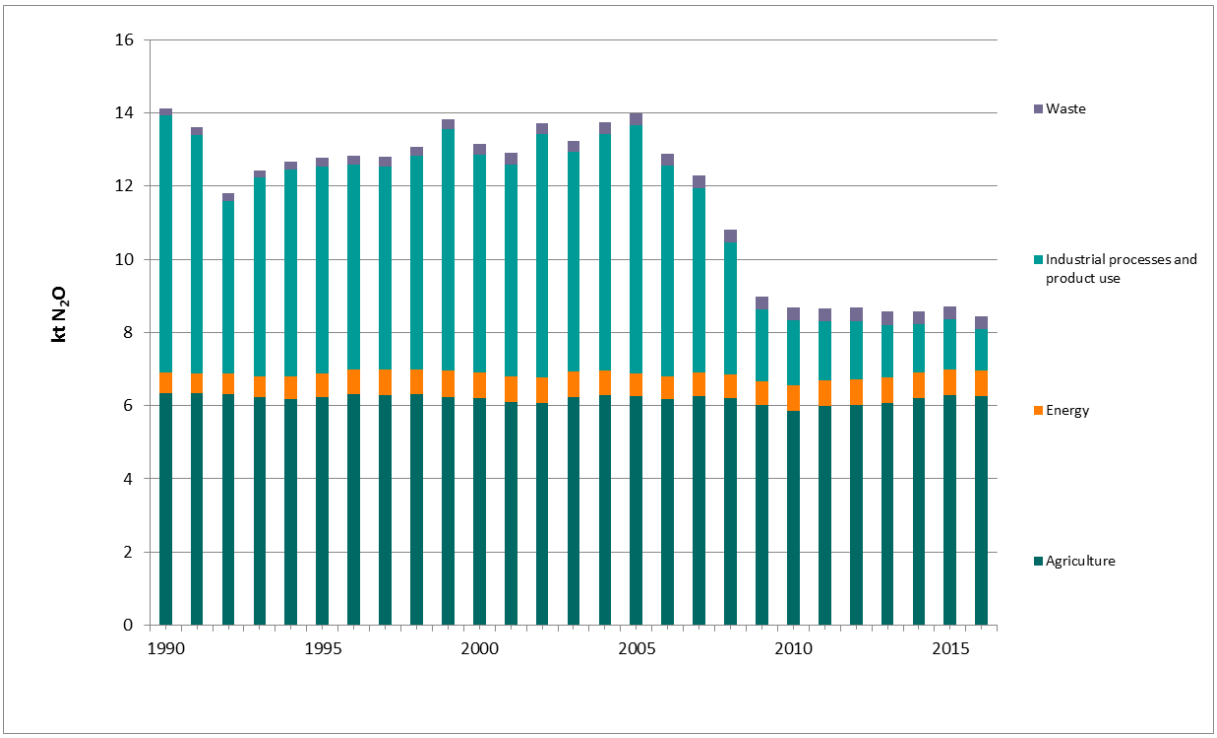


Figure 2.20. N_2O emissions for major Norwegian sources, 1990-2016.
Source: Statistics Norway/Norwegian Environment Agency

2.3.4 Perfluorcarbons (PFCs)

Aluminium production is the only source of PFC emissions in 2016. In 2016, perfluorcarbons tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) emissions from Norwegian aluminium plants were reported at 21.2 and 2.4 tonnes respectively, corresponding to a total of 0.19 million tonnes of CO_2 equivalents. Total PFCs total emissions have decreased by 95.2 per cent since 1990 following a steady downward trend as illustrated in Figure 2.21. Since 1990, emissions of CF_4 have decreased by 95.5 per cent, while the emission of C_2F_6 have decreased by 93.2 per cent.

Improvement of technology and process control in aluminium production led to a significant emissions decrease. In 1990, PFCs emissions were 4.48 kg CO_2 equivalents per tonne aluminium produced. It was reduced to 0.70 kg CO_2 equivalents per tonne aluminium produced in 2007 and to 0.15 kg CO_2 equivalents per tonne aluminium produced in 2016. Total PFCs emissions increased by 0.04 million tonnes between 2015 and 2016 due to increased production and to a low anode effect frequency for one plant in 2015.

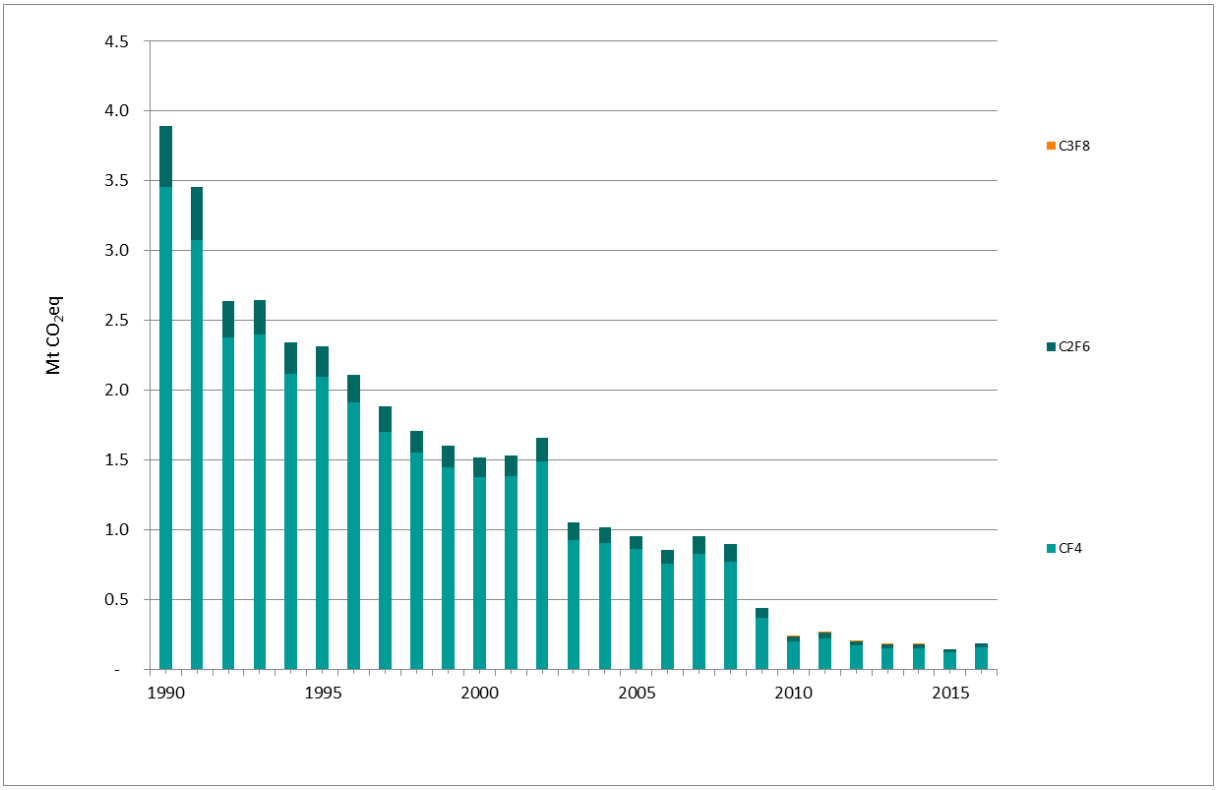


Figure 2.21. Emissions (million tonnes CO_2-eq) of PFCs in Norway, 1990-2016.
Source: Statistics Norway/Norwegian Environment Agency

Table 2.13. Emissions of PFCs in Norway in 1990-2016 in tonnes. PFC218 is in kg and total is in million tonnes of CO_2-eq.

Year	PFC14 (CF_4) (t)	PFC116 (C_2F_6) (t)	PFC218 (C_3F_8) (kg)	Total CO_2 eq. (Mt)
1990	467.36	36.15	0.00	3.89
1995	283.32	18.06	0.00	2.31
2000	186.37	11.57	0.00	1.52
2005	116.70	7.62	0.00	0.96
2006	102.06	8.59	0.00	0.86
2007	111.71	10.30	0.00	0.95
2008	104.65	10.05	0.00	0.90
2009	49.78	5.77	0.00	0.44
2010	27.35	2.97	7.44	0.24
2011	29.90	3.41	7.30	0.26
2012	22.90	2.56	6.44	0.20
2013	20.65	2.33	2.13	0.18
2014	20.32	2.36	0.18	0.18
2015	16.67	1.90	0.00	0.15
2016	21.15	2.45	0.00	0.19

Source: Statistics Norway/Norwegian Environment Agency

2.3.5 Sulphur hexafluoride (SF_6)

Until 2006, the largest source of SF_6 emissions in Norway was magnesium production. The consumption of SF_6 was reduced through the 1990s due to improvements in technology and process management, and to reductions in production levels. In 2016, the SF_6 emissions were 97.0 per cent lower than in 1990. Until 2002, SF_6 emission reductions were mainly due to the improved technology and process control within the metal industries. In 2002, production of cast magnesium closed down and production of secondary magnesium closed down in 2006.

The main other use of SF_6 is in gas insulated switchgears (GIS) and other high-voltage applications. Since the signing of a voluntary agreement in 2002, emissions from these sources have decreased and were about 55.4 per cent lower in 2016 than in 2002.

Table 2.14. SF_6 emissions (tonnes), in Norway 1990-2016.

Year	GIS	Magnesium and Aluminium Industry	Other	Total
1990	2.24	89.70	0.10	92.04
1995	3.61	21.30	0.52	25.43
2000	4.47	32.35	2.28	39.10
2005	2.30	10.05	0.64	12.99
2006	3.09	5.02	0.67	8.79
2007	2.54	NO	0.55	3.09
2008	2.06	NO	0.56	2.62
2009	1.89	NO	0.55	2.44
2010	2.46	NO	0.55	3.01
2011	1.96	NO	0.42	2.38
2012	1.93	NO	0.42	2.35
2013	2.05	NO	0.42	2.47
2014	1.78	NO	0.42	2.20
2015	1.79	NO	1.27	3.06
2016	1.53	NO	1.26	2.79

Source: Statistics Norway/Norwegian Environment Agency

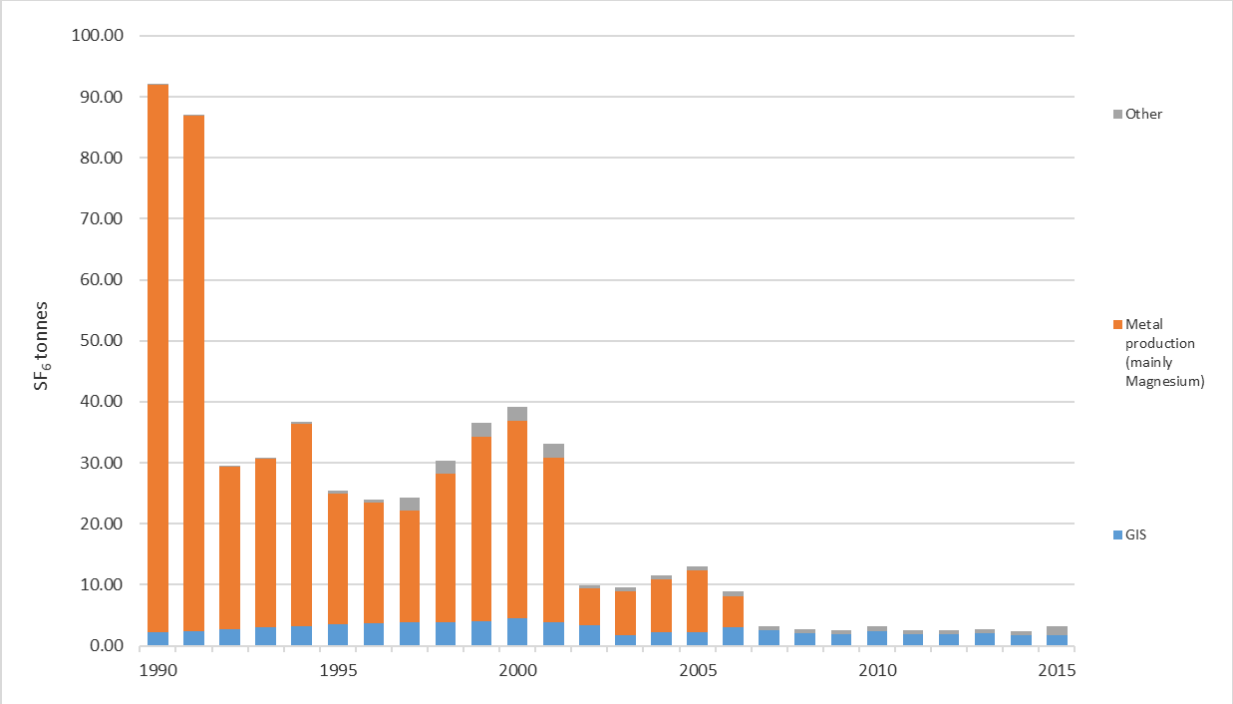


Figure 2.22. Emissions of SF_6 (tonnes) in Norway 1990-2016.
Source: Statistics Norway/Norwegian Environment Agency

2.3.6 Hydrofluorcarbons (HFCs)

The total actual emissions from HFCs used as substitutes for ozone depleting substances amounted to 1.4 million tonnes of CO_2 equivalents in 2016. It is an increase of 10.6 per cent compared to 2015. The emissions in 1990 were insignificant. Indeed, emissions have been multiplied by 15 since 1995.

The application category refrigeration and air conditioning contributes by far to the largest part of the HFCs emissions. The other categories foam/foam blowing and fire extinguishing contributes to small amounts to the overall emissions.

Figure 2.23 displays the development of HFCs emissions since 1990 and Table 2.15 presents HFCs emission values for different HFCs from 1990 to 2016. The trend is due to the strong demand for substitution of ozone depleting substances. The increase in HFCs emissions has been moderated by the introduction of a tax on HFCs in 2003.

Table 2.15. Emissions of HFCs (tonnes) and total (Mtonnes CO_2-eq.) in Norway, 1990-2016.

Year	HFC23	HFC32	HFC125	HFC134a	HFC143a	HFC152a	HFC227ea	HFC134	HFC143	Total in Mtonnes CO_2 eq.
1990	0.00	0.00	0.00	0.00	0.00	0.35	NO	NO	NO	0.000
1995	0.00	0.43	5.20	38.56	4.06	1.28	NO	NO	NO	0.092
2000	0.06	1.99	34.84	90.47	28.72	7.03	0.17	NO	NO	0.383
2005	0.15	6.06	57.24	139.43	44.83	26.80	1.01	0.84	1.11	0.614
2006	0.12	7.89	63.23	158.51	48.04	30.06	0.90	0.76	1.92	0.678
2007	0.12	9.98	64.39	184.87	46.62	31.69	1.10	0.68	1.58	0.715
2008	0.10	12.46	68.92	218.47	52.05	30.54	0.81	2.75	1.42	0.806
2009	0.09	15.89	73.86	245.08	50.44	30.75	0.94	2.16	1.28	0.856
2010	0.12	19.75	94.23	280.22	69.31	34.57	0.70	1.96	1.15	1.065
2011	0.19	22.57	98.98	305.90	64.97	34.49	2.13	1.78	1.03	1.106
2012	0.53	25.54	98.97	339.51	60.64	35.00	1.94	1.70	0.93	1.141
2013	0.38	31.11	97.35	364.36	57.43	34.59	1.16	1.55	0.84	1.155
2014	0.32	34.64	103.77	362.04	69.38	36.61	0.88	1.39	0.75	1.236
2015	0.28	39.53	111.67	346.31	66.89	37.75	1.10	1.30	0.68	1.233
2016	0.26	42.39	119.28	381.70	77.95	39.45	4.01	1.20	0.61	1.364

Source: Statistics Norway/Norwegian Environment Agency

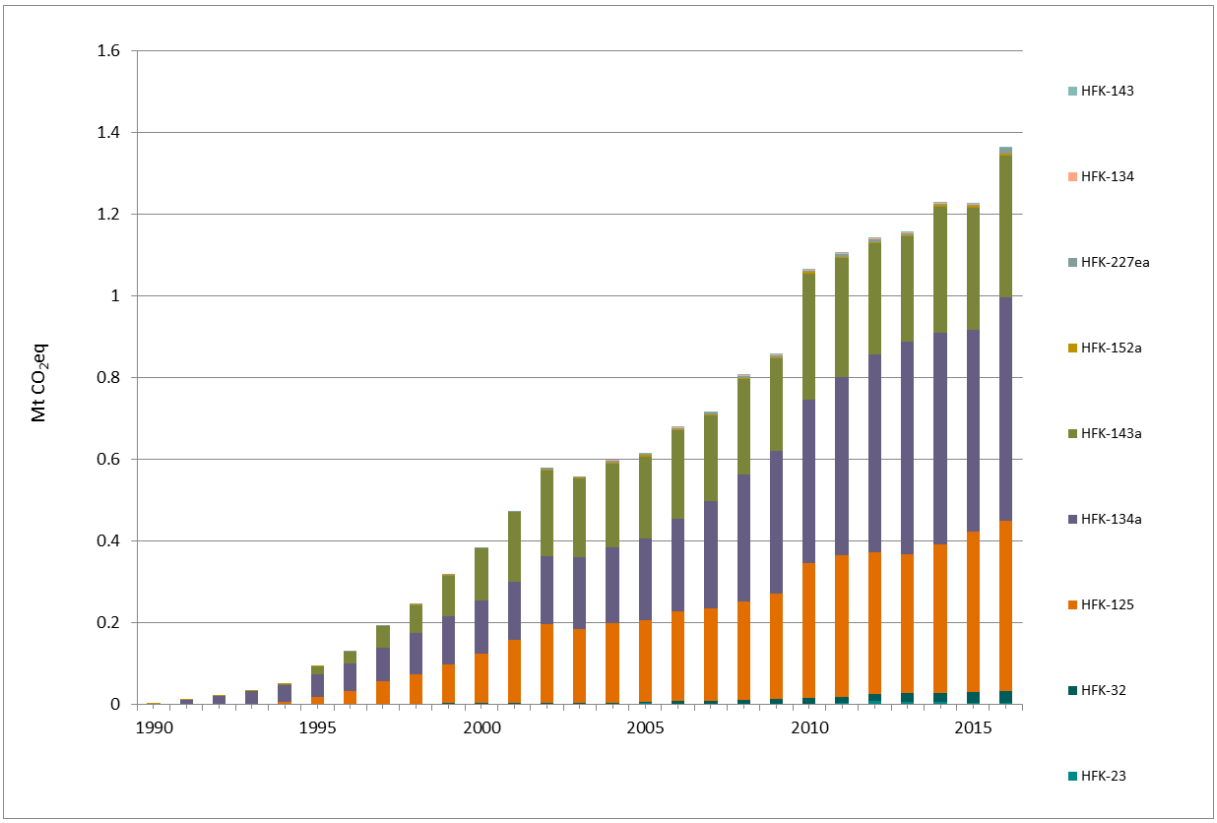


Figure 2.23. Emissions of HFCs (Mtonnes CO_2-eq.) in Norway, 1990-2016.
Source: Statistics Norway/Norwegian Environment Agency

2.4 Emission trends for indirect greenhouse gases and SO_2

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

The overall **NO_x emissions** decreased with approximately 23.8 per cent from 1990 to 2016. This can primarily be explained by stricter emission regulations with regard to road traffic, which has led to a 45.0 per cent reduction of emissions from transport since 1990. These reductions counteracted increased emissions from e.g. oil and gas production. From 2015 to 2016, the total NO_x emissions decreased by 1.9 per cent, mainly due to reduction in the transport and stationary combustion.

NMVOC emissions experienced an increase in the period from 1990 to 2001, mainly because of the rise in oil production. However, NMVOC emissions decreased by 61.9 per cent from 2001 to 2016, and were in 2016 49.5 per cent lower than in 1990. This decrease has been achieved through the implementation of measures to increase the recycling of oil vapour offshore at loading and storage terminals. From 2015 to 2016, the emissions of NMVOC decreased by 2.9 per cent.

CO emissions have decreased by 53.7 per cent over the period 1990-2016. This is explained primarily by the implementation of new emission standards for motor vehicles.

SO_2 emissions were reduced by 70.1 per cent from 1990 to 2016. This can mainly be explained by a reduction in sulphur content of all oil products and lower process emissions from ferroalloys and aluminium productions as well as refineries.

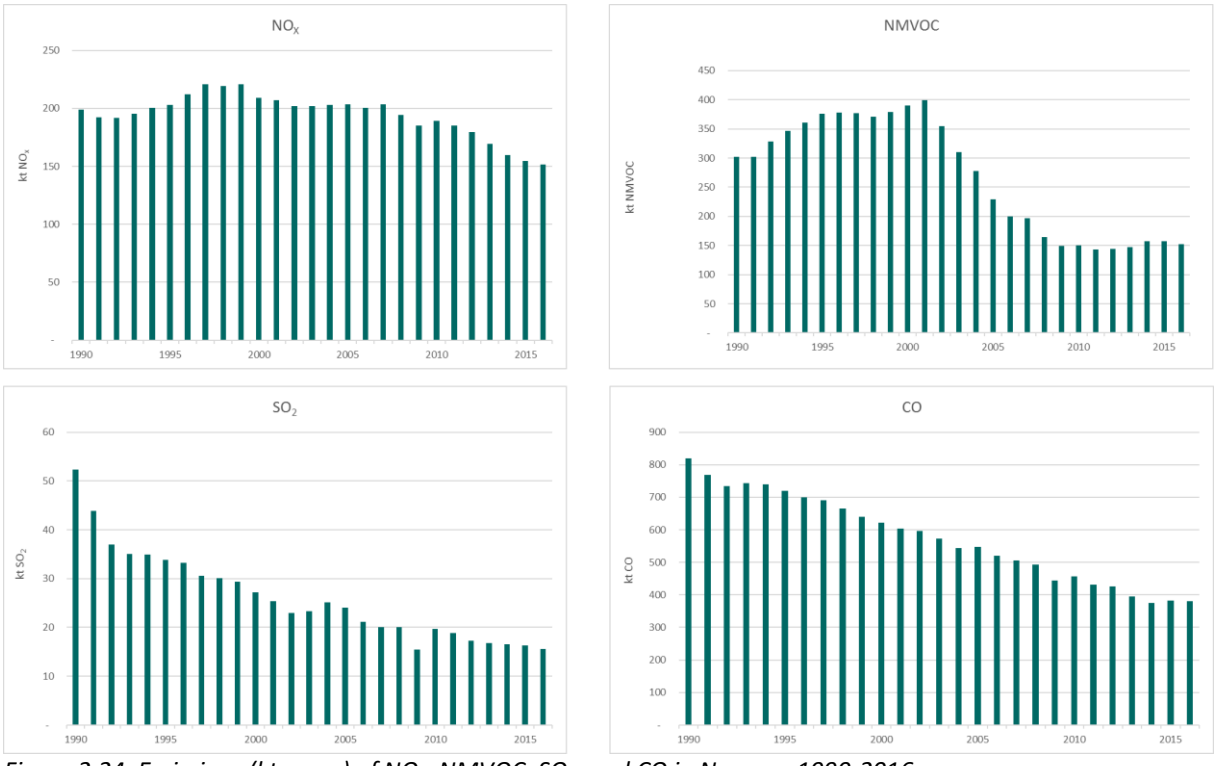


Figure 2.24. Emissions (ktonnes) of NO_x, NMVOC, SO_2, and CO in Norway, 1990-2016.
Source: Statistics Norway/ Norwegian Environment Agency

3 Energy (CRF sector 1)

3.1 Overview of sector

The Energy sector, including fugitive emissions, accounted for 73.0 per cent of the Norwegian greenhouse gas emissions in 2016. In 1990, the Energy sector's share of the total greenhouse gas emissions was 58.3 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 the 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 also give rise to significant amounts of fugitive emissions.

GHG emissions in the Energy sector have increased by 28.9 per cent from 1990 to 2016 (Figure 3.2), primarily due to increased activity in the sectors of oil and gas extraction and transport, specifically road transport. Between 1990 and 2016, there have been temporary emission reductions in the sector. Among these temporary reductions, emissions decreased by 3.8 per cent from 2007 to 2009 and by 5.1 per cent from 2010 to 2014. The former decrease is partly due to the fact that a new gas terminal started up in 2007 but had start-up problems during the first years and was only fully operational in 2009. The financial crisis also contributed to lower emissions in 2009.

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 the increase of fuel oils used during one of the coldest winters since the 1950s.

The emission reduction from 2010 to 2014 was mainly due to reversed trends in the same sector, whereas the changes from 2014 to 2014 were mainly due to changes in emissions from oil and gas extraction. In 2016, increased use of biofuels in road transport also contributed to the reduction in total emissions.

Figure 3.1 and Figure 3.2 show the trend and the relative changes to 1990, in GHG emissions for the different Energy sectors. The main emitting sectors are the energy industries sector (combustion in oil and gas production, refineries, electricity production and district heating) and the transport sector (civil aviation, road transportation, railways, navigation). Both sectors have increased since 1990, especially the energy industries sector, which has more than doubled since 1990.

The manufacturing industries and construction sector, the other fuel combustion sector[7] and the fugitive emissions from fuel sector experienced small fluctuations between 1990 and 2016. In 2016, emissions from the manufacturing industries sector and from the fugitive sector are almost as they were in 1990. On the other hand, the other fuel combustion sector underwent a decrease of 27 per cent between 1990 and 2016.

[7] Other fuel combustion sector includes both the sectors Other Combustion (CRF 1A4) and Other (CRF 1A5)

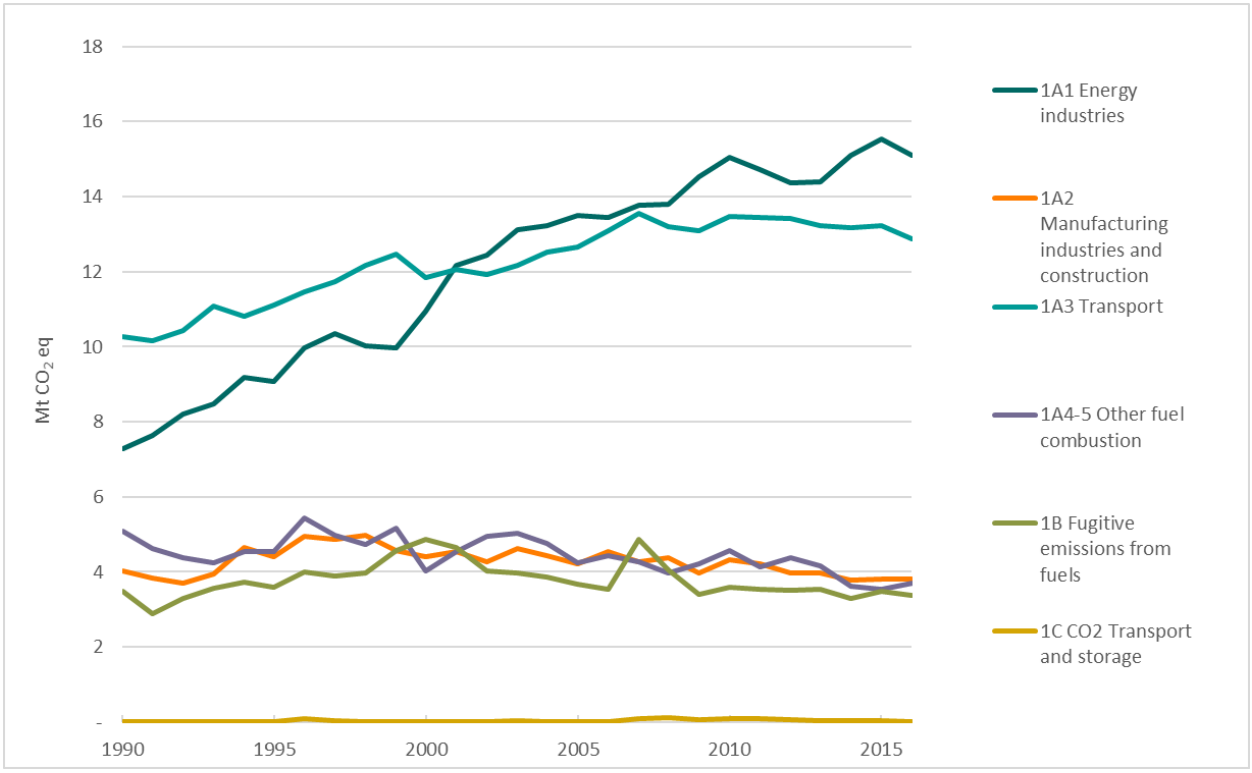


Figure 3.1. Greenhouse gas emissions from energy sectors and fugitive emissions. 1990-2016. Million tonne CO_2 equivalents. Source: Statistics Norway/Norwegian Environment Agency

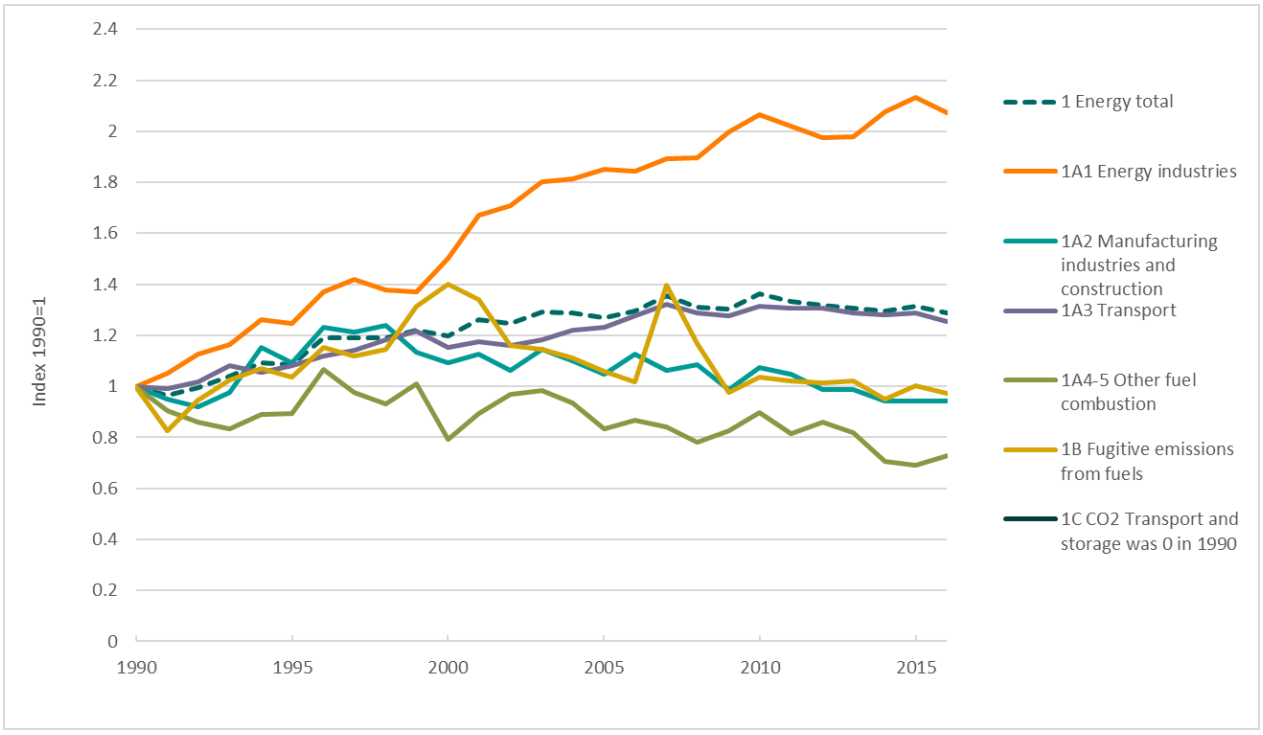


Figure 3.2. Relative changes to 1990 in GHG emissions for the energy sector including fugitive emissions. 1990-2016. Index 1990=1. Source: Statistics Norway/Norwegian Environment Agency

Transport

In 2016, the transport sector's total GHG emissions was 12.9 million tonnes CO_2 equivalents of which civil aviation contributed to 9.3 per cent, road transportation to 77.1 per cent, railways to 0.4 per cent and navigation to 13.2 per cent.

Figure 3.3 *and* Figure 3.*4 show the* trend and the relative changes of transport emissions from 1990 to 2016. They show that emissions from road transportation and particularly aviation have increased during the period, while emissions from railways decreased and emissions from navigation fluctuated. Since 1990, emissions from civil aviation and road transportation have increased by 74 and 28 per cent, respectively, while emissions from railways have decreased by 52 per cent mainly due to railways electrification. Emissions from navigation decreased by 1 per cent between 1990 and 2016.

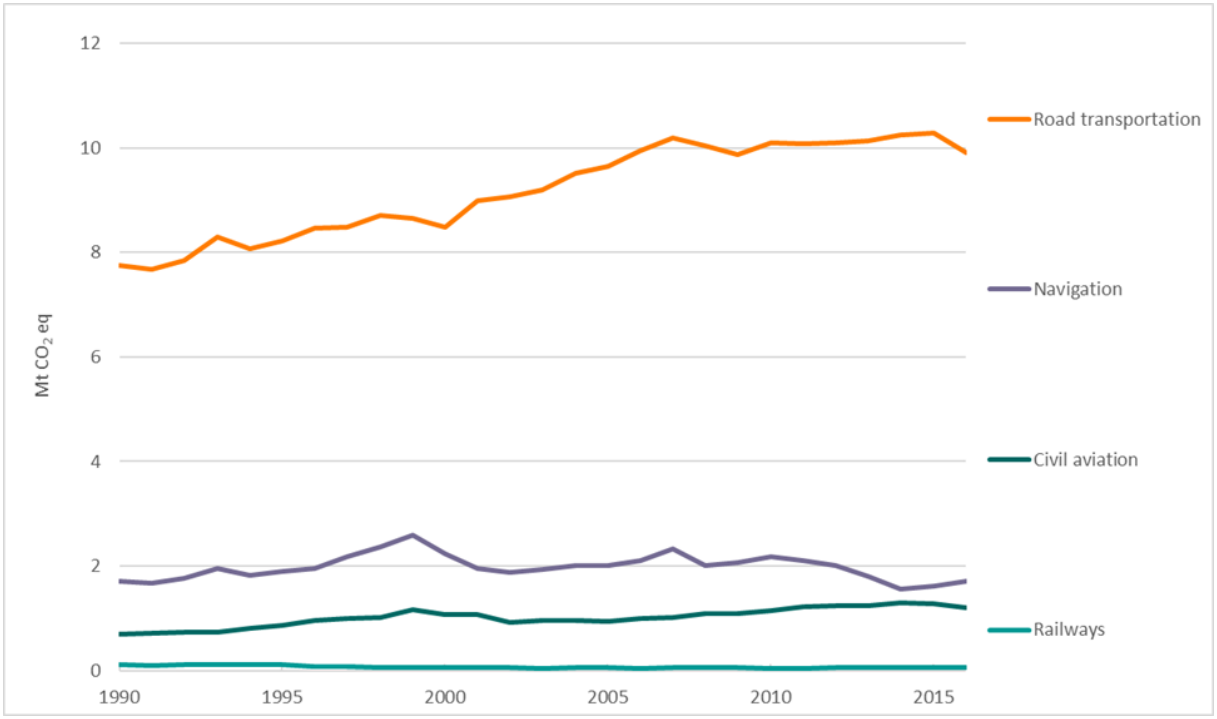


Figure 3.3. Greenhouse gas emissions from the most important transport sectors. 1990-2016. Million tonnes CO2 equivalents. Source: Statistics Norway/ Norwegian Environment Agency

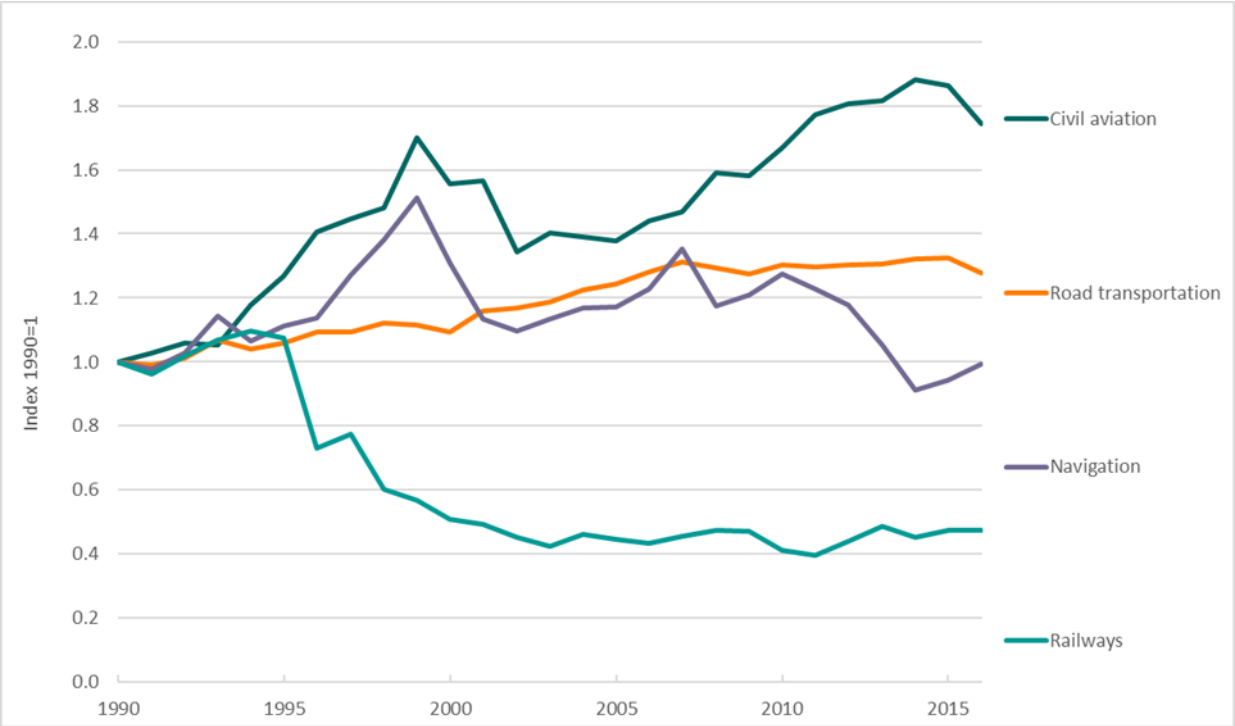


Figure 3.4. Relative changes to 1990 in GHG emissions for the most important transport sectors. Civil aviation, road transportation, navigation and other transportation. 1990-2016. Index 1990=1.
Source: Statistics Norway/Norwegian Environment Agency

Key source categories

Section 1.5 describes the overall results of the approach 2 key category analysis performed for the years 1990 and 2016. Table 3.1 gives the key categories in the energy sector in terms of total level and/or trend uncertainty for 1990 and/or 2016 in CRF order.

Table 3.1 Key categories in the Energy sector in 2016.

CRF code	Source Category	Gas	Key category according to approach	Method
1A1,1A2,1A4	Stationary combustion, Solid Fuels	CO2	Approach 1	Tier 2
1A1,1A2,1A4	Stationary combustion, Liquid Fuels	CO_2	Approach 2	Tier 2
1A1,1A2,1A4	Stationary combustion, Gaseous Fuels	CO_2	Approach 2	Tier 2
1A1,1A2,1A4	Stationary combustion, Gaseous Fuels	CH_4	Approach 2	Tier 2
1A1,1A2,1A4	Stationary combustion, Other Fuels	CO_2	Approach 2	Tier 2
1A1,1A2,1A4	Stationary combustion, Biomass	CH_4	Approach 2	Tier 2
1A3a	Civil Aviation	CO_2	Approach 2	Tier 2
1A3b	Road Transportation	CO_2	Approach 2	Tier 1a
1A3d	Navigation	CO_2	Approach 2	Tier 2
1A3d	Navigation	CH_4	Approach 2	Tier 2
1A4	Other sectors - Mobile Fuel Combustion	CO_2	Approach 2	Tier 2
1A5b	Other – Mobile	CO_2	Approach 1	Tier 2
1B1a	Coal Mining and Handling	CH_4	Approach 2	CS, Tier 2
1B2a	Fugitive emissions from oil	CO_2	Approach 2	Tier 2
1B2a	Fugitive emissions from oil	CH_4	Approach 2	Tier 2
1B2b	Fugitive emissions from natural gas	CH_4	Approach 2	CS, Tier 2
1B2c	Venting and Flaring	CO_2	Approach 2	Tier 2
1B2c	Venting and Flaring	CH_4	Approach 2	Tier 2
1C	CO_2 transport and storage	CO_2	Qualitative	CS, Tier 2

Source: Statistics Norway/Norwegian Environment Agency

In addition to source categories defined as key categories according to the approach 2 key category analysis, two source categories are defined as key according to approach 1 key category analysis. They are CO_2 Stationary combustion, solid fuels (1A) and CO_2 from Military, mobile (1A5b).

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

Emission allocation

Generally, energy combustion for energy purposes is reported in 1.A Fuel Combustion Activities, while flaring and other fugitive emissions are reported in 1.B Fugitive Emissions from Fuels. Emissions from waste incineration at district heating plants are accounted for under the energy sector, as the energy is utilized. Methane from landfills and other biogas used for energy purposes are also accounted for in this sector. Emissions from flaring in the energy sectors are reported in 1.B.2c Flaring and described in section 3.4, as this energy combustion is not for energy purposes. Emissions from burn off of coke at catalysts in refineries are reported in 1.B.2.a iv for the same reason as for

flaring. Coal and coke used as reducing agents and gas used for production of ammonia (non-energy part) are accounted for in sector 2 IPPU (chapter 4). Flaring in manufacturing industries is also reported in 2 IPPU. Flaring of landfill gas and other biogas is reported in sector 5 Waste (chapter 7). The same applies to emissions from accidental fires, etc. Emissions from burning of crop residues and agricultural waste are accounted for in sector 3 Agriculture (chapter 5).

A more detailed description of the delimitation of energy combustion is given in section 3.2.1.1.

Mode of presentation

The elaboration of the energy sector in the following starts with a general description of emissions from the energy combustion sources (section 3.2). Then followed by a description of fugitive emissions (sections 3.3 and 3.4) and a discussion on the capture and storage of CO_2 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_2 emissions from CH_4 and NMVOC

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

In the case of energy combustion, emissions from the individual combustion sources are discussed after a comprehensive presentation of the energy combustion sector as a whole (section 3.2). 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 utilisation in various industries and private households are included.

The GHG emissions from fuel combustion (1A) accounted for 66.6 per cent of national total emissions in 2016. The emissions increased by 33 per cent between 1990 and 2016. The increase is primarily due to activity growth in oil and gas extraction, which comprises the major part of energy industries sector, and in transport, mainly road transport.

Emissions from source category 1A decreased by 1.7 per cent from 2015 to 2016. After decreasing by 4.7 per cent to 2014 from a peak in 2010, the emissions rose slightly in 2015 before the decline next year. In 2016, emissions from the sector energy industries (CRF 1A1) decreased by 2.8 per cent, due to lower emissions from refineries (CRF 1A1b) and oil and gas extraction (CRF 1A1cii). Emissions from the manufacturing and construction sector (CRF 1A2) was unchanged, while the transport sector (CRF 1A3) decreased by 2,8 per cent, primarily due to increased use of biofuels. Emissions in the other combustion sector (CRF 1A4 and CRF 1A5) increased by 5 per cent.

The fuel combustion sector is dominated by emissions of CO_2, which in 2016 contributed 98 per cent to the totals of this sector (CRF 1A).

This sector hosts ten source categories defined as keys according to approach 2 key category analysis and two as key category from the approach 1 analysis, which, along with the non-key categories, are presented in detail in the following sections.

Table 3.3 presents the shares of estimated and reported emissions used in the inventory for the different sectors and for the different greenhouse gases in 2016. It shows that a large share of GHG emissions from Energy industries and Manufacturing Industries and Construction included in the Norwegian GHG Inventory are taken from annual reports sent by each plant to the Norwegian Environment Agency.[8] Such annual reports are:

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

Annex VIII QA/QC of point sources includes references to documents that in detail describe requirements for measuring and reporting, specifically for the EU ETS and the voluntary agreement.

3.2.1.1 Methodological issues

Emissions from fuel combustion are estimated at the sectoral level in accordance with the IPCC sectoral approach Tier 1/Tier 2/Tier 3. Total fuel consumption is, in many cases, more reliable than the breakdown to sectoral consumption.

[8] Former Norwegian Pollution Control Authority and Climate and Pollution Agency

The general methodology for estimating emissions from fuel combustion is multiplication of fuel consumption by source and sector by an appropriate emission factor, as shows in equation (3.1). 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 amounts 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 3.2.

In 2017, a revised version of the energy balance for 2010-2016 was published by Statistics Norway (Statistics Norway (Annually-a), Hendriks et al. (2017)). The technical system was upgraded, and several methodological changes were introduced. Conversion of the emission inventory to the new energy balance and recalculation back to 1990 could not be finalized before the 2018 emission reporting. To avoid inconsistent time series, the old energy balance for the years 1990-2015 is still used in the inventory. For 2016 Statistics Norway has updated the energy balance for 2015 with some figures for 2016. Total sales figures for petroleum products in 2016 have been used as framework.

The general method for calculating emissions from energy consumption is:

(3.1) $$Emissions(E) = Activity\ level(A) \times Emission\ Factor\ (\mathrm{EF})$$

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

(3.2) $$Emissions(\mathrm{E}) = [(\mathrm{A} - \mathrm{A_{PS}}) \times \mathrm{EF}] + \mathrm{E_{PS}}$$

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

Table 3.2 Average energy content (NCV) and density of fuels.*

Energy product	Theoretical energy content	Density
	GJ/tonne	Tonne/m^3
Coal	28.1	:
Coke	28.5	:
Petrol coke	35	:
Crude oil	42.3	0.85
Motor gasoline	43.9	0.74
Aviation gasoline	43.9	0.74
Kerosene (heating)	43.1	0.81
Jet kerosene	43.1	0.81
Auto diesel	43.1	0.84
Marine gas oil/diesel	43.1	0.84
Light fuel oils	43.1	0.84
Heavy distillate	43.1	0.88
Heavy fuel oil	40.6	0.98
Natural gas (dry gas) (land)	47.97	0.74[1]
Natural gas (rich gas) (off shore)	47.41	0.85[1]
LPG	46.1	0.53
Refinery gas	48.6	:
Blast furnace gas	:	:
Fuel gas[3]	50	:
Landfill gas[2,4]	50.2	:
Biogas[2,4]	50.2	:
Fuel wood[2]	16.80	0.5
Ethanol[2]	26.96	0.79
Biodiesel[2]	37.08	0.89
Wood waste[2]	16.25 - 18	:
Black liquor[2]	7.2 - 9.2	:
Charcoal	29.5	:
Municipal waste	10.5	:
Special waste	40.6	0.98

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

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

[2] Non-fossil emissions, not included in the inventory CO_2 totals

[3] In this inventory, fuel gas is a hydrogen-rich excess gas from petrochemical industry

[4] Landfill gas and other types of biogas are reported as methane content in the energy balance

Source: Energy statistics, Statistics Norway and Norwegian Environment Agency

For offshore activities and some major manufacturing plants (in particular refineries, gas terminals, cement industry, production of plastics, ammonia production, and methanol production), emissions of one or more compounds reported by the plants to the Norwegian Environment Agency are used, as described in equation (3.2) (see Table 3.3). 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.

Emissions are reported to the Norwegian Environment Agency under a number of different reporting obligations. Most of the CO_2 emissions (except metal production, etc.) are reported as part of the Emissions Trading System (ETS).

In the general equation (3.2), E_{PS} represents the reported emission data, while A_{PS} represents the energy consumption at the plants. Note that for most plants, reported emissions are used only for some of the substances. For the remaining substances in the inventory, the general method with standard emission factors is used.

Reported figures are used for a relatively small number of plants, but as they contribute to a large share of the total energy use, a major part of the total emissions are based on such reported figures. Table 3.3 gives an overview of the shares of estimated and reported emissions used in the inventory for the different sectors for the greenhouse gases CO_2, CH_4 and N_2O in 2016.

In 2016, 92 per cent of the CO_2 emissions from Energy Industries (oil and gas extraction and production, refineries, gas terminals, gas fired power plants and district heating plants) were based on reported emissions and 43 per cent of the CO_2 emissions from Manufacturing Industries and Construction.

Table 3.3. Share of total CO_2, CH_4 and N_2O emissions in the energy sector based on estimated and reported emission estimates for 2016.

	CO_2		**CH_4**		**N_2O**	
	Estimated	*Reported*	*Estimated*	*Reported*	*Estimated*	*Reported*
A. Fuel Combustion Activities (Sectoral Approach)	56 %	44 %	79 %	21 %	96 %	4 %
1. Energy Industries	8 %	92 %	16 %	84 %	81 %	19 %
a. Public Electricity and Heat Production	67 %	33 %	71 %	29 %	73 %	27 %
b. Petroleum Refining	0 %	100 %	76 %	24 %	100 %	0 %
c. Manufacture of Solid Fuels and Other Energy Industries	1 %	99 %	0 %	100 %	100 %	0 %
2. Manufacturing Industries and Construction	57 %	43 %	100 %	0 %	95 %	5 %
a. Iron and Steel	12 %	88 %	100 %	0 %	100 %	0 %
b. Non-Ferrous Metals	99 %	1 %	100 %	0 %	100 %	0 %
c. Chemicals	15 %	85 %	99 %	1 %	72 %	28 %
d. Pulp, Paper and Print	100 %	0 %	100 %	0 %	100 %	0 %
e. Food Processing, Beverages and Tobacco	100 %	0 %	100 %	0 %	100 %	0 %
f. Non-metallic minerals	33 %	67 %	100 %	0 %	100 %	0 %
g. Other (Oil drilling, construction, other manufacturing)	100 %	0 %	100 %	0 %	100 %	0 %
3. Transport	100 %		100 %		100 %	
a. Civil Aviation	100 %		100 %		100 %	
b. Road Transportation	100 %		100 %		100 %	
c. Railways	100 %		100 %		100 %	
d. Navigation	100 %		100 %		100 %	
e. Other Transportation (pipeline transport)	100 %		100 %		100 %	
4. Other Sectors	100 %		100 %		100 %	
a. Commercial/Institutional	100 %		100 %		100 %	
b. Residential	100 %		100 %		100 %	
c. Agriculture/Forestry/Fisheries	100 %		100 %		100 %	
5. Other (Military)	100 %		100 %		100 %	

Source: Statistics Norway, Norwegian Environment Agency

Delimitation toward industrial processes etc.

The energy combustion sector borders to several other source categories. This section presents a more detailed description of the demarcation with other sectors used in the inventory, compared to section 3.1.

Energy consumption reported as activity data in the emission inventories is generally delimited in the same way as emissions. In cases where different substances are handled differently, the delimitation of energy consumption follows the delimitation of CO_2 emissions.

Flaring is not reported as energy use under energy combustion (CRF 1A). Instead, flaring is reported

under the following source categories:

- Flaring in refineries and in exploration/extraction is reported under fugitive emissions (CRF 1B).
- Flaring in manufacturing industries is reported under industrial processes (CRF 2), particularly under chemical industry (CRF 2B). (In the energy balance, flaring in manufacturing is reported as "losses".)
- Flaring of landfill gas is reported under waste incineration (CRF 5C).

Emissions from *reducing agents* are reported under industrial processes (CRF 2). This contrasts with the delimitation in the energy balance, where use as reducing agents is reported as energy consumption.

In some special cases, CO_2 emissions from combustion are reported under other source categories, while emissions of other substances are reported in energy combustion (CRF 1A):

- CO-rich excess gas from metallurgical plants burnt on-site is reported under industrial processes (CRF 2), according to IPCC guidelines (IPCC 2006). (Gas which is sold to other plants is reported under energy combustion (CRF 1A)).
- Coal used as fuel in some metallurgical plants which also use coal as a reducing agent is reported under industrial processes (CRF 2).
- CO_2 from coke that is burnt off from catalytic crackers in refineries is reported under fugitive emissions (CRF 1B). This also applies to CO_2 from coke calcining kilns. This combustion is currently reported as energy use of CO_2-rich gas ("other gas") in the energy balance.

In these cases, energy consumption reported in the inventories follows the delimitation of the CO_2 emissions. This gives meaningful implied emission factors for CO_2, while IEFs for other substances may be skewed.

At a small number of plants, CO_2 emissions are reported in the ETS system from *derived fuels* which are not included as energy use in the energy balance. The carbon in the fuels is likely reported as feedstock in the energy balance. These cases are handled in two different ways. Both methods should give correct total CO_2 emissions, but the correspondence to reported energy data is different. In both cases, no emission of other substances from these fuels is currently estimated.

- For methanol production, CO_2 emissions from several fuels not included in the energy balance are reported as process emissions under Methanol production (CRF 2B8).
- In other cases, emissions from derived fuels are included in the total combustion CO_2 which is entered into the inventory for the plants. Thus, emissions are larger than the corresponding energy use reported in the inventory. As far as it is currently known, this method is only used when emissions from derived fuels are small relative to total fuel use in the source category, mainly in energy in manufacturing of chemicals (CRF 1A2c). The method leads to higher implied emission factors relative to standard range.

Emissions from *paraffin wax* are reported under Other Industrial processes (CRF 2G).

Combustion of *solid waste* and *hazardous waste* is reported under the energy section (district heating (CRF 1A1a) and in several manufacturing industries (CRF 1A2). No significant combustion of solid or hazardous waste occurs without energy recovery.

Combustion of *landfill gas* with energy recovery is reported under the energy section (mainly in Commercial/Institutional (CRF 1A4a)). Flaring is reported under waste incineration (CRF 5C), as mentioned above.

Emissions reported by plants: Energy data

Energy data for plants with reported emissions (A_{PS} in equation (3.2)) should be consistent both with the energy balance that is used for activity total *A* and with the reported emission data. Consistency with emission data means that the energy data should correspond to the same activity as the reported emissions.

In most cases, figures on plant energy use in the inventory are based on data reported from the plants to Statistics Norway. This ensures consistency with the energy balance.

In the emission trading system (ETS), emissions are, in most cases, reported together with data on the corresponding energy use. Usually, the energy data reported in the ETS are the same as those reported by the plants to Statistics Norway. However, for some plants, some of the energy data differ between reports to Statistics Norway and to the ETS. This leads to problems of consistency.

- In a few cases, the inventory uses plant energy data from the ETS instead of data from the energy balance of Statistics Norway. In these cases, the difference is significant, and the ETS data are deemed to be the most reliable. The emission inventory will be inconsistent with the energy balance. Currently, this applies to CO-rich excess gas in iron and steel production for 2008 and later.

In other cases, with mainly small emissions, the inconsistency between energy data from Statistics Norway (A_{PS}) and reported emissions data (E_{PS}) may lead to deviations in implied emission factors. However, the deviations are usually small, and generally, this should not be regarded as an important issue.

Emissions reported by plants: Allocation to combustion/processes

CH_4 emissions from an oil refinery are reported as a plant total, which includes both combustion and process emissions. These emissions have to be allocated to the two emission categories. Emissions from combustion are calculated from energy use with standard factors and the remaining part of reported emissions is reported in the inventory as process emissions.

Emissions reported by plants: Allocation to fuels

The following discussion is relevant for cases where emissions are reported with a fuels split. This applies to greenhouse gases reported to the UNFCCC, and to emission statistics in Statistics Norway's Statbank. In other reporting, emissions are aggregated over fuels.

For some plants and substances, emissions are reported by fuel, but in most cases reported combustion emissions are entered as a plant total. Emissions are then allocated to fuels based on standard EFs using equation (3.3):

$$E_{PS,f} = E_{PS} \times \frac{A_{PS,f} \times EF_f}{\sum_f A_{PS,f} \times EF_f} \qquad (3.3)$$

where the subscript f denotes the fuel type.

This means that any deviations in data will be distributed across all fuels at the plant. Typical situations include:

- Plants with atypical fuels which differ from standard emission factors
- Plants with errors or other inconsistencies in energy data

In such cases, implied emission factors may deviate from the standard range also for other fuels than the one really affected.

Plants/substances which are entered by fuel currently include among others:

- CO_2 emissions from natural gas in almost all activities
- CO_2 emissions from cement production, 2008 and later
- CO_2 emissions from iron and steel production, 2008 and later
- CO_2 and several other substances from oil and gas production, offshore and onshore

Except for the cases listed above, fuel specific CO_2 emissions from the emission trading system reports (ETS) are not entered into the inventory, only the total plant emission is used.

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. In 2017, a revised version of the energy balance for 2010-2016 was published. The technical system was upgraded, and several methodological changes were introduced. Conversion of the emission inventory to the new energy balance and recalculation back to 1990 could not be finalized before the 2018 emission reporting. To avoid inconsistent time series, the old energy balance for the years 1990-2015 is still used in the inventory. For 2016 Statistics Norway has updated the energy balance for 2015 with some figures for 2016. Total sales figures for petroleum products in 2016 have been used as framework.

The energy balance defines the total energy consumption for which emissions are accounted. However, as explained above, a large part of the total emissions are based on reports from plants that use much energy, i.e. offshore activities and energy-intensive industries on shore. Energy consumption from these plants is included in the energy balance. These consumptions are then subtracted from the energy balance before calculating the remaining emissions. Emissions are estimated using the standard method of multiplying energy use by emission factors described in equation (3.2).

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 surveys the flow of the different energy carriers within Norwegian territory. These accounts include energy carriers used as raw materials and reducing agents, which 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. The 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 within the different sectors.

A short summary of the determination of amounts used by the main groups of energy carriers and of the distribution between emission sources is given below. The following paragraphs give also an

explanation of the differences 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 reporting period are presented in Annex III of this report.

The independent collection of different energy carriers conducted by Statistics Norway, as described below, enables a thorough verification of the emission data reported by the entities to the Norwegian Environment Agency and Norwegian Petroleum Directorate that are 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_2 from the largest gas consumers, e.g. off shore activities, gas terminals, and petrochemical industry, are figures reported by the plants. The data are considered to be of high quality, due to the Norwegian system of CO_2 taxation on fuel combustion.

The remaining combustion of natural gas is given by Statistics Norway's annual survey on energy use in manufacturing industries and by sales figures from distributors. Some manufacturing industries use natural gas in direct-fired furnaces; the rest is burnt 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[9]. 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 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 under Petroleum refining (CRF 1A1b), emissions from flaring under fugitive emissions from Flaring (CRF 1B2c2) and emissions from cracker are reported under Refining/Storage (CRF 1B2a4). Section 3.4 (CRF 1B2a4) describes the methodology for estimating emissions from cracker. The distribution of emissions from combustion at refineries among the different categories is based on the same proportion for the whole time series. Comparisons made and previously reported to ERTs, shows consistency with what has been reported by the plants.

At some industrial plants, excess gas from chemical and metallurgical industrial processes is burnt, partly in direct-fired furnaces and partly in boilers. These amounts of gases are reported to Statistics

[9] https://www.ssb.no/en/energi-og-industri/statistikker/indenergi

Norway. A petrochemical plant generates *fuel gas* derived from ethane and LPG. Most of the gas is burnt on-site, but some fuel gas is also sold to several other plants. All use of fuel gas is reported as energy consumption in the inventory.

Several metallurgical plants generate *CO-rich excess gas* that is either burnt on-site or sold to adjacent plants. Two ferroalloy plants sell parts of their CO-rich gas to other plants (an ammonia producer, a district heating plant, iron and steel producers and mineral industries), where it is used for energy purposes. Thus, these amounts are reported as energy consumption in the inventory.

One sewage treatment plant utilizes biogas extracted at the plant, and reports quantities combusted (in turbines) and calculated CO_2 emissions. Other emissions are estimated by Statistics Norway, using the same emission factors as for combustion of natural gas in turbines.

Oil products

The total use of the different oil products is based on Statistics Norway's annual sales statistics for petroleum products[10]. The data are considered very reliable since all major oil companies selling oil products report to these statistics and have an interest in the quality of the data**.** The statistics are corrected for direct import by other importers or companies.

The use of sales statistics provides a total for the use of oil products. The use in the different sectors must sum up to this total. This is not the case for the other energy carriers. The method used for oil products defines use as identical to sales. Nevertheless, 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. It is also known that some auto diesel is used for heating. In order to balance the accounts for the different products, it has been necessary, since 1998, to transfer some amounts between products instead of using the sales figures directly. The most important transfer has been from auto diesel to light fuel oil. In addition, some auto diesel has also been transferred to heavy distillates.

Stationary combustion takes place in boilers and, in some manufacturing industries, in direct-fired furnaces. Small ovens can also be used, mainly in private households.

Mobile combustion is distributed among different sources, described in more detail under the transport sector (sections 3.2.4 to 3.2.9).

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 using of waste oil as fuel.

Coal, coke and petrol coke

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 considered of high quality. Combustion of coal and cokes takes place partly in direct-fired furnaces, partly in boilers. The minor

[10] https://www.ssb.no/en/energi-og-industri/statistikker/petroleumsalg/aar

quantities burnt in small ovens in private households are estimated based on sales figures. In addition, an insignificant figure of coal use in the agricultural sector has formerly been collected from the farmers. Since 2002, coal has not been used in Norwegian agriculture.

Biofuels

Use of wood waste and black liquor in manufacturing industries is taken from Statistics Norway's annual survey on energy use in these sectors. For the years before 2005 and for 2012, the use of wood in households is based on the annual survey on consumer expenditure which gives the amount of wood burnt. 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 period 2005-2011, the figures are based on responses to questions relating to wood-burning in Statistics Norway's Travel and Holiday Survey. The figures from the 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. Since 2013 the figure used in the emission calculations is the average of 3 quarterly surveys. Figures on some minor use in agriculture and in construction have been derived from earlier surveys for these sectors. Combustion of wood product takes place in boilers and in small ovens in private households. Consumption figures for wood pellets and wood briquettes are estimated based on annual information from producers and distributors. Data on use of peat for energy purposes are not available, but according to the Energy Farm, the center for Bioenergy in Norway, such use is very limited (Hohle 2005).

The amount of biofuels (biodiesel and bioethanol) for road transportation are reported separately in the CRF tables. Figure 3.*10* shows the consumption of biofuels in the transport sector. The amount of fuels sold is collected from the fuel marketing companies.

Waste

District heating plants and incineration plants annually report combusted amounts of waste (boilers) to Statistics Norway and the Norwegian Environment Agency. Amounts used in manufacturing industries are also reported to Statistics Norway.

According to the Norwegian Pollution Act, each incineration plant has to report emission data for SO_2, NO_X, CO, NH_3, particles, heavy metals and dioxins, and the amount of waste incinerated to the county governor. The county governor then reports this information to the Norwegian Environment Agency. If emissions are not reported, the general method used 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 buildt for the component in question. This factor is based on the ratio between previous emission figures and quantities of waste burnt. 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 reporting period 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 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 review comments, the energy balance has been further disaggregated on energy products. This more detailed presentation concerns, in particular, the years 1992-2011. For 1990 and 1991, balance sheets are presented in the old format, as technical challenges does not allow for these adjustments for these years.

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

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

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

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

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

3.2.1.3 Emission factors

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

CO_2

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

The factor of 2.34 kg/Sm^3 is the default factor used for rich gas combusted in turbines at offshore installations. However, the latest years and specifically after ETS was introduced, field specific EFs have been used in the estimation of CO_2 emissions from combustion of rich gas. More information is given below under *Offshore operations*.

Table 3.4 General emission factors for CO_2.

Energy product	**Emission factors**	
	Tonne CO_2/tonne fuel	**Tonne CO_2/TJ fuel**
Coal	2.52	89.68
Coke	3.19	111.93
Petrol coke	3.59	102.57
Crude oil	3.2	75.65
Motor gasoline	3.13	71.3
Aviation gasoline	3.13	71.3
Kerosene (heating)	3.15	73.09
Jet kerosene	3.15	73.09
Auto diesel	3.17	73.55
Marine gas oil/diesel	3.17	73.55
Light fuel oils	3.17	73.55
Heavy distillate	3.17	73.55
Heavy fuel oil	3.2	78.82
Natural gas (dry gas) (kg/Sm^3) (land)	1.99	56.08
Natural gas (rich gas) (kg/Sm^3) (off shore)	2.34	58.09
LPG	3	65.08
Refinery gas	2.8	57.61
Blast furnace gas	:	198
Fuel gas[3]	2.5	50
Landfill gas[2,4]	2.75	54.78
Biogas[2,4]	2.75	54.78
Fuel wood[2]	1.8	107.14
Ethanol[2]	1.91	70.84
Biodiesel[2]	2.85	76.86
Wood waste[2]	1.8	100-110.77
Black liquor[2]	1.8	195.65-250
Charcoal	3.299	111.83
Municipal waste	0.55	52.36
Special waste	3.2	78.82

[1] The emission factor for natural gas used in the emission inventory varies as indicated in Tables 3.5 and 3.6.
[2] Non-fossil emissions, not included in the inventory CO_2 totals.
[3] In this inventory, fuel gas is a hydrogen-rich excess gas from petrochemical industry
[4] Landfill gas and other types of biogas are reported as methane content in the energy balance
Source: Statistics Norway, Norwegian Petroleum Industry Association, SFT (1990), SFT (1996), Climate and Pollution Agency (2011b)

Offshore operations

For all years up to 2002, emissions of CO_2 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 Norwegian Environment Agency and the emission factors shown in Table 3.5. For the years 2003 and onwards,, 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 Norwegian Environment Agency.

The CO_2 emission factor used for all years leading up to 1998 and for all fields except one is one average (standard) factor based upon a survey carried out in the early 1990s (OLF 1993). From 1999 and onwards, the employed emission factors 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 EPIM Environment Hub. It is the database in which field operators report emissions data.

Since 2008, off shore gas combustion has been included in the European emission trading system (ETS).

Table 3.5. Average emission factors of CO_2 from the combustion of natural gas in turbines at offshore gas and oil fields.

	1990	1995	2000	2005	2010	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Gas turbines offshore t CO_2 /TJ	58.1	56.8	61.5	60.8	60.3	59.6	59.1	58.6	58.6	58.6	58.6	58.7	58.2	57.9	58.2

Source: Norwegian Environment Agency/Norwegian Petroleum Directorate/Environmental Web/EPIM Environment Hub (EEH)

Gas terminals

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

The CO_2 emission factors for combustion of natural gas on gas terminals are based on continuous or daily plant-specific measurements.

Since 2005, the terminals have been included in the emission trading system (ETS). The average CO_2 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_2 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_2 and reduce the CO_2 content in the sales gas to a level that is low enough for the gas market. The CO_2 content in the CRAIER gas burnt in the boiler has varied between 1.6-1.7 tonne CO_2 per tonne gas corresponding to approximately 100 tonnes CO_2 per TJ.

Table 3.6. Average emission factor for CO_2 from the combustion of fuel gas at one gas terminal.

	1990	1995	2000	2005	2010	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Average content of CO_2 in natural gas t CO_2 /TJ	56.95	61.80	57.58	56.32	56.32	56.11	55.90	56.11	55.90	55.68	55.47	55.47	55.43	55.22	55.22

Source: Norwegian Environment Agency

CH_4 and N_2O

For CH_4 and N_2O, information on emission factors is generally very limited, because, unlike the CO_2 emission factors, they depend on the source of the emissions and the sector where the emissions take place. CH_4 and N_2O emission factors for stationary combustion are default factors from IPCC (2006). Net calorific values from the energy balance have been used in order to combine the factors to primary energy data in physical units. Methane emission factor from fuel wood is taken from SINTEF (1995). Due to lack of data, some emission factors are used for sector/source combinations different from those they have been estimated for.

The general CH_4 and N_2O emission factors used in the emission inventory for this source are listed in Table 3.7 and Table 3.9, respectively. Table 3.8 and Table 3.10 display the cases where emission factors other than the general ones have been used in the calculations.

Table 3.7. General emission factors for CH_4, stationary combustion. Unit: kg CH_4 / TJ.

	Direct-fired furnaces	Gas turbines	Boilers	Small stoves	Flares
Coal	1.00	-	300.00	300.00	-
Coke	10.00	-	300.00	300.00	-
Petrol coke	3.00	-	10.00	-	-
Kerosene (heating)	**-**	-	**10.00**	10.00	-
Marine gas oil/diesel	10.00	-	10.00	-	-
Light fuel oils	-	-	10.00	10.00	-
Heavy distillate	10.00	-	10.00	10.00	-
Heavy fuel oil	**10.00**	-	**10.00**	-	-
Natural gas (dry gas) (land)	**5.00**	25.63	**5.00**	-	6.76
Natural gas (rich gas) (off shore)	**4.40**	22.58	**4.40**	-	5.96
LPG	-	-	**5.00**	5.00	-
Refinery gas	1.00	-	1.00	-	5.76
Blast furnace gas	0.67	-	**0.67**	-	-
Fuel gas	1.00	-	1.00	-	1.08
Landfill gas	5.00	**-**	5.00	-	7.37
Fuel wood	-	-	-	365.85	-
Wood pellets	-	-	11.00	300.00	-
Wood briquettes	-	-	**11.00**	-	-
Wood waste	-	-	**11.00**	-	-
Black liquor	-	-	3.00	-	-
Charcoal	200	-	-	203.4	-
Municipal waste	-	-	32.86	-	-
Special waste	30.00	-	30.00	-	-

Numbers in bold have exceptions for some sectors, see Table 3.8.

Source: IPCC (2006), SFT (1996), SINTEF (1995) and (OLF 1994)

Table 3.8. Exceptions from the general factors for CH_4, stationary combustion. Unit: kg CH_4/TJ.

Emission factor	Fuel	Source	Sectors
3.0	Kerosene (heating),marine diesel; light fuel oil, heavy distillate	Direct fired furnaces	Energy industry and manufacturing of product
2.9	heavy fuel oil	Direct fired furnaces, boilers	Energy industry and manufacturing of product
1.0	LPG	Boilers	Energy industry and manufacturing of product
1.0	Natural gas	Direct fired furnaces, boilers	Extraction of oil and gas
11.4	Natural gas	Direct fired furnaces, boilers	Energy industry and manufacturing of product
0	Blast furnace gas	Boilers	Refinery
1.0	Landfill gas, Bio gas	Gas turbines, boilers	Energy industry and manufacturing of product
30	Wood waste	Boilers	Energy industry and manufacturing of product
300	Wood briquettes	Boilers	Private households

Sources: IPCC (2006), SFT (1996), SINTEF (1995) and (OLF 1994)

Table 3.9. General emission factors for N_2O, stationary combustion. Unit: kg N_2O/TJ.

	Direct-fired furnaces	Gas turbines	Boilers	Small stoves	Flares
Coal	1.50	-	1.50	1.50	-
Coke	1.50	-	1.50	1.50	-
Petrol coke	0.60	-	0.60	-	-
Kerosene (heating)	-	-	0.60	0.60	-
Marine gas oil/diesel	0.60	0.60	0.60	-	-
Light fuel oils	-	-	0.60	0.60	-
Heavy distillate	0.60	-	0.60	0.60	-
Heavy fuel oil	0.60	-	0.60	-	-
Natural gas (dry gas) (land)	**0.10**	**0.10**	**0.10**	-	0.56
Natural gas (rich gas) (off shore)	**0.09**	**0.09**	**0.09**	-	0.50
LPG	-	-	0.10	0.10	-
Refinery gas	0.10	-	0.10	-	0.49
Blast furnace gas	0.07	-	0.07	-	-
Fuel gas	0.10	-	0.10	-	0.48
Landfill gas	0.10	0.10	0.10	-	0.03
Fuel wood	-	-	-	4.88	-
Wood pellets	-	-	4.00	4.00	-
Wood briquettes	-	-	4.00	-	-
Wood waste	-	-	4.00	-	-
Black liquor	-	-	2.00	-	-
Charcoal	4.00	-	-	1.017	
Municipal waste	-	-	4.38	-	-
Special waste	4.00	-	4.00	-	-

Numbers in bold have exceptions for some sectors, see Table 3.10.

Source: IPCC (2006), SFT (1996), SINTEF (1995) and OLF (1994)

Table 3.10. Exceptions from the general factors for N_2O, stationary combustion. Unit: kg N_2O/TJ.

Emission factor	Fuel	Source	Sectors
0.11	Natural gas	Direct-fired furnaces, gas turbines, boilers	Extraction of oil and gas

Sources: Statistics Norway

3.2.1.4 Uncertainties and time-series consistency

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

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

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

- *Use of oil products*: Total amounts are given by the petroleum sales statistics. The uncertainty for total sales are considered to be low due to reliable and complete sales statistics, CO_2-tax and other taxes. The project undertaken for the RA&SA also underlines that this statistics is reliable. However, the allocation of the total consumption to individual sources is more uncertain.
- *Reported emissions from other fuels*, primarily natural gas: Uncertainty data for emissions and energy use are provided in ETS reports. A comparison undertaken as part of the RA&SA project shows that there is good correspondence between the energy consumption by plants covered by the EU ETS and the voluntary agreement and Statistics Norway's own statistics. This also indicates that the energy use in manufacturing industry in the inventory is reliable.

These groups comprise today of about 95 per cent of CO_2 from energy and 88 per cent in 1990.

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

Time series consistency is obtained by the continuous effort to recalculate the entire time series whenever a new source is included in the inventory or new information or methodologies are obtained. However, data availability both for activity data and reported emissions have generally improved over time and new data are included in the emission estimates when deemed of better quality. This causes a degree of time series inconsistency, but the entire time series are considered when new data are included, and efforts made to take the new information into account for all years.

When it comes to activity data, the statistics that form the basis for the energy consumption are not always complete from 1990 onwards. For instance, the waste statistics that form the basis for the waste incineration started in 1995. For the years prior to this, activity data have been backwards extrapolated to ensure consistency in emission estimates.

Emissions reported from the plants are in most cases of good quality, but it may be unfeasible to obtain the estimates for the entire time series. In cases where the reported emissions are deemed to add to accuracy or level of detail in the emission inventory, and the reported figures are unavailable for parts of the time series, reported figures are used although this introduces a certain level of inconsistency. However, emissions for the rest of the time series is calculated based on fuel consumption and standard emission factors, and checks have been made to ensure that the two

methodologies gives comparable emission estimates. Times series consistency is thus considered to be met.

3.2.1.5 Category-specific QA/QC and verification

Emission sources in the energy sector are subjected to the QA/QC procedures described in Section 1.2.3 and in Annex VIII QAQC of point sources. Several documentation reports have been published describing the methodologies used for road traffic (Holmengen & Fedoryshyn 2015) and navigation (Tornsjø 2001) and (Flugsrud *et al.* 2010). The methodology for aviation is described in an internal document from Statistics Norway XXX (Skullerud 2014).

The energy statistics that form the basis for the energy balance and energy accounts are subject to individual QA/QC procedures which are not directly linked to the emission inventory system. For the survey on energy use in manufacturing industries, data are edited in a top-down manner, where large units are edited first. The responses from the plants are subject to a set of automated controls that flag outliers and other possible errors (Statistics Norway 2012). The statistics on sales of petroleum products are checked by comparing total sales for each company with additional information from the company. In addition, the companies check that the complete statistics correspond with their own figures. The companies receive tables containing their sales figures, total sales and market shares (Statistics Norway 2015).

Plant specific emission data included in the greenhouse gas inventory are as explained above based on three different reports. Firstly, the annual report that each plant with a permit from the Norwegian Environment 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. Secondly, 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. Thirdly, the Norwegian Environment Agency also receives 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 Norwegian Environment Agency through the different reporting channels described above are controlled thoroughly by the Norwegian Environment Agency and Statistics Norway. Especially the emission data plants included in the ETS and in the voluntary agreement are verified extensively. See Annex VIII QAQC of point sources.

3.2.1.6 Category-specific recalculations

Most of the recalculations have been performed for the inventory year 2015, because the energy figures for this year used in the previous inventory were preliminary. There will always be some changes in the energy figures. For petroleum products, corrections in one sector 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.

See specific sections and chapter 10 for more details.

3.2.1.7 Category-specific planned improvements

The emission estimation methodology for this source category is currently undergoing improvement, see table 10.9.

As noted in section 3.2.1.1 and elsewhere, Statistics Norway published a revised energy balance for 2010-2016 in 2017. In 2018, the balance will be extended back to 1990 and the balance data incorporated into the emission inventory. The results will be used for improving the information in CRF and NIR in the 2019 submission. A brief presentation of the project is included in section 3.6.2.

The revision will affect all subcategories. This is not further mentioned in the subsections except where the revision applies to specific ERT recommendations.

The revision will also affect the Reference Approach, correspondence with IEA reporting and reporting of feedstock/non-energy use.

3.2.2 Energy industries, 1A1 (Key category for CO_2 and CH_4)

3.2.2.1 Description

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

It is important to specify that only emissions from energy combustion for energy purposes are included in section 3.2 Energy Combustion and therefore in the source category Energy industries (CRF 1A1). Emissions from combustion not for energy purposed e.g. flaring are included in section 3.3, 3.4 and 7.5.

Emissions from drilling at moveable offshore installations are included in section 3.2. Emissions from these installations, while not in operation (during transport, etc.), are included with 1A3d Navigation.

In 2016, GHG emissions from the energy industries accounted for 38.9 per cent of the energy sector total emissions and 28.3 per cent of the total emissions in Norway. Emissions increased by 107 per cent during the period 1990-2016, primarily due to the increased activity in the oil and gas extraction sector. In 2009, however, the increase was due to approximately one million ton higher CO_2 emissions from gas fired electricity power plants, while the 2.3 per cent reduction between 2011 and 2012 is the result of decreased emissions from the same sector.

According to the approach 2 key category analysis for 1990 and 2016, this sector is, in conjunction with sectors 1A2 and 1A4, a key category with respect to:

- Emissions of CO_2 from the combustion of liquid fuels, gaseous fuels and other fuels in level in 1990 and 2016, and trend
- Emissions of CH_4 from the combustion of biomass in level in 1990 and 2016
- Emissions of CH_4 from the combustion of gaseous fuels in level in 2016 and in trend

In addition to source categories defined as key categories according to the approach 2 key category analysis, this sector is, in conjunction with sectors 1A2 and 1A4, is defined as key according to approach 1 key category analysis with respect to emissions of CO_2 from combustion of solid fuels.

3.2.2.2 Methodological issues

A description of the general method used for estimating emissions from fuel combustion is given in section 3.2.1.1 and (Statistics Norway 2013). However, most of the reported emissions in this source category are from the annual report from the entities to the Norwegian Environment Agency and the Norwegian Petroleum Directorate. The guidelines for estimating and reporting emissions are lengthy and in Norwegian, so instead of attaching these to the NIR URLs are provided in section 3.2.1.1 and in Annex VII.

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 Norwegian environment agency. The reports up to 2004 are taken from the mandatory reporting obligation that is a part of the plants permits given by the authorities and from 2005, emission data are taken from the emission trading system. The distribution of emissions between flaring and energy utilisation of refinery gas in the whole period from 1990 is based on plant and year specific figures. Emissions from energy utilization are reported in petroleum refining (CRF 1A1b) and from flaring in fugitive emissions from flaring (CRF 1B2c).

One of the refineries has a catalytic cracker. Emissions from coke burn off on the catalyst at the cracker are, since they are not for energy purposes, reported in Fugitive Emissions from Oil (CRF 1B2a).

Waste incineration – CO_2 and CH_4

Net CO_2 emissions from wood/ biomass burning are not considered in the Norwegian inventory, because the amount of CO_2 released during burning is the same as that absorbed by the plant during growth. Carbon emitted in compounds other than CO_2, e.g. as CO, CH_4 and NMVOC is also included in the CO_2 emission estimates. This double counting of carbon is in accordance with the IPCC guidelines (IPCC 2006).

Waste incineration – N_2O

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

Public electricity and heat production (CRF 1A1a) – Varying IEFs

The emission sources included in Public electricity and heat production – liquid fuels are consumption of refinery gas at gas fired power plants, consumption of fuel oils, LPG, etc. at district heating plants and consumption of fuel oils in the production of electricity sector.

Emissions from consumption of *refinery gas* included in the inventory are taken from the ETS reports and adjusted for the backflow of fuel gas to refinery. The removed amount of CO_2 is included in Petroleum refining (CRF 1A1b). The adjustment for backflow is due to the fact that the amount and

composition of the gas are measured before a separation facility that removes excess hydrogen together with some hydrocarbons.

Emissions from district heating plants and the electricity sector are based on data from the energy balance and default emission factors. Consumption of other liquid fuels is entered as totals in the table below and in the excel spreadsheet due to confidentiality.

The energy liquid carriers used in this sector are refinery gas and other liquid fuels mainly fuel oils and LPG. The change in IEFs from 2010 to 2011 was due to changes in fuel mix between years. The NCV for refinery gas is about 11 per cent higher than that for other liquid fuels, and the emission factor is 20 per cent lower. This change in energy mix explains the reduction in the IEF for liquid fuels used in this source category from 2010 to 2011.

3.2.2.3 Activity data

Electricity and heat generation and distribution

The energy producers annually report their use of different energy carriers to Statistics Norway. There is only some minor use of oil products at plants producing electricity from hydropower. Combustion of coal at Norway's only dual purpose power plant at Svalbard/Spitsbergen is of a somewhat larger size. The amount of waste combusted at district heating plants is reported annually both to Statistics Norway and the Norwegian Environment Agency, see Table 3.11. Data are considered to be of high quality.

Table 3.11. Amount of waste combusted at waste incineration plants. 1990-2016. Unit: 1000 tonnes.

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Amount of waste incinerated	385	448	587	740	1084	1323	1473	1560	1564	1604	1578

Source: Statistics Norway, Norwegian Environment Agency

Extraction of oil and natural gas

Production of oil and natural gas is the dominating sector for emissions from combustion in the energy industries in Norway. The Norwegian Petroleum Directorate reports annually the amounts of gas combusted in turbines and diesel burnt in turbines and direct-fired furnaces on the oil and gas fields. The data are considered of high quality due to the CO_2 tax on fuel combustion. The activity data are used for 1990-2002. From 2003 onwards, reported emission figures from the field operators are reported into the EPIM Environment Hub (EEH), previously Environmental Web.

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

EPIM Environment Hub (EEH) (offshore activities) is described in guidance documents (Norsk olje&gass 2012).

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 Norwegian Environment Agency and the Norwegian Petroleum Directorate. Emissions included in inventory for this category are from the gas terminals annual report to the Norwegian Environment Agency.

Oil refineries

The oil refineries annually report their use of different energy carriers to Statistics Norway. Refinery gas is the 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 Norwegian Environment Agency. Emissions from the catalytic cracker at one refinery are reported in Refining/Storage (CRF 1B2a4).

3.2.2.4 Emission factors

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

Gas in electricity generation

The CO_2 implied emission factor for use of natural gas in electricity generation varies significantly over the period, from the regular factor of 56.1 t/TJ to over 60 t/TJ. The highest value is in a year with very low emissions (7.2 kt CO_2). In the years with high emissions (>100 kt CO_2), the highest IEF is 58.4 t/TJ.

The variation is primarily a result of the economics of gas power production. Thus, the relative contributions of plants with different plant-specific factors (as based on reports to the Emissions Trading System) also vary significantly. This accounts for the changes in the time series.

Coal in electricity and heat production

The CO_2 factor for solid fuels in electricity generation is low, at 89.7 t/TJ. The emissions in this category is from use of coal at Svalbard. The coal mined at Svalbard has a low carbon emission factor.

The CO_2 factor for solid fuels in heat generation is high and variable, ranging from 164 to 202 t/TJ. The emissions in this category are from blast furnace gas wich is sold from a ferroalloy plant to heat distributors. The emissions are based on reports from the plants, from 2008 onwards as part of the Emissions Trading System.

Waste incineration

The emission factors for CO_2, CH_4 and N_2O from combustion of waste (fossil part only) are displayed in Table 3.4, Table 3.7 and Table 3.9, respectively. Emission factors for CH_4 have been calculated by SFT (1996).

The CO_2 emission factor for the fossil part of waste combusted in waste incineration plants in Norway was revised in 2014 (Fedoryshyn 2015) . The new factor is based on the assumption that 2.708 tonnes CO_2 per tonne plastic are combusted (based upon the same composition of polymers combusted as in Danish calculations (Denmark NIR 2010 (Nielsen et al. 2010)) and that 20 per cent of the combusted waste was fossil in 2009 (Norwegian Climate and Pollution Agency 2011). The new factor is a time series that is based on the mean annual change in the fossil share of combusted waste. This change is calculated using the data from Waste accounts Statistics (Statistics Norway) in the period of 1995-2011. For years when data from Waste accounts are not available, the CO_2 emission factor is held constant: in 1994 and before, the 1995 factor is used, while 2011 factor is used in the years after 2011. The energy content of waste used in the new calculation is 11.5 GJ per tonne waste and is based on a report from Avfall Norge (Marthinsen et al. 2010).

Extraction of oil and natural gas

The CO_2 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; OLF 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. Since the last few years, there has been a shift towards fields with somewhat lower carbon content, again.

Oil refineries

The CO_2 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_2/tonne fuel or tonne CO_2/TJ. High hydrogen content leads to low emission factors as measured in tonne CO_2/TJ. As an example, a gas with 40 % hydrogen and 60 % hydrocarbons with an average carbon number of 2 gives an emission factor of 50 tonne CO_2/TJ. In the Norwegian inventory, the emission factor varies in the range 45-60 tonne CO_2/TJ.

3.2.2.5 Uncertainties and time series consistency

The uncertainty analysis performed for the energy industries (Annex II) has shown that 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_2, 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_4 and N_2O are very uncertain. Distributions are strongly skewed with uncertainties which lie below and above the mean by a factor of 2 and 3, respectively.

The EU ETS emission estimates are available for all years since 2005. The information included in the ETS cannot reasonably be obtained for the time series 1990-2004. Thus, the use of this relatively new data source introduces a degree of inconsistency in the time-series. However, the energy

consumption reported under the ETS system is consistent with the energy consumption reported to Statistics Norway for individual plants. In addition, the CO_2 emission estimates are consistent with the emissions reported to EPIM Environment Hub for offshore activities and through the regular permits for land-based industries. These are the data sources used for emissions, for the years prior to the introduction of the EU ETS scheme. It has thus been assumed that time-series consistency is not significantly affected and that the emission trend is reliable.

3.2.2.6 Category-specific QA/QC and verification

The energy industries are subjected to the general QA/QC procedures described in section 1.2.3 and in Annex VIII QAQC point sources. The category-specific QA/QC described in section **Feil! Fant ikke referansekilden.** is also valid for Energy Industries.

Some category-specific QA/QC activities were conducted in the following industries:

Extraction of oil and natural gas

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

Oil refineries

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

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

3.2.2.7 Category-specific recalculations

1A1ai Public electricity and heat production: Electricity Generation

- Completeness. Figures on use of bio gas in electricity generation in 2015, which previously were missing, have been included. This causes minor emission increases for CO_2 (biomass), CH_4 and N_2O.

1A1aiii Public electricity and heat production: Heat plants

- Completeness. Figures on use of bio gas in heat plants in 2015, which previously were missing, have been included. This causes minor emission increases for CO_2 (biomass), CH_4 and N_2O.

3.2.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.2.3 Manufacturing industries and construction, 1A2 (Key category for CO_2 and CH_4)

3.2.3.1 Description

A description of the general method used for estimating emissions from fuel combustion is given in section 3.2.1.1 and in Statistics Norway (2013). 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, i.e. 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 is accounted for under the industrial processes sector (CRF 2).

Emissions from this sector contributed to 7.1 per cent of the national GHG total in 2016. Emissions from the sector decreased by 5.6 per cent from 1990 to 2016. The metal production and pulp and paper sectors have increased emissions from 2015 to 2016, while emissions from the other sectors decreased.

According to the Approach 2 key category analysis for 1990 and 2016, this sector is, in conjunction with sectors 1A1 and 1A4, a key category with respect to:

- Emissions of CO_2 from the combustion of liquid fuels, gaseous fuels and other fuels in level in 1990 and 2016, and trend
- Emissions of CH_4 from the combustion of biomass in level in 1990 and 2016
- Emissions of CH_4 from the combustion of gaseous fuels in level in 2016 and in trend

In addition to source categories defined as key categories according to the Approach 2 key category analysis, this sector is, in conjunction with sectors 1A1 and 1A4, is defined as key according to Approach 1 key category analysis with respect to emissions of CO_2 from combustion of solid fuels.

3.2.3.2 Methodological issues

A description of the general method used for estimating emissions from fuel combustion is given in section 3.2.1.1. For many plants the emission figures are based on reported figures from the plants to the Norwegian Environment Agency. Indeed, in 2016, these plants accounted for 43 per cent of the CO_2 emissions from the sector (Table 3.3). The general calculation method, amount of fuel combusted multiplied with a fuel specific emissions factor, is valid for both estimates performed by Statistics Norway and emissions reported by the plants to the Norwegian Environment Agency in this sector.

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 are 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, since 2005, industry not included in the ETS. Industry has, in the different voluntary agreements, committed themselves to reduce their greenhouse gas emissions as a group. As part of the agreements, industry has every year reported

detailed AD and emissions to the Norwegian Environment Agency. The voluntary agreement has involved industry i.e. ferroalloy, aluminum, ammonia. From 2013 most of these industries are also part of the ETS.

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.

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

EU ETS

The guidelines for the EU ETS emission reports (Miljødirektoratet 2015) are consistent with the European Union's guidance documents (European Comission). A description of annual normal permit and reporting to the Norwegian Environment Agency is available at the Miljødirektoratet webpage (Miljødirektoratet 2016).

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 under process emissions (CRF 2B1), see Section 4.3.1. Emissions included in the inventory are from the plant's annual report to the Norwegian Environment Agency.

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

Motorized equipment

Motorized equipment used in manufacturing and construction have been included in this category (CRF 1A2g). Methodologies, activity data and emissions factors are detailed in section 3.2.9.

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 in a few major plants within the industry, from which data have been collected both in the current and in 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; 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 3.2.9.

3.2.3.4 Emission factors

Emission factors used in this source category are presented in detail section 3.2.1.3. This section provides information on sectors with variable or deviating implied emission factors in the CRF tables.

Chemical industry (1A2c) – liquid fuels

The IEF for liquid fuels in chemical industry is outside the range of regular liquid fuels due to the use of hydrogen-rich fuel gas.

The liquid energy carriers used in this sector are fuel gas and other liquid fuels, like fuel oils, LPG and oxy gas. Emission sources included in the use of liquid fuels in Chemical industry, are consumption of fuel gas in different chemical productions, e.g. production of ethylene, propylene, polypropylene, polyethylene, and consumption of liquid fuels like fuel oils, LPG and oxy gas. Emissions from consumption of *fuel gas* included in the inventory are taken from ETS reports. Emissions reported by the ETS entities are considered being accurate and lead to a lower IEF since 2008.

Emissions of other liquid fuels included in the inventory are mainly based on data from the energy balance and default emission factors. One exception is emissions from oxy gas from one ETS report.

The ETS reports from *one plant* until 2010 did not report fuel specific emissions. Instead, emissions are reported based on mass balance calculations. For these years, emissions were allocated to fuels based on fuel consumption data reported to Statistics Norway.

The low IEF is due to a high share of hydrogen rich fuel gas (e.g. 68 per cent in 2011), but activity data are confidential.

Ammonia

The LPGs used as fuels in the ammonia production is mainly a mix of propane/butane with the emission factor of 3.01 tonne CO_2 per tonne gas and ethane with an emission factor of 2.93 tonne CO_2 per tonne gas. For a few years, a small amount of a light fuel gas (composition of 60 per cent H_2 and 40 per cent CH_4) from a producer of plastic is used with an emissions factor of 2.4 t CO_2 per tonne gas.

Chemical industry (1A2c) – solid fuels

The CO_2 IEF for solid fuels in chemical industry is outside the range of regular solid fuels due to the use of CO-rich blast furnace gas as a fuel. This gas is sold from a ferroalloy producer and is mainly used as fuel in ammonia production and is reported under solid fuels. The gas has an average plant-specific emission factor of 198 t CO_2/TJ, but inconsistensies in the energy statistics lead to implied emission factors in the range of 190-264 tonne CO_2/TJ. The default emission factor for blast furnace gas in the 2006 guidelines is 70.8 tonnes C/TJ, or 260 tonnes CO_2/TJ (IPCC 2006).

Pulp and paper (1A2d) – biomass

The CO_2 IEF for biomass in the pulp and paper industry varies significantly due to changes in the relative amounts of different fuels. The emissions are primarily from black liquor with plant-specific emission factors in the range of 200-250 t CO_2/TJ and from wood waste with an emission factor of 111 t CO_2/TJ. In 2013, a large plant using black liquor closed down. This led to a large shift to wood waste in the fuel composition, with a corresponding drop in the IEF.

Non-metallic minerals (1A2f) – biomass

The CH_4 IEF for biomass in the minerals industry varies significantly due to changes in the relative amounts of different fuels. The emissions are primarily from charcoal with an emission factor of 200 kg CH_4/TJ and from wood waste with an emission factor of 30 kg CH_4/TJ. Most of the fuel consumption is wood waste, but in some years the use of charcoal leads to strong increases in the average IEF, in particular for 2003. Emissions of CO_2 and N_2O are similar for the fuels, and the IEFs for these gases vary little among years.

3.2.3.5 Uncertainties and time series consistency

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 in Annex II.

The EU ETS emission estimates are available for all years from 2005. For the time period 1990-2004 there are no data from ETS. Thus, the use of this relatively new data source introduces a degree of inconsistency in the time-series. However, the energy consumption reported under the ETS system is consistent with the energy consumption reported to Statistics Norway for individual plants. In addition, the CO_2 emission estimates are consistent with the emissions reported through the regular permits for land-based industries. These are the data sources used for emissions for the years prior to the introduction of the EU ETS scheme. It is thus assumed that time-series consistency is not significantly affected and that the emission trend is reliable.

No other time series inconsistencies are known for this sector.

3.2.3.6 Category-specific QA/QC and verification

QC of plant specific data performed by the inventory compilers in the Norwegian Environment Agency before handing over the data to Statistics Norway to be included in the inventory is quite extensive. The QC is described in section 1.2.3 of the NIR and also in Annex VIII QAQC of point sources, section 5 Current QA/QC procedures and data sources. This is an annual QC.

3.2.3.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

3.2.3.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.2.4 Transport – Civil Aviation, 1A3a (Key category for CO_2)

3.2.4.1 Description

In 2016, emissions from this source category amounted to 9.3 per cent of the total emissions from transport and 2.2 per cent of the GHG national total. From 1990 to 2016, these emissions increased by 74 per cent due to activity growth. Emission fluctuations over time have been dictated by the activity growth rates. In 2016, GHG emissions from aviation were 6.3 per cent lower (81 kt CO_2 equivalents) than in 2015. During the period 1990-2016, the average annual growth in emissions was 2.2 per cent. The growth amounted to 6.1 per cent between 1990 and 1999, and 0.1 per cent between 1999 and 2016. This indicates that the growth in emissions from domestic aviation was substantial higher in the 90ies than it has been since.

According to the approach 2 key category analysis, Civil aviation is a key category with respect to CO_2 emissions in level both in 1990 and in 2016, and in trend. Emissions of CH_4 and N_2O from this source category are insignificant.

3.2.4.2 Methodological issues

The calculation methodology applied is described in Skullerud (2014). According to the IPCC Good Practice Guidance, the methodology used is approach 2 based on the detailed methodology described in EEA (2001); (EEA 2013). 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 air traffic companies. This data includes 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. The consumption of jet kerosene in domestic air traffic are directly based on reported figures. Domestic consumption of jet kerosene has been reported to Statistics Norway by airlines since 1993. The survey is annual, but data from the surveys of 1993 and 1994 has not been used, as one of the largest airlines in Norway was not included. Domestic consumption prior to 1995 is estimated by extrapolation on the basis of domestic kilometres flown and is, thus, more uncertain. 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 Table 3.12 and Table 3.13.

The Norwegian Petroleum Industry Association provides CO_2 emission factors for the combustion of jet fuel and gasoline (Finstad et al. 2002). The CO_2 emission factor used for aviation gasoline is 71.3 tonne CO_2 per TJ and has been applied to all small aircraft. All other aircraft use jet fuel (kerosene) with an emission factor of 73.1 tonne CO_2 per TJ.

For N_2O, 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_4, given in Olivier (1991), to be 10 per cent of total VOC. This is, however, only valid for LTO since studies indicate that only insignificant amounts of methane is emitted during the cruise phase. No methane is therefore calculated for the cruise phase and all emissions are assumed to be NMVOC (HC). The VOC emission factors are aircraft specific as given in EEA (2013).

For NMVOC and CH_4 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 total fuel consumption from a bottom-up analysis based on EEA data.

Emission factors were calculated with activity data for 1989, 1995, 2000 and 2012. Factors for the years 1990-1994, 1996-1999 and 2000-2011 were interpolated. Factors after 2012 were kept constant (Skullerud 2014).

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

Table 3.12. General emission factors for aviation. Unit: CO_2: tonne/TJ, CH_4 and N_2O: kg/TJ

	CO_2		**CH_4**		**N_2O**
Source	**Aviation gasoline**	**Jet kerosene**	**Aviation gasoline**	**Jet kerosene**	**Aviation gasoline/ Jet Kerosene**
Charter/scheduled flights					
Domestic					
LTO (0-100 m)		73.1		**2.99**	2.3
LTO (100-1000 m)		73.1		**2.99**	2.3
Cruise (Above 1000)		73.1		**0**	2.3
International					
LTO (0-100 m)		73.1		**2.09**	2.3
LTO (100-1000 m)		73.1		**2.09**	2.3
Cruise (Above 1000)		73.1		**0**	2.3
Helicopters					
LTO (0-100 m)		73.1		74.2	2.3
LTO (100-1000 m)		73.1		74.2	2.3
Cruise (Above 1000)		73.1		0	2.3
Small aircraft					
LTO (0-100 m)	71.3		82.2		2.3
LTO (100-1000 m)	71.3		35.3		2.3
Cruise (Above 1000)	71.3		0.0	-	2.3

Bold numbers are different for different years, see Table 3.13.

Source: IPCC (2000) and Finstad et al. (2002)

Table 3.13. Time series of variable CH_4 emission factors from the combustion of jet kerosene in aviation[1]

		CH_4 Emission Factor (kg/TJ)			
Sector	**Source**	**1989**	**1995**	**2000**	**2012**
Domestic	0-100 m	2.00	19.91	4.06	2.99
	100-1000 m	0.32	3.27	0.67	2.99
	cruise	0.00	0.00	0.00	0.00
International	0-100 m	0.95	2.00	3.34	2.09
	100-1000 m	0.16	0.32	0.58	2.09
	cruise	0.00	0.00	0.00	0.00

[1]) Factors for 1989, 1995, 2000 and 2000 are estimated as given in the table. Factors for intervening years are calculated by linear interpolation. Factors before 1989 and after 2012 are kept constant.
Source: IPCC (2000) and Finstad et al. (2002)

3.2.4.5 Uncertainties and time series consistency

Activity data

The uncertainty in the activity data for civil aviation is estimated to be ±20 per cent of the mean, primarily due to the difficulty in separating domestic emissions from emissions from fuel used in international transport (Rypdal & Zhang 2000). In a study on emissions from aircraft Finstad et al. (2002), 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. This may also, to a certain degree, affect the time series consistency.

Emission factors

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

3.2.4.6 Category-specific QA/QC and verification

There is no category-specific QA/QC procedure for this sector. See Annex V for the description of the general QA/QC procedure.

3.2.4.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

3.2.4.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.2.5 Transport – Road Transportation, 1A3b (Key category for CO_2)

Road traffic accounted for 77.1 per cent of the total GHG emissions from transport and for 18.6 per cent of the national GHG total in 2016.

During the period 1990-2016, an increase in emissions of 27.7 per cent took place in road transportation.

According to the approach 2 key category analysis for 1990 and 2016, this sector is a key category with respect to emissions of CO_2 in level in 1990 and 2016, and trend.

Passenger cars (PC): Since 1990, emissions from PCs have increased by 3.2 per cent, while vehicle kilometers have increased by 54 per cent and the number of PCs has grown by 65 per cent. The difference between growth in emission and growth in driven kilometers can be explained by the use of more fuel efficient vehicles in the period, and by the switch from petrol to diesel driven personnel cars. The switch has specifically been higher since 2007, due to the CO_2 differentiated tax on new personnel cars implemented that year. However, recently the shift in sales has been back to petrol and to electric vehicles. In addition, the consumption of biodiesel and bioethanol has increased since 2006 with a particularly large jump in 2016, see Figure 3.*10*, and hence contributes to the CO2 emission decrease.

Emissions from **light commercial vehicles** (LCV) and **heavy duty vehicles** (HDV) increased by 120 and 63 per cent, respectively, during the period 1990-2016.

PC's contribution to total CO_2 emissions from road traffic decreased from 65.9 per cent in 1990 to 53.2 per cent in 2016. Light commercial vehicles (LCV) and heavy duty vehicles (HDV) increased their contribution to total emissions for road traffic from 8.8 to 15.1 per cent, and 23.0 to 29.4 per cent, respectively, from 1990 to 2016.

The increase in LCV's share of the total emissions from road traffic illustrates the increase of goods transport since 1990 as a consequence of increased trade and consumption of goods due to economic growth.

HDVs consist of trucks and buses but it is specifically trucks that are responsible for the increase of emissions from 1990. This increase is due to economic growth which led to increased activity in the building and construction sector but also to the fact that the trucks have larger motors and are heavier in general.

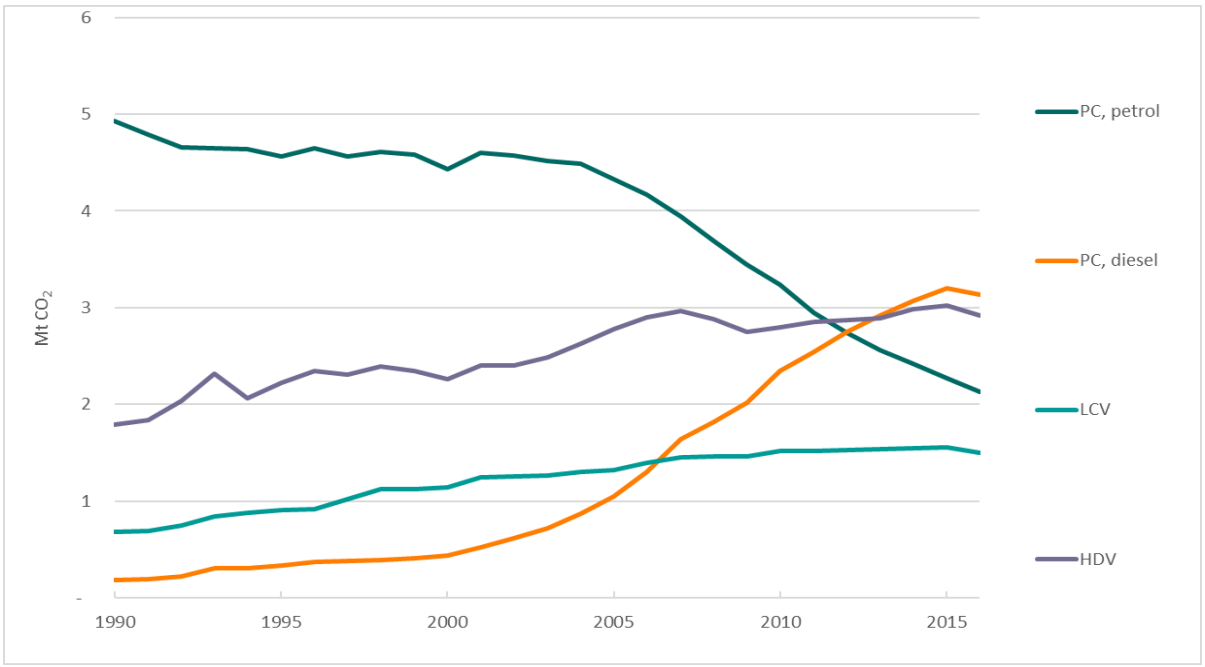


Figure 3.5. Emissions of CO2. PC petrol and diesel, LCV and HDV.
Source: Statistics Norway/Norwegian Environment Agency

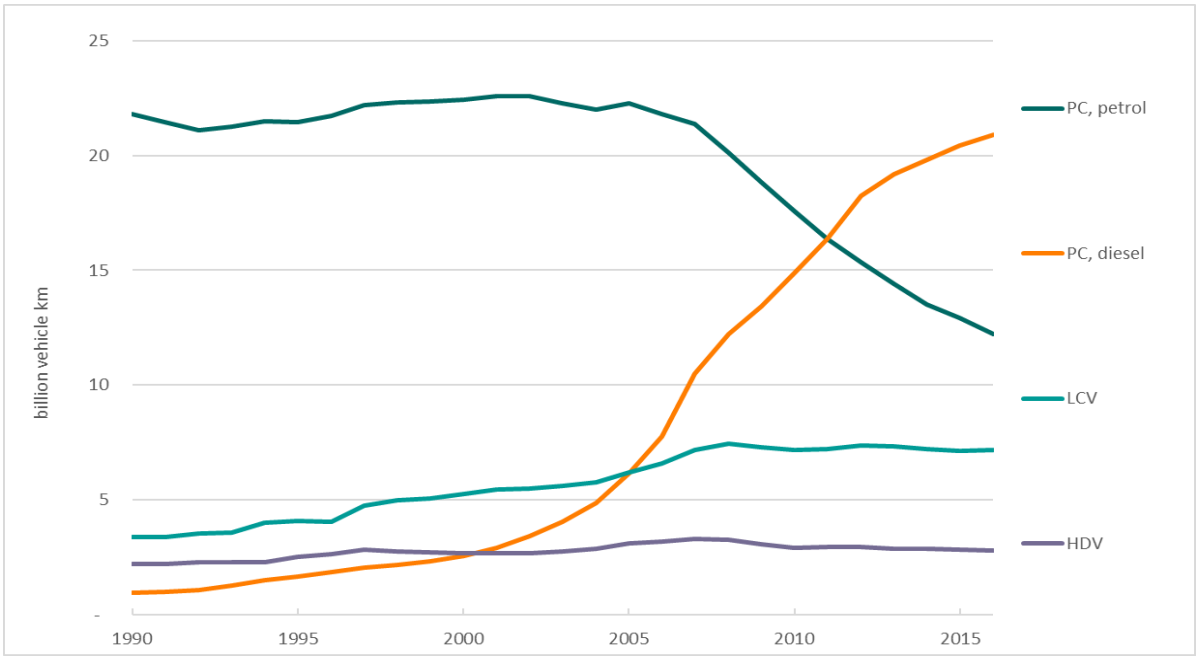


Figure 3.6. Vehicle kilometer. PC petrol and diesel, LCV and HDV.
Source: Statistics Norway/Norwegian Environment Agency

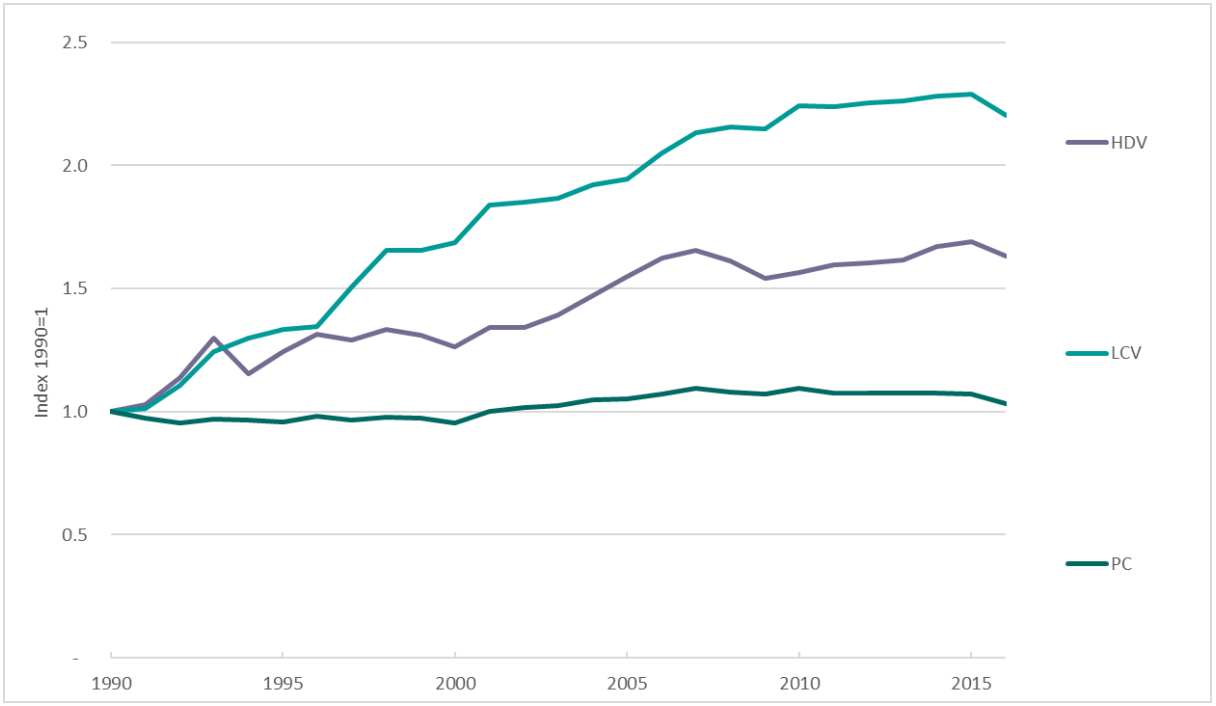


Figure 3.7. Relative change to 1990 in total CO2 emissions from PC, LCV and HDV. Index 1990=1
Source: Statistics Norway/Norwegian Environment Agency

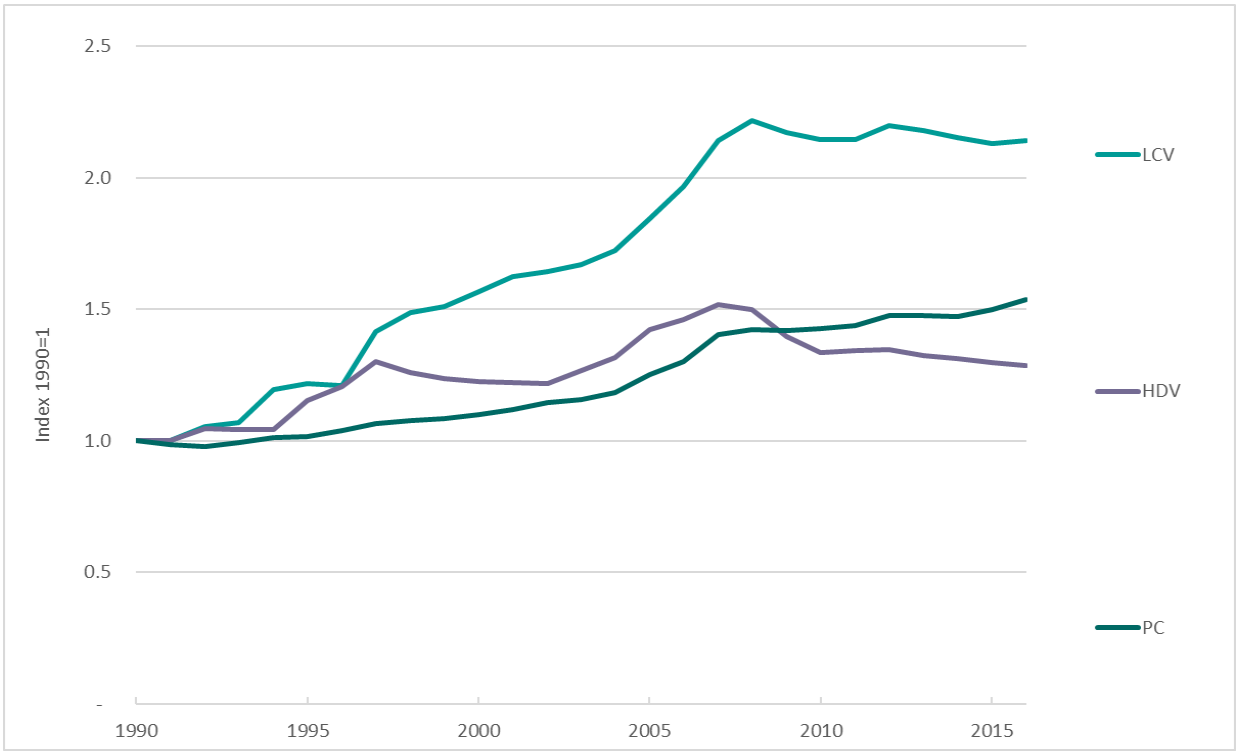


Figure 3.8. Relative change to 1990 in total vehicle km. PC, LCV, HDV. Index 1990=1
Source: Statistics Norway/Norwegian Environment Agency

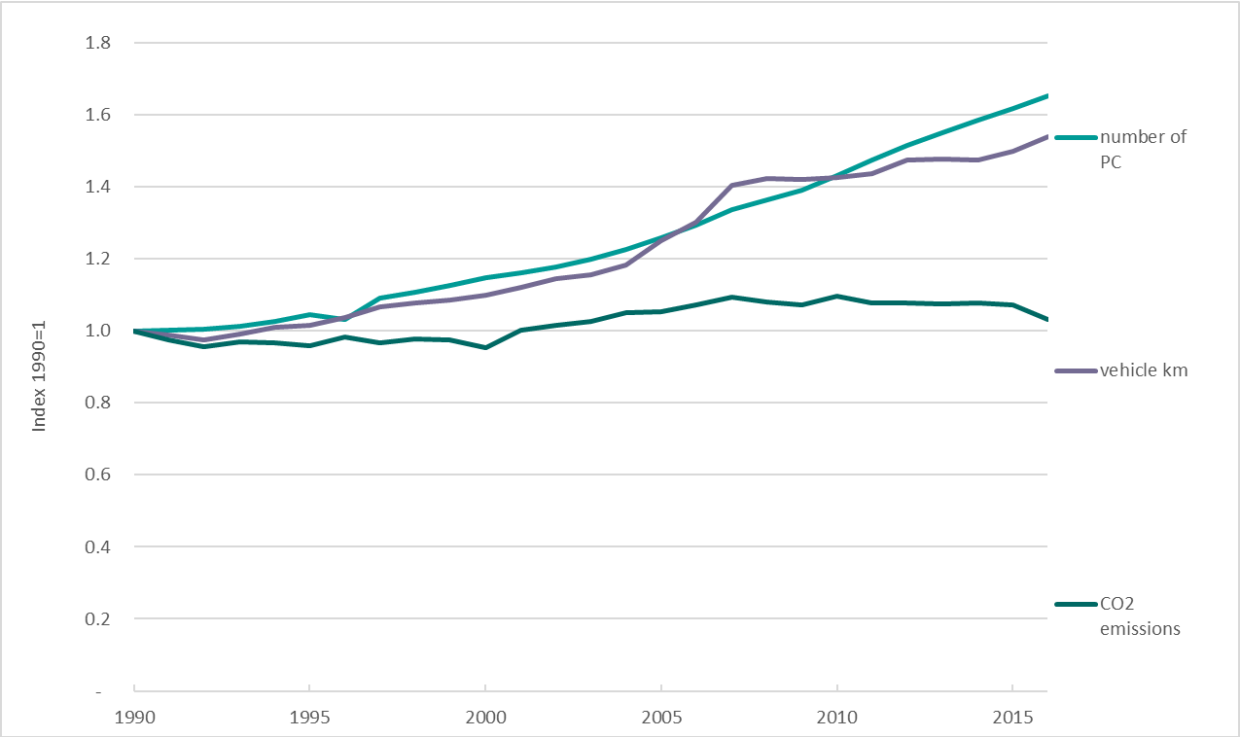


Figure 3.9. Relative change to 1990 in number of passenger cars, CO2 emissions and vehicle kilometers. Index 1990=1. Source: Statistics Norway/Norwegian Environment Agency

3.2.5.1 Methodological issues

Total emissions of CO_2 have been estimated directly from total consumption of each fuel. The consumption of gasoline for road traffic has been 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 has been 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 have been 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 v3.3; INFRAS (2017)).

Estimates of emissions of other pollutants than CO_2 are estimated by the HBEFA model (INFRAS 2017). The model uses a mileage approach:

*Emissions = mileage * emission per km*

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

The HBEFA model provides emission factors and possibilities for calculating emissions for segments and sub-segments for six vehicle classes: 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-6). The segments used for Norway in the HBEFA model are presented in Table 3.14.

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 the amount of driving on roads with slopes ranging from -6 per cent to 6 per cent is specified for each traffic situation.

Hot emission factors are provided on the disaggregated level of sub segments and traffic situations with different gradients, and 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.

Table 3.14. Segments used for Norway in the HBEFA

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

3.2.5.2 Activity data

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

- *Total fuel consumption:* the total amounts of fuels consumed are corrected for off-road use (in boats, snow scooters, motorized equipment, etc.). These corrections are estimated either from assumptions about the number of units, annual operation time, and specific fuel consumption, or from assumptions about and investigations of the fraction of consumption used off-road in each sector. Statistics Norway's sales statistics for petroleum products supplies the data for total fuel consumption (Statistics Norway, Annually). See *Figure 3*.10, which shows the fuel consumption split between fossil petrol and diesel and biofuels (biodiesel and bioethanol). Consumption of biofuels is included in the inventory from 2004. In 2016, 90 per cent of biofuels used was biodiesel and 10 per cent was bioethanol.

- *Number of vehicles*: the number of vehicles in the various categories and age groups is taken from the statistics on registered vehicles, which receives data from the official register of the Norwegian Directorate of Public Roads. The model input is number of vehicles per vehicle class for each inventory year, and the share of vehicles for any given combination of segment and fuel type. This data are combined with information on the introduction of technology classes to provide number of vehicles within each sub segment. The information on introduction of technology classes are for recent years, based on information from the official register of the Norwegian Directorate of Public Roads and on legislation for the years in which the information in the register is insufficient.
  - The HBEFA model distinguishes between two types of buses: urban buses mainly used for urban driving, and coaches, mainly used for rural and motorway driving. Due to lack of specific information to make this split in the national vehicle register, the distinction between urban buses and coaches are based on a methodology used in Sweden (Swedish Environmental Protection Agency 2011), where the split is made based on the ratio *p/w*. Here, *p* is equal to the maximum allowed number of passengers (number of seats plus number of allowed standing passengers), and *w* is equal to the gross vehicle weight. These data are available in 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 2010b). For earlier years, most figures are determined from surveys by Statistics Norway or the Institute of Transport Economics. In some instances, assumptions are needed.
  - The statistics on number of vehicles depict the vehicle fleet per December 31st of the inventory year, while the statistics on mileages represents annual driving for the entire year, including vehicles that have been scrapped or in other ways been in the vehicle fleet for only parts of the inventory year. To adjust for this discrepancy for the years 2005-2016, mean annual

driving lengths for each vehicle category have been adjusted upwards in such a way that the totals correspond to the total annual traffic activity from the statistics on annual driving lengths.

- The average annual mileages vary as a function of age, with older vehicles generally driving shorter annual distances than newer vehicles. The correction of driving as a function of vehicle age is based on odometer readings taken during the roadworthiness test. The functions are calculated as the mean of the years 2005-2016, 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 & 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 (Björketun & 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. Data are allocated by speed limits, road type, area type (urban/ rural), and vehicle size (small/ large). Traffic on municipal roads 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. Data are based on measurements from the Norwegian meteorological institute.

- *Trip length and parking time distributions* are calculated from the Norwegian Travel survey (Vibe 1993). The distributions are given on hourly basis.

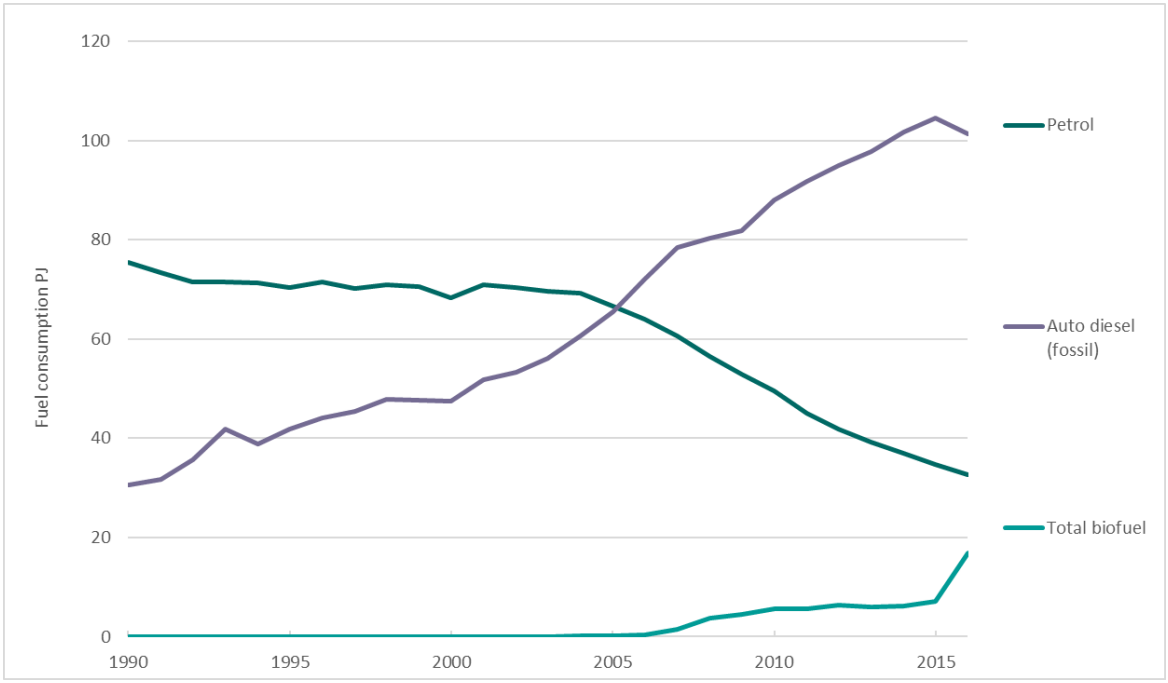


Figure 3.10. Consumption of gasoline, auto diesel and biofuel for road transportation. 1990-2016. PJ
Source: Statistics Norway

3.2.5.3 Emission factors

Emission factors (except CO_2) are taken from the Handbook of Emission Factors (HBEFA; (INFRAS 2017)). Factors are given as emission per vehicle kilometres for detailed combinations of sub segments and traffic situations.

CO_2

Emission factors for CO_2 are given by fuel type in Table 3.4. The factor for fossil motor gasoline is 71.3 tonne CO_2 per TJ, while the factor for auto diesel is 73.55 tonne CO_2 per TJ. The CO_2 factors used for ethanol is 70.84 tonne CO_2 per TJ and for biodiesel 76.86 tonne CO_2 per TJ.

Table 3.15 shows average CO_2 emissions per year and vehicle category, as calculated by the use of HBEFA.

Table 3.15. Average CO_2 emission from different vehicle classes, including cold start emissions and evaporation. 1990-2016. Unit: g/km.

	Motor gasoline				Auto diesel		
	Passenger cars	**Light commercial vehicles**	**Heavy duty vehicles**	**Motorcycles**	**Passenger cars**	**Light commercial vehicles**	**Heavy duty vehicles**
1990	209	184	482	71	189	215	834
1995	208	185	482	72	188	215	837
2000	206	186	482	73	185	216	839
2005	205	186	482	74	181	217	804
2006	203	187	482	76	177	217	820
2007	201	187	482	77	175	216	794
2008	198	188	482	79	172	215	791
2009	196	188	482	81	170	215	775
2010	192	191	482	82	161	217	802
2011	189	191	482	83	160	216	817
2012	187	190	482	84	158	215	810
2013	185	189	483	84	157	213	810
2014	184	187	483	83	156	210	810
2015	182	186	483	82	155	207	812
2016	181	185	483	82	155	205	825

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

CH_4 and N_2O

Table 3.16. General CH_4 and N_2O emission factors from use of natural gas and LPG for passenger cars and heavy duty vehicles.

Source	**Fuel**	**CH_4 kg/TJ**	**N_2O kg/TJ**
Passenger cars	Natural gas	7.36	0.72
	LPG	22.4	0.97
Heavy duty vehicles	Natural gas	689	9.0

Source: HBEFA (INFRAS 2017), COPERT 5, IPCC (2006)

Table 3.17. Average N_2O emission factors from road traffic including cold start emissions and evaporation. 1990-2016. Unit: g/km.

	Motor gasoline				Auto diesel		
	Passenger cars	Other light duty vehicles	Heavy duty vehicles	Motorcycles	Passenger cars	Other light duty vehicles	Heavy duty vehicles
1990	0.0072	0.0068	0.0071	0.0013	0.0000	0.0000	0.0087
1995	0.0075	0.0068	0.0071	0.0013	0.0000	0.0000	0.0088
2000	0.0078	0.0069	0.0071	0.0013	0.0000	0.0000	0.0088
2005	0.0082	0.0072	0.0071	0.0014	0.0000	0.0000	0.0085
2006	0.0086	0.0076	0.0071	0.0014	0.0000	0.0000	0.0087
2007	0.0092	0.0083	0.0071	0.0014	0.0002	0.0004	0.0086
2008	0.0100	0.0090	0.0071	0.0015	0.0006	0.0010	0.0087
2009	0.0102	0.0097	0.0071	0.0015	0.0010	0.0014	0.0085
2010	0.0101	0.0103	0.0071	0.0015	0.0015	0.0020	0.0089
2011	0.0101	0.0108	0.0071	0.0016	0.0020	0.0025	0.0091
2012	0.0101	0.0113	0.0071	0.0016	0.0024	0.0030	0.0089
2013	0.0101	0.0122	0.0071	0.0016	0.0028	0.0033	0.0088
2014	0.0101	0.0131	0.0071	0.0016	0.0032	0.0035	0.0085
2015	0.0098	0.0115	0.0071	0.0015	0.0035	0.0037	0.0080
2016	0.0096	0.0116	0.0071	0.0015	0.0037	0.0038	0.0078

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

Table 3.18. Average CH_4 emission factors from road traffic including cold start emissions and evaporation. 1990-2016. Unit: g/km.

	Motor gasoline				Auto diesel		
	Passenger cars	Other light duty vehicles	Heavy duty vehicles	Motorcycles	Passenger cars	Other light duty vehicles	Heavy duty vehicles
1990	0.1149	0.1143	0.0935	0.2128	0.0065	0.0065	0.0217
1995	0.1106	0.1146	0.0935	0.2094	0.0063	0.0066	0.0220
2000	0.1065	0.1129	0.0935	0.2054	0.0060	0.0066	0.0223
2005	0.1022	0.1092	0.0935	0.1990	0.0056	0.0066	0.0223
2006	0.0972	0.1047	0.0935	0.1918	0.0053	0.0066	0.0214
2007	0.0919	0.0989	0.0935	0.1851	0.0050	0.0063	0.0202
2008	0.0839	0.0925	0.0935	0.1767	0.0047	0.0059	0.0190
2009	0.0774	0.0871	0.0935	0.1720	0.0044	0.0056	0.0172
2010	0.0705	0.0822	0.0935	0.1700	0.0041	0.0053	0.0156
2011	0.0643	0.0770	0.0935	0.1827	0.0038	0.0049	0.0144
2012	0.0588	0.0714	0.0934	0.2041	0.0035	0.0045	0.0134
2013	0.0535	0.0643	0.0934	0.2297	0.0032	0.0041	0.0125
2014	0.0484	0.0584	0.0934	0.2619	0.0028	0.0037	0.0118
2015	0.0438	0.0542	0.0934	0.2850	0.0025	0.0034	0.0110
2016	0.0393	0.0501	0.0934	0.2919	0.0021	0.0030	0.0103

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

NO_2 from gasoline fuelled PC: The N_2O EF in the HBEFA is from the COPERT IV model. In addition to the "normal" reduction of the EF according to the Euro-classes, the N_2O EF is influenced by the sulphur content. Indeed, a lower sulphur content of gasoline leads to a reduced deactivation of the catalyst and reduced N_2O formation. This finding is backed up by several international peer-reviewed papers.

The sulphur content in petrol was 0.3 per cent in 2004 and 0.05 per cent in 2005. This sharp drop in sulphur content explains the decrease in N_2O EF between 2004 and 2005. See Table 3.17. Similar development in the N_2O EF can also be seen in countries, which also use the HBEFA model, e.g. Switzerland and Sweden.

CH_4 and N_2O from biofuels/biomass in road transport

In the inventory, the same emission factors for CH_4 and N_2O are used for biofuels as for corresponding fossil fuels. Thus, the average IEF for biomass in road transport is a function of the fractions of ethanol and biodiesel in the biofuel mix. Initially, the small biofuel amounts were almost exlusively biodiesel, but in recent years ethanol has had a growing share of the mix.

3.2.5.4 Uncertainties and time series consistency

The uncertainty in the activity data and the CO_2 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_4 and N_2O, 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.

The total consumption of petrol and auto diesel, and hence the CO_2 emissions from these fuels, are well known. The uncertainty for petrol is related to allocation to non-road use, while the uncertainty connected to consumption of auto diesel in road traffic is the share illegal use diesel without road tax.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category. The data quality is generally better for the latter part of the time series.

3.2.5.5 Category-specific QA/QC and verification

The comparison of bottom-up estimates of fuel consumption from HBEFA with total sales (category-specific QA/QC) reveals a discrepancy of 5-15 per cent. This is deemed to be a reasonable difference. This discrepancy is handled differently for different emission components. The total consumption of each type of fuel is the most important parameter in relation to the reporting requirements of the UNFCCC, as this forms the basis for the calculation of CO_2 from road traffic. One kilogram of gasoline or auto diesel yields a fixed amount of CO_2 irrespective of vehicle type.

The methodology used for calculating N_2O and CH_4 emissions from road transport has been discussed in previous reviews. Emissions are calculated based on vehicle kilometres driven and not by fuel consumption. Calculations of CH_4, N_2O and many other components reported to CLRTAP (e.g. NO_X and particulates), depends on more detailed information about vehicle types and driving patterns, and thus, a more detailed model (for example HBEFA) should be applied. The relationship between emissions and fuel consumption must be considered differently for the emission components that depends directly on the composition and quantity of fuel (CO_2, SO_2 and heavy metals) and those who,

to a larger extent, depend on the type of vehicle and driving mode (e.g. NO_x, CH_4, N_2O, NH_3, CO, particles).

Fuel consumption is not an input to HBEFA, where emissions are calculated based on mileage and number of vehicles in each sub-segment of vehicle classes, as well as other data sets, such as cold start and age distribution of mileage. Fuel consumption is however calculated in the model similarly to emission calculations. The estimated fuel consumption for the country as a whole can be compared with fuel sales from statistics on deliveries of petroleum products and the energy balance. The comparison shows that the fuel consumption calculated in HBEFA are systematically lower than the fuel in the energy balance, and that the difference is greater for auto diesel than for petrol. The difference has been between approximately 1 and 10 per cent for gasoline, and 4 and 15 per cent for diesel in the reporting period. Exceptions are 1990 and 1991 for auto diesel when the difference was very small, and 1993, when the difference was almost 30 per cent. There is no obvious increasing or decreasing trend in the deviations, but there seems to be a correlation between the deviation of petrol and diesel.

It is not known why there is a discrepancy between the consumption of energy balance and bottom-up calculations in HBEFA, but there are several possible explanations as to why fuel sold does not match the fuel consumption calculated from road transport emission model:

1. *Fuel purchased by foreign vehicles:* Foreign vehicles is not included in the vehicle register statistics, even though they drive on Norwegian roads. Similarly, no fuel bought by Norwegian vehicles abroad is sampled. It is likely that there is no systematic "fuel tourism" across the Norwegian border, as there are no significant price differences between fuel prices in Norway and Sweden. The current calculations are based on the assumption that driving in Norway by foreign vehicles equals the driving of Norwegian vehicles abroad.
2. *Vehicles drive longer in reality than what the model calculates:* Seeing as the Technical Inspection of vehicles is a new data source for mileage, it is hard to imagine that mileages in the model are systematically underestimated. Motorcycles do not have such a Technical Inspection. They can however not explain the discrepancy between the calculated and the amount of fuel sold. For example, they mostly run on gasoline, while the largest deviation is within auto diesel.
3. *Driving patterns:* There may be elements in the driving patterns that cause fuel consumption per kilometre per vehicle to be higher than what the model calculates. One possible reason here is that the fuel consumptions stated in the vehicle type approvals are used as part of the input to the model, and there is an ongoing discussion about whether these systematically underestimates consumption. These data are however available only for the latter part of the series, and cannot explain the discrepancies in the 1990s.
4. *Non-road use:* The allocation of fuels to non-road use is associated with some uncertainty.

Whether the emission calculations should be corrected for differences in fuel consumption depends on the pollutants in questions. For those components that are directly dependent on the amount of fuel (CO_2, SO_2, heavy metals), it will always be appropriate to use the fuel consumption from the energy balance as a basis for calculation. For the other emission components, the decision on whether to correct for total fuel consumption or not will depend on what is causing the discrepancy between fuel consumption calculated in the model and fuel consumption in the energy balance. If the reason is that the total mileage is underestimated in the model, and that the energy balance

represents a "truer" picture of the consumption of fuels, emissions should be corrected. If the discrepancy, however, is due to an underestimation of the fuel consumption per kilometre, the emission estimates should not be corrected unless one finds a clear correlation between changes in consumption per kilometre and emissions per kilometre for the relevant emission components. As long as the reason for the discrepancy stay unknown, an assessment of data quality in the various input data is crucial to determining whether emissions should be reconciled against fuel sales or not.

In the previous road transport emission model (SFT 1993), (SFT 1999d), the emissions of all substances were corrected to account for the discrepancy between the energy balance and the model calculations, because the energy balance was considered the most secure data source. When HBEFA was introduced as the computational model, a new data source was also introduced, namely the mileage statistics at Statistics Norway. These statistics are based on data from periodical technical inspections, and goes back to 2005. This important new data source is considered to be of good quality, and it has changed the assessment of whether the emissions shall be corrected for the consumption of energy balance or not. There is no reason to believe that the total driving lengths are underestimated, and we consider it likely, that the reason for the discrepancy lies in the estimates of fuel consumption per kilometer. The energy balance is based on the assessment that Norwegian purchases abroad correspond to foreign purchases in Norway, and the same assessment is applied to the emissions calculations. We have not found any reason to believe that the reasons for the discrepancies in fuel consumption are directly correlated with driving behaviour. It has therefore been assessed that HBEFA estimates of pollutants that are not directly related to fuel consumption should not be reconciled with fuel consumption.

There are currently no comprehensive statistics on foreign vehicles driving in Norway. One possible explanation for the discrepancy between the calculated fuel consumption in HBEFA and sold quantity of fuel is that foreign driving in Norway exceeds Norwegian of vehicles driving abroad. There has been an issue that the proportion of heavy vehicles with foreign vehicles increases. However, we see no clear increasing trend in the difference between the model results and sales. Better data related to foreign driving in Norway and the Norwegian driving vehicles abroad would strengthen or refute the current assumption that these two balance each other out.

3.2.5.6 Category-specific recalculations

1A3bi-iv Road transport

- Accuracy. Revised emission factors. A revised version of the Handbook of Emission Factors (HBEFA) has been taken into use. The new version contains updated factors for emissions of nitrogen oxides from new diesel cars (Euro 4 and higher). The update has resulted in significantly higher emissions of nitrogen oxides from personal cars (1A3bi), and also minor changes in emission of methane and nitrous oxide. The revision also affects emissions from military vehicles reported in 1A5b.
- Reallocation. The revised version of HBEFA also result in reallocation of CO_2 emissions from category 1A3bi to the categories 1A3bii-iv for the years 2007 to 2015. The relative changes in the emissions are small, below one per cent for 1A3bi-iii, and below three per cent for 1A3biv.

3.2.5.7 Category-specific planned improvements

The emission estimation methodology for this source category is currently undergoing improvement, see table 10.9.

Activity data for LPG will be revised as part of the implementation of new energy balance.

3.2.6 Transport – Railways, 1A3c

3.2.6.1 Description

Railway traffic in Norway uses mainly electricity (auto diesel is used at a small number of lines, for shunting etc.). There is also a minor consumption of coal in museum railways. In 2016, GHG emissions from this source category accounted for 0.4 per cent of the total emissions from transport. Emissions from railways decreased by 52.5 per cent from 1990 to 2016.

3.2.6.2 Methodological issues

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

3.2.6.3 Activity data

Consumption figures for auto diesel used in locomotives are collected annually from the Norwegian State Railways. Consumption of coal is estimated based on information from different museum railways; the same figure is used for all years from 1990.

3.2.6.4 Emission factors

The emission factors used in this source category are displayed in Table 3.4 for CO_2 and Table 3.20 for CH_4 and N_2O.

General emission factors for coal are used in the calculations.

3.2.6.5 Uncertainties and time series consistency

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

A general assessment of time series consistency has not revealed any inconsistencies in the emission estimates for this category, but there is, as described in section **Feil! Fant ikke referansekilden.**, differences before and after 1998 in results from QA/QC checks.

3.2.6.6 Category-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 Category-specific recalculations

There have been no recalculations performed for this source category this year.

3.2.6.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.2.7 Transport – Navigation, 1A3d (Key category for CO_2 and CH_4)

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 3.2.10.

Greenhouse gas emissions from navigation constituted 3.2 per cent of the national GHG total in 2016 and 13.2 per cent of emissions from transport. Emissions from shipping have decreased by 0.7 per cent from 1990 to 2016. From 1990 to 2016, the average annual decrease in GHG emissions from navigation was 0.03 per cent. Between 1990-1999 and 1999-2016, the annual average growth were 4.7 and -2.4 per cent, respectively. The increased emissions in the 90ies can, to a large extent, be explained by the growing activity in the oil and gas sector in general but especially by the fast growing production of crude oil and hence the increasing demand for ships transporting the oil from the oil fields to land. Due to the decreasing production of crude oil since 2001, the demand for transport of crude oil has been reduced. Nevertheless, this reduction has been counteracted by growth in demand in other segments of transport.

Navigation is a key category with respect to CO_2 emissions in level both in 1990 and in 2016 and, for CH_4, in level in 2016 and 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 energy industries (CRF 1A1) described in section 3.2.2 and navigation: Emissions from drilling are reported under energy industries 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 3.7.1.2), in accordance with the IPCC guidelines (IPCC 2006).

Annual emissions are estimated from sales of fuel in domestic shipping, using average emission factors in the calculations.

For 1993 and 1998, (Tornsjø 2001), 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 give figures on the use of marine gas oil, heavy distillates and heavy fuel oil in domestic navigation. Information on fuel used in the ship categories in the bottom-up analysis is mainly given by data from the Business Sector's NO_x-fund for 2007 and by earlier Statistics Norway analyses for 1993 and 1998 (Tornsjø 2001), and 2004. Data on fuel consumed by public road ferries are available from the Directorate of Public Roads.

Fuel sales to the oil and gas extraction sector includes stationary and mobile consumption at offshore facilities as well as comsumption at supply ships and other supporting vessels. These sales asplit between navigation and energy industries. Information on use for drilling, stationary combustion etc., has been taken from the oil companies' reports to the Norwegian Environment Agency and the Norwegian Petroleum Directorate. These reports are found in *EPIM Environment Hub,* a database operated by the Norwegian Oil Industry Association (OLF), Norwegian Petroleum Directorate and the Norwegian Environment Agency. Consumption for these activities is reported under Energy industries (CRF 1A1c-ii). Only the remaining part of sales, assumed to be for drilling rigs during transit, supply ships, etc., is included with Navigation.

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_2

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

- Marine gas oil/diesel and special distillate: 73.55 tonne per TJ
- Heavy fuel oil: 78.82 tonne per TJ

CH_4 and N_2O

For liquid fuels, the general/standard emission factors for CH_4 and N_2O used in the emission inventory are taken from IPCC/OECD: 0.23 kg CH_4/tonne fuel and 0.08 kg N_2O/tonne fuel.

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

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

Some natural gas is combusted in ferry transportation and offshore supply; the CH_4 emission factors used are based on the emission factors in

Table 3.19. 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 3.19. Methane emission factors for vessels using LNG as fuel gas

Vessel category	Methane emission factor (kg CH_4 /tonne LNG)	Methane emission factor (kg CH_4/ TJ)
Ferry (currently lean burn engines only)	44	917
Offshore supply (Currently dual fuel engines only)	80	1668

Source: MARINTEK (2010), and estimations from Statistics Norway

The IPCC factor for N_2O from liquid fuels is also used for LNG.

3.2.7.5 Uncertainties and time series consistency

An important source of uncertainty is assumed to be estimation of fuel used by fishing vessels. There is also an uncertainty connected to the fuel use for other domestic sea traffic due to uncertainty in the sale statistics for petroleum products. Important sources of uncertainty are also delimitation of national sea traffic and the emission factors.

The uncertainty in the activity data for navigation is assessed to be ±20 per cent. With regard to emission factors the uncertainty for ships and fishing vessels is ±3 per cent of the mean for CO_2. For CH_4 and N_2O the corresponding uncertainties lie in the ranges -50 to +100 and -66 to +200 (see also Annex II).

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

3.2.7.6 Category-specific QA/QC and verification

As mentioned, emission estimates for ships have been made bottom-up for 1993 and 1998 (Tornsjø 2001) 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 data sales 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 has not 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 Category-specific recalculations

There have been no recalculations performed for this source category this year.

3.2.7.8 Category-specific 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 pollutants from ships to sea. The Norwegian Environment Agency was co-financing the project. In 2015 the delimitation of activities was improved in order to correspond better to definitions in the inventory. A project in collaboration with Statistics

Norway and the Norwegian Coastal Administration is currently looking into how these analyses can be used to improve or verify the inventory for navigation.

3.2.8 Transport – Other transportation, 1A3e

3.2.8.1 Description

In old submissions, this source category included emissions from motorized equipment. Since the previous submission, emissions have been reported under the accurate sectors according to the guidelines (IPCC 2006) i.e., CRF 1A2, 1A4 and 1A5.

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. For the integrated facilities, the total CO_2 emissions from each facility are reported under the ETS system and are of high quality. The emissions might be split into production and transport using surrogate data, but the accuracy for the two fractions would be much lower than for the total. As a consequence, all emissions from pipelines have been reported under 1A1 Energy Industries.

3.2.9 Motorized equipment (incl. in 1A2, 1A4 and 1A5)

3.2.9.1 Description

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 estimated using a common methodology but are reported under several source categories:

- Manufacturing and construction: IPPC 1A2g-vii
- Commercial and institutional: IPPC 1A4a-ii
- Households: IPPC 1A4b-ii
- Agriculture/Forestry/Fishing: IPCC 1A4c-ii
- Military: IPCC 1A5b

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

3.2.9.2 Methodological issues

Emissions are estimated through the general methodology described in section 3.2.1.1, involving consumption figures and appropriate emission factors.

3.2.9.3 Activity data

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

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

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

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

Consumption of *auto diesel* is based on data from the energy balance. Auto diesel used in off road vehicles has no road tax from 1993. Total use of auto diesel in motorized equipment is given as the difference between total sales tax free diesel and estimated use for railway transportation. It is important to bear in mind that the total consumption of auto diesel in motorized equipment from 1993 is considered being of good quality since, there is from 1993, no road tax on this part of the auto diesel. Auto diesel used for motorized equipment is, as well as for road traffic, subject to CO_2 tax.

3.2.9.4 Emission factors

The emission factors used are presented in Table 3.20 and Table 3.21.

Emission factors for tractors have been used for tax-free auto diesel consumption in agriculture and forestry, while emission factors for construction machinery have been used for tax-free auto diesel consumption in all other industries and households.

The emission factors used in the emission model are calculated from the basic factors in Winther and Nielsen (2006), weighted by the age and engine rating distribution of the tractor and construction machinery populations, as well as assumptions on motor load and operating hours and the introduction scheme for emission regulations by the EU (Stage I, II, III and IV).

Emission factors for snow scooters are adapted from the factors for mopeds and motorcycles in the road traffic emission model.

Table 3.20. General emission factors for other mobile sources.

Source	Fuel	CH_4 kg/TJ	N_2O kg/TJ
Railway	Auto diesel	4.18	27.84
	Coal	9.96	1.82
Small boats 2 stroke	Motor gasoline	116.17	0.46
Small boats 4 stroke	Motor gasoline	38.72	1.82
	Auto diesel	4.18	0.70
Motorized equipment 2 stroke	Motor gasoline	**136.67**	0.46
Motorized equipment 4 stroke	Motor gasoline	**50.11**	**1.59**
	Auto diesel	**3.94**	3.23
	Light fuel oils	3.94	3.23

Snow scooters have the same emission factors as those for Mopeds, see Table 3.17 and Table 3.18

Bold figures have exceptions for some sectors, see Table 3.21.

Sources: Bang (1993), (SFT 1999d) and Statistics Norway (2014b)

Table 3.21. Exceptions from the general factors for greenhouse gases and precursors for other mobile sources.

Component	Emission factor (kg/TJ)	Fuel	Source	Sectors
CH_4	141.23	Motor gasoline	Motorized equipment 2 stroke	Agriculture
CH_4	84.28	Motor gasoline	Motorized equipment 4 stroke	Agriculture
CH_4	178.65	Motor gasoline	Motorized equipment 2 stroke	Forestry and logging
CH_4	187.94	Motor gasoline	Motorized equipment 2 stroke	Private households
CH_4	127.61	Motor gasoline	Motorized equipment 4 stroke	Private households
CH_4	4.18	Auto diesel	Motorized equipment 4 stroke	Private households
N_2O	3.06	Auto diesel	Motorized equipment 4 stroke	Agriculture and forestry
N_2O	1.86	Motor gasoline	Motorized equipment 4 stroke	Agriculture and forestry, Fishing, Energy sectors, Mining/Manufacturing

Sources: Bang (1993), (SFT 1999d) and Statistics Norway (2002)

3.2.9.5 Uncertainties and time series consistency

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).

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

3.2.9.6 Category-specific QA/QC and verification

There is no category-specific QA/QC procedure for this sector. For a description of the general QA/QC procedure (see Section 1.2.3).

3.2.9.7 Category-specific recalculations

Recalculations (if any) are described in sections 3.2.4.7 (1A2) and 3.2.10.6 (1A4) and in chapter 10.

3.2.9.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.2.10 Other Sectors, 1A4 (Key category for CO_2 and CH_4)

3.2.10.1 Description

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

In 2016, fuel combustion in agriculture, forestry and fisheries accounts for 44 per cent of the emissions of this source category. In 2016, the emissions from the whole sector amounted to 3.5 million tonnes CO_2-equivalents and constitute of 6.5 per cent of national total GHG. The sectors emissions decreased by 25.4 per cent from 1990 to 2016. Throughout the period 1990-2016, emissions have fluctuated although with a decreasing trend. The low decreasing trend is mainly due to reduced consumption of fuel oil in the commercial, institutional and households sectors.

According to the Aproach 2 key category analysis for 1990 and 2016, this sector is, in conjunction with sectors 1A1 and 1A2, a key category with respect to:

- Emissions of CO_2 from the combustion of liquid fuels, gaseous fuels and other fuels in level in 1990 and 2016, and trend
- Emissions of CH_4 from the combustion of biomass in level in 1990 and 2016.
- Emissions of CH_4 from the combustion of gaseous fuels in level in 2016 and in trend

This sector is also an Approach 2 key category with respect to CO_2 emissions in mobile fuel combustion in level in 1990 and 2016.

In addition to source categories defined as key categories according to the Approach 2 key category analysis, this sector is, in conjunction with sectors 1A1 and 1A4, defined as key according to Approach 1 key category analysis with respect to emissions of CO_2 from combustion of solid fuels.

3.2.10.2 Activity data

Motorized equipment

Activity data are as described in section 3.2.9.

Households

Use of wood in households for the years from 2005 to 2011 and after 2013 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. For the periode 2005 to 2011 the figure used in the emission calculations is the average of 5 quarterly surveys. Since 2013 the figure used in the emission calculations is the average of 3 quarterly surveys. For the years before 2005 and for 2012, figures are based on the amount of wood burnt 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 has been replaced by imports from abroad. Figures for LPG have been collected from the suppliers. Heavy fuel oil data have been taken from the sales statistics for petroleum products. As the consumption of each energy carrier shall balance against the total sales in the sales statistics, use of fuel oil, kerosene and heavy distillates in households is given as the residual after consumption in all other sectors has been assessed. Use of natural gas has been based on sales figures reported to Statistics Norway from the distributors.

Agriculture

Data on energy use in hothouses are collected in surveys performed regularly. Sales figures are used to project the figures for consumption of oil products in the years between. For biofuels and LPG, figures are interpolated for years not included in surveys. The Agricultural Budgeting Board has figures on the use of gasoline, auto diesel and fuel oil in agriculture excluding hothouses. A figure on the minor use of coal was previously collected annually from the only consumer. Since 2002, however, there has been no use of coal in the Norwegian agricultural activities. Use of natural gas in agriculture, which has increased considerably since it first was registered in 2003, is based on sales figures reported to Statistics Norway from the distributors.

Fishing

Figures on the use of marine gas oil, heavy distillate and heavy fuel oil are identical with the registered sales to fishing vessels in the sales statistics for petroleum products. In addition to these figures on use in large fishing vessels, a minor figure on estimated use of gasoline in small fishing boats is also included.

Commercial and institutional sectors

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

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

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

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

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

3.2.10.3 Emission factor

The emission factors used in this source category are presented in sections 3.2.1.3 and 3.2.9.4.

3.2.10.4 Uncertainties

Uncertainty in *fishing* is described together with navigation in section 3.2.7.

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 has also been necessary to adjust figures for other sectors in order to get consumption figures for households that look reasonable. Hopefully, new surveys will improve the quality of these figures in the future.

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

The uncertainty in the activity data for this source category is ±20 per cent of the mean for solid and liquid fuels, and ±30 per cent of the mean for biomass and waste (see Annex II).

3.2.10.5 Category-specific QA/QC and verification

There is no category-specific QA/QC procedure for this sector. For a description of the general QA/QC procedure (see section 1.2.3).

3.2.10.6 Category-specific recalculations

1A4b Residential

- Accuracy. Country specific emission factor for emissions of N_2O from residential wood burning has replaced the general emission factor from IPCC 2006 Guidelines. This has decreased N_2O emissions for all years, ranging from 54 to 59 tonnes annually.
- Consistency. Emission factor for CH_4 from charcoal has been changed from 6 to 5.9, in accordance with the factor used for manufacturing industries. Causes marginal emission reductions.

3.2.10.7 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.2.11 Other emissions from energy combustion, 1A5

This source includes emissions from fuel use in military stationary and mobile activities, and the use of lubricants in mobile combustion.

3.2.11.1 Description

Military

Emissions of CO_2 from the other mobile sub-sector (1A5b) appear to be a key category according to approach 1 key source analysis.

Emissions from non-fuel use of liquid fuels

In the energy balance, small amounts of gasoline, autodiesel and residual fuel oil is reported as used for non-fuel purposes. A fraction of this consumption is estimated to result in emissions to air, while the remaing fractions remain in products or enter waste streams.

Lubricants in mobile combustion

Two-stroke petrol engines are lubricated by adding oil to the petrol. The oil is thus combusted, and converts to CO_2. As lubricant, oil in two-stroke petrol is not included in the Norwegian energy statistics, a separate estimation must be performed in order to obtain completeness.

3.2.11.2 Activity data and Emission factors

Military

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. Emission factors used for stationary activities are presented in section 3.2.1.3 and emission factors used for mobile activities are presented in the corresponding transport sectors (see sections 3.2.4 to 3.2.9). The stationary and mobile emissions from the Norwegian military activities for the years 1990-2016 are presented in Table 3.22.

Table 3.22. Stationary and mobile emissions from military activities. 1990-2016.
CO_2 in 1000 tonnes, CH_4 and N_2O in tonnes

	1A5a Military – stationary			1A5b Military – mobile		
	CO_2	***CH_4***	***N_2O***	***CO_2***	***CH_4***	***N_2O***
1990	62.45	8.49	0.51	393.74	15.20	12.06
1995	48.06	6.75	0.43	406.12	11.24	12.55
2000	40.63	5.62	0.35	137.53	7.54	4.14
2005	54.36	7.39	0.44	240.55	12.63	6.78
2010	36.82	8.28	1.46	229.64	73.96	6.88
2011	29.95	6.97	1.24	211.59	71.76	6.35
2012	23.91	5.49	1.05	235.89	80.12	6.97
2013	19.83	4.44	0.86	245.79	126.06	7.28
2014	14.22	2.34	0.31	240.11	165.21	7.17
2015	13.64	2.20	0.28	214.25	126.62	6.37
2016	13.93	2.24	0.29	230.37	126.79	6.88

Sources: Statistics Norway

Emissions from non-fuel use of liquid fuels

Activity data: Total non-fuel domestic consumption of fuel oils was obtained from the Norwegian energy balance. The quality of the data is mixed throughout the time series. Annual surveys of feedstock use were performed for 1993-2001. For 2002 a different type of survey was used. Results from this survey are used for 2002-2009. For 2010 new estimates were made based on expenditure

data, and these results have been used for subsequent years. The changes in method have led to breaks in the time series.

In this inventory, no attempt has been made to splice the different methods in the energy balance.

In addition to gas/diesel oil, gasoline and residual fuel oil has been recorded earlier in the time series.

Times series for the non-fuel use of these fuels are given in section 3.6.3 on feedstocks etc.

Fraction emitted: Gas/diesel oil and gasoline: 0.5, and residual oil: 0.11.

Emission factors: General emission factors for liquid fuels were obtained from Table 3.4, Table 3.8 and Table 3.9. The selected factors are 3 kg CH_4/TJ and 0,6 kg N_2O/TJ.

Lubricants in mobile combustion

The amount of combusted lubricant oil is proportionate to the consumed two-stroke petrol. The blend ratio is assumed to be falling linearly from 3 per cent in 1990 to 2 per cent in 2012, based on Internet search (retailers and discussion fora 2014, pages in Norwegian only). Parts of the two-stroke petrol are blended abroad (petrol retailers pers. comm., 2014), and the estimated CO_2 emission from this lubricant oil is hence included in the emission estimates for petrol. The share being blended abroad is not known, and is assumed to be 50 per cent.

The amount of oil giving emissions not already accounted for is estimated by multiplying the two-stroke petrol consumption by the oil blend ratio and the share of petrol being blended in Norway:

$$E = A \times R \times D \quad (3.4)$$

where:

E *= emission*

A *= consumed two-stroke petrol*

R *= blend ratio (oil:petrol)*

D *= share of two-stroke petrol being blended domestically*

CH_4 and N_2O

The conversion from tonnes of consumed lubricant to tonnes of emitted CO_2, is performed based on IPCC default factors for energy content (NCV) and carbon content per unit of energy.

Table 3.23. Conversion factors used to estimate CO_2 emissions.

Factor	Value	Unit
Net calorific value (*NCV*)	0.0402	TJ/tonne
Carbon content (*CC*)	20	Tonne C/TJ

Source : IPCC (2006)

N_2O and CH_4 emissions have been estimated as fixed fractions of the CO_2 emission, based on IPCC default factors.

Table 3.24. Conversion factors used to estimate CH_4 and N_2O emissions.

Factor	Value	Unit
CH_4	0.00286	Tonne CO_2 eq/tonne CO_2 emitted
N_2O	0.00254	Tonne CO_2 eq/tonne CO_2 emitted

Source : IPCC (2006)

3.2.11.3 Uncertainties

Military

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

Lubricants in mobile combustion

The uncertainty in the emissions estimate from lubricant use in two-stroke petrol engines is assumed to be moderate. The total consumption of gasoline is well known, while the amount going to two-stroke petrol engines is estimated. The uncertainty in the activity data is assumed to be 20 per cent, based on the uncertainty in the road traffic estimation (see section 3.2.5). The uncertainty of the carbon content is an IPCC default value, and the NCV uncertainty is assumed to be equally large. Based on these uncertainties, the overall uncertainty of the emissions from lubricating oil used in two-stroke petrol engines is estimated to be 30 per cent.

3.2.11.4 Category-specific recalculations

1A5b Military

- Accuracy. Revised emission factors for military road traffic – see description under 1A3b above.

3.2.11.5 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.3 Fugitive Emissions from Coal Mining and Handling, 1B1a (Key category for CH_4)

3.3.1 Description

Coal has been shipped from Svalbard since 1907. There were in 2016 two coal mines at Spitsbergen (the largest island in the Svalbard archipelago) operated by a Norwegian company and from 2017 it is only one Norwegian mine left. The second mine was opened 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 and included in the Norwegian greenhouse gas inventory. Until 1998, there was production in two Russian coal mines, Barentsburg and Pyramiden, but since then, production takes place only in the Barentsburg mine. The Norwegian mines and Pyramiden are defined as surface mines, whereas Barentsburg is an underground mine.

Abandoned underground mines is included in the inventory. The emissions is reduced from about 10,600 tonne in 1990 to 5,500 tonne CO_2 in 2016 that is a decrease of 48 per cent.

In 2005 there was a fire in one of the Norwegian coal mines and this caused that the production was almost halved from 2004 to 2005 as Figure 3.*11* illustrates it. The emissions from this fire are included in the inventory. The CO_2 emissions from the fire are estimated to approximately 3,000 tonne.

Russian production has since 2001 been considerably smaller than the production in the Norwegian mines. In 2008 a fire started in the Russian mine at Barentsburg. Shortly after the fire started, the mine was filled with water and hence there were no significant emissions from the fire. This is the reason why emissions from the fire are not estimated. The production in 2008 and 2009 was therefore very small. In autumn 2010, ordinary production was restarted. Russian activity data are more uncertain than the Norwegian, which causes a correspondingly higher uncertainty in the emission figures.

At Svalbard there were a smouldering fire in the mine Pyramiden, the Russian mine that was closed down in 1998. At an inspection in 2005, no emissions were registered, which indicates that the fire had 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.

Emissions from NMVOC and particles from handling of coal are included.

Figure 3.*11* shows that the production of coal at Svalbard has increased 8 per cent from 1990 to 2016. There was a peak in the production in 2007 when the production was nearly five times higher than in 1990. The production increased 80 per cent from 2000 to 2001 due to the start up of a new Norwegian mine. The production of coal was 27 per cent lower in 2016 than in 2015. It is the production from the Norwegian surface mines that was reduced by 30 per cent. This was due to that the mines were preliminary stopped this year. In 2017 the Norwegian government decided to close down one of the mines permanently.

The emissions from mining were in 2016 estimated to 38,000 tonnes CO_2 equivalents. The emissions decreased by 13 per cent from 2015 and 2016. Total production of coal in 2016 was 1.0 million tonne.

CH_4 from coal mining is defined as key category according to Approach 2 in both level and trend and only in trend according to Approach 1.

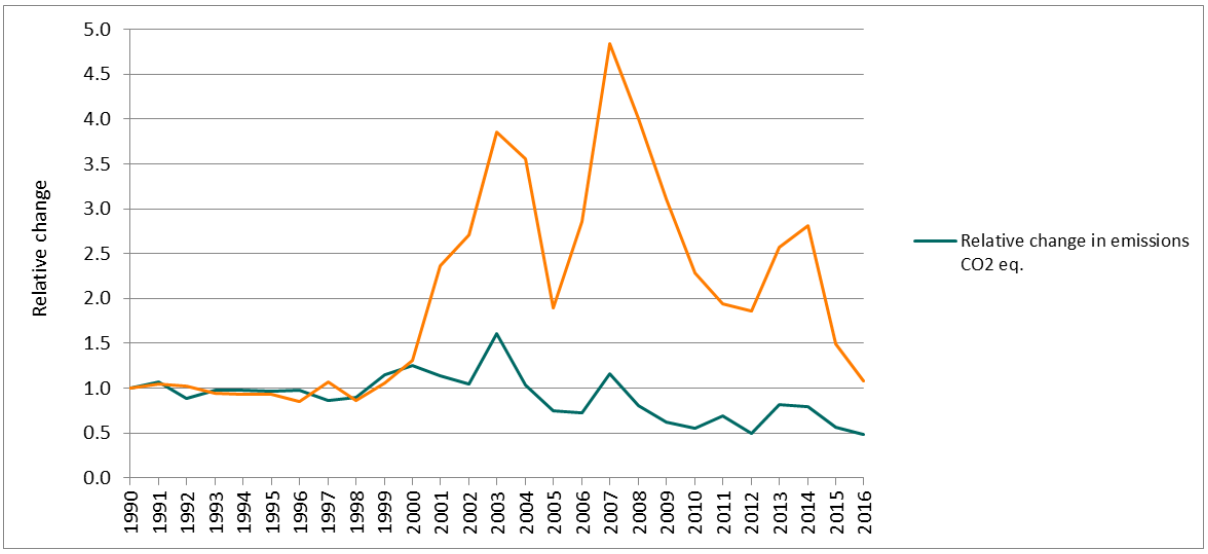


Figure 3.11. Coal productions in Norway excluded abandoned underground mines. 1990-2016. Relative change in production and GHG emissions. 1990=1.
Source: Statistics Norway/Norwegian Environment Agency

3.3.2 Methodological issues

CO_2

Indirect CO_2 emissions from methane and NMVOC oxidized in the atmosphere are calculated by multiplying the calculated CH_4 and NMVOC emissions with, respectively, the factors 2.75 tonne CO_2 per tonne CH_4 and 2.2 tonne CO_2 per tonne NMVOC. (see Chapter 9 for more information about indirect CO_2).

CH_4

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

NMVOC

NMVOC emissions from handling of coal are estimated by multiplying the amount of coal extracted (raw coal production) with Tier 2 emission factors from EMEP/EEA Guidebook (2013).

Abandoned underground mines

Methane emissions from abandoned underground mines have been calculated with a Tier 1 methodology from the 2006 IPCC Guidelines, using the following formula:

$$CH_4\ emissions = Number\ of\ abanodoned\ coal\ mines\ remaining\ unflooded * Fraction\ of\ gassy\ coal\ mines * Emission\ factor * Conversion\ factor$$

The conversion factor is the density of CH_4 and converts volume of CH_4 to mass of CH_4. The conversion factor (density) has a value of 0.67 $*10^{-6}$ Gg m^{-3}.

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.

Abandoned underground mines

Information on the history of mining at Svalbard was obtained from the Directorate of Mining with the Commissioner of Mines at Svalbard in 2014. The information from the directorate included assessment of degree of flooding. Where no information about flooding is available, the mines are included in the number of abandoned mines remaining unflooded, in order to avoid underestimation. Table 3.25 gives an overview of the number of abandoned mines remaining unflooded for different time periods of abandonment, as well as the used fractions of gassy mines for each time period.

Table 3.25 Number of mines abandoned from 1901-present.

Time of abandonment	Number of abandoned mines remaining unflooded	Fraction of gassy mines
1901-1925	6	0.5
1926-1950	3	0.3
1951-1975	7	0.4
1976-2000	6	0.3
2001-present	0	0.0

Source: Directorate of Mining (2014)

It is assumed that all historic coal mining activities in Norway has taken place at Svalbard.

3.3.4 Emission factors

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 AS (2000).

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

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

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

Considering the measurements it was therefore decided to use 0.54 kg methane per tonne coal as

emission factor when calculating methane emissions from coal mining in Norway.

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

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

NMVOC

Emission factors for NMVOC are taken from EMEP/EEA Guidebook (2013). The Tier 2 factors used are 3 kg NMVOC per tonne coal for surface mines and 0.2 kg NMVOC per tonne coal for underground mines.

Abandoned underground mines

The fraction of gassy mines is determined by the Norwegian Environment Agency based on information about geological characteristics of the different geographic areas of Svalbard, obtained from Bergfald & Co AS (2000) and Directorate Mining with the Commissioner of Mines at Svalbard.

Default emission factors from the tier 1 methodology of the 2006 IPCC Guidelines are used (Table 3.26).

Table 3.26 Emission factors used for calculating emissions from abandoned underground mines. Million m^3 CH_4 /mine.

	Time period of abandonment				
Inventory year	**1901-1925**	**1926-1950**	**1951-1975**	**1976-2000**	**2001-present**
1990	0.281	0.343	0.478	1.561	NA
1991	0.279	0.34	0.469	1.334	NA
1992	0.277	0.336	0.461	1.183	NA
1993	0.275	0.333	0.453	1.072	NA
1994	0.273	0.33	0.446	0.988	NA
1995	0.272	0.327	0.439	0.921	NA
1996	0.27	0.324	0.432	0.865	NA
1997	0.268	0.322	0.425	0.818	NA
1998	0.267	0.319	0.419	0.778	NA
1999	0.265	0.316	0.413	0.743	NA
2000	0.264	0.314	0.408	0.713	NA
2001	0.262	0.311	0.402	0.686	5.735
2002	0.261	0.308	0.397	0.661	2.397
2003	0.259	0.306	0.392	0.639	1.762
2004	0.258	0.304	0.387	0.62	1.454
2005	0.256	0.301	0.382	0.601	1.265
2006	0.255	0.299	0.378	0.585	1.133
2007	0.253	0.297	0.373	0.569	1.035
2008	0.252	0.295	0.369	0.555	0.959
2009	0.251	0.293	0.365	0.542	0.896
2010	0.249	0.29	0.361	0.529	0.845
2011	0.248	0.288	0.357	0.518	0.801
2012	0.247	0.286	0.353	0.507	0.763
2013	0.246	0.284	0.35	0.496	0.73
2014	0.244	0.283	0.346	0.487	0.701
2015	0.243	0.281	0.343	0.478	0.675
2016	0.242	0.279	0.34	0.469	0.652

Source: IPCC (2006)

3.3.5 Uncertainties and time-series consistency

The uncertainty in the activity data concerning Norwegian coal production is regarded as being low. The uncertainty in Russian data is regarded being 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 Rypdal and Zhang (2000), when an IPCC default emission factor was used. In Rypdal and Zhang (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 AS (2000). This should indicate that the chosen emission factor is rather conservative.

A general assessment of time series consistency has not revealed any time series inconsistencies in

the emission estimates for this category.

For abandoned underground mines the same data source is used for the entire time series, and no time series inconsistencies are identified for the calculation of CH_4 emissions from.

3.3.6 Category-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 Norwegian Environment Agency carry out internal checks of the emission time-series and corrections are made when errors are detected; see Section 1.2.3 for general QA/QC procedures.

For abandoned underground mines no category-specific QA/QC routines are in place for the emission estimates.

3.3.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

3.3.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.4 Fugitive Emissions from Oil and Natural Gas – 1B

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 maybe for additional 40 years. This illustrates the huge amount of oil and gas in that field area. 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 2014 there were 78 fields in production on the Norwegian continental shelf included 4 fields that came into production in 2014. Additional 4 fields are being developed and started production in 2015, two fields in 2016 and 5 in 2017. Two fields on the Norwegian continental shelf closed down in 2014 and 2015 and four in 2016. By turn of the year 2017/2018 there were 85 fields in production and nine 9 fields were under development.

The overall trend is that the production of oil, gas and NGL and condensate is decreasing since top was reached in 2004. Figure 3.12 below shows the net sale production of oil, gas and NGL and condensate in the period 1974-2016. The total production of oil and gas was 86 per cent higher in 2016 than in 1990 and 1.1 per cent higher than in 2015. The production of oil increased by 3.4 per cent in 2016 and gas production decreased 0.4 per cent. Maximum production that was reached in 2004 was approximately 264 mill Sm^3 oil equivalents. This was an increase since 1990 of 111 per cent. In 2016 the total production was 12 per cent *lower* than the all-time high production in 2004. The maximum production of oil was reached in 2000 and in 2016 the production was 42.3 per cent lower than in 2000. Production data also shows that the production of gas in 2010 was then for the first time higher than the production of oil and in 2016 the sale gas production was about 24.1 per cent higher than the sale production of oil. For more information about the Norwegian petroleum sector (OED 2016).

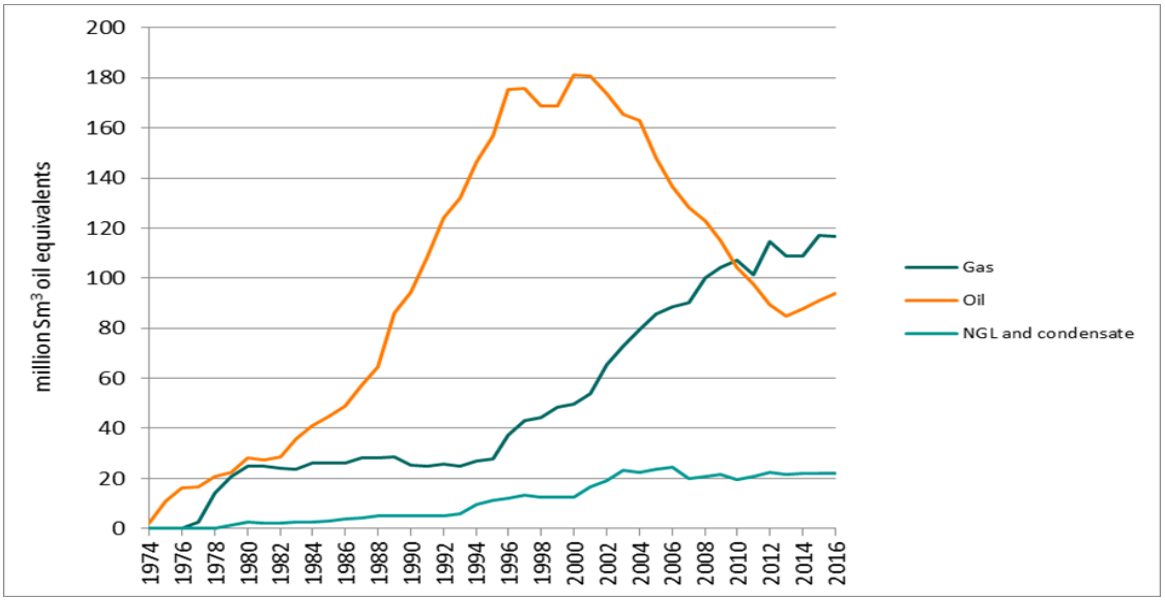


Figure 3.12. Net sale production of oil, gas and NGL and condensate. 1974-2016. Million Sm3 oe.
Source: Statistics Norway

The sector Fugitive Emissions from Oil and Natural Gas (2B) includes fugitive emissions mainly connected to oil and gas exploration and production and gas terminals and refineries. Emissions from combustion for energy purposes in the source categories mentioned above are reported in source category 1.A.c. This is emissions from combustion of natural gas and diesel in turbines, motors and boilers. See below for description of methodology for reported fugitive emissions.

As response to the 2009 annual review report sale production of oil, NGL and condensate are reported in the CRF in source category 1.B.2.a.2 Production oil and sale production of gas in 1.B.2.b.2 Production/processing gas.

3.4.1.1 Fugitive emissions 1990-2016

Fugitive emissions from oil, natural gas and venting and flaring contribute 6.2 per cent to the total GHG emissions in Norway in 2016 and with 8.4 per cent of the total GHG emissions in the energy sector. This includes emissions from burn off of coke on the catalysts at one refinery. Without the latter source category fugitives emissions from what we define as oil and gas exploration and production contribute 4.3 per cent to the total GHG emissions in Norway in 2016 and with 5.9 per cent of the total GHG emissions in the energy sector.

Figure 3.13 below shows the trend in fugitive emissions from oil and gas production, venting and flaring including burn off of coke at catalytic cracker while Figure 3.14 shows relative change in emissions for the same emission sources. The total sector emissions decreased by 0.3 per cent from 1990 to 2016 and the emissions decreased by 3 per cent from 2015 to 2016. In 2015 the emissions increased due to increased flaring at one gas terminal and flaring from three new fields, specifically from one, that started producing in 2015. There were in 2015 growth in emissions from cracker due to increased production after maintenance revision in 2014. The growth in emission in 2015 counteracted in some extent by reduced emissions from venting. In 2016 the emissions from the sector was partly reversed mainly due to reduced emissions from catalytic cracker.

The fugitive emissions *excluded* emissions from burn off of coke at catalytic cracker at refinery, which are connected to oil and gas exploration and production, decreased by 7.3 per cent between 1990-2016 while the production of oil and gas increased by 86 per cent. The different development in emissions and production is mainly explained by measures taken to reduce NMVOC emissions from storage and loading of crude oil offshore and onshore and that flaring of gas is for most years lower than in 1990. More information about flaring off shore is given below.

From Figure 3.13 you can also see that the total emissions from the source category increased substantially from 2006 to 2007-08 and that the emissions today are at 2005 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_2 emissions from the burn off of coke at catalytic cracker, that is reported in sector 2.B.2.a.iv Refining/Storage, decreased by about 28 per cent in 2014 due to that there was maintenance revision of the refinery. In 2015 and 2016 the CO_2 emissions was almost back to the same level as before 2014.

Figure 3.13 shows the emissions from source categories in absolute values and Figure 3.14 shows the relative change in emissions compared to 1990. The total emissions for the two source categories

with highest emissions, flaring and fugitives from oil including burn off of coke at catalytic cracker (Figure 3.13) contribute over the years to between 60 and 80 per cent of the sector total. However, emissions from transport that is indirect CO_2 emissions of NMCOC and CH_4 from storage and loading of crude oil offshore and onshore is reduced substantially due to measures implemented. The reduction was compensated with increased emissions from catalytic cracker. Emissions from venting have increased in orders of magnitude from 1990, especially from 2002, and the emissions were about 0.6 million CO_2 equivalents in 2016.

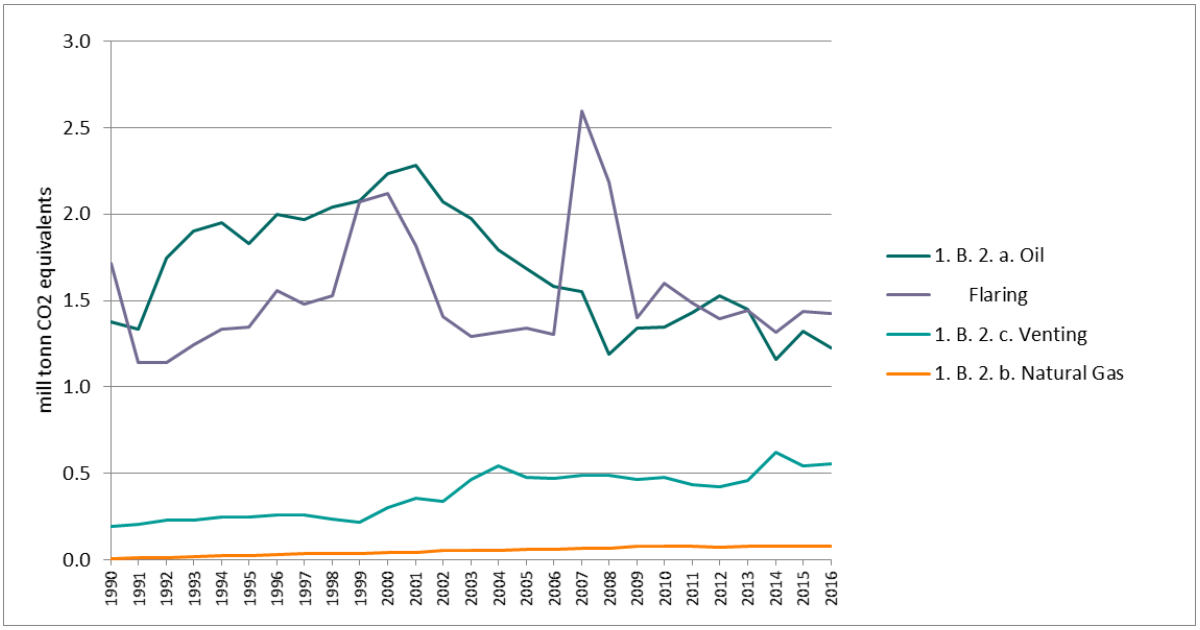


Figure 3.13. Fugitive emissions from oil and gas production included catalytic cracker at refinery. Million tonne CO_2 equivalents.
Source: Statistics Norway/Norwegian Environment Agency

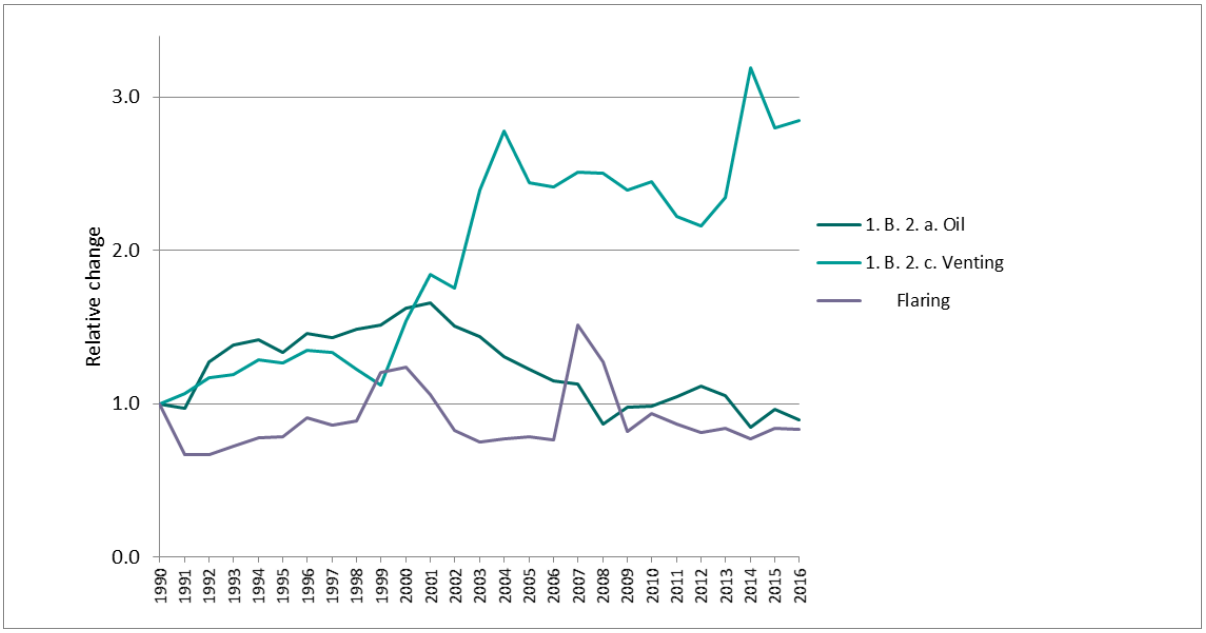


Figure 3.14. Relative change in fugitive emissions in CO_2 equivalents from oil and gas included catalytic cracker. 1990=1.
Source: Statistics Norway/Norwegian Environment Agency

3.4.1.2 Emissions from flaring in oil and gas exploration and production

In 2016, CO_2 emissions from flaring off shore contributed with 2.5 per cent to the total GHG emissions in Norway. The CO2 emissions from flaring were about 30 per cent lower in 2016 than it was in 1990. While the oil and gas production were about 86 per cent higher, see Figure 3.15. The reduced CO2 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 start-ups, 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. The even higher increase in emissions from flaring in 2007-08 was due to start-up problems at a new LNG plant.

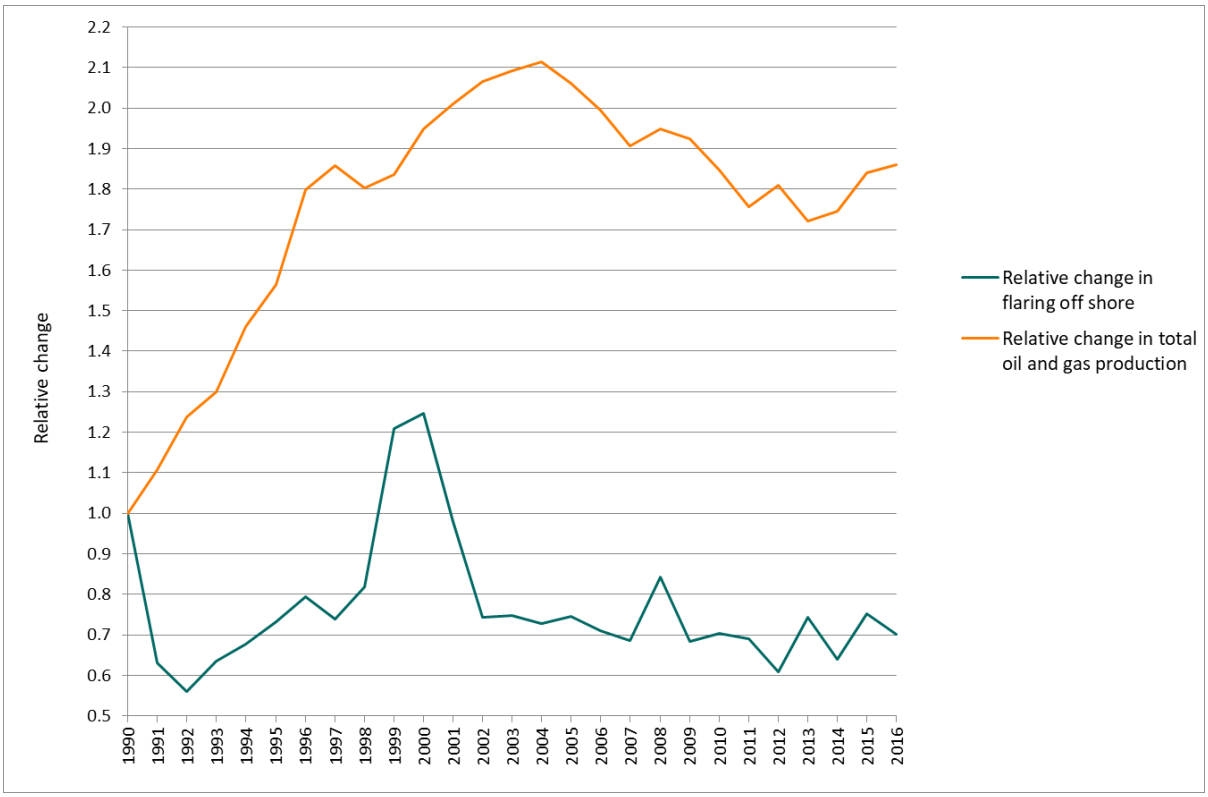


Figure 3.15. Relative change in CO_2 emissions from flaring off shore and total production of oil and gas. 1990-2016. 1990=1.
Source: Statistics Norway/Norwegian Environment Agency

3.4.1.3 Number of exploration and development wellsbores

Figure 3.16 shows the number of exploration wellbores on the Norwegian continental shelf started up in the period 1990-2016. The activity for exploration has been high most of the years with 1994, 1999, 2002-2004 and especially 2005 as years with low activity. In average 37 exploration wells have been started each year from 1990. The timeserie for all exploration wellbores is reported in CRF Reporter in 1B2a1 Exploration and therefore IE is reported in 1B2b1 Exploration.

The total numbers of development wellbores (production, observation and injection) are shown in Figure 3.17.

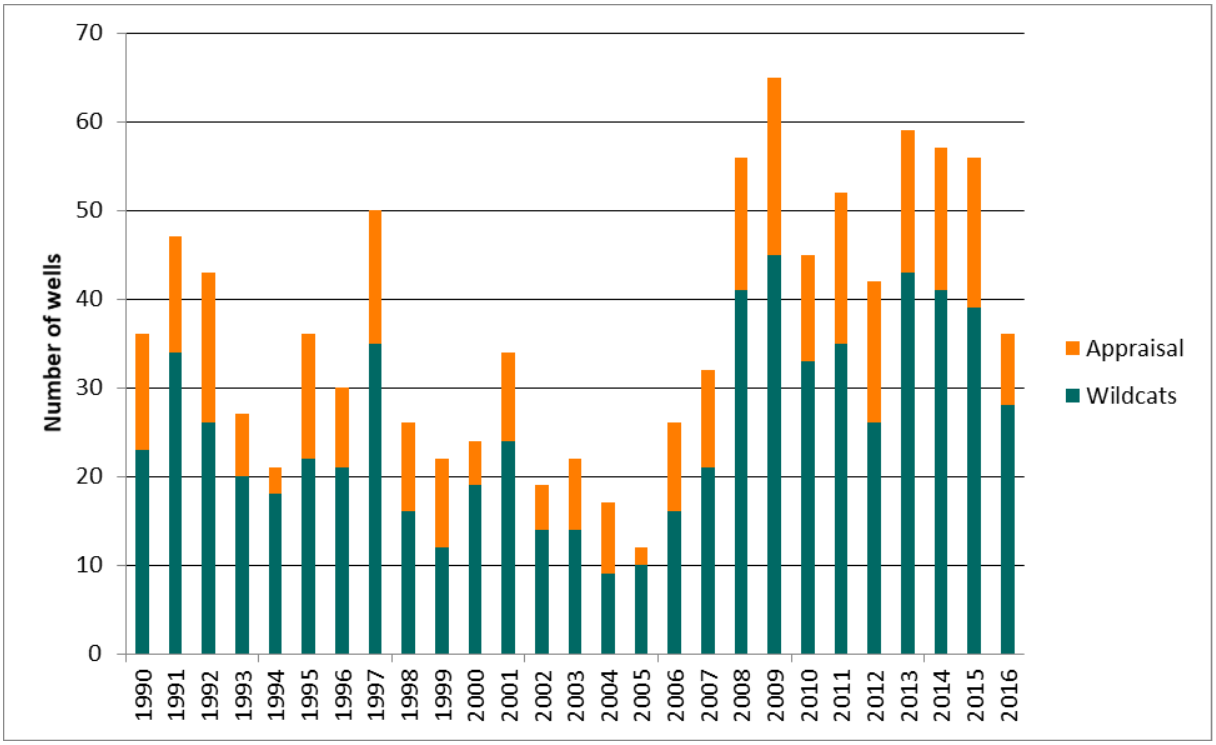


Figure 3.16. Exploration wellbores. Number of wildcats and appraisal wells started. 1990-2016.
Source: Norwegian petroleum directorate

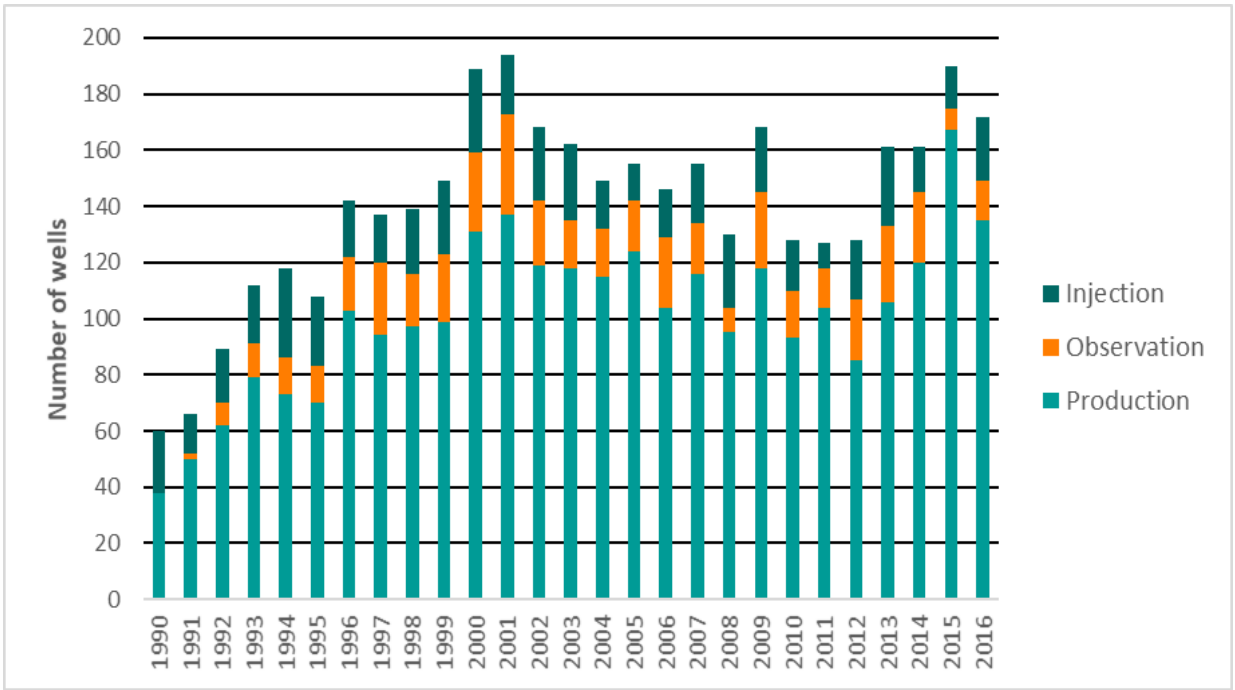


Figure 3.17. Production wellbores. Number of production, observation and injection wells. 1990-2016.
Source: Norwegian petroleum directorate

3.4.1.4 Overall description of methodology for fugitive emissions from fuels

Table 3.27 gives an overview over methodology (tier), EF and AD for each source category within the sector used in the calculations of the fugitive emissions of CO_2, CH_4, N_2O and NMVOC. The table shows if the EF and/or AD used in the calculation are CS or PS. The notation R/E in the table indicates that emission estimates is based on reporting from the entities (R) or calculated (E) by Statistics Norway; see e.g. Section 3.4.4.2 about flaring. Basically emissions estimates up to about 2002 are carried out by Statistics Norway.

Fugitive and vented emissions from oil and gas activities are included in 1.B.2.c Venting. Flaring are reported in 1B.2.c ii and includes emissions from flaring at oil and gas fileds off shore, gas terminals and refineries.

Fugitive emissions (gas leaks) from the following source categories are included in 1.B.2.c Venting and therefor the notation key is IE in CRF:

- exploration and production of oil
- exploration, production/processing and transmission of gas.

ERT's have rised question to why we are not separating fugitive and vented emissions in the inventory. From our knowledge, fugitive emissions from off shore activities represent about 10 per cent of total fugitive and vented emission. This assumption is based on a survey performed in 2016 (Norwegian Environment Agency 2016). The inventory for fugitive and vented emissions are mostly based on reports from the field operators, see Table 3.28, and we have today not enough information to separate the emissions between the two sources. From our judgment, the accuracy of the emissions will not improve if the emissions were distributed between the source categories 1B2a ii and 1B2b ii. The reporting is from our understanding also in accordance with the reporting guidelines.

Table 3.28 shows the shares of total CO_2, CH_4 and N_2O emissions in the sector that is based on reported and estimated estimates in 2016. From the table you can see that about 90 per cent of the CO_2 and CH_4 emissions in the sector, included coal mining, are based on reports from the plants, mainly off shore installations. N_2O is based on estimates performed by Statistics Norway.

Sector 1.B.2.a Oil:

- *CO_2:* 86 per cent of the emissions in the source category are based on *reports.* The emissions are from catalytic cracker at one oil refinery and indirect CO_2 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_4.
- *CH_4:* 100 per cent is based on *reports* from refineries and oil and gas installations.

1.B.2.b Natural gas:

- *CO_2*: 100 per cent is *estimated* and is indirect CO_2 based on mostly reported CH_4 emissions from gas terminals
- *CH_4*: 72 per cent of the emissions is based on *reported* emissions from gas terminals.

1.B.2.c Venting and flaring

- CO_2: 92 per cent of the emissions are based on *reports* mostly from the oil and gas installations.
- CH_4: 99 per cent of the emissions are based on *reported* emissions from the oil and gas installations.

Table 3.27. Fugitive emissions from oil and natural gas. Emission sources, compounds, methods, emission factors and activity data included in the Norwegian GHG Inventory.

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

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

Table 3.28. Fugitive emissions from oil and natural gas. Share of total CO_2, CH_4 and N_2O emissions in the sector based on estimated and reported emission estimates for 2016.

	CO_2		CH_4		N_2O	
	Estimated	**Reported**	**Estimated**	**Reported**	**Estimated**	**Reported**
1B Fugitive emissions from fuels	11 %	89 %	12 %	88 %		0 %
1.B.1.a Coal Mining	100 %	0 %	100 %	0 %	100 %	0 %
1.B.2.a Oil	14 %	86 %	0 %	100 %	100 %	0 %
1.B.2.b Natural gas	100 %	0 %	28 %	72 %	100 %	0 %
1.B.2.c Venting and flaring	8 %	92 %	1 %	99 %	100 %	0 %

3.4.2 Fugitive Emissions from Oil, 1.B.2.a (Key category for CO_2)

3.4.2.1 Description

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

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

Loading, unloading and storage of crude oil on the oil fields offshore and at oil terminals on shore causes direct emissions of CH_4 and indirect emissions of CO_2 from oxidized NMVOC and CH_4. Non-combustion emissions from Norway's two oil refineries (a third was closed down in 2000) include CO_2, CH_4 and NMVOC. It is important to have in mind that included in source category 1.B.2.a.iv is CO_2 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_2 emissions.

Loading and storage of crude oil, distribution of gasoline, direct CO_2 emissions from burn off of coke on catalytic cracker at a refinery are according to Approach 1 and 2 *key category* in level and trend for CO_2 and only in level for CH_4.

3.4.2.2 Methodological issues

Loading and storage of crude oil off shore and on shore

The general method for calculating emissions of CH_4 and NMVOC from loading and storage of crude oil are:

field specific amount of crude oil loaded and stored multiplied with field specific emission factors.

For the years 1990-2002 the emissions of CH_4 and NMVOC is calculated by Statistics Norway. The calculation is based on the field specific amounts of crude oil loaded and stored multiplied with field specific emission factors. Field specific activity data and emission factors (the latter only to the Norwegian Environment Agency) used in the calculation were annually reported by the field operators to Statistics Norway and the Norwegian Environment 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 Norwegian Environment Agency and used in the QC of the emission figures calculated by Statistics Norway.

From 2003, emission of CH_4 and NMVOC from loading and storage of crude oil on shuttle tankers included in the GHG Inventory are based on reported emission figures from the oil companies. Emissions, activity and emissions factors with and without VRU are reported from each field operator into the database EPIM Environment Hub (EEH), previously Environmental Web. The database is operated by the Norwegian Petroleum Directorate, the Norwegian Environment Agency and [1]The Norwegian Oil Industry Association. The method for calculating the emissions is the same as for 1990-2002.

An agreement was established 25 June 2002 between the Norwegian Pollution Control Authority (now Norwegian Environment Agency) and VOC Industrisamarbeid (a union of oil companies operating on the Norwegian continental shelf) aiming to reduce NMVOC emissions from loading and storage of crude oil off shore. So in addition, *also from 2003*, the emission of CH_4 and NMVOC from loading and storage of crude oil on shuttle tankers is reported annually to the Norwegian Environment Agency by the "VOC Industrisamarbeid" in the report "VOC Industrisamarbeid. NMVOC reduksjon bøyelasting norsk sokkel" (VOC Cooperation. Reduction of NMVOC from buoy loading on the Norwegian continental shelf). The report include e.g. details of ships buoy loading and which oil fields the oil has been loaded /stored at, amount of oil loaded, EFs with and without VRU. The method for calculating the emissions is the same as for 1990-2002.

Norway considers that the method for calculating the CH_4 and NMVOC emissions from loading and storage of crude oil is consistent for the period 1990-2014.

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 Norwegian Environment Agency. At one of the terminals VRU for recovering NMVOC was installed in 1996. The calculation of the emissions of CH_4 and NMVOC at both terminals is based upon the amount of crude oil loaded and oil specific emission factor dependent of the origin of the crude oil loaded.

The reported indirect CO_2 emissions from the oxidation of CH_4 and NMVOC in the atmosphere for this source category is calculated by Statistics Norway, see Chapter 9.

Refining/Storage – 1.B.2.A.iv

The direct emissions of CO_2, CH_4 and NMVOC included in the inventory are reported by the refineries to the Norwegian Environment Agency. The direct CO_2 emissions reported in this sector originate from the burn off of coke on the catalyst and from the coke calcining kilns at one refinery. The emissions from the catalytic cracker are included in the Norwegian ETS and the emissions reported in source category 1.B.2.a. iv is from the ETS and is therefore regarded being of high quality. The CO_2 emissions from catalytic cracker and calcining kilns are calculated from the formula:

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

- the amount of stack gas (RG) is measured continuously
- the density of the stack gas is 1.31 kg/Nm^3

- volume percentage of CO_2 is based on continuously measurements. However, if the refinery can document that the volume percentage of CO_2 is not fluctuating more than 2 per cent from last year report it is not mandatory to have continuous measurements.

Statistics Norway calculates the indirect CO_2 from oxidized CH_4 and NMVOC.

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 Norwegian Environment 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 Norwegian Environment Agency and the Norwegian Petroleum Directorate.

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

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

Refining – 1.B.2.a.iv

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

Gasoline distribution – 1.B.2.a.v

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

3.4.2.4 Emission factors

Loading and storage of crude oil off shore and on shore

From 1990 to 2002 emission factors used in the calculation of CH_4 and NMVOC emissions from loading and storage of crude oil offshore and on shore are field/plant specific and were reported to the Norwegian Environment Agency and the Norwegian Petroleum Directorate in an annual report. The Norwegian Environment Agency forwarded the emission factors to Statistics Norway that calculated the emissions.

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

The emission factors that the field operator use in their calculations is reported to the Norwegian Environment Agency and the Norwegian Petroleum Directorate. They report emissions factor with and without VRU and the split between CH_4 and NMVOC. The emission factors are reported by the field operators into the database EPIM Environment Hub (EEH), previously Environmental web.

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

Refining/Storage – 1.B.2.A.iv

The CO_2 emissions from the burn off of coke from the catalytic cracker are calculated as described above under Methodological issues. The CO_2 IEF in CRF is calculated from the emissions from catalytic cracker at one refinery and the amount of crude oil refined at three refineries up to 2002 and thereafter two refineries. This may indicate a low IEF compared to other party's IEF, and, if so, it explains the low IEF.

The emission factor used in the calculation of methane emissions from the largest refinery is based upon measurements using DIAL (Differential absorption LIDAR). A new measurement program was initiated in 2009. An annual EF is deduced from the measured methane emissions and the crude oil throughput. The average EF for the period 2009-2013 is used for the years before the current program was initiated, *i.e.* 1990-2008.

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 and time-series consistency

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.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

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. These data are 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 Norwegian Environment Agency and the Norwegian Petroleum Directorate. We have not found any discrepancy of significance between the data from the two data sources.

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

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

3.4.2.7 Category-specific recalculations

1B2a3 Oil and natural gas: Transport

- Correction of error. NMVOC emissions in 2015 increase by 20 tonnes, due to previously use of an erroneous figure. Corresponding change in indirect CO_2.

1B2a4 Refining/storage

- Revised data. Reported CH_4 figure from one plant in 2015 has been increased by 8 tonnes. Corresponding change in indirect CO_2.

1B2av Distribution of oil products

- Revised data. Marginal reduction in activity data in 2015, causes corresponding reduction in indirect CO_2 from NMVOC emissions.

3.4.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.4.3 Fugitive Emissions from Natural Gas, 1.B.2.b (Key category for CH_4)

3.4.3.1 Description

Sector 1.B.2.b covers fugitive emissions of CH_4 and NMVOC and indirect emissions of CO_2 from the two gas terminals and emissions from *distribution* of natural gas. For 1.B.2.b.i Exploration and ii Production/Processing, see section 3.4.1.

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

The rationale for this allocation is that emissions from transmission and storage in the extraction and export sector cannot be split from emissions from extraction and processing emissions at integrated facilities. The emissions from the domestic system might be split. However, the data in 1.B.2.b.iv *Transmission and storage* would then be misleading, as they would cover only a small fraction of Norwegian emissions for this activity. Thus, emissions from 1.B.2.b.iv are reported as "included elsewhere".

CH_4 from natural gas is according to Approach 2 *key category* with respect to trend.

3.4.3.2 Methodological issues

Gas terminals

Fugitive emissions of CH_4 and NMVOC from gas terminals are annually reported from the terminals to the Norwegian Environment 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

Norway has chosen to calculate data for gas transmission and distribution based on the default emission factor from the IPCC 2006 Guidelines. This was decided as conclusion to the discussion with the expert review team during the review of NIR 2016

Only emissions of CH_4 are reported in 1.B.2.b.v. CO_2 emissions are reported as "included elsewhere". According to the energy statistics, the total consumption data refer to amounts fed into the domestic transmission and distribution systems. The same activity data are used for calculating emissions from combustion of the natural gas. Any carbon leakage before combustion would thus be included as CO_2 in the combustion emissions in 1A. This applies to both direct emissions of CO_2 and indirect CO_2 emissions from CH_4 leakage. Direct emissions of CO_2 are likely to be very small: Using the default values from IPCC (2006) they would be 25 tonnes or less throughout the time series.There was no activity in this sector until 1994.

3.4.3.3 Activity data

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

Gas distribution

Data on use of natural gas from the energy statistics are used. From the total domestic consumption including energy sectors the following consumption is excluded:

- Consumption in the gas extraction and processing industry, offshore and onshore, whose emissions from transport is included in 1.B.2.b.vi *Other leakage*
- Consumption for methanol production, whose emissions from transport is included in 2.B.8.a *Methanol*. The plant has its own gas pipeline from an offshore gas field, and emissions from transmission is included with other process emissions at the plant.

The remaining consumption of natural gas is distributed to final consumption by pipeline or LNG systems. An increasing fraction of the consumption is LNG.

The same activity data are used for transmission and distribution. The factors from IPCC (2006) shown below actually refer to amount of *marketable gas* (transmission/storage) and *utility sales* (distribution).

3.4.3.4 Emission factors

Gas distribution

Emission factors from IPCC (2006) are used for the emission estimates, as shown in Table 3.29. The factors refer to pipeline distribution. As no tier 1 methodology was available for LNG distribution, and data for a tier 2 or 3 approach could not be obtained within the available time frame, the factors are used for all Norwegian activity as defined above.

Table 3.29. Emission factors for gas distribution.

Category	*Subcategory*	*Emission source*	*Value*	*Selected value*	*Uncertainty*
Gas Transmission and Storage	Transmission	Fugitives	6.6 E-05 to 4.8 E-04	2.73 E-04	±100%
		Venting	4.4 E-05 to 3.2 E-04	1.82 E-04	±75%
	Storage	All	2.5 E-05	2.5 E-05	-20 - 500%
Gas Distribution	All	All	1.1 E-03	1.1 E-03	-20 - 500%

Source: IPCC (2006), vol 2 Energy, table 4.2.4.

3.4.3.5 Uncertainties and time-series consistency

The uncertainty in the emission factors for fugitive methane from natural gas is estimated to be -50/+100 per cent and in the activity data $\pm$ 3 per cent.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

3.4.3.6 Source-specific QA/QC and verification

Reported emissions are compared with previous years' emissions.

3.4.3.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

3.4.3.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.4.4 Fugitive Emissions from Venting and Flaring, 1.B.2.c (Key category for CO_2 and CH_4)

3.4.4.1 Description

Included in sector *1.B.2.c Flaring* are emissions from flaring of gas off shore from extraction and production, at gas terminals and at refineries and the emissions is reported in sector 1.B.2.c.ii. Emission of CO_2, CH_4 and N_2O 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_2, CH_4 and NMVOC from exploration and production drilling of gas and oil. The major source is cold vent and leakage of CH_4 and NMVOC from production drilling.

The sector 1.B.2.c *Venting* includes emissions of CH_4 and NMVOC and hence indirect CO_2 emissions from cold venting and diffuse emissions from extraction and exploration of oil and gas. 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.

Venting and other emissions connected to CCS is reported in 1C.See Section 3.5 and Annex IV CO_2 capture and storage at the oil and gas production field Sleipner Vest and Hammerfest LNG (Snøhvit gas-condensate field) for description of this source.

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

CO_2 and CH_4 from venting and flaring is according to Approch 1 and 2 *key category* with respect to both level and trend.

3.4.4.2 Methodological issues

Venting

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

Flaring

Flaring of gas off shore - CO_2

The general method for calculating CO_2 emissions from flaring off shore is the amount of gas flared at each field multiplied by field specific emissions factors.

Gas specific data about the gas flared is not available for all flares and years. Therefor the method used for calculating emissions for this source category is not exactly the same for all years.

Estimations of CO_2 1990-2007.
For the period 1990-2007 the emissions is estimated from the amount of gas flared per field and emission factor based on EU ETS data for 2013. See information below in sub-chapter Emission factors about the emission factors that are used.

Estimations of CO_2 after 2007.
The EU ETS data are reported annually to the Norwegian Environment Agency. From 2008, emissions of CO_2 from flaring used in the inventory is estimated in this way

- Reported EU ETS emissions from flares based on CMR data are used unchanged
- Fields where some flares are with and some are without CMR data: then an average EF for the field based on the CMR data for 2014 is calculated and used for the flares using default EF. For the first years with EU ETS this method is often used for the fields as a whole and thereafter up to 2014 in a decreasing scope
- Gas fields with flaring but without any CMR data in 2014. Then the average emissions factor for 2014 of 2.694 CO_2 per Sm^3 based on all CMR data is used.

We consider that the method is consistent for all years.

Estimations of CH_4 and N_2O from flaring of gas off shore

Estimated emissions of CH_4 from flaring of gas off shore is calculated by Statistics Norway for 1990-2002 and is thereafter based on reported emission data from the field operators to the Norwegian Petroleum Directorate and the Norwegian Environment Agency. N_2O emissions from flaring is estimated by Statistics Norway for all years.

Well testing

Emissions of CH_4 and N_2O from flaring of *oil in well testing* is estimated for all years by Statistics Norway based on the amount of oil well tested reported annually by the field operators to the Norwegian Petroleum Directorate and the Norwegian Environment Agency. The same emission factors are used for the whole period. CO_2 emissions from well testing is based on the plants annual report.

Gas terminals

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

Refineries

The *refineries* reports annually CO_2 emissions from flaring to the Norwegian Environment Agency. The emissions are calculated by multiplying the amount of gas flared with plant specific emission factors. See additional information section 3.2.1.2.

3.4.4.3 Activity data

Venting

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

Flaring

Amounts of gas flared at offshore oil and gas installations are reported on a monthly basis by the operators to the Norwegian Petroleum Directorate.

Amounts of gas flared at the four gas terminals are reported to the Norwegian Petroleum Directorate and the Norwegian Environment 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 3.30 or field specific factors. Some of the EFs in the table are more accurate (more decimals) than those given in this table in previous submissions. The reference for the default factors is Aker Engineering (1992).

Table 3.30. Default emission factors for cold vents and leakage at oil and gas fields off shore. Emissions are given per Sm^3 of processed gas.

	NMVOC	**CH_4**	
	Emission factor	**Emission factor**	**Calculation method**
Emission source	**[g/Sm^3]**	**[g/ Sm^3]**	
Glycol regeneration	0.065	0.265	
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 [1]	0.4	0.36	Tonne per start up
Depressurization of equipment	0.005	0.016	
Instrument flushing and sampling	0.00021	0.00005	
Purge and blanket gas [1]	0.032	0.023	
Extinguished flare	0.014	0.015	
Leaks in process	0.007	0.022	
Depressurization of annulus	0.000005	0.000005	
Drilling	0.550	0.250	Tonne per well

[1] The gas source is standard fuel gas.

Source: Aker Engineering (1992)

Flaring

Flaring off shore – CO_2

It is mandatory for oil and gas field operators included in the EU ETS to use field or flare specific emissions factor in the calculation of CO_2. If not flare specific factor is used the default emissions factor is 3.73 kg CO_2 per Sm^3. The default emission factor is often considerable higher than measured emission factors. This has motivated the field operators to establish flare and field specific emissions factors. So in 2013, there are flare specific factors for a majority of the flares.

The field specific factors are estimated in a model developed by the Christian Michelsen Resarch (CMR) institute. The estimations are based on measurements with ultrasound of mass and volume on each flare.

There is several flares on a field but flare specific emissions factor are not estimated for all flares. For each field it is estimated a field specific emissions factor based on the flares with measurement data. For 2013, it is also calculated an average emissions factor of 2.637 kg CO_2 per Sm^3 for all flares at all fields with measurements data.

Emissions factors 1990-2007

An annual emission factor is estimated from the field specific CMR measurements from 2013 weighted with the amount of flared gas for each field. The amount of gas for 1990-99 are from the Norwegian Petroleum Directorate and from Environmental Web/EPIM Environment Hub (EEH) for 2000-2015.

Emissions factors after 2007

For the years after 2007 there is information in the EU ETS about each single flare. At most fields there are a mixture of flares with CMR emission factors and default factors.

The emission factors used for calculation of emissions after 2007 is explained in sub-chapter "*Estimations of CO_2 after 2007"* above.

Table 3.31 presents the average EF for flaring off shore for the period 1990-2016.

Gas terminals

In Table 3.31, the CO_2 emission factors for flaring at one gas terminals are shown. The CO_2 emissions from flaring at that gas terminal were in 2016 a little bit more than 50,000 tonne.

Well testing

Emission factors used in the calculations for well testing are shown in Table 3.30. During the review of the 2008 inventory submission the expert review team raised question to that CH_4 and N_2O from well testing off shore were not included in the inventory. Norway then estimated the emissions of CH_4 and N_2O and presented the result for the expert review team. The emission estimates was for the first time included in the inventory in the 2010 submission.

Table 3.31. Emission factors for flaring of natural gas at off shore oil fields and one gas terminal on shore. 1990-2016

	Average emission factor for flaring at one gas terminal	**Average emission factor for flaring off shore**
	tonne CO_2 /tonne natural gas	*kg CO_2/Sm^3 natural gas*
1990	2.7	2.70
1991	2.7	2.66
1992	2.7	2.73
1993	2.7	2.80
1994	2.7	2.79
1995	2.7	2.69
1996	2.7	2.66
1997	2.7	2.69
1998	2.7	2.74
1999	2.7	2.75
2000	2.7	2.73
2001	2.7	2.65
2002	2.7	2.68
2003	2.7	2.63
2004	2.7	2.63
2005	2.7	2.62
2006	2.69	2.63
2007	2.67	2.66
2008	2.67	2.64
2009	2.67	2.85
2010	2.65	2.89
2011	2.76	2.93
2012	2.75	2.80
2013	2.62	2.71
2014	2.59	2.77
2015	2.53	3.02
2016	*2.59*	*3.14*

Source: Norwegian Environment Agency/Norwegian Petroleum Directorate/Statistics Norway

Table 3.32. Emission factors for flaring in connection with well testing

Compounds (unit)	**unit/tonne flared oil**	**Source**	**unit/kSm^3 flared natural gas**	**Source**
CO_2 (tonnes)	3.20	SFT (1990)	2.34	SFT (1990)
CH_4 (tonnes)	0.0004[1]	Same factors as for fuel oil used for	0.00024	(IPCC 1997a)
N_2O (tonnes)	0.00003[1]	boilers in manufacturing	0.00002	OLF (2009)
NMVOC (tonnes)	0.0033	OLF (2009)	0.00006	OLF (2009)
CO (tonnes)	0.018	OLF (2009)	0.0015	OLF (2009)

[1]*The Norwegian Oil Industry Association*

3.4.4.5 Uncertainties and time-series consistency

The uncertainty in the amount of gas flared is in Rypdal and Zhang (2000) regarded as being low, ±1.4 per cent, due to that there is a tax on gas flared and there is requirement by law that the gas volume flared is measured (Norwegian Petroleum Directorate 2001). The uncertainty in the CO_2 emission factor for flaring is ±10 (Statistics Norway 2000).

The uncertainty in the amount of gas flared is in regarded as being low, ±1.4 per cent, based on data reported in the emission trading scheme (Climate and Pollution Agency 2011a) and assumptions in Rypdal and Zhang (2000). The uncertainty in the CO_2 emission factor for flaring is ±4.5 (Climate and Pollution Agency 2011a) and Rypdal and Zhang (2000).

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

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

3.4.4.6 Source-specific QA/QC and verification

Statistics Norway gathers activity data used in the calculation from the Norwegian Petroleum Directorate. The figures are quality controlled by comparing them with the figures reported in the field operators annually report to the Norwegian Environment Agency and the Norwegian Petroleum Directorate and time series are checked.

Statistics Norway and the Norwegian Environment Agency perform internal checks of the reported data for venting from the field operators. Some errors in the time-series are usually found and the field operators are contacted and changes are made. The same procedure is followed to check the amount of gas reported as flared. The quality of the activity data is considered to be high due to that there is a tax on gas flared off shore. The Norwegian Petroleum Directorate has a thorough control of the amount of gas reported as flared. The oil and gas sector is included in the EU ETS from 2008.

3.4.4.7 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.5 CO_2 capture and storage at oil and gas production fields, 1C (Key Category for CO_2)

3.5.1 Overview

This chapter describes emissions related to the capture, transport and storage of CO_2 from natural gas produced at the gas-condensate field Sleipner Vest, including gas fromthe Gudrun field and the gas field Snøhvit.

Emissions occur primarily from venting of captured CO_2 when the injection facilities are not operating. Smaller emissions occur from a number of minor sources such as leakage from compressors. No emissions are reported from pipeline transport or from the CO_2 reservoirs.

The emissions are reported under 1C *CO_2 Transport and storage*. The emissions were until NIR 2016 reported in 1B2c together with indirect CO_2 emissions from CH_4 and NMVOC from venting and other fugitive emissions. The reporting in CRF Table1.C also includes data on total CO_2 capture and injected amounts.

3.5.2 CO_2 capture and storage at the oil and gas production field Sleipner Vest

3.5.2.1 Description

The natural gas in the Sleipner Vest offshore gas-condensate field in the North Sea contains about 9 per cent CO_2. The CO_2 content has to be reduced to about 2.5 per cent to meet sales gas specifications. The CO_2 removed amounts to about 1 million tonnes per year.

When Sleipner Vest was planned around 1990 the considerations were influenced by the discussions about strategies to reduce greenhouse gas emissions and a possible national tax on CO_2-emissons (introduced in 1991 and extended in 1996). It was therefore decided that the removed CO_2 should be injected for permanent storage into a geological reservoir. The selection of an appropriate reservoir is essential for the success of geological storage of CO_2. In the search for a suitable reservoir the operators were looking for a saline aquifer with reasonable high porosity and a cap rock above to prevent leakage. Furthermore, the CO_2 should be stored under high pressure – preferably more than 800 meters below the surface. Under these conditions CO_2 is buoyant and less likely to move upwards than CO_2 in gaseous form.

The Utsira Formation aquifer, which is located above the producing reservoirs at a depth of 800 – 1000 meters below sea level, was chosen for CO_2 storage because of its shallow depth, its large extension (which guarantees sufficient volume), and its excellent porosity and permeability (which is well suited for high injectivity). The formation is overlain by a thick, widespread sequence of Hordaland Group shales, which should act as an effective barrier to vertical CO_2 leakage, see Figure 3.18.

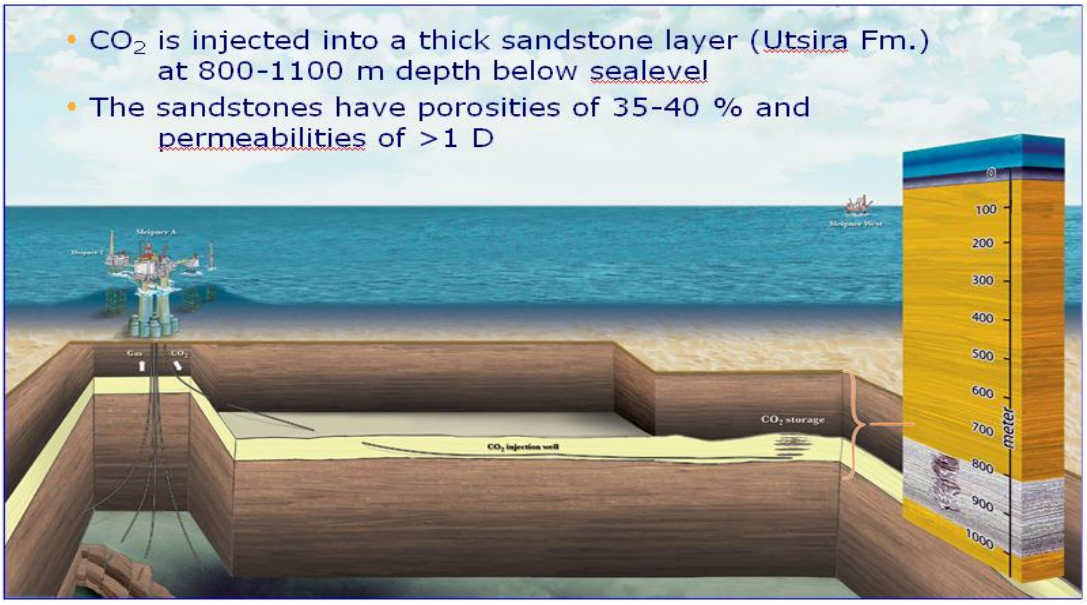


Figure 3.18. CO_2 capture from Sleipner Vest well stream and storage at Sleipner.
Source: Statoil

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

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

The field and the injection program has been in operation since 1996. Statoil monitors the injected CO_2 with respect to leakages by 4 D seismic surveys.

Investigations carried out so far show that the injected CO_2 is kept in place without leaking out. In case unexpected CO_2 movements take place beyond the capture rock in the future it can be registered by the monitoring techniques. Table 3.33 gives the amount of CO_2 injected since the project started in 1996.

Table 3.33. CO_2 from the Sleipner field injected in the Utsira formation.

Year	CO_2 (ktonnes)	Year	CO_2 (ktonnes)	Year	CO_2 (ktonnes)
1996	70	2003	914	2010	743
1997	665	2004	750	2011	929
1998	842	2005	858	2012	842
1999	971	2006	820	2013	702
2000	933	2007	921	2014	658
2001	1 009	2008	814	2015	707
2002	955	2009	860	2016	632

Source: Statoil/The Norwegian Environment Agency

When the injection is stopped due to maintenance or any unplanned reasons, the captured CO_2 is vented to the atmosphere. The amount of CO_2 vented to the atmosphere is included in the greenhouse gas inventory reported under 1B2c – see section3.4.4. In 2015, this emission amounted to 0,8 ktonnes CO_2. The emission data for the previous years is presented in Table 3.34.

Table 3.34. Emissions of CO_2 vented from the Sleipner Vest CO_2 –injection plant due to inaccessibility of the injection facility.

Year	CO_2 (ktonnes)	Year	CO_2 (ktonnes)	Year	CO_2 (ktonnes)
1996	81.0	2003	23.9	2010	0.9
1997	29.0	2004	21.4	2011	2.4
1998	4.2	2005	6.2	2012	5.9
1999	9.1	2006	2.5	2013	5.0
2000	8.3	2007	6.4	2014	5.4
2001	3.1	2008	13.6	2015	0.8
2002	87.6	2009	4.6	2016	4,6

Source: The Norwegian Environment Agency

The status by 31.12.2016 is that 16, 7 million tonnes CO_2 have been injected and stored in the Utsira Formation and 0, 33 million tonnes CO_2 have been vented. Figure 3.19 shows the yearly injected and vented volumes for the entire injection period on Sleipner.

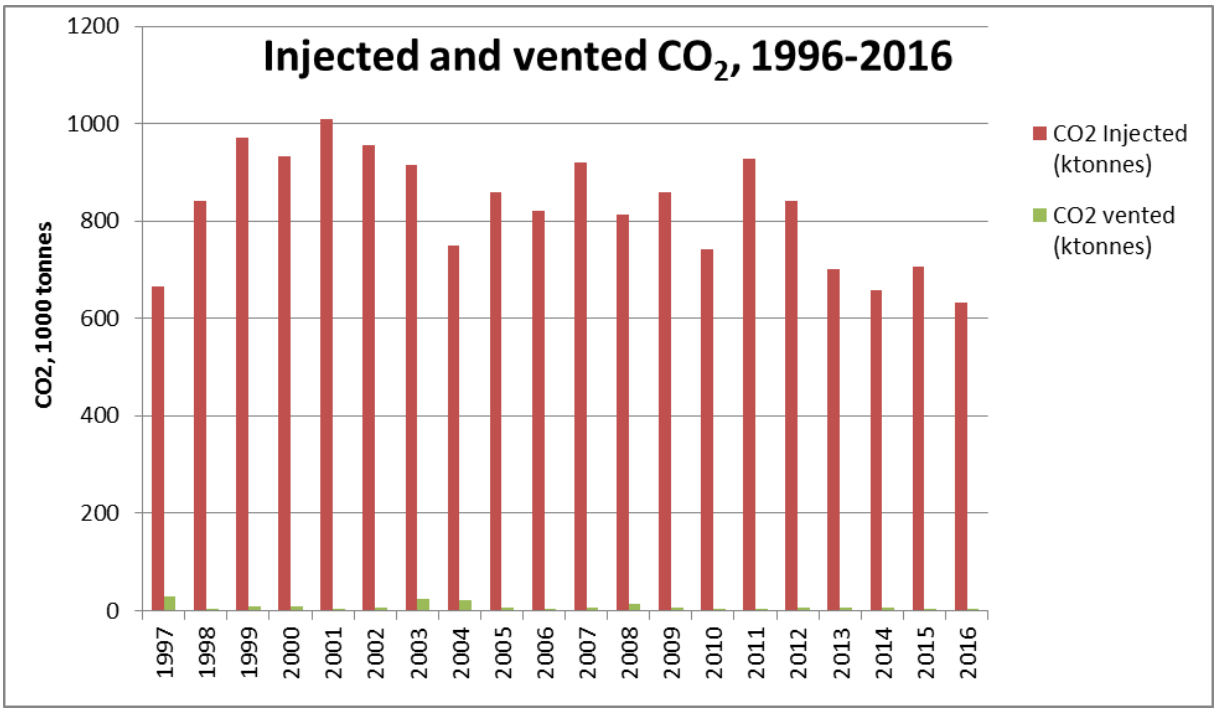


Figure 3.19. Injected and vented CO_2 at Sleipner Vest.
Source: Norwegian Environment Agency

Diffuse emissions from the CO_2-capture plant (amineabsorber) and the CO_2-compressor is estimated to about 1006 tonnes CO_2/year and these figures are included in CRF Table1.C

The compressorized CO_2 is transported by pipeline to the well head (injecton well). The transport distance is 350 m and is controlled by pressure monitoring. Methodological issues

The reported data covers emissions to the atmosphere e.g. when the injection system is out of operation. These emissions are determined by continuous metering of the gas stream by VCONE-meter. The reported amounts of CO_2 injected in the Utsira formation are based on continuous metering of the gas stream by orifice meter. The composition of the CO_2-stream is stable, about 98% CO_2 and the remaining 2% mainly methane and heavier hydrocarbons.

The diffuse emissions are estimated on the basis of equipment specific leakage factors. CO_2-dectectors are monitoring almost all potential leakages sources (e.g. flanges).

The Sleipner CO_2-injection project is considered as the first industrial-scale, environmentally driven CO_2-injection project in the world. In order to document what happens with the CO_2 a European research project initially called SACS ("The saline aquifer carbon dioxide storage project") was organized around it. The SACS project ended in 2002 and was succeeded by the ongoing EU-co-funded CO2STORE and ECO2. 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 migration of carbon dioxide through the aquifer is recorded by seismic surveys. Base line 3D seismic data were acquired in 1994, prior to injection, and the first repeat survey was acquired in 1999, when some 2.28 mill tonnes of CO_2 had been injected into the reservoir. This was followed by 4-D seismic surveys in 2001, 2002, 2004, 2006, 2008, 2010, 2013 and

2016. The monitoring methodology and the results of the monitoring are described in Annex IV written by Statoil.

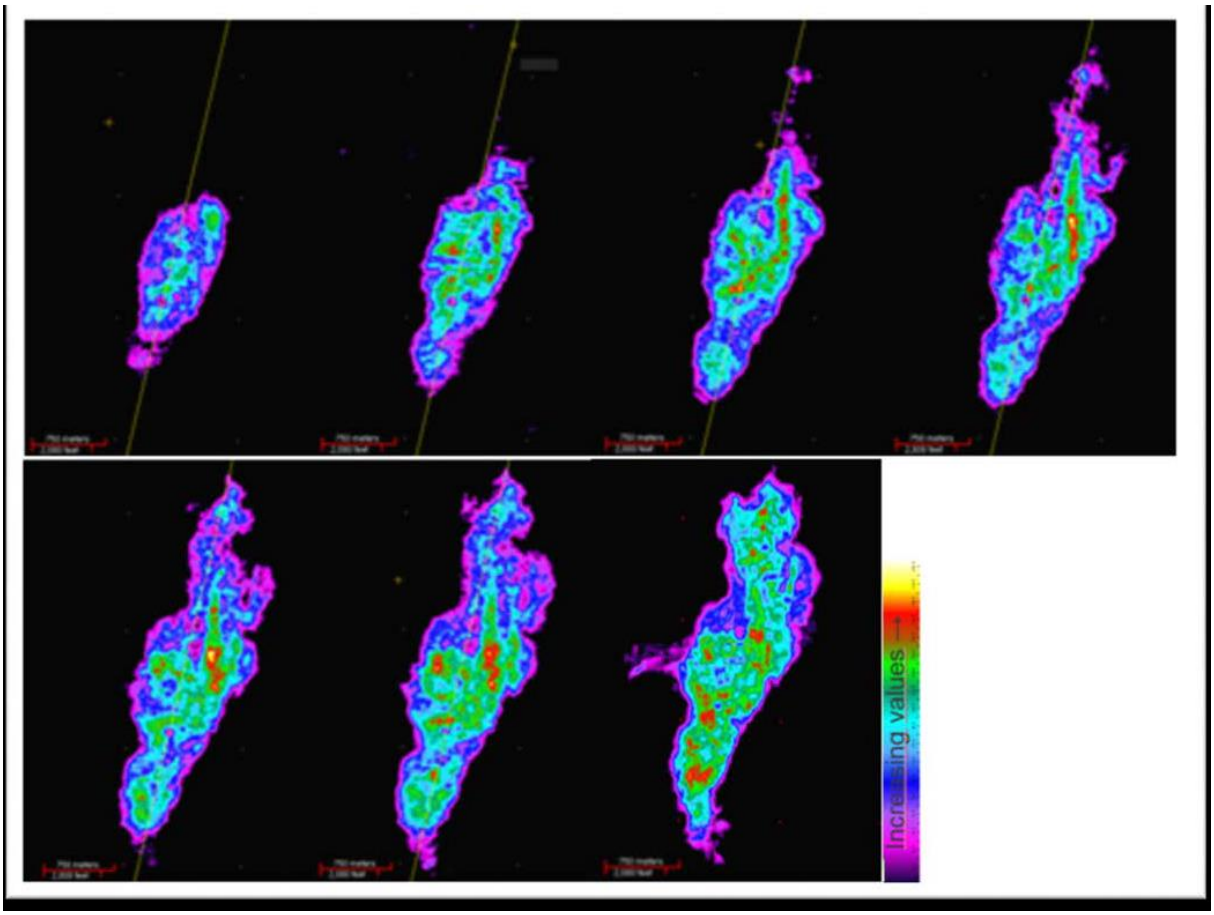


Figure 3.20 Results of seismic monitoring Sleipner Vest, 1998-2016. Accumulated amplitudes on the differences between 1994 and respectively 2001, 2004, 2006, 2008, 2010, 2013 and 2016. Source: Statoil

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

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

The results show that neither of these eventualities has occurred. is no sign of CO_2 above the top of Utsira Formation.

Results from the projects are published in several reports and articles such as:

- EU (2002)
- Arts et al. (2005)
- Chadwick et al. (2004)
- Chadwick et al. (2005)

A more detailed list of publications and presentations is given in Annex IV. The project has confirmed that sound waves reflect differently from carbon dioxide and salt water. Comparing seismic data collected before and after injection started has allowed researchers to show how CO_2 deep inside the Utsira formation migrates (see Figure AVI-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_2 within the reservoir, both as high amplitude reflections and as a pronounced velocity pushdown (see *Figure 3.20* and Figure AIV4 in Annex IV).

The data also resolve a vertical CO_2 chimney, which is regarded the primary feeder of CO_2 in the upper part of the bubble.

Flow simulation models, which match the 4D seismic data reasonably well, have been used to predict the CO_2 behaviour, see Figure 3.21.

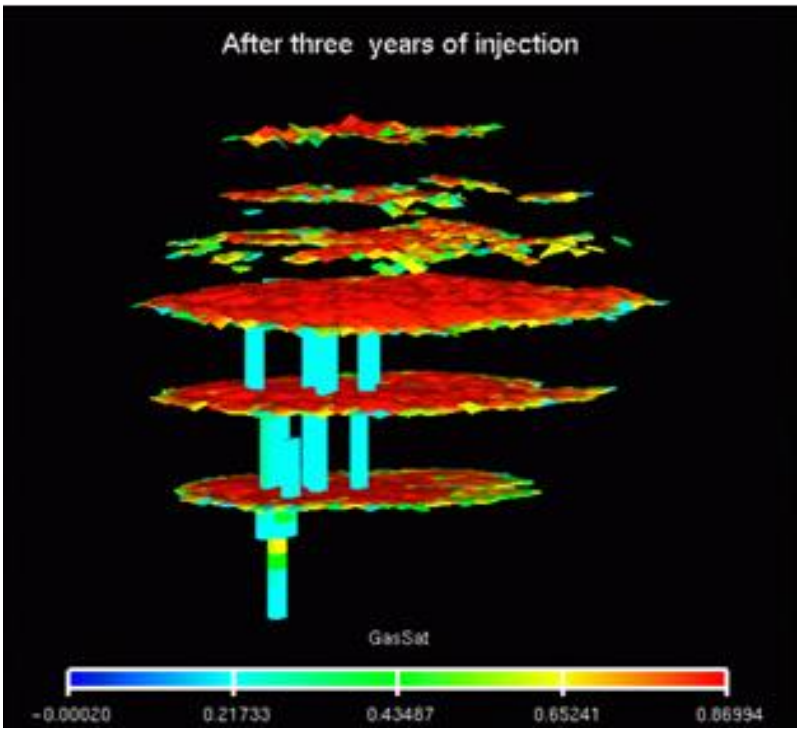


Figure 3.21. Flow simulation of CO_2 Sleipner Vest.
Source: Statoil

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

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

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

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

3.5.2.2 Uncertainties

The reported data covers emissions to the atmosphere e.g. when the injection system is out of operation. The accuracy in these measurements made by VCONE-meter is $^{+}$/- 5 per cent. The orifice

meter used to meter the amount of CO_2 injected in the Utsira formation have $^{+}$/- 3 per cent accuracy. So far there has not been detected any leakage from the storage.

3.5.2.3 Category-specific QA/QC and verification

The results are promising and the injected gas remains in place. Storage of CO_2 is regulated by the Pollution Control Act and the specific regulations of geological storage of CO_2 (entered into force January 1, 2016). Pursant the the Pollution Control Act and the specific regulations, the operator shall hold a permit. According to the permit conditions Statoil shall monitor the CO_2-storage. Statoil reports annually the amount of CO_2 injected and emitted to The Norwegian Environment Agency. The injected CO_2 is so far proven to be removed from the atmosphere and hence, it is not reported as emissions in the emission inventory. When the injection of CO_2 is stopped for maintenance purposes, the operator pays a CO_2-tax for the emissions. From 2013 these emissions are included in the EU-ETS. In the national emissions inventory the amount of CO_2 vented is reported under 1C2a - Injection.

3.5.2.4 Category-specific recalculations

There have been no recalculations performed for this source category this year.

3.5.2.5 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.5.3 CO_2 capture and storage at Hammerfest LNG/the gas-condensate production field Snøhvit

3.5.3.1 Description

The natural gas in the Snøhvit gas-condensate subsea field in the Barents Sea contains about 5-7.5 % CO_2. Prior to the LNG production the CO_2 has to be removed removed to avoid it freezing out in the downstream liquefaction process. The facilities for separation and injection of CO_2 are placed onshore at the Hammerfest LNG process plant at Melkøya.

An amine absorption unit performs the separation. The recovered CO_2 is condensed and recompressed before transported by a subsea pipeline and re-injected into Tubåen and Stø reservoir. A schematic of the CO_2 re-injection system is shown in Figure 3.22 About 0.73 Mtonnes CO_2 are removed from the feed gas every year at full production. During the expected lifetime of the field, about 23 million tonnes CO_2 from the feed gas will be removed and re-injected.

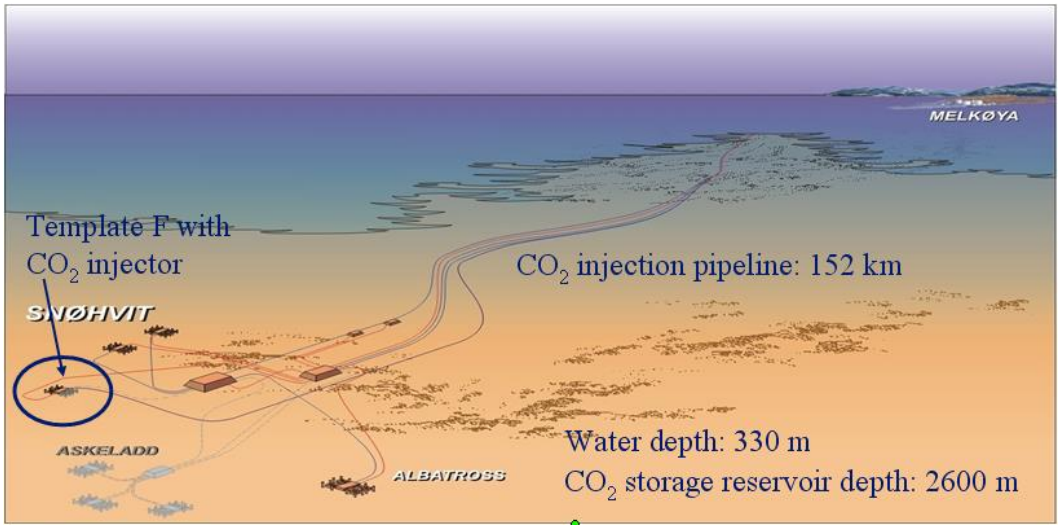


Figure 3.22. Snøhvit Field overview.
Source: Statoil

Reservoir

Several geological structures in the Snøhvit area were evaluated for disposal of CO_2. The four structures identified as possible candidates for CO_2 storage 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 were considered as immature for CO_2 storage for the Snøhvit CO_2 storage project because the reservoir data was not sufficiently detailed and there are no current plans for exploration drilling (ref: Plan for Development and Operation). The Tubåen formation was choosen as the primary storage location.

Hammerfest LNG (former Snøhvit LNG Statoil) was granted a permit pursuant to the Pollution Control Act to inject 730 000 tonnes of CO_2 per year into the geological formation, Tubåen in 2004. The permit was issued by the Norwegian Environment Agency. The production started in 2008.

In March 2011, the injection point was moved from Tubåen to the Stø reservoir, due to lower injectivity in Tubåen than expected.

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

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

Stø water zone formation, which is the bottom of the current producing gas reservoir, was perforated for injection. The water zone has a thickness of 42 metres. Core samples show that the formation consists of relatively sand. The porosity and permeability are 15% and 400md, respectively (Table 3.35) Formation depth is 2450 m below sea level.

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

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

Table 3.35. Key parameters for injection well F-2 H and Tubåen reservoir at the Snøhvit field. Stø reservoir pressure is being depleted by field production.

Key Parameters	**Tubåen**	**Stø**
Initital reservoir pressure	288 bar	255 bar
Initial temperature	98 C	98 C
Porosity	10-16%	15%
Permeability	200-800 md	400 md
Reservoir depth	2600 m	2450 m
Water depth at F-template	330m	330m
Length pipeline from Melkøya	152km	152km

Location of the CO_2 injection well F-2 H.

The CO_2 injection well is located at the F-segment at the western part of the Snøhvit reservoir (Figure 3.23). The injection pipeline is 152 km long (Figure 3.22). A new injection well, located in the G-segment, has been established in 2016.

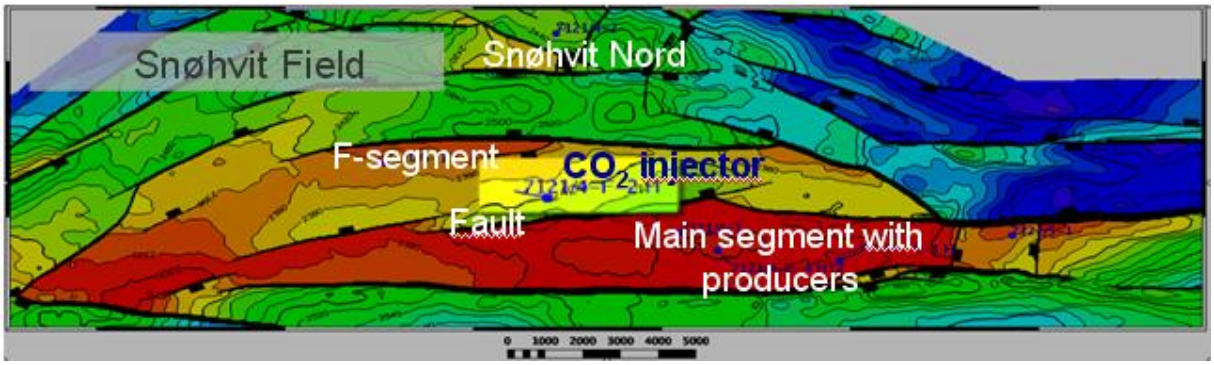


Figure 3.23. Location of the CO_2 well at the Snøhvit field.
Source: Statoil

At the beginning, to keep the CO_2 as deep as possible, it was decided to perforate the mid and lower part of Tubåen as shown in Figure 3.24. Since injection was changed to Stø, additional perforations were done in the bottom of Stø as shown in Figure 3.24.

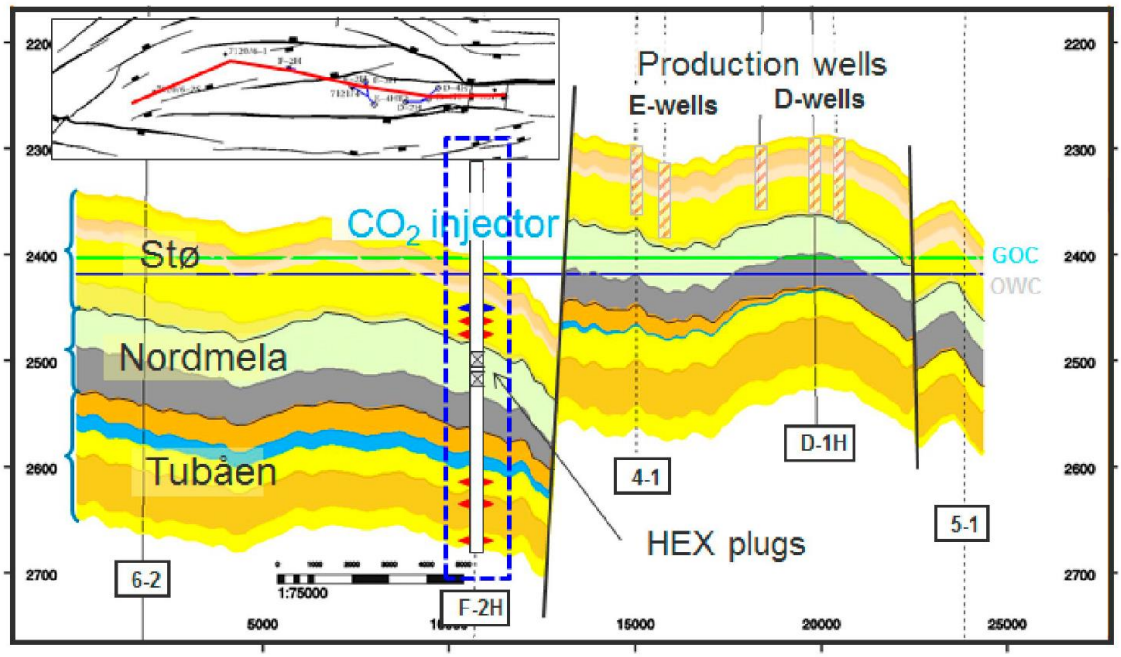


Figure 3.24. Cross-section of F-segment where CO_2 is injected, Snøhvit field formation.
Source: Statoil

CO_2 injected and vented

The status by 31.12.2016 is that 1 087 ktonnes CO_2 have been injected into the Tubåen Formation and 3 256 ktonnes have been injected into the Stø Formation, and 556 ktonnes CO_2 have been vented (Table 3.36). CO_2 venting occurs when the CO_2 reinjection system has to be shut down. The maximum vent rate is almost equal to the CO_2 removal flow rate. A separate vent stack for the CO_2 is provided at the plant.

Table 3.36. Injected and vented CO_2 Hammerfest LNG/Snøhvit field.

Year	CO_2 injected (ktonnes	CO_2 vented (ktonnes)	Year	CO_2 injected (ktonnes	CO_2 vented (ktonnes)
2007	0	71	2012	490	55
2008	197	93	2013	469	27
2009	308	50	2014	587	37
2010	460	93	2015	679	39
2011	403	87	2016	750	4

The following Figure 3.25 shows the yearly injected at in the Tubåen/Stø formation at the Snøhvit field and vented volumes for the injection period at Hammerfest LNG. These figures are reported to the Norwegian Environment Agency on a yearly basis.

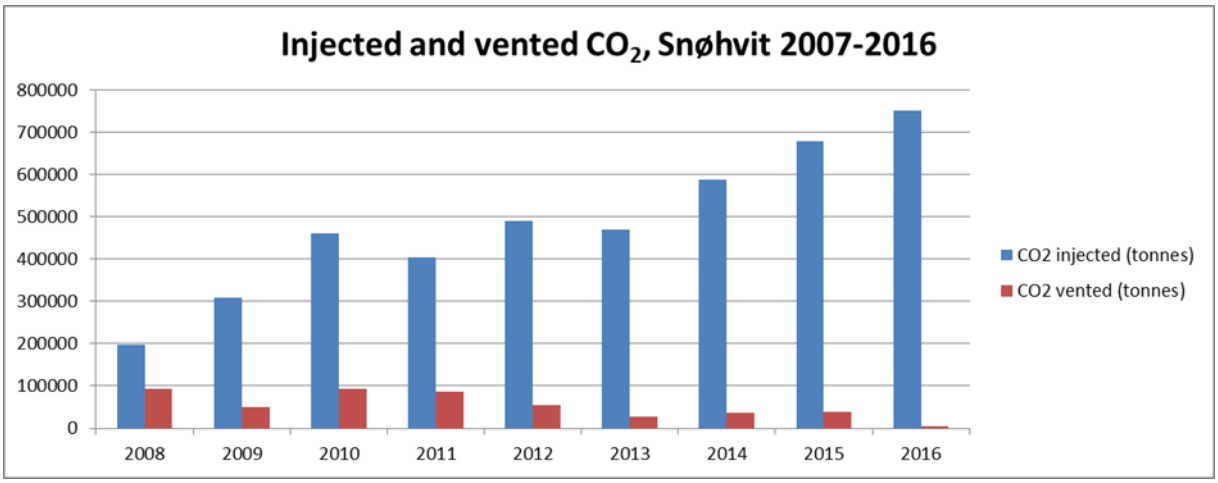


Figure 3.25. Injected and vented CO2 at the Snøhvit field and Hammerfest LNG.
Source: Statoil

3.5.3.2 Methodological issues

CO_2 injection well specification

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

CO_2 re-injection system

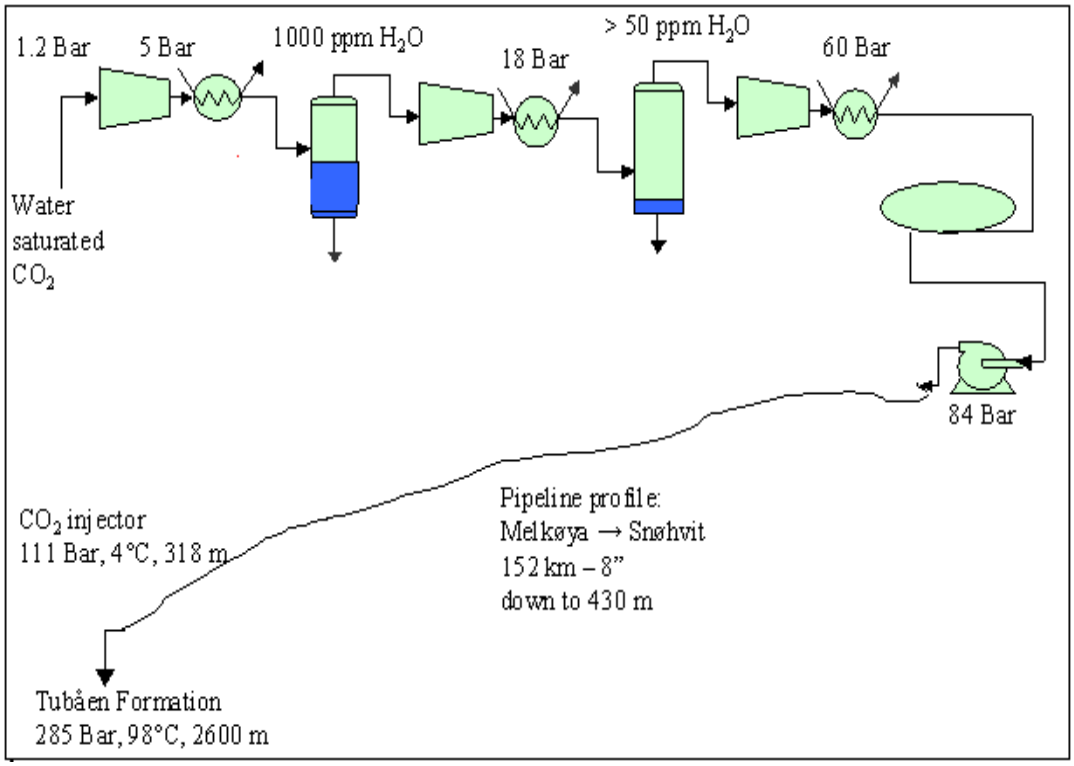


Figure 3.26. Schematic of the CO2 injection system in the Snøhvit area.
Source: Statoil

CO_2 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_2 venting to atmosphere

The reported data covers CO_2 emissions to the atmosphere, e.g. when the injection system is out of operation. These emissions are measured by a venturi flow meter.

Flow metering of the well stream to the CO_2 injector is measured by an orifice meter.

Gas composition of injected or vented gas from the CO_2 injector is controlled by analyses. This is primarily done as a quality assurance of the CO2 removal system (system 22). Analyses have shown that composition is 99.549 weight % CO2, 0.0066 weight % H2S, 0.331% CH4 and 0.088 weight % NMVOC. It has been agreed that in the reports to the environmental authorities, ventilated gas shall be reported as 100% weight CO_2.

Transport and diffuse sources

Based on our best knowledge we anticipate that there are no emissions from pipeline transport. The pipeline and injection well are continuously monitored by pressure monitoring (downhole well, choke, export pump). The pipeline and injection well are also subject to acoustic deep water survey and visual inspection by Remote Operated Vehicle in order to detect any sign of corrosion or irregularities which may cause leakages. 2D and 3D seismic surveys are carried out on a regular basis. Based on 3D seismic data 4D seismic is used to monitor CO_2 movement in vertical and horizontal direction, detect leakages or unexpected migration of CO_2 in the geological formation.

Reservoir monitoring by seismic

4D seismic monitoring was carried out in 2011, 2012 and 2014 in order to monitor the CO_2 plume migration inside the Stø formation and its movement towards the gas zone. Strong focus has also been on optimizing the reservoir simulation model in order to match the 4D observation. Reservoir simulation model is the main tool for predicting CO_2 flow in the future.

The strong 4D signal is mainly related to the fluid replacement effect, CO_2 replacing water. Some of the 4D signal close to the injector is also most likely related to thermal fracturing because of cold CO_2 injection. The CO_2 follows the Stø2 layer and does not seem to migrate up into Stø 3 due to the much lower permeability in Stø3 compared to Stø 2.

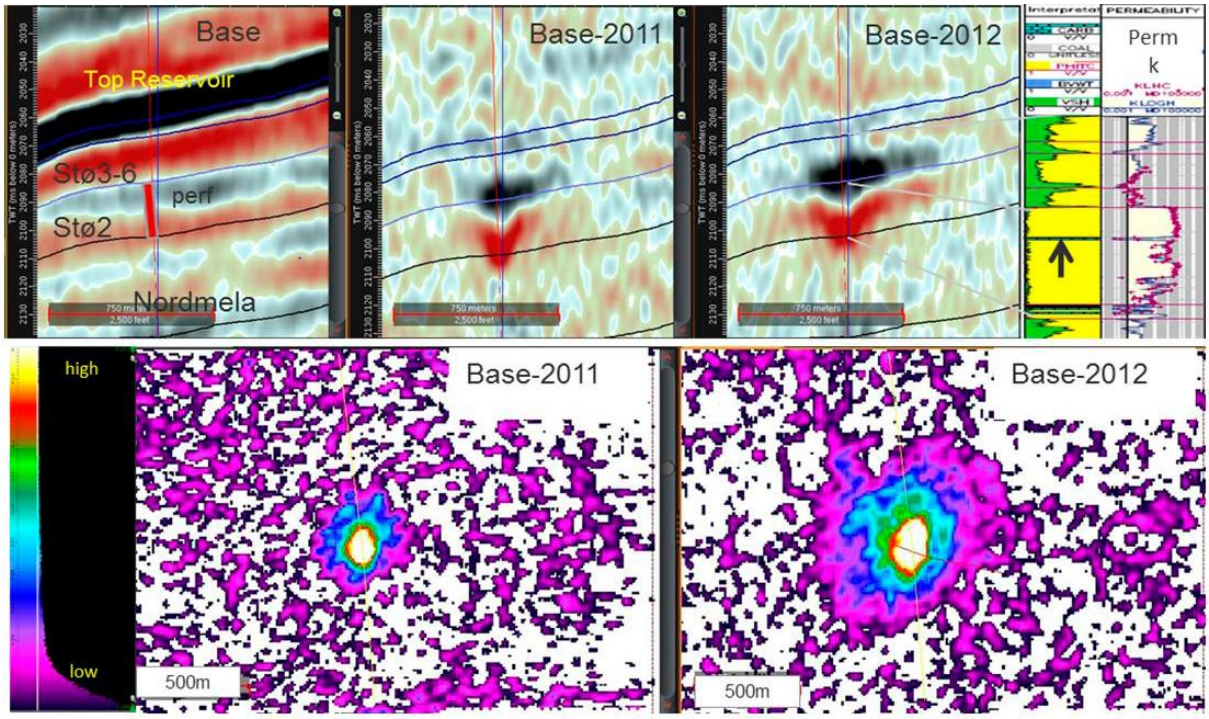


Figure 3.27 The upper figures show the differences from 2009 to 2012. The lower figures show 4D amplitude maps on CO_2 plume for 2009-2011 (left) and 2009-2012 (right).
Source: Statoil

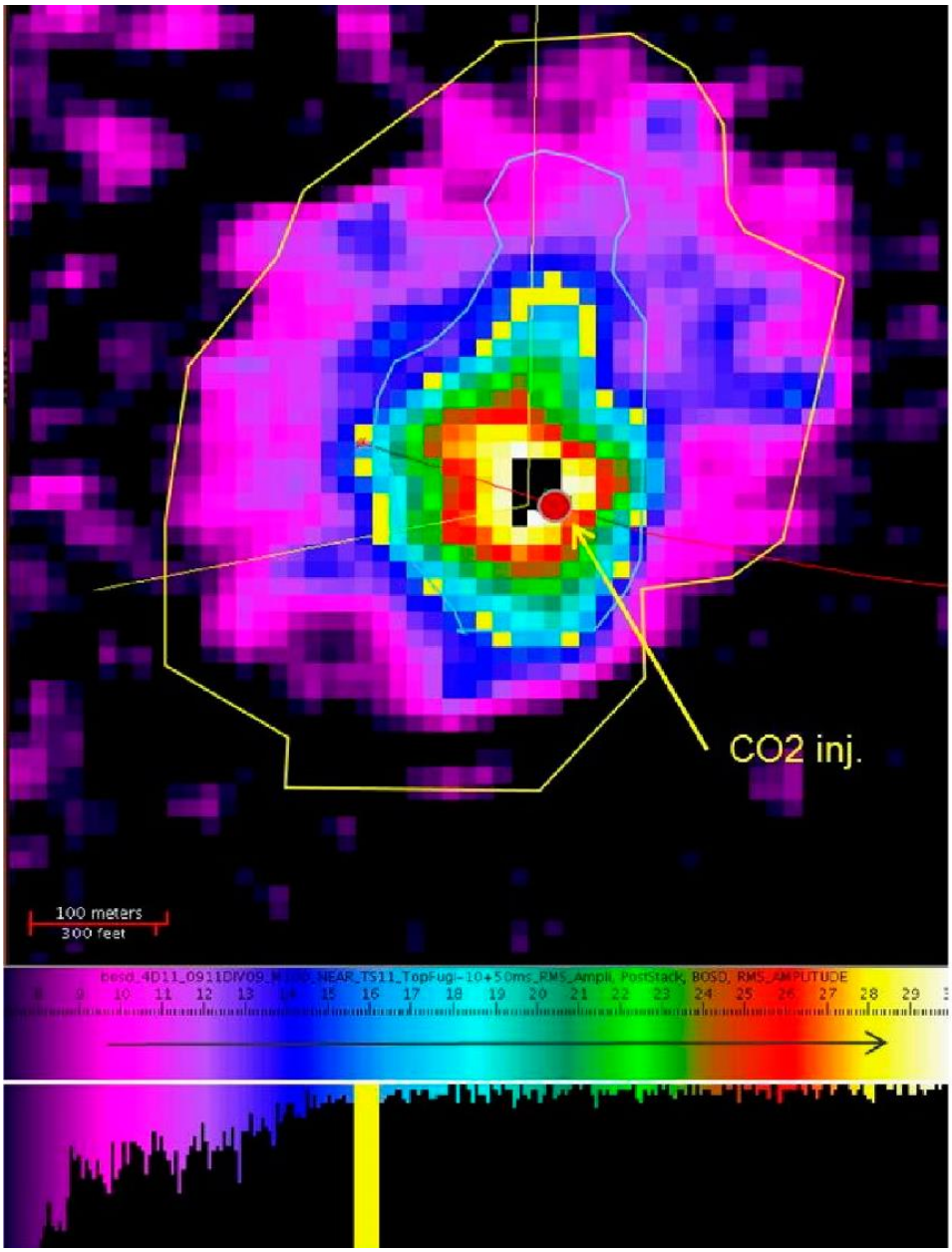


Figure 3.28. Seismic 4D amplitude map from 2011, showing a clear anomaly around the CO_2 injector Pressure/temperature gauge, reservoir modeling and prediction of reservoir performance in Tubåen.

The pressure development in the injection well is monitored on a daily basis by using data from the pressure and temperature (PT) gauge installed in the well. Due to problems during drilling there is diameter restriction in the well and the PT gauge had to be installed about 600 m above the reservoir. Actual bottom hole pressure is estimated based on gauge measurements and CO_2 PVT (pressure, volume, temperature). An Eclipse 300 Compositional simulation model is used for prediction pressure development in the well. In this model CO_2 is injected into the water filled Stø reservoir. Using this model, it has proven to be easy to match the CO_2 plume size/shape geometry in this model with time-lapses seismic data. A weakness of the model is that it does not include temperature and other advanced simulation physical effects. Temperature effects are likely in the near well area as CO_2 at 21 ˚C is injected into a reservoir of initially 91 ˚C.

Since mid 2011 CO_2 in liquid phase has been injected to Stø water saturated formation. The well has shown that its ability to receive injected CO_2 is stable. This is confirmed by weekly monitoring.

As can be seen from Figure 3.29, the reservoir pressure (green line) has depleted since May 2011 until December 2014. This is due to production of the gas zone above the water zone, from the gas zone.

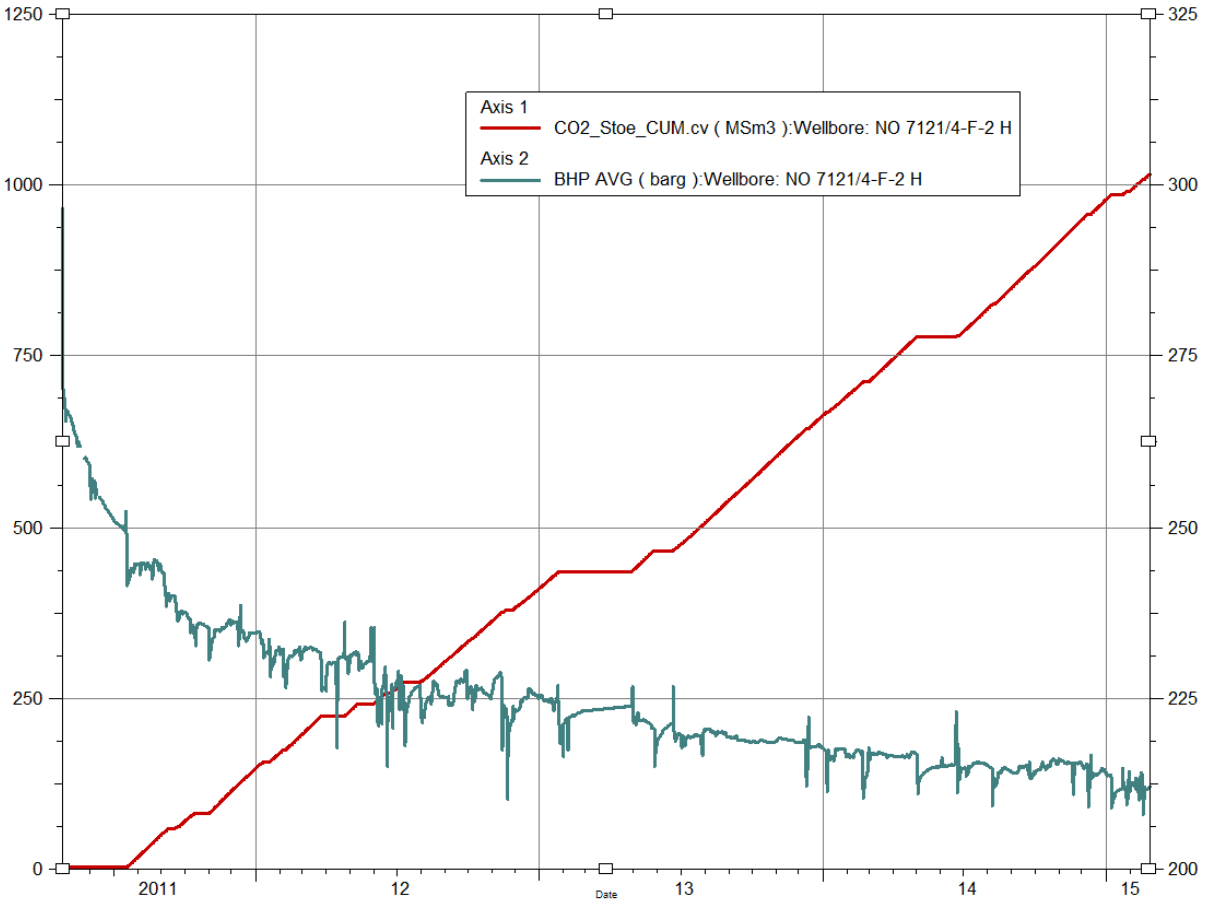


Figure 3.29. History pressures and volume injection into Stø formation.
Source: Statoil

Gravimetric monitoring

A baseline gravity and seafloor subsidence monitoring survey was carried out over the Snøhvit and Albatross fields in June 2007. The closest benchmark is 419 m from the CO_2 injection well. A total of 76 sea floor benchmarks were deployed at the start of the survey, and relative gravity and depth was measured. A new gravity monitoring was carried out in spring 2011. Comparison of 2011 and 2007 gravity measurements confirmed the prognoses.

3.5.3.3 Category-specific QA/QC and verification

Operators for CO_2-storage projects have to apply for a permit pursuant to the Pollution Control Act. In accordance with the permit provisions, Statoil has implemented system for monitoring the CO_2-storage. So far there is no sign of emissions to the water column or the atmosphere from the injected CO_2. Hence the CO_2 injected is not reported as emissions in the emission inventory. Statoil pays a CO_2-tax for the emissions when the injection facility is out of operation due to maintenance etc. From 010113 these emissions are also regulated under the emission trade scheme (EU-ETS). The

emissions of CO_2 and the amount of CO_2 injected are reported to the Norwegian Environment Authority. In the emissions inventory the of amount CO_2 vented at Hammerfest LNG (Snøhvit CO_2 storage project) – is reported under 1C2a - Injection 1B2c.

Statoil performs internal QA/QC for the ongoing CO_2 studies.

3.5.3.4 Category-specific recalculations

There have been no recalculations performed for this source category this year.

3.5.3.5 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

3.5.3.6 Activities and future plans

Stø formation was perforated in April 2011 and is currently injecting in this zone. Injection was monitored every week by a fall-off test performed during stable conditions. During 2014 monitoring was done on a monthly basis by the fall-off test. Injection of CO_2 has been stable and there are no well integrity issues related to operation of the well.

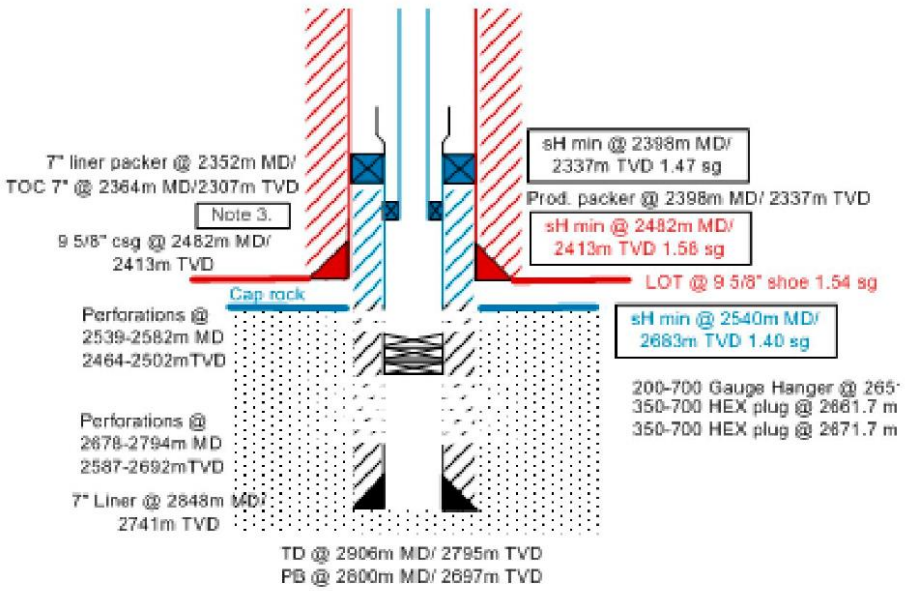


Figure 3.30. CO_2 injector current completion.
Source: Statoil

The challenge of production CO_2 from Snøhvit field has led to a great effort to find solutions that makes the CO_2 injection as robust as possible. The authorities have been kept informed about the situation and the activities and measures planned. A monitoring program covering the period 2011-2020 has been submitted to the environmental authorities.

A new injector well has been established and was put into operation 4Q 2016. This well will be the primary injection well in 2017.

Based on the experience using 4D seismic monitoring in 7120/F-2H it is very likely that 4D seismic monitoring will work well for the new CO_2 injector that is located in the G-segment.

3.5.3.7 CO_2 projects outside Statoil ASA using Snøhvit data

The EU project CO2ReMoVe plans to perform a complete performance and risk assessment for the Snøhvit project by complementing the work done under the CASTOR umbrella. Particular attention will be paid to potential vertical CO_2 migration to the upper gas field and lateral migration, potential flow through deteriorated wells and through undetected faults. The geochemical interaction between CO_2, 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_2 Storage- Critical Elements and Superior Strategy). Based on this information, specific research tasks may be defined.

3.6 Cross-cutting issues

3.6.1 Sectoral versus reference approach

In the reviews of the Norwegian greenhouse gas inventory submitted in 2011 and 2012 the ERTs raised potential problems with non-inventory elements of Norway's annual submission under the Kyoto Protocol. In the review of the 2011 inventory Norway was asked to explain the difference between Reference Approach (RA) and Sectoral Approach (SA). An analysis included in the resubmitted 2012 NIR in May concluded that the difference was mainly due to statistical differences in the energy balance. In the 2012 review Norway was asked to analyze and improve the statistical balance. This work was concluded in 2016, and the results are presented in the report Statistical differences for primary energy products (Statistics Norway 2016b). Implementation of the suggested improvements are summarized in Section 3.6.2.

Norway has in this year's NIR calculated energy consumption and CO_2 emissions from energy combustion based on Reference Approach (RA) and Sectoral Approach (SA). The supply side in the RA is from the previous version of the national energy balance, which is included in Annex III in the NIR. The inventory (the SA) does not use the new energy balance published by Statistics Norway in 2017. As discussed in section 3.2.1, conversion of the emission inventory to the new energy balance could not be finalized before the 2018 emission reporting. To avoid inconsistent time series, the previous version of the energy balance for the years 1990-2015 is still used in the inventory. For this reason, the previous version of the energy balance is still used also in the RA.

For 2016, the data in the RA is based on data from revised energy balance. This differs from the method used in the inventory, where the data for 2015 from the previous balance was updated with some figures for 2016, particularly total sales figures for petroleum products. Thus, the inventory for 2016 and the balance data used in the RA are not coherent in the same way as for 1990-2015.

The old energy balance differs from energy balance data reported to the IEA with respect to delimitations, definitions, and revision level. The correspondence between reporting to the IEA and the data used in the RA and SA is expected to become better and more transparent when the new technical solution is used both for national and international reporting, see Section 3.6.2.

Sectoral versus reference approach. The result of the estimation with the two methods is shown in Table 3.37. There are large differences between the output from RA and SA, both for the energy consumption data and the CO_2 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_2 emissions are 0 to 9 percentage points higher. The highest discrepancy for CO_2 is in 1999-2001 and in 2004-2006. For 2016, the difference for CO_2 is 6 per cent. The large discrepancies are primarily due to statistical differences in the energy balance, as shown below.

A detailed analysis of the relationship between the RA and SA and the energy balance is given in annex XI. The main conclusion is that the difference between the energy consumption in RA and SA is primarily due to statistical differences in the energy balance (column *b*). In addition, a number of other smaller differences were identified. The remaining difference between RA and SA after adjusting for these items is within +/- 2 per cent for all years except 1990, where it is -3 per cent. The reference approach may be an important tool for verification of the sectoral approach used in the inventory. The analyses undertaken in the present and the previous NIRs have shown that the

difference between RA and SA is mainly due to the statistical difference in the energy balance, and that important parts of the consumption block in the EB are unlikely to have major completeness issues. If the statistical differences are due to problems in the supply block of the balance, then resolving these problems will only affect the RA, but not the SA and the reported emissions.

Table 3.37 Comparison of fuel consumption and CO_2 emission data between the Reference Approach[1] (RA) and the Sectoral Approach (SA). 1990-2016.

	Fuel consumption			CO_2 emissions		
Year	**RA, apparent consumption (PJ)**	**SA (PJ)**	**Difference RA-SA (%)**	**RA (Gg)**	**SA (Gg)**	**Difference RA-SA (%)**
1990	335	385	-12.8	24 040	26 189	-8.2
1991	400	381	5.1	28 409	25 783	10.2
1992	379	388	-2.3	26 603	26 254	1.3
1993	378	404	-6.4	26 461	27 253	-2.9
1994	404	424	-4.8	28 617	28 666	-0.2
1995	431	422	2.2	30 272	28 615	5.8
1996	397	460	-13.6	28 030	31 281	-10.4
1997	450	464	-3.1	31 667	31 366	1.0
1998	508	464	9.6	35 494	31 373	13.1
1999	566	463	22.2	39 853	31 630	26.0
2000	654	453	44.5	45 906	30 700	49.5
2001	611	479	27.7	41 671	32 753	27.2
2002	509	485	5.0	35 379	32 980	7.3
2003	546	505	8.1	37 776	34 308	10.1
2004	647	509	27.1	45 813	34 335	33.4
2005	599	501	19.4	42 712	34 056	25.4
2006	637	522	22.0	45 869	34 927	31.3
2007	501	530	-5.4	34 489	35 287	-2.3
2008	589	530	11.3	40 904	34 754	17.7
2009	564	542	4.2	39 343	35 173	11.9
2010	654	558	17.3	44 616	36 720	21.5
2011	549	543	1.0	38 128	35 834	6.4
2012	538	539	-0.4	37 145	35 424	4.9
2013	613	537	14.1	42 002	35 082	19.7
2014	581	539	7.8	39 904	34 978	14.1
2015	593	547	8.4	40 537	35 369	14.6
2016	489	532	-8.1	32 546	34 765	-6.4

[1] *Apparent energy consumption (excluding non-energy use, reductants and feedstocks).*

Source: Statistics Norway/Norwegian Environment Agency

3.6.2 Quality controls within reference and sectoral approach

As mentioned in section 3.6.1 above, the ERT in 2012 asked for explanations to the high statistical difference between supply and use of petroleum products in the Norwegian official Energy Balance. In response to this Statistics Norway led a project that concluded with annex XII to the 2013 national inventory report (NIR 2013). A follow-up project run in 2013-2014 concluded with annex XII to NIR 2014. Remaining issues were further investigated in a third follow-up project in 2014-2015.

The three part-projects combined constitute the main parts of the report (Statistics Norway 2016b)). The following text is an abstract of the report and the conclusions and recommendation is to be found in the report.

For several years there has been a problem regarding statistical difference between the supply and use of petroleum products in the Norwegian Energy Balance. This should not be unexpected from a country exporting almost 90 per cent of its petroleum products. Just minor discrepancies between production and export on the supply side of the balance may result in significant imbalances with the use side figures. There has, however, been a tendency for a positive bias in the statistical difference for a long time, which has caused uncertainty whether the domestic use of petroleum products might have been underestimated. Therefore a project was launched in 2012 in order to address the bias and make corrections if possible.

In Norway, most of the produced petroleum products are *primary*[11], while most of the domestic use relates to *secondary* petroleum products. Hence, separate energy balances for *primary and secondary* petroleum products were elaborated in the project. To further increase the transparency, more detailed product categories and one transfer item were elaborated as well. New data on primary petroleum products were identified and collected, in order to establish alternative export figures and new revision controls. No alternative data on secondary petroleum products was found, and hence these products were not prioritized.

The new export data is consistent with the production figures, and most discrepancies can be discussed with the data owner without breaking the confidentiality rules. Hence, the new data provides a solid basis for quality control. A similar crosschecking of the original export data from the external trade statistics (ETS) is tedious, or for some products almost impossible. Moreover, corrections must be made in the energy balance to obtain consistency between the export and production data.

All new data is readily available from the Norwegian Petroleum Directorate, one terminal and one pretreatment facility, respectively, and suitable for routine revision control. Compiling them for use in the energy balance is relatively simple. One dataset is not distributed by destination country, and in international reporting of country specific figures this data should instead be used to adjust the current ETS export data.

[11] *Primary* means unrefined (incl. pretreatment like fractionation and stabilization). *Secondary* means refined into finished products or semi-manufactured products for use as raw material in manufacturing

Based on new and original data, two alternative detailed energy balances for primary petroleum products were established, for revision purposes. Most causes of statistical difference for primary petroleum products were found due to the new data and revision methods, and the statistical differences for these products were significantly reduced.

The major part of the recommendations from the analysis are now implemented in the energy balance, while some of the remaining will be implemented as part of the revised energy balance system.

Improvements implemented in the old version of the energy balance:

- New annual statistics on sales of petroleum products, based on detailed information on every delivery sent by the companies (SA).
- New collection of supplementary data, including detailed shipment data from the Norwegian Petroleum Directorate, export from one terminal and one crude petroleum pretreatment plant (RA).
- New revision methods for production, export and stock change micro data on all primary petroleum products (excl. dry gas), applying both former and new data. The supplementary data are as well used to estimate the export of crude oil according to a new method. The crude oil figures are cross checked at most detailed level against Statistics Norway's external trade statistics (RA).
- Cross check of dry gas micro data against Statistics Norway's external trade statistics (RA).
- Stock data from one previously missing terminal (RA).
- The improvements are implemented in the energy balance for 2015, and partly for 2014.

Improvements to be implemented in the revised energy balance:

- LPG from one refinery was found to be propylene, which is not a typical energy product. The propylene is used as raw material in chemical industry. The use as raw material is not part of the energy balance, and hence a statistical difference occurs. This will be solved in the new energy balance (RA).

The new revision method has revealed underreporting of shipments of Norwegian NGL/LPG products from one UK sales point and a small underreporting of shipments of crude oil from another UK sales point, rendering the statistical difference for these product categories still on the positive side on average.

All improvements on statistical differences concern primary petroleum products, while no methods for reducing the statistical difference of refined petroleum products were found due to lack of supplementary data.

Table 3.38 Statistical difference for primary petroleum products in the energy balance. PJ. 2015.

		NGL/LPG	Natural gas	Crude oil
1	Primary energy production	389.80	4 297.51	3 220.53
1.1.1	Prod. of prim. energy carriers	366.21	4 284.02	3 220.53
1.1.2	Flaring	-	13.49	-
1.2	Prod. of sec. energy carriers	23.59	-	-
2	Imports	14.67	-	48.18
3	Exports	311.02	4 054.12	2 673.88
4	International bunkers	-	1.27	-
5	Changes in stocks (+ = net decrease,- = net increase)	-5.31	-	-6.64
6	Total energy supply (1+2-3-4+5)	88.14	242.13	588.19
8	Transformation	11.72	15.85	576.67
9	Energy industries own use	0.15	180.35	-
10	Non energy use	43.06	23.02	-
11	Losses in transport and distribution	-	0.21	-
12	Statistical differences (6+8-9-10-12)	25.03	5.38	11.51
13	Final energy consumption, excl. non-energy use	8.18	17.32	-

New platform for energy balance and energy accounts: Statistics Norway has had a project running over several years on improving the energy balance and the energy accounts. The main phase was published in 2017 with results for 2010-2016 (Statistics Norway (Annually-a), Hendriks et al. (2017)).The project entails both new technical solutions and methodological changes. The project is expected to streamline national and international reporting of energy statistics, and increase consistency in the different reportings. The relationships with other statistics will be improved, in particular with respect to emissions to air from energy use. It will also improve transparency between energy and emission statistics.

Finalization of project has been delayed, and extension of the time series back to 1990 has not been published as of april 2018. To avoid inconsistent time series, the old energy balance for the years 1990-2015 is still used in the inventory.

Within the emissions statistics, integration with the new energy balance will be a major part of improvement work in 2018, with publication of results planned for December 2018.

3.6.3 Feedstocks and non-energy use of fuels

Emissions from the use of feedstock are according to the IPCC guidelines 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.

Table 1Ad Feedstocks and non-energy use of fuels in the CRF is filled in with fuels that are used as feedstock or any other non-energy use according to the energy balance. The data in the energy balance are adjusted with respect to reducing agents that are considered as fuel use in the energy balance, but accounted as IPPU emissions in the inventory.

The table also includes information of the amount of carbon excluded. The excluded amount

corresponds to the fuel quantity except for emissions that are included as energy combustion in 1A. These emissions comprise the following categories, which are further described in section 3.2.11:

- A fraction of non-fuel use of gasoline, gas/diesel oil and residual fual oil is assumed to be emitted to air. The emissions are reported under 1A5a *Non-fuel use*.
- Emisssions from use of lubricants in 2-stroke engines are reported under 1A5b. Emissions from other lubricants is on the other hand reported in IPPU under 2D2 *Lubricants* and are as such accounted as carbon excluded.

The following table gives balances relevant fuels. The table shows that the fuel amounts reported in as fuel combustion in 1A and the carbon excluded from the Reference approach add up to the total fuel cuantity for feedstock and other noen fuel use.

Table 3.39 Balances for fuels for which emissions from feedstock and non-fuel use are partly reported in the Energy sector. 1990-2015

		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
1AD Feedstock etc., reported Fuel quantity												
Gasoline	TJ	-	11	15	-	-	-	-	-	-	-	-
Gas Diesel Oil	TJ	-	110	126	493	0.23	0.23	0.23	0.23	0.23	0.23	-[1]
Residual fuel oil	TJ	-	570	611	918	-	-	-	-	-	-	-
Lubricants	TJ	4 422	3 457	3 578	2 734	1 648	1 648	1 487	201	1 688	1 769	2 090
Reported in Energy Sectoral Approach (1A), Activity data												
1A5a Non-fuel use	TJ	-	124	138	348	0.12	0.12	0.12	0.12	0.12	0.12	0.12[1]
of which Gasoline	TJ	-	6	8	-	-	-	-	-	-	-	-
of which Gas Diesel Oil	TJ	-	55	63	247	0.12	0.12	0.12	0.12	0.12	0.12	0.12[1]
of which Residual fuel oil	TJ	-	63	67	101	-	-	-	-	-	-	-
1A5b Lubricants	TJ	84	78	69	58	40	39	39	39	39	39	39
Remainder, excluded from Reference Approach												
Gasoline	TJ	-	6	8	-	-	-	-	-	-	-	-
Gas Diesel Oil	TJ	-	55	63	247	0.12	0.12	0.12	0.12	0.12	0.12	-[1]
Residual fuel oil	TJ	-	507	544	817	-	-	-	-	-	-	-
Lubricants	TJ	4 338	3 379	3 509	2 675	1 608	1 609	1 449	162	1 650	1 730	2 052
Remainder, excluded from Reference Approach as reported in 1AD												
Gasoline	kt C	-	0.11	0.15	-	-	-	-	-	-	-	-
Gas Diesel Oil	kt C	-	1.11	1.26	4.95	0.002	0.002	0.002	0.002	0.002	0.002	-[1]
Residual fuel oil	kt C	-	10.91	11.70	17.57	-	-	-	-	-	-	-
Lubricants	kt C	86.77	67.58	70.18	53.51	32.16	32.18	28.98	3.25	33.00	34.60	41.03

[1]) There is a small discrepancy for gas diesel oil in 2016 between SA data in 1A5a and RA data in 1AD. The discrepancy, which corresponds to less than 10 t CO_2, is due to different methods in RA and SA for 2016. See section 3.6.1.

Norway has in several revision reports been asked to provide more information on feedstock and to ensure the quality of the reporting. Implementation of these recommendations has been postponed, pending the completion of a project in Statistics Norway on technical and methodological aspects of

the energy balance and energy accounts. As noted in section 3.6.2, results from this project is expected to be available in 2018. The reporting on feedstocks etc. will then be improved in the NIR 2019.

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 (IPCC 2006). The estimated emission figures are reported separately and are presented in Table 3.40.

In 2016 CO_2 emissions from ships and aircraft in international traffic bunkered in Norway amounted to a total of 2.2 million tonnes, which corresponds to 4.1 per cent of the total Norwegian CO_2 emissions. The CO_2 emissions from bunkers have increased by 3 per cent from 1990 to 2016 and decreased by 6.9 per cent in 2016.

During the period 1990-2016, emissions of CO_2 from marine bunkers decreased by 55 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 78 per cent in the period 1997-2016.

The CO_2 emissions from international air traffic bunkered in Norway was in 2016 1.5 million tonne. The emissions in 2016 was nearly 150 per cent higher compared to 1990. The largest part of the growth has been after 2003 where the emmissions have been doubled until today. In 2016 the emissions were 2 per cent higher than in 2015.

Table 3.40 Emissions from ships and aircraft in international traffic bunkered in Norway, 1990-2016. 1000 tonnes. CO_2 in Mtonnes.

	Aviation							**Marine**						
	CO_2	***CH_4***	***N_2O***	***NO_X***	***CO***	***NMVOC***	***SO_2***	***CO_2***	***CH_4***	***N_2O***	***NO_X***	***CO***	***NMVOC***	***SO_2***
1990	0.6	0.0	0.0	2.4	1.1	0.2	0.1	1.5	0.1	0.0	26.4	1.4	1.1	9.9
1991	0.6	0.0	0.0	2.2	1.1	0.2	0.1	1.3	0.1	0.0	22.3	1.2	0.9	9.7
1992	0.6	0.0	0.0	2.3	1.3	0.3	0.1	1.6	0.1	0.0	28.0	1.5	1.2	12.3
1993	0.6	0.0	0.0	2.4	1.5	0.4	0.1	1.7	0.1	0.0	29.9	1.6	1.3	13.5
1994	0.6	0.0	0.0	2.3	1.6	0.5	0.1	1.8	0.1	0.0	32.9	1.8	1.4	14.0
1995	0.6	0.0	0.0	2.2	1.6	0.5	0.1	2.3	0.2	0.1	40.1	2.2	1.7	13.7
1996	0.7	0.0	0.0	2.6	1.7	0.5	0.1	2.5	0.2	0.1	44.5	2.4	1.9	15.4
1997	0.8	0.0	0.0	2.9	1.8	0.5	0.1	3.0	0.2	0.1	54.2	2.9	2.3	18.8
1998	0.8	0.0	0.0	3.0	1.7	0.4	0.1	2.9	0.2	0.1	51.7	2.6	2.2	14.5
1999	0.9	0.0	0.0	3.5	1.7	0.3	0.1	2.7	0.2	0.1	47.8	2.4	2.0	12.4
2000	0.9	0.0	0.0	3.3	1.5	0.1	0.1	2.6	0.2	0.1	47.3	2.4	2.0	10.6
2001	0.8	0.0	0.0	3.1	1.3	0.1	0.1	2.6	0.2	0.1	47.2	2.4	2.0	12.8
2002	0.7	0.0	0.0	2.8	1.1	0.1	0.1	2.1	0.1	0.1	37.2	1.9	1.6	7.0
2003	0.7	0.0	0.0	2.9	1.1	0.1	0.1	2.1	0.1	0.1	36.7	1.9	1.6	8.0
2004	0.8	0.0	0.0	3.3	1.3	0.1	0.1	2.0	0.1	0.0	35.0	1.8	1.5	7.8
2005	0.9	0.0	0.0	3.7	1.4	0.1	0.1	2.3	0.2	0.1	39.8	2.1	1.7	8.6
2006	1.1	0.0	0.0	4.5	1.6	0.1	0.1	2.3	0.2	0.1	39.5	2.1	1.7	5.1
2007	1.2	0.0	0.0	4.7	1.6	0.1	0.1	2.1	0.2	0.1	35.6	1.9	1.6	5.5
2008	1.1	0.0	0.0	4.5	1.5	0.1	0.1	2.1	0.2	0.1	34.9	1.9	1.6	6.1
2009	1.1	0.0	0.0	4.5	1.4	0.1	0.1	1.8	0.1	0.0	28.8	1.6	1.3	4.7
2010	1.3	0.0	0.0	5.3	1.6	0.1	0.1	1.5	0.1	0.0	23.5	1.3	1.1	4.7
2011	1.2	0.0	0.0	5.0	1.5	0.1	0.1	1.5	0.1	0.0	23.8	1.4	1.2	4.1
2012	1.4	0.0	0.0	6.0	1.7	0.2	0.1	1.5	0.1	0.0	22.3	1.3	1.1	3.4
2013	1.5	0.0	0.0	6.5	1.8	0.2	0.1	1.5	0.1	0.0	21.6	1.3	1.1	3.8
2014	1.6	0.0	0.1	7.0	2.0	0.2	0.1	1.0	0.1	0.0	14.9	0.9	0.8	2.1
2015	1.5	0.0	0.0	6.6	1.9	0.2	0.1	0.8	0.1	0.0	11.2	0.7	0.6	1.0
2016	1.5	0.0	0.0	6.4	1.8	0.2	0.1	0.7	0.0	0.0	9.8	0.6	0.5	0.3

Source: Statistics Norway/Norwegian Environment 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 Tier 2 CORINAIR methodology. The methodology is based on detailed information on types of aircraft and number of LTOs, as well as cruise distances.

Activity data

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

Emission factors

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

3.7.1.4 Precursors

Emissions of NO_X from international sea traffic in 2016 were about 9.8 ktonnes, a decrease of 12 per cent from 2015.

NO_X emissions from international aviation amounted to 6.4 ktonnes in 2016, a decrease of 2 per cent from 2015.

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

3.7.2 CO_2 emissions from biomass

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

Emission factors for biomass are shown in Table 3.4. Details are given in the sector chapters where necessary.

4 Industrial processes and product use (CRF sector 2)

4.1 Overview of sector

The chapter provides descriptions of the methodologies used to calculate emissions of greenhouse gases from industrial processes and product use (IPPU). Only non-combustion emissions are included in this chapter. Emissions from fuel combustion in Industry are reported in Chapter 3 (Energy).

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. Norway has a long experience of using GHG emissions from industrial point sources in the national GHG inventory. The Norwegian Environment Agency has been given the authority to manage and enforce the Pollution Control Act, the Product Control Act and the Greenhouse Gas Emission Trading Act. The Norwegian Environment Agency grants permits, establishes requirements and sets emission limits, and carries out inspections to ensure compliance. This is one of the core responsibilities of the agency.

For verification purposes, the IEFs for several of the source categories reported by Norway were in 2014 compared with what other Annex I countries had reported using a tool developed by the UNFCCC.[12]

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 Norwegian Environment Agency. Such annual reports are reports as required by their regular permit, reports as required by the permit under the EU emission trading system (EU ETS) and reports as required by the voluntary agreement up to the year 2012 when the agreement terminated. 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 is normally collected by Statistics Norway.

Indirect emissions of CO_2 from oxidized CH_4 and NMVOC for some source categories are included in the IPPU sector. The indirect emissions of CO_2 are calculated by Statistics Norway and are based on the emissions of CH_4 and NMVOC. See chapter 9 for more details. The IPPU sector contributed to a total of about 119 000 tonnes of indirect CO_2 in 1990 and to a total of about 110 000 tonnes of indirect CO_2 in 2016. The majority of these emissions are reported in 2D (Non-energy products from fuels and solvent use).

Table 4.1 gives an overview of the Norwegian IPPU sector. The GHG emissions from IPPU in 2016 were about 8.6 million tonnes CO_2-equivalents, or 16.2 per cent of the total GHG emissions in Norway. The corresponding percentage in 1990 was 28.0 per cent. The emissions from this source category have decreased by 40.5 per cent from 1990 to 2016 and increased by 1.9 per cent from 2015 to 2016. The decrease from 1990 to 2016 is mainly due to reduced PFC emissions from production of aluminium and SF_6 from production of magnesium. The reduction in the SF_6 emissions is due to the closing down of production of cast magnesium in 2002, improvements in the GIS-sector

[12] http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php

and an almost end in the use of SF_6 as tracer gas. In June 2006, the magnesium recycling foundry also closed down. In addition, N_2O emissions from nitric acid production have decreased substantially since 1990.

Table 4.1 Emission trends for IPPU categories (ktonnes CO_2-equivalents).

Category	1990	1990, % of IPPU	2015	2016	2016, % of IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2A	727.7	5.0	987.1	971.6	11.3	33.5	-1.6
2B	3 250.5	22.4	1 201.2	1 075.8	12.5	-66.9	-10.4
2C	10 113.3	69.8	4 640.4	4 805.0	55.7	-52.5	3.5
2D	287.5	2.0	204.0	211.3	2.4	-26.5	3.6
2E	0.0	0.0	1.1	1.1	0.0		0.0
2F	0.0	0.0	1 232.9	1 363.6	15.8	3 106 145.2	10.6
2G	87.5	0.6	91.8	84.1	1.0	-3.9	-8.4
2H	31.3	0.2	108.6	115.6	1.3	269.6	6.5
Total	14 497.8	100.0	8 467.1	8 628.2	100.0	-40.5	1.9

Source: Statistics Norway and the Norwegian Environment Agency

The Metal industry (2C) contributed to 55.7 per cent of the total GHG emissions from Industrial Processes in 2016, mainly from production of ferroalloys and aluminium, and in 1990 the contribution was 69.8 per cent. The other main contributing sectors in 2016 were Product uses as substitutes for ODS (2F), Chemical Industry (2B), and Mineral Industry (2A) with 15.8, 12.5 and 11.3 per cent, respectively, of the total GHG emissions in this sector.

Table 4.2 shows the source categories in IPPU that have been identified as key categories from either approach 1 or 2 in the 1 key category analysis.

Table 4.2 Key categories in the sector Industrial processes and product use.

CRF code	Source category	Gas	Key category according to approach	Method
2A1	Cement Production	CO_2	1	Tier 3
2A2	Lime production	CO_2	1	Tier 3
2B1	Ammonia Production	CO_2	1	Tier 2
2B2	Nitric Acid Production	N_2O	2	Tier 3
2B5	Carbide production	CO_2	2	Tier 2
2B6	Titanium dioxide production	CO_2	1	Tier 2
2B8	Petrochemical and carbon black*	CO_2	1	Tier 2
2C2	Ferroalloys production	CO_2	2	Tier 2/3
2C3	Aluminium production	CO_2	2	Tier 2/3
2C3	Aluminium production	PFCs	2	Tier 2
2C4	Magnesium production	SF_6	1	Tier 2
2D1	Lubricant use	CO_2	1	Tier 2
2F	Product uses as substitutes for ODS	HFCs	2	Tier 2

Sources: Statistics Norway and the Norwegian Environment Agency

** In the key category analysis, 2B8a, 2B8b and 2B8c have been aggregated to 2B8.*

4.2 Mineral industry – 2A

The sector category Mineral industry includes CO_2 emissions in the source categories cement production, lime production, glass production, ceramics, other uses of soda ash, non metallurgical magnesia production and other process use of carbonates. Table 4.3 shows that components included in the inventory, the tier method used and whether the source categories are key categories or not.

Table 4.3 Mineral industry. Component included in the inventory, tier of method and key category.

Source category	CO_2	Tier	Key category
2A1. Cement production	R	Tier 3	Yes
2A2. Lime production	R	Tier 3	Yes
2A3. Glass production	R	Tier 3	No
2A4a. Ceramics	R	Tier 3	No
2A4b. Other uses of soda ash	E	Tier 1	No
2A4c. Non metallurgical magnesium production	R	Tier 3	No
2A4d. Other process use of carbonates	R	Tier 2	No

R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated. NA = Not Applicable. NO = Not Occuring. IE = Included Elsewhere.

Table 4.4 shows the trends for 2A as a whole and for the various source categories. The CO_2 emissions from this sector category were a little less than 1 million tonnes in 2016, this accounts for 11.3 per cent of the total emission from the IPPU-sector. The emissions from this sector have increased with 33.5 per cent from 1990-2016, mainly due to increased production of clinker and lime in more recent years. The emissions from this sector category decreased by 1.6 per cent from 2015 to 2016.

Table 4.4 Emission trends for 2A Mineral industry (kt CO_2 equivalents).

Source category	1990	1990, % of IPPU	2015	2016	2016, % IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2A1. Cement production	634.3	4.4	671.5	684.5	7.9	7.9	1.9
2A2. Lime production	49.8	0.3	221.3	218.6	2.5	338.6	-1.2
2A3. Glass production	5.6	0.0	6.8	6.6	0.1	19.0	-1.7
2A4a. Ceramics	3.7	0.0	0.0	0.0	0.0	-100.0	
2A4b. Other uses of soda ash	9.0	0.1	1.1	3.0	0.0	-66.6	179.8
2A4c. Non metallurgical magnesium production	0.0	0.0	68.5	40.8	0.5		-40.4
2A4d. Other process use of carbonates	25.3	0.2	17.9	18.0	0.2	-28.8	0.6
2A. Total	727.7	5.0	987.1	971.6	11.3	33.5	-1.6

Source: Statistics Norway and Norwegian Environment Agency

Table 4.5 and Table 4.6 show that most of the limestone and dolomite uses within the IPPU sector are within 2A. In addition to uses in the IPPU sector, there are reported emisisons in 3G from the use of limestone and dolomite.

Table 4.5 Balance in ktonnes for the use of limestone for which IPPU emissions are reported.

Limestone use	2014	2015	2016
2A1 - Cement production	1 653	1 526	1556
2A2 - Lime production	498	504	490
2A4a – Ceramics	1	0	0
2A4c – Non-metallurgical magnesium production	0	0	0
2A4d – Other process uses of carbonates	0	0	0
2C2 - Production of ferroalloys	71	61	51
2H1 – Pulp and paper	19	20	22
Total limestone	2 242	2 112	2 119

Sources: Statistics Norway and the Norwegian Environment Agency

Table 4.6 Balance in ktonnes for the use of dolomite for which IPPU emissions are reported.

Dolomite use	2014	2015	2016
2A2 - Lime production	22	19	27
2A4c – Non-metallurgical magnesium production	164	147	90
2A4d – Other process uses of carbonates	16	15	11
2A3 - Glass production	8	11	11
2C2 - Production of ferroalloys	3	4	6
Total dolomite	**214**	**196**	**145**

Sources: Statistics Norway and the Norwegian Environment Agency

A QA/QC exercise was undertaken for the 2016 NIR to elaborate a mass balance of the limestone and dolomite used in the country. There was no information that indicated that there were other emissive uses of limestone and dolomite that were not reported, and the QA/QC exercise confirmed this. The uses with no emisisons are according to the Geological Survey of Norway slurry and crushed rock for filling.

A potential use of limestone is in flue gas desulphurization (FGD), but this is not used in Norway. In Norway, the industry primarily uses the sea water scrubbing technology. This combined with closures of some industrial plants, increasingly strict requirements on the sulphur content in various oil products, the introduction of a SO_2 tax and requirements for industry to reduce its emissions have decreased the SO_2 emissions.

4.2.1 Cement Production, 2A1 (Key category for CO_2)

4.2.1.1 Category description

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

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

CO_2 from cement production is defined as a key category according to the approach 1 analysis.

4.2.1.2 Methodological issues

The emissions of CO_2 from clinker production included in the GHG inventory are reported by the two producers in their annual report under their regular permit and under the EU ETS to the Norwegian Environment Agency. Before entering the EU ETS, the plants used a tier 2 methodology while they now use a tier 3 methodology. The plants report data on the types and quantities of carbonates consumed to produce clinker, as well as their emission factors. The reported emissions include Cement Kiln Dust (CKD). Until 2009, both plants have used a conversion factor of 1. This means that all Ca and Mg have been assumed to be carbonates. From 2010, the largest plant has reported conversion factors that are less than 1 (0.948 or higher). The smaller plant has continued to use a conversion factor of 1.

4.2.1.3 Activity data

The amount of clinker, CKD and other carbonates that the plants use in their calculation are reported by the plants to the Norwegian Environment Agency. The annual total clinker production is reported in the CRF Table 2(I).A-Hs1 and Table 4.7 shows the clinker production for some selected years in the time series.

Table 4.7 Norwegian clinker production (ktonnes).

Year	Clinker production
1990	1 244.1
1995	1 682.9
2000	1 649.6
2005	1 454.3
2007	1 636.8
2008	1 534.0
2009	1 528.3
2010	1 433.8
2011	1 415.4
2012	1 399.1
2013	1 399.8
2014	1 374.9
2015	1 284.1
2016	1 306.3

Source: Norwegian Environment Agency

4.2.1.4 Emission factors

CO_2

The emission factors used are plant specific. The factors are dependent on the chemical composition of the clinker i.e. the content of Ca and Mg. The fraction of CaO from non-carbonate sources like ashes is subtracted. The emission factors are calculated particularly for the two Norwegian factories. Prior to entering the EU ETS, the emission factors did not vary much and tended to be around 0.530 tonne CO_2 per tonne clinker for one plant (Tokheim 2006) and 0.541 tonne CO_2 per tonne clinker as recommended by SINTEF (1998e) for the other plant. The IPCC default emission factor is 0.52 tonne CO_2/tonne clinker. After entering the EU ETS, the plants face stricter requirements concerning how

their EF are determined and the EFs may vary more from one year to another. The same emission factors are used for CKD as for clinker production.

4.2.1.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

The two plants have reported their emissions to the Norwegian Environment Agency for many years. Cement production was included in the EU ETS in 2005. After entering the EU ETS, the plants face stricter requirements concerning how AD and EF are determined and the EFs will vary more from one year to another. The reduction in IEF from 2009 to 2010 is a consequence of lower EFs in 2010 for both plants. The EF for the plant producing about 70% of the total production decreased the most, pushing the IEF for total production down. This explains the inter-annual variations in the IEF in the end of the time series.

4.2.1.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The emissions are covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the Norwegian Environment Agency's inventory team.

Statistics Norway occasionally calculates alternative emission figures for CO_2 and compares them with the emission figures reported by the plants to the Norwegian Environment Agency to check if they are reasonable. The calculations are based on the clinker production (reported annually from the plants to the Statistic Norway. The calculated emission figures have agreed quite well with emissions figures reported by the plants.

4.2.1.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.2.1.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.2.2 Lime Production, 2A2 (Key category for CO_2)

4.2.2.1 Category description

Three plants that produce lime in Norway reported CO_2 emissions from processes to the Norwegian Environment Agency and all three plants are covered by the EU ETS. The large increase in CO_2 emissions from lime production from 1990 is due to increased production at existing plants and the establishment of a new plant in 2007 with large production. CO_2 from lime production is defined as a key category according to the approach 1 analysis.

4.2.2.2 Methodological issues

All three plants calculate the emissions of CO_2 based on the input of limestone and dolomite and

plant specific emission factors for CO_2 from limestone and dolomite respectively. This is in accordance with the reporting requirements of the EU ETS and is in line with the tier 3 method of the IPCC 2006 GL. The activity data is corrected for lime kiln dust (LKD).

The emissions are reported to the Norwegian Environment Agency. For one of the plants, the Norwegian Environment Agency has estimated the emissions for 2002-2004 based on activity data and plant specific emission factors. The Norwegian Environment Agency has also interpolated the emissions for the years 1991-1997 for the same plant.

The plants used a conversion factor of 1 up to and including 2007 (one plant) or 2008 (two plants). This means that all Ca and Mg have been assumed to be carbonates. Since then, the plants have reported conversion factors that are less than 1.

4.2.2.3 Activity data

The activity data used for the reported emissions is the input of limestone and dolomite and this is reported annually to the Norwegian Environment Agency. Nearly all production in Norway consists of quicklime, but there is also some dolomitic lime.

Even though the emissions are calculated based on limestone and dolomite consumption, Norway reports final lime production values as AD in CRF Table 2(I).A-Hs1 in order to assist with comparability across Parties. Table 4.8 shows the lime production and consumption in 2A for some of the years in the time series. The amounts of dolomite used in lime production are shown in Table 4.6.

Table 4.8 Lime production and consumption (ktonnes in 2A).

Year	Production	Consumption
1990	62.0	116.3
1995	86.8	162.7
2000	84.6	158.9
2005	102.6	197.6
2007	122.8	227.8
2008	189.0	338.1
2009	188.8	324.3
2010	315.2	576.5
2011	294.4	524.1
2012	289.0	531.6
2013	293.5	518.1
2014	295.3	521.5
2015	286.1	524.8
2016	293.4	519.1

Source: Norwegian Environment Agency

4.2.2.4 Emission factors

The plants use plant specific emission factors for limestone and an emission factor of 0.474 tonnes CO_2 per tonne dolomite used.

4.2.2.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

Figure 4.1 shows the IEFs for lime production for both consumption and production as AD. Using final lime production values as AD results in IEFs closer to the default IPCC EF, but also to less stable IEFs as it varies more than if consumption is used as AD.

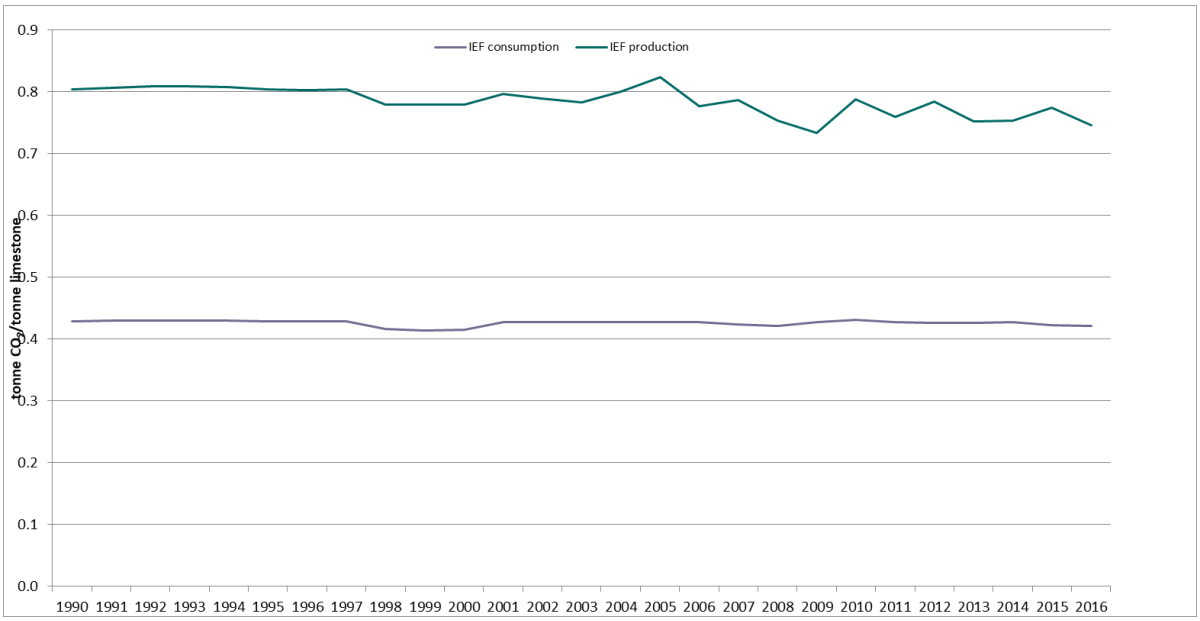


Figure 4.1 IEF (tonne CO_2 per tonne limestone) using consumption or production as AD.
Source: Norwegian Environment Agency

4.2.2.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The emissions are covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by Norwegian Environment Agency's inventory team.

4.2.2.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.2.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.2.3 Glass production, 2A3

4.2.3.1 Category description

Three plants producing glass or glass fibre are included in the emission inventory, based on emission reports to the Norwegian Environment Agency. All three plants are covered by the EU ETS.

4.2.3.2 Methodological issues

Two plants producing glass wool and one plant producing glass fibre report emission figures on CO_2 to the Norwegian Environment Agency. The two glass wool producing plants report emissions from the use of soda ash, limestone and dolomite, while the glass fibre producer reports emissions from the use of limestone and dolomite.

4.2.3.3 Activity data

The aggregated use of soda ash, limestone and dolomite is reported as activity data in CRF Table 2(I).A-Hs while details for the use of soda ash and dolomite are shown in Table 4.9 and Table 4.6. For years where reported emission figures are not available, the AD has been estimated based through interpolation.

4.2.3.4 Emission factors

The emission factors used are 0.41492 tonnes CO_2/tonne soda ash (2006 IPCC GL), 0.477 tonnes CO_2/tonne dolomite (EU ETS) and 0.44 tonnes CO_2/tonne limestone (EU ETS).

4.2.3.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.2.3.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The emissions are covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by Norwegian Environment Agency's inventory team.

4.2.3.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.2.3.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.2.4 Ceramics, 2A4a

4.2.4.1 Category description

One plant that produced bricks until 2014 is included in the emission inventory, based on emission reported to the Norwegian Environment Agency. The plant was covered by the EU ETS.

4.2.4.2 Methodological issues

The plant reported emission figures of CO_2 to the Norwegian Environment Agency. The emissions are calculated by multiplying the amount of limestone and clay used in its production with emission factors.

4.2.4.3 Activity data

The amount of limestone and clay used in the production of bricks was reported each year from the plant to the Norwegian Environment Agency. Due to lack of activity data for some years, the emissions from the use of clay have been estimated for the years 1990-2007. The amounts of limestone used are reported in CRF Table 2(I).A-Hs1.

4.2.4.4 Emission factors

The EF of 0.44 tonnes CO_2 per tonne limestone used by the brick producing plant is the standard EF used in the EU ETS for limestone. The plant uses an emission factor of 0.088 tonnes CO_2 per tonne clay used.

4.2.4.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

The emissions reported under 2A4a include emissions from the use of clay, but the AD in the CRF is limestone only. The use of clay has decreased since 1996 and this explains the overall decrease in IEF for 2A4a. Calculations show that the IEF for CO_2 from limestone and dolomite use only is more stable than when the emissions from the of clay also are included.

4.2.4.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The emissions are covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the Norwegian Environment Agency's inventory team.

4.2.4.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.2.4.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.2.5 Other uses of soda ash, 2A4b

4.2.5.1 Category description

There are no data on soda ash in Norway in production statistics (PRODCOM) from Statistics Norway, so all soda ash is imported. Soda ash is used and reported in 2A3 (glassworks), 2C3 (aluminium production) and 2C7aii (nickel production). The import of soda ash is higher than the sum of the

amounts consumed in these industries. This use is assumed to be emissive and the corresponding CO_2-emissions are estimated and reported here under 2A4b.

4.2.5.2 Methodological issues

The emission figures for CO_2 are estimated by multiplying the amount of soda ash assumed to be emissive with an emission factor.

4.2.5.3 Activity data

The activity data is total import of soda ash minus consumption in glass wool, nickel and aluminium production. The amounts of soda ash are reported in CRF Table 2(I).A-Hs1 and are shown in Table 4.9.

Table 4.9 Balance for soda ash use for Norway (ktonnes).

Year	Import	2A4b (other uses of soda ash)	2A3 (Glassworks)	2C3 (Aluminium production)	2C7ii (Nickel production)
1990	45.1	21.7	4.2	0.9	18.3
1995	55.0	24.5	4.2	0.9	25.3
2000	49.1	17.0	5.3	0.9	25.8
2005	63.8	21.3	5.4	0.9	36.1
2007	53.9	16.7	3.5	0.9	32.7
2008	59.6	22.9	3.5	0.9	32.3
2009	41.4	1.8	3.5	0.9	35.1
2010	34.9	-	3.5	0.9	33.6
2011	48.7	10.7	3.6	0.9	33.4
2012	42.1	-	3.7	0.9	38.1
2013	51.8	11.1	4.0	0.9	35.8
2014	47.5	5.1	3.4	1.1	37.8
2015	44.1	2.6	4.0	1.2	36.2
2016	47.8	7.2	3.7	0.9	36.0

Source: Statistics Norway and Norwegian Environment Agency

4.2.5.4 Emission factors

The emission factor for soda ash use is 0.41492 tonnes CO_2/tonne soda ash from the IPCC 2006 Guidelines (IPCC 2006).

4.2.5.5 Uncertainties and time-series consistency

As we do not have sufficient information to determine where the rest of the imported soda ash has been consumed, there is some uncertainty as to whether all soda ash consumption in fact is emissive. There is also some uncertainty associated with the foreign trade statistics, as well as with the assumption that the CO_2 is emitted the same year as the soda ash are imported. According to the IPCC Guidelines 2006, there is negligible uncertainty associated with the emission factor, given that the correct emission factor is applied (IPCC 2006).

A general assessment of time series consistency has not revealed any time series inconsistencies in

the emission estimates for this category.

4.2.5.6 Category-specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. However, when the calculation first was included in the inventory, a comparison was made between figures on net import of soda ash in foreign trade statistics and in the Norwegian Product Register. Import figures from the Product Register for the period 2000-2011 never constituted more than 41 % of the amounts imported according to foreign trade statistics. Thus, it was assumed that the net import in the foreign trade statistics is a good proxy for the total quantity of soda ash used in Norway.

4.2.5.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.2.5.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category. In the future, we might examine what these other uses of soda ash actually are in order to confirm whether they are emissive or not.

4.2.6 Non-metallurgical magnesium production, 2A4c

4.2.6.1 Category description

One plant whose main activity is producing magnesium oxide from limestone and dolomite is included in the emission inventory. The plant was established in 2005 and is covered by the EU ETS.

4.2.6.2 Methodological issues

The plant reports emission figures of CO_2 to the Norwegian Environment Agency. The emissions are calculated by multiplying the amount of limestone and dolomite used in its production with emission factors.

4.2.6.3 Activity data

The amount of limestone and dolomite used in the production is reported each year from the plant to the Norwegian Environment Agency. The aggregate amounts of limestone and dolomite used are reported in CRF Table 2(I).A-Hs1 and Table 4.10 shows the usage for some selected years in the time series.

Table 4.10 Usage (kt) of limestone and dolomite in the non-metallurgical magnesium production.

Year	limestone use	dolomite use
2005	0.0	1.4
2007	0.0	3.7
2008	1.5	23.9
2009	0.8	9.7
2010	1.4	0.0
2011	0.0	0.0
2012	0.0	14.2
2013	0.0	124.5
2014	0.0	163.7
2015	0.0	147.3
2016	0.0	90.2

Source: Norwegian Environment Agency

4.2.6.4 Emission factors

The plant has used the EF equal to the standard EF used in the EU ETS for limestone before it entered the EU ETS and uses plant specific EFs after it has entered the EU ETS. The plant does not use limestone every year, and the EFs for 2006, 2008, 2009 and 2010 are in the range of 0.41-0.4504. The EF for the dolomite used is equal to the standard EF used in the EU ETS (0.45) for 2005, 2006 and 2007 before it entered the EU ETS. From 2008 the plant has used plant specific EFs in the range of 0.46-0.495096639.

With the exception of 2012 and 2015-2016, the plant has used a conversion factor of 1. This means that for most years, all Ca and Mg have been assumed to be carbonates.

4.2.6.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.2.6.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The emissions are covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the Norwegian Environment Agency's inventory team.

4.2.6.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.2.6.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.2.7 Other process use of carbonates, 2A4d

4.2.7.1 Category description

The emissions from five plants are reported here under 2A4d. The CO_2 emissions from two plants producing leca are included in the emission inventory, based on emission reports to the Norwegian Environment Agency. One of the plants stopped its production in 2004 and the existing plant is covered by the EU ETS. The third plant has neutralized sulphuric acid waste primarily with limestone and fly ash, but uses now only fly ash. The use of fly ash reduces the CO_2 emissions compared with when limestone is used. The CO_2 emissions from two plants producing rock wool are also included in the emission inventory, based on emission reports to the Norwegian Environment Agency.

4.2.7.2 Methodological issues

The two plants producing leca report their use of dolomite and the corresponding CO_2 emissions to the Norwegian Environment Agency. The leca producer that still is in production also reports some minor emissions from the use of clay and these are included in the inventory. For the plant neutralizing sulphuric acid waste, the emissions are calculated by multiplying the amounts of limestone and ash used to neutralize sulphuric acid waste with emission factors. The two plants producing rock wool report their use of dolomite and limestone and the corresponding CO_2 emissions to the Norwegian Environment Agency.

4.2.7.3 Activity data

The activity data is primarily the use of dolomite and limestone. For years where reported emission figures are not available, the AD has been estimated based through interpolation. The aggregate amounts of limestone and dolomite used by the plants included in 2A4d are reported in the CRF Table 2(I).A-Hs1 and are shown in Table 4.11 for some selected years in the time series.

Table 4.11 Use (kt) of limestone and dolomite in 2A4d (other process use of carbonates).

Year	limestone use	dolomite use
1990	49.572	5.338
1995	42.963	7.759
2000	73.126	7.376
2005	59.012	13.098
2007	53.847	11.027
2008	60.050	9.567
2009	3.818	13.235
2010	0.000	8.677
2011	33.205	14.413
2012	5.915	18.906
2013	33.932	17.719
2014	0.000	16.336
2015	0.000	15.263
2016	0.000	11.452

Source: Norwegian Environment Agency

In addition, clay is used by the leca producer that still is in production and ash is used by the plant neutralizing sulphuric acid waste.

4.2.7.4 Emission factors

An EF of 0.48 t CO_2/t dolomite was used by the leca producer that closed down in 2004. At that time, there was no standard EF for dolomite. We assume that the EF of 0.48 is derived from the standard factors for $CaCO_3$ and $MgCO_3$ and an assumption of the ratio of these in the dolomite. For the leca producer that still is in production, the EF (for dolomite) for 1990-2011 is 0.477, and has since then used standard EF from the EU ETS and plant-specific EFs in the range of 0.466-0.48. The EFs for the use of clay from 2013 and onwards ranges between 0.01596492-0.01974294. The plant that neutralizes sulphuric acid waste uses an emission factor of 0.44 t CO_2/t limestone. For fly ash, IEFs for the years 2010-2016 have been calculated by the Norwegian Environment Agency to be in the range of 40 to 140.2 kg CO_2/t fly ash based on activity data and emisisons. The IEF of 68.5 kg CO_2/t fly ash for 2010 has been used for the years 1997-2009. The two plants producing rock wool use emisisons factors of 0.44 t CO_2/t limestone and 0.481 t CO_2/t dolomite.

4.2.7.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category. The IEF is relatively stable 1990-2008, variations may be due to emisisons from the use of clay and ash that are not included as AD in the CRF. The IEF since 2008 varies more and this is primarily due to a shift from using limestone to ash at the plant that neutralizes sulphuric acid waste.

4.2.7.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The existing plant producing leca is covered by the EU ETS and the emissions are verified annually. The emissions are checked both by the case handler and by the Norwegian Environment Agency's inventory team. The reported emissions from the plant that neutralizes sulphuric acid waste occurs under its regular permit and are checked both by the case handler and by the agency's inventory team.

4.2.7.7 Category-specific recalculations

Consistency. Process emissions of CO_2 from the use of dolomite in one plant have been increased for the years 1994-2007. The increase ranges from 80 tonnes in 1994 to 2 700 tonnes in 2007. The reason for the increase is to improve the consistency of the time series.

Updated activity data (correction of error). Process emissions of CO_2 from the use of dolomite and fly ash in one plant has been revised due to new information from the plant. The plant informed that limestone has been replaced completely by fly ash and provided new information on the use of limestone and fly ash for parts of the time series. This results in higher emissions in the range of about 1 100 to 18 100 tonnes CO_2 in the years 1997-2008 and lower emissions in the range of of 11 300 to 15 200 tonnes CO_2 in the years 2009-2010 and 2014-2015.

4.2.7.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.3 Chemical industry – 2B

In the Norwegian inventory, there are different activities included under Chemical Industry. Nearly all emissions figures from this industry included in the inventory are reported figures from the plants to the Norwegian Environment Agency. Table 4.12 shows the GHGs that are emitted from each source category, tier of methodology and if the source category is key category or not.

Table 4.12 Chemical industry. Components included in the inventory, tier of method and key category

Source category	CO_2	CH_4	N_2O	NMVOC	Tier	Key category
2B1. Ammonia production	R	NA	NA	NA	Tier 2	Yes
2B2. Nitric acid production	NA	NA	R	NA	Tier 3	Yes
2B5a. Silicon carbide production	R+E	R/E	NA	NA	Tier 2	Yes
2B5b. Calcium carbide production	R	NA	NA	R	Tier 1	No
2B6. Titanium dioxide production	R	NA	NA	NA	Tier 2	Yes
2B8a. Methanol production *	R	R+E	R	R+E	Tier 2	Yes**
2B8b. Ethylene production *	R+E	R	R	R	Tier 2	Yes**
2B8c. Ethylene dichloride and vinyl	R+E	R	NA	R	Tier 2	Yes**
2B10. Other (production of fertilizers)	NA	NA	R+E	NA	Tier 2	No

R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated. NA = Not Applicable. NO = Not Occuring. IE = Included Elsewhere.

**Minor N_2O emissions from 2B8a and 2B8b are reported under 2B10 Petrochemical N_2O in the CRF, but are included in Table 4.13 below.*

*** In the key category analysis, 2B8a, 2B8b and 2B8c have been aggregated to 2B8 which has been identified as a key category.*

Table 4.13 shows the trends for 2B as a whole and for the various source categories. The GHG emissions from this sector category were about 1.1 million tonnes in 2016, this is 12.5 per cent of the total emission from the IPPU-sector. The emissions from this sector decreased by 66.9 per cent from 1990, mainly due to lower emissions from the production of nitric acid, ammonia and carbide. The emissions decreased by 10.4 per cent from 2015 to 2016.

Table 4.13 Emission trends for 2B Chemical industry (kt CO_2 equivalents).

Source category	1990	1990, % of IPPU	2015	2016	2016, % of IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2B1. Ammonia production	500.1	3.4	458.4	384.6	4.5	-23.1	-16.1
2B2. Nitric acid production	1 993.3	13.7	251.6	241.3	2.8	-87.9	-4.1
2B5a. Silicon carbide	230.2	1.6	46.1	50.3	0.6	-78.2	9.0
2B5b. Calcium carbide	178.1	1.2	0.0	0.0	0.0	-100.0	
2B6. Titanium dioxide	201.1	1.4	162.8	147.6	1.7	-26.6	-9.3
2B8a. Methanol production	0.0	0.0	101.7	127.1	1.5		25.0
2B8b. Ethylene production	70.9	0.5	39.5	43.8	0.5	-38.2	10.9
2B8c. Ethylene dichloride and	18.7	0.1	15.3	13.5	0.2	-27.8	-11.7
2B10. Other (production of	58.0	0.4	125.9	67.7	0.8	16.7	-46.2
2B. Total	3 250.5	224	1 201.2	1 075.8	12.5	-66.9	-10.4

Source: Statistics Norway and Norwegian Environment Agency

4.3.1 Ammonia Production, 2B1 (Key category for CO_2)

4.3.1.1 Category 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_2 is recovered from the production process.

CO_2 from ammonia production is defined as a key category according to the approach 1 analysis.

Figure 4.2 shows the time series for the gross CO2 emissions, amount of recovered CO2 and the net CO2 emissions. The variations from 1998 to 1999 and 1999 to 2000 are likely to be a result of the plant upgrading production capacity and energy efficiency in 1999-2000. The increase in emisisons from 2014 to 2015 is due to an expansion in production capacity in which imported ammonia is replaced with own ammonia production.

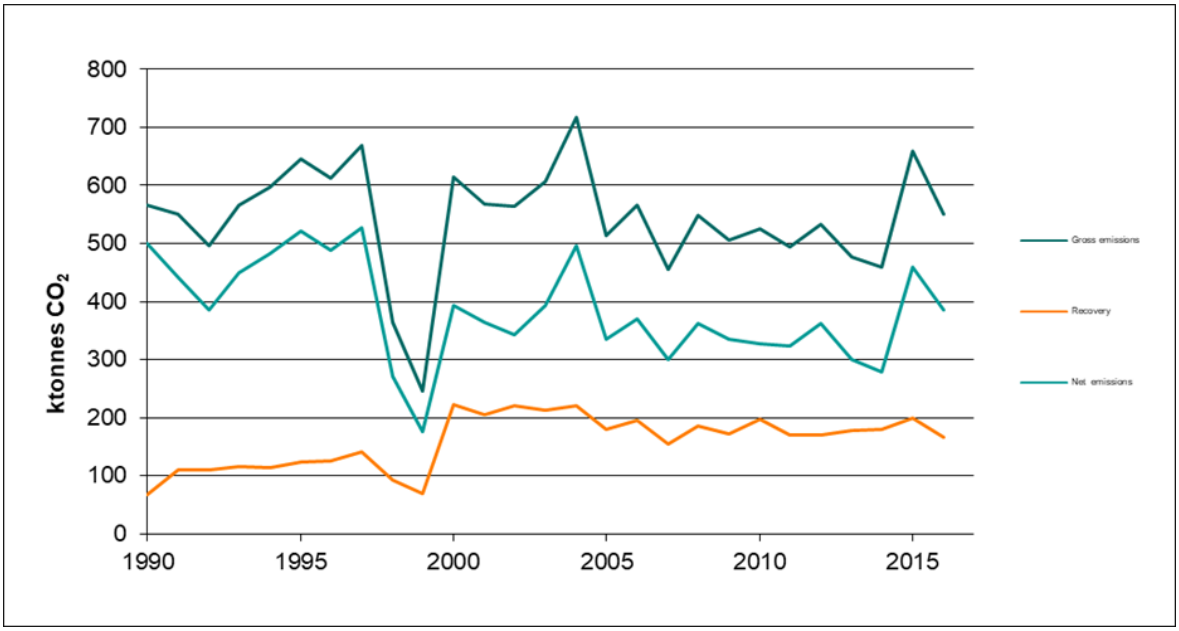


Figure 4.2 CO_2 emissions from production of ammonia.
Source: Norwegian Environment Agency

4.3.1.2 Methodological issues

The CO_2 emission figures in the Norwegian emission inventory model are based on annual reports from the plant. The plant calculates the emissions by multiplying the amount of each gas used with gas specific emission factor.

The plant has reported consistent figures back to 1990. A part of the CO_2, which is generated during the production process, is captured and sold to other objectives et cetera soft drinks, and therefore deducted from the emission figures for this source. In accordance with the footnote 5 in CRF table 2(I)-A-H, the amount recovered that is not exported is included in 2H2 Food and Drink.

4.3.1.3 Activity data

The total amount of gas consumed is annually reported by the plant to the Norwegian Environment Agency. The use of the different gases varies from one year to another. 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 an alternative method.

4.3.1.4 Emission factors

The plant emission factors used in the calculations of emissions are calculated based on the composition of the gases consumed. The plant states that the composition is based on daily analysis and that the composition of each gas (their emission factor) is stable.

4.3.1.5 Uncertainties and time-series consistency

The amount of gas is measured by using turbine meters and the meters are controlled by the Norwegian Metrology Service. The uncertainty in the measurement of propane and butanes is calculated to ± 0.2 and ethane ± 0.13 per cent. The mix of propane/butanes is as average 60 per cent propane and 40 per cent butanes.

There are some large inter-annual variations in the IEF. The variations from 1998 to 1999 and 1999 to 2000 are likely to be a result of the plant upgrading production capacity and energy efficiency in 1999-2000. Figure 4.2 shows that there was a large drop in emissions and recovery in 1999. We do not have explanations for the variations from 1996 to 1997 and 1997 to 1998. The IEF of 1.8 in 1997 indicates that the emissions may have been overestimated or the production may have been underestimated. It is challenging to investigate this further as more data is not available and since the data quality at that time is poorer than now. Since the plant has reported under the voluntary agreement for 2008-2012 and under the EU ETS from 2013, the data quality has improved as Figure 4.3 shows a relatively stable IEF for the end of the time series.

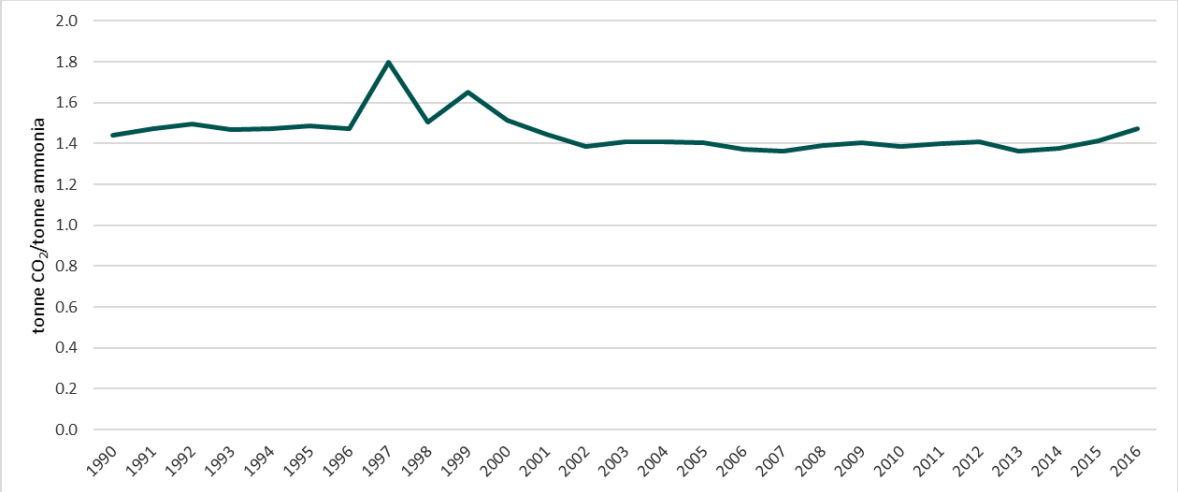


Figure 4.3 IEF for process emissions of CO_2 from ammonia production (tonne CO_2/tonne ammonia). Source: Norwegian Environment Agency

4.3.1.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plant has reported under the voluntary agreement and the emissions are now covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

The figures reported from the plant are occasionally compared to calculations done by Statistics Norway based on total amount of gas consumed and an emission factor on 3 tonne CO_2/tonne LPG. The calculated emissions figures have agreed quite well with emissions figures reported by the enterprise.

4.3.1.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.3.1.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category. We have investigated the issue of the IEFs to the extent possible and the IEF of 1.8 in 1997 indicates that the emissions may have been overestimated or the production may have been underestimated.

4.3.2 Production of Nitric Acid, 2B2 (Key category for N_2O)

4.3.2.1 Category description

There are two plants in Norway producing nitric acid and these plants are covered by the EU ETS. Nitric acid is used as a raw material in the manufacture of nitrogenous-based fertilizer. The production of nitric acid (HNO_3) generates nitrous oxide (N_2O) and NO_X as by-products of high temperature catalytic oxidation of ammonia (NH_3). N_2O from nitric acid production is defined as a key category according to the approach 2 analysis.

Table 4.14 compares the Norwegian plant-specific production technologies compared with the technologies described in table 3.3 in the IPCC 2006 Guidelines (IPCC 2006).

Table 4.14 Production process and default factors for nitric acid production.

Production process	**N_2O Emission Factor (relating to 100 percent pure acid)**
A. Plants with NSCR[13] (all processes)	2 kg N_2O/tonne nitric acid ±10%
B. Plants with process-integrated or tailgas N_2O destruction	2.5 kg N_2O/tonne nitric acid ±10%
C. Atmospheric pressure plants (low pressure)	5 kg N_2O/tonne nitric acid ±10%
D. Medium pressure combustion plants	7 kg N_2O/tonne nitric acid ±20%
E. High pressure plants	9 kg N_2O/tonne nitric acid ±40

Source: IPCC (2006)

[13] A Non-Selective Catalytic Reduction (NSCR)

The two plants have together five production lines. Four of the production lines are a mix of technology C and D in Table 4.14 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_2O decomposition by extension of the reactor chamber. Since then, all production lines have to a certain extent been equipped with this technology. Figure 4.4 shows that the production specific N2O emissions were reduced substantially in the early 1990s 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 came from that line. The reduced emissions from 2006 are due to the installation of the earlier mentioned technology. There was a large increase in production of about 43 percent from 2009 to 2010 that came after a decrease in production of about 26 percent from 2008 to 2009. The low production level in 2009 reflects the lower economic activity due to the economic recession.

4.3.2.2 Methodological issues

N_2O

The two plants report the emissions of N_2O to the agency. The N_2O emissions have been continuously measured since 1991 at one production line and from 2000 at another. The emissions at the three other production lines were based on monthly and weekly measurements, but are from 2008 based on continuous measurements.

4.3.2.3 Activity data

The plants report the amounts of N_2O in the gas, based on continuous measurements. The plants also report the production of HNO_3 to the agency.

4.3.2.4 Emission factors

Not relevant.

4.3.2.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II. The uncertainty in the measurements was in 2000 estimated by the plant to ±7. However, in the 2006 report to the Norwegian Envionment Agencyone plant reports that the uncertainty in measurement of N_2O is calculated to ±1-3 per cent.

The inter-annual changes of IEFs are likely to be explained by variations in the level of production between the lines with different IEFs. Figure 4.4 shows that the IEF for nitric acid production has been substantially decreased from 1990 to 2016. The low production level in 2009 reflects the lower economic activity due to the economic recession.

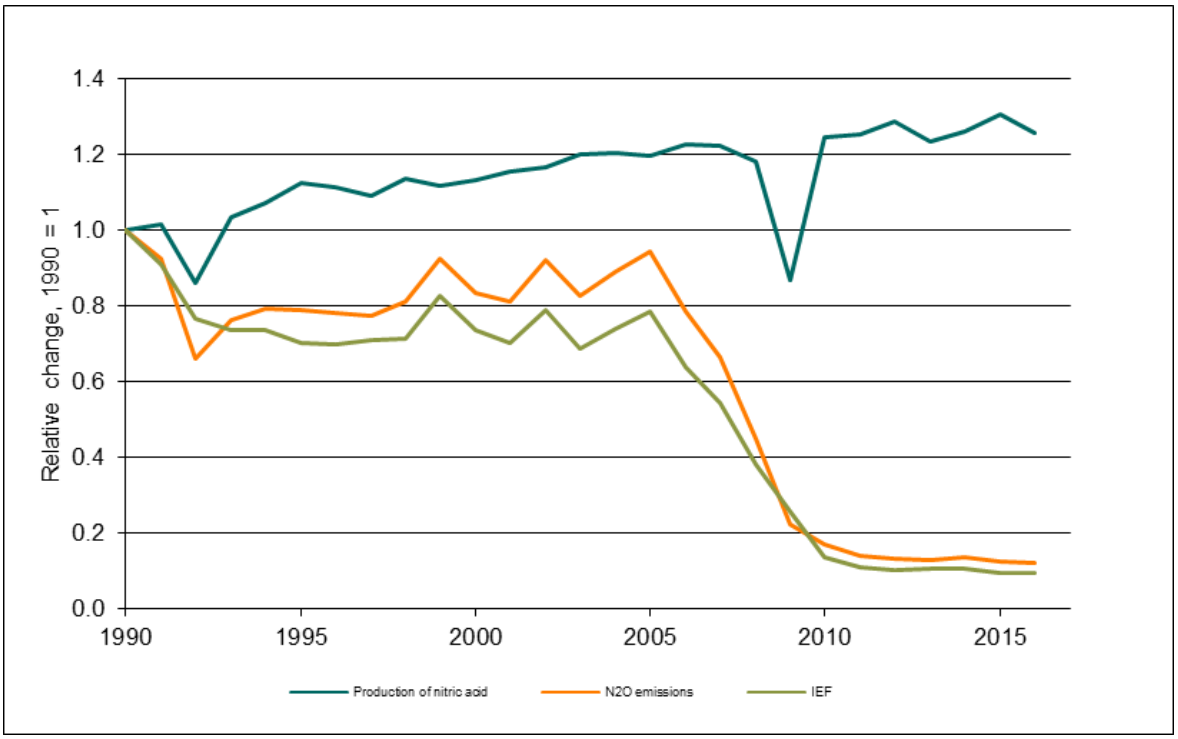


Figure 4.4 Relative change in total emissions, total production and IEF for nitric acid production. 1990=100
Source: Norwegian Environment Agency

4.3.2.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The emissions are covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.3.2.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.3.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.3.3 Silicon carbide, 2B5a (Key category for CO_2)

4.3.3.1 Category description

Silicon carbide has been produced at three plants until 2006 when one plant was closed down. The plants were included into the EU ETS from 2013. Silicon carbide (SiC) is produced by reduction of quartz (SiO_2) with petrol coke as a reducing agent.

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

$CO \rightarrow CO_2$

In the production of silicon carbide, CO_2 and CO is released as a by-product from the reaction between quartz and carbon. Methane (CH_4) may be emitted from petrol coke during parts of the process and sulphur origin from the petrol coke.

The large decrease in emisisons since 1990 is due to reduced production and that one plant was closed down in 2006. The fluctuation in emissions over the years is due to variation in production of crude silicon carbide. There was a large production decrease from 2002 to 2003 and an increase from 2009 to 2010 and this is due to a low production level in 2009. The production level in 2009 is also lower than 2008 and reflects the lower economic activity due to the economic recession.

CO_2 from carbide production is defined as a key category according to the approach 2 analysis.

4.3.3.2 Methodological issues

The emissions are based on an EF-based method (using crude silicon carbide production as activity data) and is regarded as being a Tier 2 method in IPCC (2006).

CO_2

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

CO_2 from process is calculated based on the following equation:

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

The three production sites have used amount of produced crude silicon carbide as activity data in the calculation of CO_2 emissions.

NMVOC

Emission figures are reported to the Norwegian Environment Agency by the plants. The emissions are calculated by multiplying annual production of silicon carbide by an emission factor.

Indirect emission of CO_2 is calculated by Statistics Norway based on the emission of CH_4.

CH_4

The emission of CH_4 from production of silicon carbide is calculated based on the following equation:

(4.4) $CH_4 = \sum Activity\ data_i * Emission\ factor_i$

The three production sites have used amount of produced crude silicon carbide as activity data and a plant specific emission factor.

4.3.3.3 Activity data

The activity data used by the plants for the calculation of CO_2, CH_4 and NMVOC are the amount of produced crude silicon carbide. For the calculations of indirect CO_2, the AD is the amount of CH_4.

4.3.3.4 Emission factors

CO_2

All three sites use the country-specific emission factor that is the basis for the IPCC (2006) default factor of 2.62 ton CO_2/tonne crude silicon carbides, see Table 4.17.

CH_4

For calculation of methane emissions the country-specific emission factor 4.2 kg CH_4/tonne crude SiC is used, see Table 4.15. Documentation of the choice and uncertainties of the emission factor is given under Uncertainties.

Table 4.15 Emission factor for CO_2 and CH_4 used for silicon carbide production.

Component	Emission factor	Source
CO_2	2.62 tonnes CO_2/tonnes crude SiC	IPCC 2006
CH_4	4.2 kg CH_4 /tonnes crude SiC	CS

NMVOC

From 2007 and onwards the emission factor is based on measurements made once a year. The emission factors for one of the plants is stable at around 10.8 t NMVOC/kt Sic while the emission factor at the other plant is less stable and increasing. The concerned plant has responded that the variations are within the expected variations. For previous years, the emission factor for one of the plants is more or less constant whereas the emission factor for the second plant varies.

4.3.3.5 Uncertainties and time-series consistency

CO_2

Activity data

The three productions sites use the amount of produced crude silicon carbide as activity data. The uncertainty of the activity data is related to the uncertainty of the weighing equipment and is calculated to be ± 3 per cent.

Emission factor

The emission factor of 2.62 tonne CO_2/tonnes SiC has an estimated uncertainty range of – 16 % to -+7 %. This can be explained due to variations in raw materials as well as process variations, and is based on previous development of country specific emissions factors (SINTEF 1998d).

The carbon content in coke is varying, normally from 85 to 92 % carbon. The coke is also varying in the content of volatile components, e.g hydrocarbons. There are also variations in the process itself. The Acheson process is at batch process, and the reactions include many part reactions that differ from batch to batch, because of variations in the mix of quarts and coke, the reactivity of the coke etc. The process variations described above is the reason why the factor presented in tonne CO_2/tonn coke used is not constant. For one plant, the factor is in the range 1.07-1.27. For the other plant, one also has to consider the closed plant, 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.

Prior to 2006, the emissions were based on a mass-balance method (input of reducing agents). The justification of changing method is that the IEF tonne CO_2 /tonne coke varies over the years due to variation in carbon content in coke and that this variation is larger or in the same order of variation that the production of crude silicon carbide. In addition, there is a relatively large difference in the

carbon consumption data in the early 1990s due to the use of purchase data as a proxy for carbon consumption. The silicon carbide production data in the early 1990s especially is considered being more accurate than the coke consumption.

Emissions

The total uncertainty of the resulting emissions of CO_2, based on uncertainties in activity data and emissions factor, is calculated to be in the range of – 20 % to + 10 %.

CH_4

Activity data

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

Emission factor

The emission factor of 4.2 kg CH_4/tonne SiC is used, and the uncertainty level is estimated to be ± 30%.

The calculation of emission factor and the uncertainty level is explained below. The production of SiC is a batch process with duration of about 43 hours. The CH_4-concentration (ppm) is monitored continuously the first 6.5 hours. After this, only control monitoring is carried out. The results show that the concentration of CH_4 is peaking in the first hour of the process, giving a CH_4 concentration 10 – 15 times higher than in the last 36 hours of the process. A typical level of the concentration of CH_4 is given in Figure 4.5. If the CH_4-concentration is averaged over the total batch time of 43 hours, this will give an emissions factor of 4.2 kg CH_4/tonne SiC, i.e. 3.5 kg CH_4/tonne petrol coke.

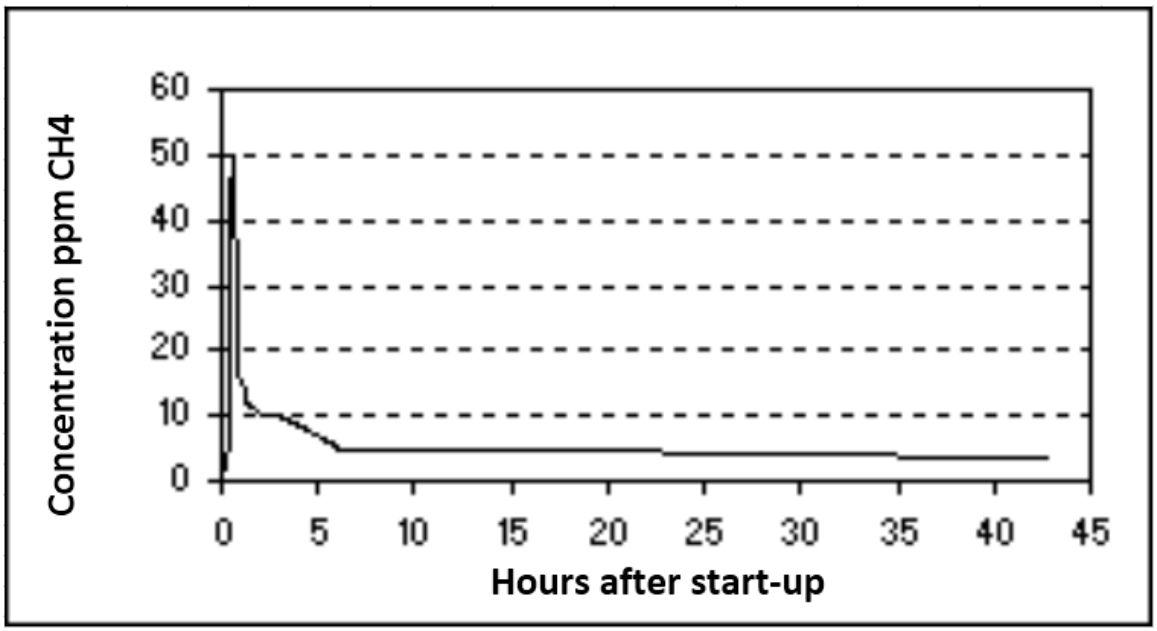


Figure 4.5. Concentration of CH_4 for one batch of SiC.

To establish the uncertainty level, the following assessments were done:

- The uncertainty in monitoring of concentration is normally ± 5 per cent (expert judgment).

- The uncertainty of monitoring of the amount of gas is within ± 15 per cent (type of monitoring equipment).
- The uncertainty of the production of SiC for each batch is stable, and is assessed to be within a level of ± 5 per cent.
- The uncertainties of raw materials and process variation add ± 5 per cent.

If these uncertainties are added, the estimate result of total uncertainties for the resulting emissions of CH_4 is ± 30 per cent.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.3.3.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plants have reported under the voluntary agreement and the emissions are now covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.3.3.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.3.3.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.3.4 Calcium carbide, 2B5b

4.3.4.1 Category description

One plant in Norway was producing calcium carbide until 2003 and the emissions from this source were about 178 000 tonnes CO_2 in 1990. The production of calcium carbide generates CO_2 emissions when limestone is heated and when petrol coke is used as a reducing agent.

The reaction

(4.5) $CaCO_3 \rightarrow CaO + CO_2$

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

The reactions

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

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

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

4.3.4.2 Methodological issues

The CO_2 figures in the inventory are based on emission figures reported from the plant to the agency. The emission estimates are based on the amount of calcium carbide produced each year and an

emission factor estimated by SINTEF (1998d). 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 the agency.

4.3.4.4 Emission factors

The emission factor used by the plants in the calculation of CO_2 has been estimated to be 1.69 tonne/tonne CaC_2 by SINTEF (1998d). An additional 0.02 t CO_2 /t CaC_2 from fuel is reported in the Energy chapter.

4.3.4.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.3.4.6 Category-specific QA/QC and verification

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

4.3.4.7 Category specific recalculations

There have been no recalculations performed for this source category this year.

4.3.4.8 Category-specific planned improvements

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

4.3.5 Titanium dioxide production, 2B6 (Key category for CO_2)

4.3.5.1 Category description

One plant producing titanium dioxide slag is included in the Norwegian Inventory and it was included in the EU ETS in 2013. 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_2 are emitted during the production process.

CO_2 from titanium dioxide production is defined as a key category according to the approach 1 analysis.

4.3.5.2 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_2 captured in the products.

4.3.5.3 Activity data

The carbon inputs are dominated by coal, but there is also some pet coke, electrodes, carbides and some masses. The CO_2 captured in the products is then subtracted in order to estimate the net emissions. Table 4.16 shows the carbon balances for 2014-2016.

Table 4.16 Carbon balances (tonnes CO_2) for titanium dioxide production.

Activity data	**2014**	**2015**	**2016**
Coal	278 576	172 794	*151 796*
Coke (tonne dry weight)	16	0	*0*
Electrode mass (tonne dry weight)	3 756	4 178	*3 092*
Carbides	535	284	*126*
Melting mass	165	105	*97*
Clay	31	18	*20*
Ore	266	158	*140*
Slag	-3 725	-3 523	*-1 123*
Iron	-15 588	-11 229	*-6 551*
Net CO_2 emissions	**264 030**	**162 786**	***147 597***

Source: Norwegian Environment Agency

4.3.5.4 Emission factors

Since a mass balance is used, it is the carbon contents of the carbon materials that go into the mass balance that are used.

4.3.5.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.3.5.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plant has reported under the voluntary agreement and the emissions are now covered by the EU ETS and the emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.3.5.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.3.5.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.3.6 Methanol, 2B8a

4.3.6.1 Category description

One plant established in 1997 produces methanol and it is covered by the EU ETS. Natural gas and oxygen are used in the production of methanol. The conversion from the raw materials to methanol is done in various steps and on different locations at the plant. CH_4, N_2O and NMVOC are emitted during the production process. The emissions reported in this category includes flaring and combustion of fuels derived from the natural gas feedstock.

The CO_2 emissions from other energy combustion are included under 1.A.2.C. Indirect emissions of CO_2 are calculated by Statistics Norway based on the emission of CH_4 and NMVOC, see chapter 9 for details about EFs.

4.3.6.2 Methodological issues

The plant reports emission figures of CO_2, CH_4, N_2O and NMVOC to the Norwegian Environment Agency. The reported emissions from flaring and combustion of derived fuels are based on the amounts of gas multiplied by emission factors while the diffuse CH_4 and NMVOC emissions are estimated through the use of the measuring method DIAL (Differential Absorption LIDAR) about every third year since 2002. The plant was divided into various process areas and measurements were taken for at least two days for all process areas. The DIAL method results in an emission factor per operating hour and this forms the basis for the plant's reported diffuse NMVOC and CH_4 emissions from the production of methanol. This method has been used from 2008 and onwards. The time series for the years 1997-2007 are based on the results from 2008 together with the production levels of methanol for these years.

Minor N_2O emissions (28 to 220 tonnes CO_2 equivalents) are reported under 2B10 Petrochemical N_2O in the CRF. The NMVOC emissions included in the inventory are based on the reported emissions from the plant as these appear to be consistent.

4.3.6.3 Activity data

The annual emissions from flaring and combustion of derived fuels are based on the reported combusted amounts. The activity data used to calculate the indirect CO_2 emissions are the diffuse emissions of CH_4 and NMVOC.

4.3.6.4 Emission factors

CO_2

The plant concerned is part of the EU ETS and the EFs for flaring and combustion of derived fuels are reported annually since 2008.

4.3.6.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

As the reported emissions have varied greatly (e.g. emissions from flaring were much higher in 2000 than in 1999 and 2001), IEFs based on production figures will also fluctuate.

4.3.6.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plant is covered by the EU ETS and the emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.3.6.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.3.6.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.3.7 Ethylene, 2B8b

4.3.7.1 Category description

Two plants report emissions under this source category and they are both covered by the EU ETS. One of the plants produces ethylene while the other produces polyethylene and polypropylene.

The majority of the emissions reported here are from flaring. In addition, CH_4 and NMVOC emissions are reported from leakages in the process. Indirect emissions of CO_2 from CH_4 and NMVOC are also calculated and reported. Minor N_2O emissions (19 to 558 tonnes CO_2 equivalents) are reported under 2B10 Petrochemical N_2O in the CRF.

4.3.7.2 Methodological issues

CO_2, CH_4 and NMVOC

Direct emissions are annually reported to the agency. CO_2 from flaring is based on gas specific emissions factors and activity data. CH_4 and NMVOC emissions reported are based on measurements.

Indirect emissions of CO_2 calculated by Statistics Norway are based on the emission of CH_4 and NMVOC.

4.3.7.3 Activity data

For CO_2 from flaring, the annual emissions from flaring are based on the combustion of natural gas in the flare. The activity data used to calculate the indirect CO_2 emissions are the diffuse emissions of CH_4 and NMVOC.

4.3.7.4 Emission factors

CO_2

The plants report the emission factors used as part of their reporting under the EU ETS.

4.3.7.5 Uncertainties and time-series consistency

Uncertainty estimates are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.3.7.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plants are covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.3.7.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.3.7.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.3.8 Ethylene dichloride and vinyl chloride monomer, 2B8c

4.3.8.1 Category description

A plant producing vinyl chloride reports CO_2 process emissions that stem from recycling hazardous waste to hydrochloric acid. CH_4 and NMVOC emissions are reported from leakages in the process

4.3.8.2 Methodological issues

CO_2, CH_4 and NMVOC

The plant has annually reported process emissions to the agency. From 2013 and onwards, the reported CO_2 emissions are based on measurements of the amounts of gas multiplied by emission factors. For the years prior to 2013, the reported CO_2 emisisons are based on the amount of hazardous waste recycled to hydrochloric acid multiplied by emission factors. The CH_4 and NMVOC emissions are reported annually to the Norwegian Environment Agency and are based on measurements.

Indirect emissions of CO_2 calculated by Statistics Norway are based on the emissions of CH_4 and NMVOC.

4.3.8.3 Activity data

The plant has reported the amounts of gas relevant for estimating CO_2 emissions for the years 2013-2016 and the amounts of recycled hazardous waste for 2010-2012. The amounts of CH_4 are reported in the CRF.

4.3.8.4 Emission factors

The emission factors used to estimate CO_2 emisisons for the years 2013-2016 are in the range of 0.040503-0.045577 tonnes CO_2/tonne gas respectively. The emission factors used to estimate CO_2 emisisons for the years 2010, 2011 and 2012 are 1.1, 1.1 and 1.08 tonnes CO_2/tonne recycled hazardous waste respectively. The emission factors are all plant specific. See chapter 9 for details concerning the EFs used for indirect CO_2 emissions from CH_4 and NMVOC.

4.3.8.5 Uncertainties and time-series consistency

Although two different methods have been used to estimate the CO_2 emissions from recycling hazardous waste, we have no indications that the time series is not consistent. Uncertainty estimates for greenhouse gases are given in Annex II.

4.3.8.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plant is covered by the EU ETS and the emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.3.8.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.3.8.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

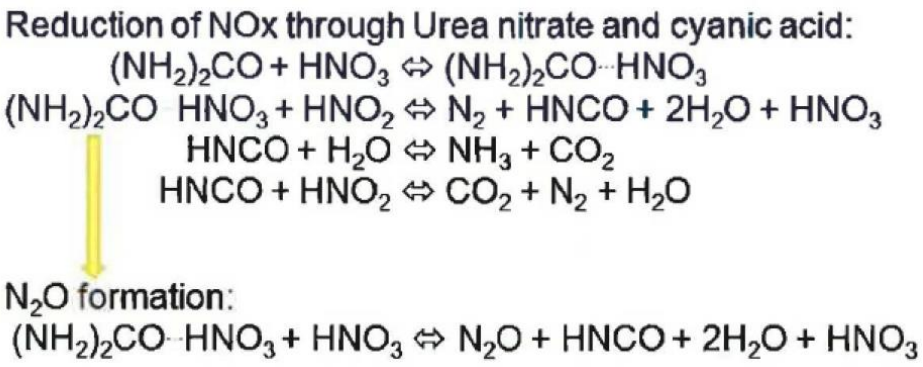
4.3.9 Other, production of fertilizers, 2B10

4.3.9.1 Category description

A plant producing fertilizers has since 2011 reported N_2O emissions from its production to the agency. Urea nitrate is added to the process to reduce the formation of NOx emissions and this process forms N_2O emissions.

4.3.9.2 Methodological issues

According to the plant, the formation of NOx is reduced through the use of urea nitrate and cyanic acid. The process forms N_2O, see formulas below.



The emissions of N_2O are based on measurements of gas volumes and samples are taken for analysis by gas chromatograph. The plant has reported N_2O emissions for 2011-2015 and the Norwegian Envionment Agencyhas estimated the emissions for the years 1990-2010 2010 based on producion levels and assumptions about the IEF. There are many factors that influence the emissions and these have varied over time. Such factors are production levels, composition of phosphates, use of urea etc. The plant's reporting of emissions for the years 2011-2013 results in an average IEF of 0.27 kg N_2O per tonne produced fertilizer. This IEF was used to estimate the emisisons for the years 2007-2010 as the factors influencing the emisisons were similar to 2011-2013. In the years 2002-2006, the plant used more of one type of phosphate than in the period 2007-2013 and the IEF is therefore assumed to be 25% lower. The use of the phosphate type was even larger in the years 1990-2001 and the the IEF is therefore assumed to be 50% lower than for the years 2007-2013.

4.3.9.3 Activity data

See description in chapter 4.3.9.2. Although there are several factors that influnece the emissions, the production of fertilizers is included as activity data in CTF table 2(I).A-Hs1.

4.3.9.4 Emission factors

See description in chapter 4.3.9.2.

4.3.9.5 Uncertainties and time-series consistency

The estimates for the years 1990-2010 are very uncertain since there are many factors that could influence the emissions. Chapter 4.3.9.2 describes how the emisisons for 1990-2010 were estimated and explains the differences in IEF over time. Uncertainty estimates for greenhouse gases are given in Annex II.

4.3.9.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The emissions in this category are not covered by the EU ETS, but the emissions have been reported for the years 2011-2014 and are considered and tracked by the agency's inventory team.

4.3.9.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.3.9.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.4 Metal industry – 2C

The Metal industry in Norway includes plants producing iron and steel, ferroalloys, aluminum, magnesium, zink, anodes and nickel, see Table 4.17. Nearly all emissions figures from the production of metals included in the inventory are figures reported annually from the plants to the agency.

Table 4.17 Metal industry. Components included in the inventory, tier of method and key category.

Source category	CO_2	CH_4	PFCs	SF_6	Tier	Key category
2C1a. Iron and steel production	R	NA	NA	NA	Tier 3	No
2C2. Ferroalloys production *	R	R	NA	NA	Tier 2/3	Yes
2C3. Aluminium production	R	NA	R	R	Tier 2/3	Yes
2C4. Magnesium production	E	NA	NA	R	Tier 2	Yes
2C6. Zink production	R + E	NA	NA	NA	Tier 2	No
2C7i. Anode production	R	NA	NA	NA	Tier 2	No
2C7ii. Nickel production	R	NA	NA	NA	Tier 2	No

R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated. NA = Not Applicable. NO = Not Occuring. IE = Included Elsewhere.

** Small N_2O emissions (2 800 to 6 300 tonnes CO_2 equivalents) from 2C2 are reported under 2C7i Ferroalloys N_2O in the CRF, but are included in Table 4.18 below.*

Table 4.18 shows the trends for the sector Metal Production (2C) as a whole and for the various source categories. The GHG emissions from this sector category were about 4.8 million tonnes in 2016, this is 55.7 per cent of the total emission from the IPPU-sector. The largest contributors to the GHG emissions from Metal industry in 2016 are Ferroalloy production and Aluminum production. The emissions from this sector decreased by 52.5 per cent from 1990. The reduction since 1990 is due to decreased PFC and SF_6 emissions that again were due to improvement in technology aluminum production, the close down of a magnesium plant in 2006 and generally lower production volumes. The emissions increased by 3.5 per cent from 2015 to 2016. There was a large increase in emissions from 2009 to 2010, this is mainly due to a low production level for ferroalloys in 2009. The production level in 2009 is also lower than 2008 and reflects the lower economic activity due to the economic recession.

Table 4.18 Emission trends for 2C Metal industry (kt CO_2 equivalents).

Source category	1990	1990, % IPPU	2015	2016	2016, % IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2C1a. Iron and steel production	12.4	0.1	28.3	26.8	0.3	116.8	-5.2
2C2. Ferroalloys production	2 560.0	17.7	2 516.5	2 616.9	30.3	2.2	4.0
2C3. Aluminium production	5 313.8	36.7	2 002.3	2 061.5	23.9	-61.2	3.0
2C4. Magnesium production	2 172.8	15.0	0.0	0.0	0.0	-100.0	
2C6. Zink production	3.0	0.0	2.6	2.2	0.0	-26.8	-17.1
2C7i. Anode production	7.6	0.1	15.0	14.9	0.2	96.3	-0.8
2C7ii. Nickel production	43.8	0.3	75.8	82.8	1.0	88.9	9.2
2C. Total	10 113.3	69.8	4 640.4	4 805.0	55.7	-52.5	3.5

Source: Statistics Norway and Norwegian Environment Agency

4.4.1 Steel, 2C1a

4.4.1.1 Category description

Norway includes one plant producing steel that is covered by the EU ETS and the activity data in the CRF is steel produced.

4.4.1.2 Methodological issues

Emission figures of CO_2 annually reported to the Norwegian Envionment Agencyare used in the Norwegian GHG Inventory. This reporting includes both the reporting under the EU ETS and reporting as required under its regular emission permit. The emission figures are based on mass balance calculations.

The total emissions from steel production cover emissions from industrial processes and from combustion, but only the process emissions are reported in this sub-category.

For the years 1998-2001 and 2005 and onwards we have detailed emission distributed between combustion and processes from the plant. The process emissions in 1990, 1992-1997 have been estimated on the basis of CO_2 emissions per ton steel produced in 1998 multiplied with the actual production of steel. The reason for using the IEF for 1998 is because the plant provided detailed information when it applied for allowances under the EU ETS. For 2002-2004 the same method is used but then we have used the 2005 process emissions per ton steel produced. The reason for using the IEF for 2005 for these years is because this was the first year these emissions were part of the EU ETS and they are considered to be the best data available. The process emissions prior to 2005 have to a large extent therefore been estimated based on the process emissions per ton steel produced in 1998 and 2005, this explains the increasing variation in the CO_2 IEF for steel after 2005 since the emissions from 2005 and onwards are based on annual reported data from the EU ETS.

4.4.1.3 Activity data

The process CO_2 emissions stem from an Electric Arc Furnace (EAF) where scrap iron is melted with other carbon materials. The emissions from the scrap iron are calculated based on the use of each types of scrap iron and the appurtenant content of carbon in each type of scrap iron. E.g. in 2010 the plant used 10 types of scrap iron. The types of scrap iron are according to the UK steel protocol and the carbon content in the types of scrap used varies from 0.15 per cent up to 4 per cent. The other input materials to the EAF are coal, lime and the metals ferromanganese, ferrosilicon and silicomanganese and electrodes. The outputs are steel, dust and slag. The net emissions from the mass balance are the process emissions.

Since the plant is part of the EU ETS and Norway makes reported data publically available, the mass balances for 2008-2012 can be found through the agency's web pages.[14]

[14] For the years 2005-2012: http://www.miljodirektoratet.no/no/Tema/klima/CO2_kvoter/Klimakvoter-for-industrien/Klimakvoter-for-2008-2012/ (In Norwegian)

4.4.1.4 Emission factors

Since a mass balance is used, it is the carbon contents of the carbon materials that go into the mass balance that are used. For the scrap iron, all ten types of scrap iron have their own carbon content.

4.4.1.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.4.1.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plant is covered by the EU ETS and the emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.4.1.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.4.1.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.4.2 Production of Ferroalloys, 2C2 (Key category for CO_2)

4.4.2.1 Category description

There are 12 plants producing ferroalloys in Norway and the plants were included in the EU ETS in 2013. One plant closed down in 2001, two plants were closed down during 2003 and two in 2006. The plant that was out of production in 2006 started up again in 2007. Ferrosilicon, silicon metal, ferromanganese and silicon manganese are now produced in Norway. Ferrochromium was produced until the summer in 2001. Ferro silicon with 65 to 96 per cent Si and silicon metal with 98-99 per cent Si is produced. The raw material for silicon is quarts (SiO_2). SiO_2 is reduced to Si and CO using reducing agents like coal, coke and charcoal.

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

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

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

The CO is a result of the production process. In open or semi- closed furnaces the CO reacts with air and forms CO_2 before it is emitted. This is due to high temperature and access to air in the process. In a closed furnace the CO does not reach to CO_2 as there are no access to air (oxygen) in the process. The waste gas is then led from furnace and used as an energy source or flared and is reported under the relevant Energy sectors. The technical specification of the furnaces is irrelevant since emissions are calculated using a mass balance or calculated by multiplying the amount of reducing agents in dry weight with country specific EFs.

Several components are emitted from production of ferroalloys. Emission of CO_2 is a result of the oxidation of the reducing agent used in the production of ferroalloys. In the production of FeSi and silicon metal NMVOC and CH_4 emissions originates from the use of coal and coke in the production processes. From the production of ferro manganes (FeMn), silicon manganes (SiMn) and ferrochromium (FeCr) there is only CO_2 emissions.

Measurements performed at Norwegian plants producing ferroalloys indicate that in addition to emissions of CO_2 and CH_4 also N_2O is emitted. Due to the CRF, the N_2O emissions are reported in 2C7i.

The large increase in emissions from 2009 to 2010 is due to a low production level for ferroalloys in 2009. The production level in 2009 is also lower than 2008 and reflects the lower economic activity due to the economic recession.

CO_2 emissions from production of ferroalloys is defined as a key category according to the approach 2 analysis.

4.4.2.2 Methodological issues

CO_2

The methods used in the calculation of CO_2 emissions form production of ferroalloy is in accordance with the method recommended by the IPCC (2006). Emissions are reported by each plant in an annual report to the agency.

The plants have used one of the two methods below for calculating CO_2-emissions:

1. Mass balance; the emissions for CO_2 is calculated by adding the total input of C in raw materials before subtracting the total amount of C in products, wastes and sold gases (Tier 3).
2. Calculate emission by multiplying the amount of reducing agents in dry weight with country specific emission factors for coal, coke, petrol coke, electrodes, anthracite, limestone and dolomite (Tier 2).

Each plant has for consistency just used one method for the entire time series.

Indirect emissions of CO_2 are calculated based on the emission of CH_4 and are reported in this sub-category.

CH_4 and N_2O

The emissions of CH_4 and N_2O are calculated by multiplying the amount of ferroalloy produced with an emission factor. Emissions are reported by each plant in an annual report to the agency.

Plants producing ferro manganese, silicon manganese and ferrochromium do not emit emissions of CH_4 and N_2O.

NMVOC

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

4.4.2.3 Activity data

CO_2

Calculation of emissions is based on the consumption of gross reducing agents and raw materials (carbonate ore, limestone and dolomite). Note that the use of limestone and dolomite and the corresponding emissions are included here under 2C2.

Table 4.19 shows the amount of reducing agents used as activity data in the CRF for some selected years. The reducing agents include the use of bio carbon and the use increased from about 2001.

Table 4.19 Tonnes of reducing agents in the ferroalloys production for some selected years.

Activity data	1990	2000	2010	2014	2015	2016
Coal (dry weight)	395 255	544 946	360 291	533 928	490 798	496 292
Coke (dry weight)	379 028	450 096	328 013	340 369	349 898	366 508
Electrodes	34 748	48 137	48 813	54 433	51 547	50 052
Petrol coke	8 423	12 935	7 793	16 841	15 220	18 210
Pulverised coke	-	0	9 708	13 852	14 012	13 305
Bio carbon	16 565	17 451	104 013	144 461	144 639	164 535
Total	834 019	1 073 565	858 631	1 103 885	1 066 114	1 108 903
Bio as % av total	2 %	2 %	12 %	13 %	14 %	15 %

Source: Norwegian Environment Agency

CH_4 and N_2O

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

NMVOC

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

4.4.2.4 Emission factors

CO_2

The carbon content of each raw materials used in the Tier 3 calculation is from carbon certificates from the suppliers. The carbon in each product, CO gas sold et cetera is calculated from the mass of product and carbon content. In the Tier 2 calculation the emission factors are as listed in Table 4.20.

Table 4.20 Emission factors from production of ferroalloys. Tonnes CO_2/tonne reducing agent or electrode

	Coal	Coke	Electrodes	Petrol coke	Carbonate ore	Dolomite Limestone
Ferro silicon	3.08	3.36	3.36	--	--	--
Silicon metal	3.12	3.36	3.54	--	--	--
Ferro chromium	--	3.22	3.51	--	--	--
Silicon	--	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), SINTEF (1998c), SINTEF (1998a)

CH_4 and N_2O

Measurements performed at Norwegian plants producing ferro alloys indicate emissions of N_2O in addition to CH_4. The emissions of CH_4 and N_2O are influenced by the following parameters:

- The silicon level of the alloy (65, 75, 90 or 98 % Si) and the silicon yield
- The method used for charging the furnace (batch or continuously)
- The amount of air used to burn the gases at the top controlling the temperature in off gases.

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_4 and N_2O are based upon, are presented in SINTEF (2004). A summary of the report is given in the publication "Reduction of emissions from ferroalloy furnaces" (Grådahl et al. 2007). The main focus for the studies has been NO_X emissions. However, the emissions of CH_4 and N_2O have also been measured.

Full scale measurements have been performed at different industrial FeSi/Si furnaces. The average CH_4 and N_2O concentrations in the ferroalloy process are with some exceptions a few ppm. For N_2O and CH_4 the exception is during spontaneous avalanches in the charge (i.e. collapse of large quantities of colder materials falling into the crater or create cavities) occur from time to time, see Figure 7 in Grådahl et al. (2007). In the avalanches the N_2O emissions go from around zero to more than 35 ppm. The avalanches are always short in duration. There are also increased N_2O emissions during blowing phenomenon.

The EF used in the inventory represents the longer-term average N_2O and CH_4 concentration measurements outside the peaks in concentrations. The peaks in concentration occur due to avalanches (sudden fall of large amount of colder charge into the furnace) that occur from time to time is not fully reflected in the EFs. The EFs used we regard as conservative particular for the early 1990s when the avalanches were more frequent than the latest years.

All companies apply sector specific emission factors in the emission calculation, see Table 4.21. 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.

NMVOC

Statistics Norway uses an emission factor of 1.7 kg NMVOC/tonne coal or coke in the calculations (Limberakis et al. 1987).

Table 4.21 Emission factors for CH_4 and N_2O from production of ferroalloys.

	Si-met			FeSi-75%			FeSi-65%		
Alloy, charging routines and temperature	**Batch-charging**	**Sprinkle-charging [1]**	**Sprinkle-charging and >750°C [2]**	**Batch-charging**	**Sprinkle-charging [1]**	**Sprinkle-charging and >750°C [2]**	**Batch-charging**	**Sprinkle-charging [1]**	**Sprinkle-charging and >750°C [2]**
kg CH_4 per tonne metal	0.1187 (M)	0.0881 (M)	0.1000 (E)	0.0890 (E)	0.0661 (E)	0.0750 (E)	0.0772 (E)	0.0573 (E)	0.0650 (E)
kg N_2O per tonne metal	0.0433 (E)	0.0214 (E)	0.0252 (E)	0.0297 (E)	0.0136 (E)	0.0161 (E)	0.0117 (E)	0.0078 (E)	0.0097 (E)

[1] Sprinkle-charging is charging intermittently every minute.
[2] Temperature in off-gas channel measured where the thermocouple cannot 'see' the combustion in the furnace hood.
M=measurements and E= estimates based on measurements

4.4.2.5 Uncertainties and time-series consistency

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

The IEF (tonne CO_2/tonne reducing agent) for the ferroalloys production has a downward trend from around the year 2001. This is due to the increased use of bio carbons. Fluctuations in the IEF can also be due to variations in use of the various reducing agents, amounts of sold CO and production of ferro alloy products.

4.4.2.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plants have reported under the voluntary agreement and the emissions are now covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

Statistics Norway makes in addition occasional quality controls (QC) of the emission data on the basis of the consumption of reducing agents they collect in an annual survey and average emission factors.

4.4.2.7 Category-specific recalculations

Revised data. Changes in reported figures on CO_2, CH_4 and N_2O from one plant in 2011 and N_2O in 2012. CO_2 increased by 56 ktonnes in 2011, other changes are minor.

4.4.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.4.3 Aluminium production, 2C3 (Key Category for CO_2 and PFC)

4.4.3.1 Category description

One open mill in Norway has handled secondary aluminium production, but it closed down in 2001. Minor emissions of SF_6 in the period 1992-2000 are therefore included in the inventory.

There are seven plants in Norway producing primary aluminium and they were included into the EU ETS in 2013. 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 CO_2 and perfluorocarbons (PFCs). The emission of CO_2 is due to the electrolysis process during the production of aluminium.

There has been a substantial reduction in the total PFC emissions from the seven Norwegian aluminium plants in the period from 1990 to 2016. 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 in kg CO_2 equivalents per tonne aluminium were reduced from 2.99 in 1990 to 2.30 in 1991 and 1.12 in 1992 and respective values for Soederberg were 6.45, 6.09 and 5.78. In 2016 the specific PFC emissions for prebaked and Soederberg were 0.15 and 0.11 kg CO_2-equivalent, see Figure 4.6 and Table 4.22.

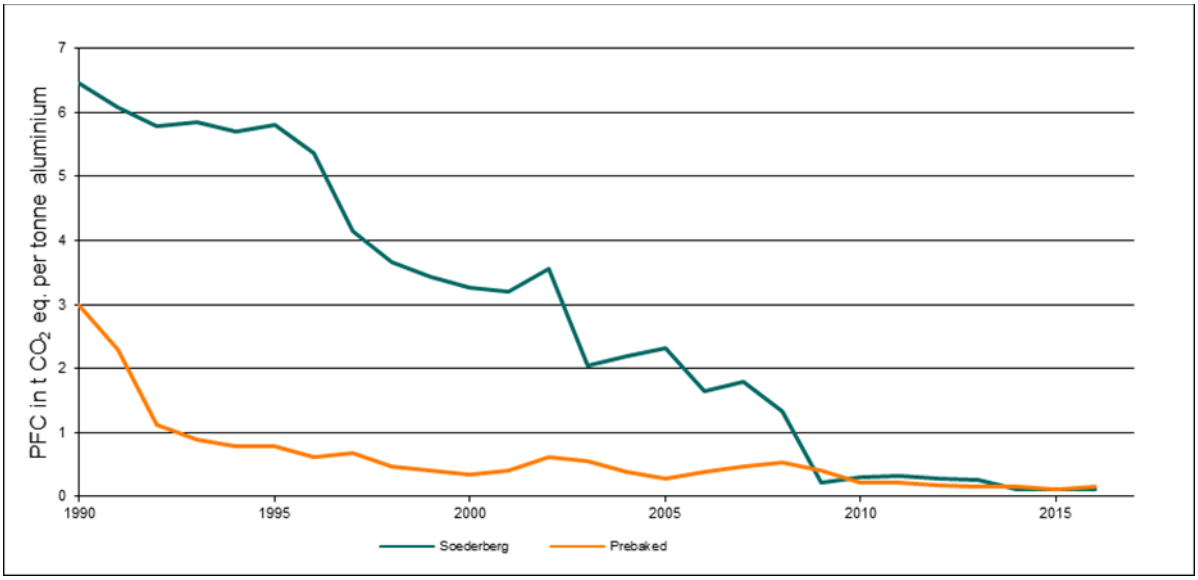


Figure 4.6 PFC in kg CO_2 equivalent per tonne aluminium.
Source: Norwegian Environment Agency

Table 4.22 Shares of the technologies used in aluminum production and the PFC IEFs.[15]

Year	Share of production from Soederberg technology	Share of production from pre-baked technology	PFC IEF Soderberg	PFC IEF pre-baked
1990	43%	57 %	6.45	2.99
1995	39 %	61 %	5.81	0.78
2000	39 %	61 %	3.26	0.35
2005	20 %	80 %	2.32	0.28
2007	17 %	83 %	1.80	0.47
2008	15 %	85 %	1.33	0.53
2009	8 %	92 %	0.21	0.41
2010	8 %	92 %	0.31	0.21
2011	8 %	92 %	0.33	0.23
2012	7%	93%	0.29	0.15
2013	8%	92%	0.26	0.15
2014	8%	92%	0.10	0.16
2015	8%	92%	0.12	0.12
2016	8%	92%	0.11	0.15

Source: Norwegian Environment Agency

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 2016. Two new plants with prebaked technology were established in 2002 and plants using Soederberg technology were closed down in the period 2002-2009. The shares of the two technologies and their PCF IEFs are shown in Table 4.22. The PFCs emissions from production of aluminium have decreased by 94.9 per cent from 1990 to 2016.

The PFC emissions per tonne aluminium produced in Norway was 4.48 kg CO_2 equivalents in 1990 and 0.15 kg CO_2 equivalents in 2016. This is a reduction of 96.7 per cent from 1990 to 2016.

An increase in production capacity is also included in the modernisation, leading to higher total emissions of CO_2.

PFCs and CO_2 emissions from aluminium production are both identified as key categories according to the approach 2 analysis.

4.4.3.2 Methodological issues

CO_2

The inventory uses the emission figures reported to the Norwegian Envionment Agency calculated by each plant. 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.

For the years including 2012, the aluminium industry calculated the CO_2 emissions separate for each technology on the basis of consumption of reducing agents. This includes carbon electrodes,

[15] PFC in kg CO_2 equivalents per tonne aluminium

electrode mass and petroleum coke. The emissions factors are primarily calculated from the carbon content of the reducing agents.

The following methods were used up to 2012:

CO_2 from Prebake Cells

(4.9) Q = A*C*3.67

Where
Q is the total yearly emissions of CO_2
A is the yearly net consumption of anodes
C is per cent carbon in the anodes
3.67 is the mol-factor CO_2/C

CO_2 from Soederberg Cells

*(4.10) Q = S*3.67*(K*C1+P*C2)*

Where
Q is the total yearly emissions of CO_2
S is the yearly consumption of Soederberg paste
K is the share of coke in the Soederberg paste
P is the share of patch in the Soederberg paste
K+P=1
C1 is the fraction of carbon in the coke. Fraction is per cent Carbon/100
C2 is the fraction of carbon in the peach. Fraction is per cent Carbon/100

From 2013 and onwards, the CO_2 emissions from Soederberg cells and from Prebake cells are calculated using the mass balance methodology that considers all carbon inputs, stocks, products and other exports from the mixing, forming, baking and recycling of electrodes as well as from electrode consumption in electrolysis. We have no indications that this has resulted in an inconsistent time series.

PFCs

Perfluorinated hydrocarbons (PFCs), e.g. tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6), are produced during anode effects (AE) in the Prebake and Soederberg cells, when the voltage of the cells increases from the normal 4-5V to 25-40V. During normal operating condition, PFCs are not produced. The fluorine in the PFCs produced during anode effects originates from cryolite. Molten cryolite is necessary as a solvent for alumina in the production process.

Emissions of PFCs from a pot line (or from smelters) are dependent on the number of anode effects and their intensity and duration. Anode effect characteristics will be different from plant to plant and also depend on the technology used (Prebake or Soederberg).

During electrolysis two per fluorocarbon gases (PFCs), tetrafluormethane (CF_4) and heksafluorethane (C_2F_6), may be produced in the following reaction:

Reaction 1

$$4Na_3AlF_6 + 3C \rightarrow 4Al + 12NaF + 3CF_4$$

Reaction 2

$$4Na_3AlF_6 + 4C \rightarrow 4Al + 12NaF + 2C_2F_6$$

The national data are based on calculated plant specific figures from each of the Norwegian plants. A Tier 2 method is used in the 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 4.23, 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:

kg CF_4 per year = S_{CF4} • AEM • MP and

kg C_2F_6 per year = kg CF_4 per year • $F_{C2F6/CF4}$

Where:

S_{CF4} = "Slope coefficient" for CF_4, (kg $_{PFC}/t_{Al}$/anode effect minutes/cell day

AEM = anode effect minutes per cell day

MP = aluminium production, tonnes Al per year

$F_{C2F6/CF4}$ = weight fraction of C_2F_6/CF_4

Table 4.23 Technology specific slope and overvoltage coefficients for the calculation of PFCs emissions from aluminium production.

Technology [a]	**"Slope coefficient"** [b, c] **(kg $_{PFC}/t_{Al}$)/ (anode effect/cellday)**		**Weight fraction C_2F_6/CF_4**	
	S_{CF4}	**Uncertainty** (±%)	$F_{C2F6/CF4}$	Uncertainty (±%)
CWPB	0.143	6	0.121	11
SWPB	0.272	15	0.252	23
VSS	0.092	17	0.053	15
HSS	0.099	44	0.085	48

a. Centre Worked Prebake (CWPB), Side Worked Prebake (SWPB), Vertical Stud Søderberg (VSS), Horizontal Stud Søderberg (HSS).

b. Source: Measurements reported to IAI, US EPA sponsored measurements and multiple site measurements.

c. Embedded in each slope coefficient is an assumed emission collection efficiency as follows: CWPB 98%, SWPB 90%, VSS 85%, HSS 90%. These collection efficiencies have been assumed based on measured PFC collection fractions, measured fluoride collection efficiencies and expert opinion.

"Slope coefficient": The connection between the anode parameters and emissions of PFC.

Measurements of PFCs at several aluminium plants have established a connection between anode parameters and emissions of CF_4 and C_2F_6. The mechanisms for producing emissions of PFC are the same as for producing CF_4 and C_2F_6. The two PFC gases are therefore considered together when PFC emissions are calculated. The C_2F_6 emissions are calculated as a fraction of the CF_4 emissions.

The Tier 2 coefficients for Centre Worked Prebaked cells (CWPB) are average values from about 70 international measurement campaigns made during the last decade, while there are fewer data (less than 20) for Vertical Stud Soederberg cells (VSS). The main reason for the choice of the Tier 2 method is that the uncertainties in the facility specific slope coefficients is lower than the facility specific based slope coefficients in Tier 3. This means that there is nothing to gain in accuracy of the data by doing measurements with higher uncertainties.

"Slope coefficient" is the number of kg CF_4 per tonne aluminium produced divided by the number of anode effects per cell day. The parameter cell day is the average number of cells producing on a yearly basis multiplied with the number of days in a year that the cells have been producing.

Sulphur hexafluoride (SF_6)

SF_6 used as cover gas in the aluminium industry is assumed to be inert, and SF_6 emissions are therefore assumed to be equal to consumption. At one plant SF_6 was used as cover gas in the production of a specific quality of aluminium from 1992 to 1996. The aluminium plant no longer produces this quality, which means that SF_6 emissions have stopped.

4.4.3.3 Emission factors

The PFC emissions are calculated using the Tier 2 recommended values by IAI (2005) for CF_4 (the slope coefficients of 0.143 kg CF_4/tonne Al/anode effect minutes per cell day for CWPB and 0.092 for VSS). The amount of C_2F_6 is calculated from the Tier 2 values for CF_4, where the weight fraction of C_2F_6 to CF_4 is set equal to 0.121 for CWPB and 0.053 for VSS. This is consistent with the 2006 IPCC GL. All values 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 the agency.

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 and time-series consistency

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.

Chapter 4.4.3.1 explains the downward trend of the IEF for PCF emissions, but there are also some inter-annual changes that can be explained. The reduced IEF for Soederberg from 2002 to 2003 is due to the fact that one plant using this technology closed down and had no production in 2003. This plant produced 18% of the aluminium produced with this technology in 2002 and had an IEF in 2002 that was the highest among all the plants producing with Soederbeg technology in that year. The reduced IEF for Soederberg from 2008 to 2009 is due to the fact that another plant using this technology closed down in 2009. This plant produced 56% of the aluminium produced with this technology in 2008 and the production in 2009 was minor. The plant's IEF in 2008 was the highest among all the plants producing with Soederberg technology in that year. The reduction in IEF for prebaked from 2014 to 2015 and then an increase from 2015 to 2016 is due to a very low anode effect frequency in 2015 for one plant.

CO_2

The implied emission factor for CO_2 is relatively stable over the time series. The largest inter-annual changes in the IEF are from 2009 to 2010 and from 2010 to 2011 and can be explained by production problems at one plant in 2010. The concerned plant produced about 18% of the total aluminium in 2010 and uses the prebaked technology. Its CO_2 IEF in 2010 was unusually high since the consumption of anodes per tonne aluminium produced were 22 per cent higher in 2010 than in comparable years.

With the inclusion of the aluminium and anode production in the EU ETS system from 2013, a new methodology was introduced for the calculation of CO_2 emissions from anode production in integrated aluminium and anode plants. For one plant, it was no longer possible to split CO_2 process emission between aluminium and anode production and all the emissions from this plant are reported in 2C3.

4.4.3.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plants have reported under the voluntary agreement and the emissions are now covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

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 Norwegian Envionment Agency contacts the plant to discuss the reported data and changes are made if necessary.

The Norwegian Envionment Agency has annual meetings with the aluminium industry where all plants are represented. This forum is used for discussion of uncertainties and improvement possibilities. The agency's auditing department are regularly auditing the aluminium plants. As part of the audits, their system for monitoring, calculation and reporting of emissions are controlled.

The emission figures reported by the plants are also occasionally controlled by Statistics Norway. Statistics Norway make their own estimates based on the consumption of reducing agents and production data collected in an annual survey and average emission factors.

4.4.3.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.4.3.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.4.4 Magnesium production, 2C4 (Key category for SF_6)

4.4.4.1 Category 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_2 and CO emissions. During the calcinations of Dolomite ($MgCa(CO_3)_2$) to magnesium oxide, CO_2 is emitted. During the next step, magnesium oxide is chlorinated to magnesium chloride and coke is added to bind the oxygen as CO and CO_2. SO_2 is emitted due to the sulphur in the reducing agent used.

In the foundry, producing cast magnesium, SF_6 is used as a cover gas to prevent oxidation of magnesium. The Norwegian producers of cast magnesium has assessed whether SF_6 used a cover gas reacts with other components in the furnace. The results indicate that it is relatively inert, and it is therefore assumed that all SF_6 used as cover gas is emitted to the air.

The emissions decreased due to improvements in technology and in process management. The primary magnesium production stopped in 2002 and only secondary production is retained and this production has no CO_2 emissions from processes. During 2006 also the production of remelting Mg stopped and since then there were no emissions from this source.

SF_6 emissions from magnesium foundries is defined as a key category according to the approach 1 analysis.

4.4.4.2 Methodological issues

CO_2

The Norwegian emission inventory uses production data as activity data. The CO_2 emissions are therefore calculated by using annual production volume and the emission factor recommended by SINTEF (SINTEF 1998e). This is considered to be in line with the tier 2 method in the IPCC 2006 Guidelines (IPCC 2006).

SF_6

The consumption of the cover gas SF_6 is used as the emission estimates in accordance with the tier 2 method in the IPCC 2006 Guidelines (IPCC 2006). The plant reported the emissions each year to the agency.

4.4.4.3 Activity data

In the GHG emission inventory we have used production volumes as activity data in the calculation of CO_2. The plant reported the consumption of SF_6 to the agency.

4.4.4.4 Emission factor

An emission factor of 4.07 tonnes CO_2/tonnes produced magnesium is used to calculated the annual emissions of CO_2 (SINTEF 1998e).

4.4.4.5 Uncertainties and time-series consistency

The uncertainty estimates are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.4.4.6 Category-specific QA/QC and verification

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

4.4.4.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.4.4.8 Category-specific planned improvements

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

4.4.5 Zinc production, 2C6

4.4.5.1 Category description

One plant in Norway produces zinc and the plant's main products are zinc, zick-alloys and aluminiumfluoride. The plant has reported process emission of CO_2 from the use of ore materials for the year 2012 and onwards.

4.4.5.2 Methodological issues

CO_2

The tier 1 method and a default EF from the 2006 IPCC GL is not applicable since the plant uses an electrolytic process and the 2006 IPCC GL states that this does not result in non-energy CO_2 emissions. However, the plant reports some process emissions of CO_2 from the use of ore materials using a mass balance approach for both roasting and sintering. This is 2 method that is more accurate than the tier 1 method because it takes into account the materials and the variety of furnace types

used rather than assumong industry-wide practices. Emission figures have been reported by the plant to the Norwegian Envionment Agency for the year 2012 and onwards and the agency has estimated the emissions for the years 1990-2011 by correlating the annual production levels of zinc with the ratio between process and combustion emisisons in 2012. For the years 1990-1993 with no production data available, the emissions have been set equal to the emissions in 1994.

4.4.5.3 Activity data

The plant has reported the amounts of ore materials used for the year 2012 and onwards and it ranges from about 144 000 to 298 000 tonnes.

4.4.5.4 Emission factors

The plant has reported emission factors for the ore materials used for the year 2912 and onwards. The emission factors (t C/t ore material) ranges from 0.00148 to 0.0062.

4.4.5.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.4.5.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plant reports annually through its permit and the agency's inventory team tracks emissions and AD for the plant.

4.4.5.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.4.5.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.4.6 Anode production, 2C7i

4.4.6.1 Category description

Four plants in Norway produce anodes and they were included into the EU ETS in 2013. Three plants produce prebaked anodes and one plant produces coal electrodes. These are alternatives to the use of coal and coke as reducing agents in the production process for aluminium and ferroalloys. The anodes and coal electrodes are produced from coal and coke. The production of anodes and coal electrodes leads to emissions of CO_2.

4.4.6.2 Methodological issues

The emissions of CO_2 from the production of anodes are calculated by each plant and the method is based on the Aluminium Sector Greenhouse Gas Protocol by the International Aluminium Institute (IAI 2005).

The fourth plant produces coal electrodes and Søderberg anodes for ferroalloy production. The emissions are calculated from the consumption of anthracite and petrol coke. In addition, pitch is included in production. The calculations of CO_2 from processes are uptime in hours multiplied with EF for each feedstock. When calcinations of anthracite the EF are 167 kg CO_2 per uptime hour and for petrol coke the EF is 238 kg CO_2. In addition, there are emissions from energy use that is reported in the Energy sector.

From 2012, there was a methodological challenge for integrated anode and aluminum production plants since reported EU ETS data do not provide information to split emissions on the two processes. Equation 4.21 from the 2006 IPCC Guidelines are not used for calculating these emissions in the EU ETS system, where emissions are calculated based on a carbon mass balance approach without information on ash and sulphur content. Therefore, some emissions that previously were reported under 2C7ai are from the inventory year 2013 included under 2C3.

4.4.6.3 Activity data

See methodological issues.

4.4.6.4 Emission factors

See methodological issues.

4.4.6.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.4.6.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plants have reported under the voluntary agreement and the emissions are now covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.4.6.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.4.6.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.4.7 Nickel production, 2C7ii

4.4.7.1 Category description

One plant in Norway produces nickel. During the production of nickel, CO_2 is emitted from the use of soda ash.

4.4.7.2 Methodological issues

CO_2 emission figures are annually reported from the plant to the agency.

4.4.7.3 Activity data

The activity data is the annual amounts of soda ash used in the production process, see Table 4.9.

4.4.7.4 Emission factors

An emission factor of 0.41492 tonnes CO_2/tonne soda ash is used for the calculations.

4.4.7.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.4.7.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plant reports as required by its regular permit and has also reported under the voluntary agreement. The agency's inventory team tracks emissions and AD for the plant.

4.4.7.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.4.7.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.5 Non-energy products from fuels and solvent use – 2D

Norway reports the source categories lubricants use, paraffin wax, solvent use, road paving with asphalt and asphalt roofing under the category 2D, see Table 4.24.

Table 4.24 Non-energy products from fuels and solvent use. Components included in the inventory, tier of method and key category.

Source category	CO_2	Tier	Key category
2D1. Lubricants use	E	Tier 2	Yes
2D2. Paraffin wax use	E	Tier 1	No
2D3a. Solvent use	E	Tier 2	No
2D3b. Road paving with asphalt	E	Tier 1	No
2D3d. Other (use of urea)	E	Tier 1	No

R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated. NA = Not Applicable. NO = Not Occuring. IE = Included Elsewhere.

Table 4.25 shows the emission trends for 2D as a whole and for the various source categories. The GHG emissions from this sector category were about 0.2 million tonnes in 2016, this is 2.4 per cent of the total emission from the IPPU-sector. The emissions from this sector decreased by 26.5 per cent from 1990 and the emissions increased by 3.6 per cent from 2015 to 2016.

Table 4.25 Emission trends for 2D Non-energy products from fuels and solvent use (kt CO_2 equivalents).

Source category	1990	1990, % of IPPU	2015	2016	2016, % of IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2D1. Lubricants use	167.1	1.2	35.1	42.3	0.5	-74.7	20.5
2D2. Paraffin wax use	6.2	0.0	48.3	46.0	0.5	638.3	-4.7
2D3a. Solvent use	114.1	0.8	106.9	107.3	1.2	-6.0	0.3
2D3b. Road paving with asphalt	0.0	0.0	0.0	0.0	0.0	45.8	4.6
2D3d. Other (use of urea)	0.0	0.0	13.7	15.6	0.2		14.5
2D. Total	287.5	2.0	204.0	211.3	2.4	-26.5	3.6

Source: Statistics Norway and Norwegian Environment Agency

4.5.1 Lubricant use, 2D1 (Key category for CO_2)

4.5.1.1 Category description

Lubricants are mostly used in transportation and industrial applications, and are partly consumed during their use. It is difficult to determine which fraction of the consumed lubricant is actually combusted, and which fraction is firstly resulting in NMVOC and CO emissions and then oxidised to CO_2. Hence, the total amount of lubricants lost during their use is assumed to be fully oxidized and these emissions are directly reported as CO_2 emissions.

Emissions from waste oil handling are reported in the Energy Sector (energy recovery) and in the Waste sector (incineration).

CO_2 emissions from lubricants use is defined as a key category according to the approach 1 analysis.

4.5.1.2 Methodological issues

The CO_2 emissions from lubricant use are estimated by multiplying sold amounts of lubricants (m^3) by density, country specific oxidation factors, default NCV value (TJ/tonne), default C content (tonne/TJ) and the mass ratio of CO_2/C:

(4.11) $E_p = A_p * d * NCV * ODU_p * CC * 44/12$

where:

E_p = CO_2 emission from product group *p*

A_p = Sold amount of lubricant from product group *p* (activity data)

d = Density

NCV = Net calorific value for lubricants

ODU_p = Fraction being oxidized during use from product group *p*

CC = Carbon content

The method is applied to subgroups of lubricants, as does the tier 2 method in the 2006 guidelines. However, even though the lubricant product groups in the Norwegian inventory are more detailed than in the tier 2 method, no distinction is made between lubricant oil and lubricant wax in the activity data. Thus, tier 1 factors are applied for *NVC* and *CC*.

It is assumed that all lubricant consumption and oxidation occurs within the sales year.

4.5.1.3 Activity data

The sold amount of lubricant by product group is given in Statistics Norway's statistics on sales of petroleum products, see Table 4.26. This statistics is based on reporting from the oil companies, and divides the lubricant into five product groups (numbered 204 – 208, see Table 4.26 and Table 4.27).

Table 4.26 Sold amounts of lubricants, except to foreign navigation (1.000 m3), 1990 – 2015.

Year	201	202	203	204	205	206	207	208
1990	99 637	0	0	0	0	0	0	0
1995	40 583	0	0	23 270	0	22 726	0	0
2000	0	29 369	12 734	9 160	13 724	18 594	0	0
2005	0	0	0	13 215	10 751	5 919	33 671	4 233
2007	0	0	0	12 271	13 589	6 035	35 381	4 879
2008	0	0	0	13 316	13 130	4 520	35 923	4 975
2009	0	0	0	10 809	12 573	6 642	34 104	4 967
2010	0	0	0	10 412	12 189	4 147	35 434	5 514
2011	0	0	0	9 432	12 897	7 763	35 661	6 230
2012	0	0	0	9 405	11 665	4 188	31 168	5 813
2013	0	0	0	10 161	12 515	5 195	37 047	5 944
2014	0	0	0	5 655	13 627	4 898	28 504	5 973
2015	0	0	0	4 419	11 612	2 317	25 416	5 188
2016	0	0	0	5 230	13 352	3 300	29 586	5 922

Source: Statistics Norway

Historically, all lubricant was allocated to product group 201. From 1995 product group 204 and 206 were separated out, and from 1998 the remainder of 201 was split into the product groups 202, 203 and 295. Product groups 207 and 208, which were established in 2003, are reallocations of group 202 and 203.

Table 4.27 Lubricant product groups in the sales of petroleum statistics.

Product group	Product group (text)
201	Lubricants
202	Auto motor and gear oil
203	Navigation and aviation motor and gear oil
204	Industrial lubricants
205	Hydraulic oils
206	Process and transformer oil
207	Motor oil
208	Gear oil

Source: Statistics Norway

The sales statistics does not distinguish between lubricant wax and lubricant oil, and hence the default average (tier 1) carbon content (*CC*) factor was used.

4.5.1.4 Emission factors

ODU factors

The factors for oxidation during use (ODU) for are product groups 204 to 208 are shown in Table 4.28. The factors were found by contacting a broad selection of users and purchasers of lubricant oils, as well as branch organisations and interest groups. We have here assumed that loss during use corresponds to oxidation during use, as described above. As the former product groups 201 – 203 are not covered in the report (Weholt et al. 2010), ODUs for these product groups were estimated. The ODU for product group 202 and 203 is simply the average of the ODUs for product number 207 and 208. For product group 201 the ODU in 1990 to 1994 was estimated as the weighted average of ODU for product group 202 to 206, based on sold amounts in 1998. In 1995 to 1997 it was estimated from product group 202, 203 and 205 in 1998.

Table 4.28 Oxidation during use (ODU) factors.

Product group	ODU factor	Source *(L = literature, E = estimated)*
201 (1990 to 1994)	0.67	E
201 (1995 to 1997)	0.17	E
202	0.175	E
203	0.175	E
204	0.75	L
205	0.15	L
206	0.90	L
207	0.25	L
208	0.10	L

Source: Weholt et al. (2010)

The statistics on sold lubricant include oil combusted in two-stroke petrol engines, and hence considerations must be made in order to avoid double counting. However, the report (Weholt et al. 2010), which is quite detailed when describing the elaboration of ODU factors, does not mention consumption in two-stroke petrol engines. We therefore assume that consumption in two-stroke petrol engines are omitted in the ODU factors, and thus no correction for double counting is necessary.

Other factors

The figures on sold lubricants are given in m^3, and must be converted to tonnes. The density varies between different lubricant types, and based on sources available on the Internet it is estimated to 0.85 m^3/tonne as an average for all lubricant types, see Exxonmobile (2009) and Neste_Oil (2014). The conversion from tonnes of consumed lubricant to tonnes of emitted CO_2 is peformed based on IPCC default factors for energy content (NCV) and carbon content per unit of energy see Table 4.29. This conversion method implicitly adjusts for the content of non-hydrocarbons.

Table 4.29 Other factors.

Factor	Value	Unit	Source
Density (*d*)	0.85	m^3/tonne	Producers
Net calorific value (*NCV*)	0.0402	TJ/tonne	IPCC 2006 GL
Carbon content (*CC*)	20	Tonne C/TJ	IPCC 2006 GL

4.5.1.5 Uncertainties and time-series consistency

The uncertainty in the estimated emissions from lubricant use (except in two-stroke petrol engines) is assumed to be rather low. The uncertainty in the activity data is assumed to be 5 per cent, see Table 4.30, in line with the IPCC guidelines for counties with well developed energy statistics. Also the uncertainty of the carbon content is an IPCC default value, and the NCV uncertainty is assumed to be equally large. The uncertainty estimate for the density is based on an expert judgement of the available data on the Internet.

The uncertainty of the country specific ODU estimate is set much lower than for the IPCC default value. This is partly due to the thorough evaluation in the report (Weholt et al. 2010), and partly due to estimations based on the ODUs from this report combined with sales and waste collection statistics, which states that 85 to 90 per cent of all waste lubricant oil is collected by Statistics Norway (Statistics Norway & SOE Norway 2014). This rather high collection percentage seems reasonable, due to a refund scheme for waste oil combined with strict control of the collected amounts. Higher ODUs would increase this percentage, and vice versa.

Table 4.30 Uncertainty estimates (per cent).

Parameter	Uncertainty
Activity data (*A*)	5
Oxidation during use (*ODU*)	5
Density (*d*)	3
Net calorific value (*NCV*)	3
Carbon content (*CC*)	3

Based on these uncertainties, the overall uncertainty of the emissions from lubricating oil (except from use in two-stroke petrol engines) is estimated at 20 per cent.

The split of lubricants between different product groups in the activity data have varied throughout the time series, and the level of detail is lower at the beginning of the time series. This might potentially introduce some time series inconsistencies. However, this variation is taken into account for the used ODU factors, and no significant time series inconsistencies are thus expected.

4.5.1.6 Category-specific QA/QC and verification

Emissions from lubricant use are calculated in Excel sheets before being included in the main model. Activity data for the calculations of emissions from lubricants are subject to checks for consistency compared to previous years. Major discrepancies are examined. Periodically, sales statistics are compared to waste statistics as a quality control of level. In addition, the emission estimates are subject to the general QA/QC procedures (see chapter 1.2.3) when included in the main model.

4.5.1.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.5.1.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.5.2 Paraffin wax use, 2D2

4.5.2.1 Category description

Paraffin waxes are produced from crude oil and used in a number of different applications, including candles, tapers and the like. Combustion of such products results in emissions of fossil CO_2. Emissions

from the incineration of products containing paraffin wax, such as wax coated boxes, are covered by emissions estimates from waste incineration.

4.5.2.2 Methodological issues

Emissions of CO_2 from the burning of candles, tapers and the like are calculated using a modified version of equation 5.4 for Waxes – Tier 1 Method of the 2006 IPCC Guidelines:

(4.12) *Emissions = PC* PF * CC_{Wax} * 44/12*

Where:

- Emissions = CO_2 emissions from waxes, tonne CO_2
- PC = total candle consumption, TJ
- PF = fraction of candles made of paraffin waxes
- CC_{Wax} = carbon content of paraffin wax (default), tonne C/TJ (Lower Heating Value basis)
- 44/12 = mass ratio of CO_2/C

Consumption figures on paraffin waxes are multiplied by the default net calorific values (NCV). Net consumption in calorific value is then converted to carbon amount, using the value for carbon content (Lower Heating Value basis) and finally to CO_2 emissions, using the mass ratio of CO_2/C.

4.5.2.3 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.

4.5.2.4 Emission factors

Parameter values used in the emissions calculations are given in Table 4.31.

Table 4.31 Parameters employed when calculating emissions.

Parameters	Factor	Unit	References
Net calorific value (NCV)	40.20	TJ/Gg	2006 IPCC
Carbon content (CC_{Wax}, Lower Heating Value basis)	20.00	tonnes C/TJ =	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.

4.5.2.5 Uncertainties and time-series consistency

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.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.5.2.6 Category-specific QA/QC and verification

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

4.5.2.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.5.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.5.3 Solvent use, 2D3a

4.5.3.1 Category description

The use of solvents leads to emissions of non-methane volatile organic compounds (NMVOC) which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidise to CO_2, which is included in the total greenhouse gas emissions reported to UNFCCC. As explained in chapter 9, the indirect CO_2 emissions from oxidized CH_4 and NMVOC are calculated from the content of fossil carbon in the compounds.

Solvents and other product use are non-key categories.

4.5.3.2 Methodological issues

The general model used is a simplified version of the detailed methodology described in chapter 6 of the EMEP/CORINAIR Guidebook 2007 (EEA 2007). It represents a mass balance *per substance*, where emissions are calculated by multiplying relevant activity data with an emission factor. For better coverage, point sources reported from industries to the Norwegian Environment Agency and calculated emissions from a side model for cosmetics are added to the estimates. A detailed description of method and activity data is available in 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[16]. The list is supplemented by NMVOC reported in the UK's National Atmospheric Emissions Inventory (AEA 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 (now called Norwegian Environment 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_2

The use of solvents leads to emissions of non-methane volatile organic compounds (NMVOC) which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidise to CO_2, which is included in the total greenhouse gas emissions reported to UNFCCC.

4.5.3.3 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

[16] "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."

(2014c)), including private households (no NACE), or a combination of both. As a consequence, the identification of specific substances, products or industrial sectors that have a major influence on the emissions is greatly facilitated.

Cosmetics

The side model for cosmetics is updated each year with data on from the Norwegian Association of Cosmetics, Toiletries and Fragrance Suppliers (KLF).

Point sources

Data from nine point sources provided by the Norwegian Environment Agency is added to the emissions estimates. The point sources are reported from the industrial sector "Manufacture of chemicals and chemical products" (NACE 24). In order to avoid double counting, NMVOC used as raw materials in this sector are excluded from the emission estimates from the Product Register data.

4.5.3.4 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 (EEA 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 when the model was first developed by Holmengen and Kittilsen (2009) and several improvements of single emissions factors have been made in the following years.

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.

4.5.3.5 Uncertainties and time-series consistency

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. The activity data from the Swedish Product register has an uncertainty of about 15 per cent (Skårman et al. 2006). 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.

A detailed description of the uncertainty analysis is available in 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 4.32 and Table 4.33.

Table 4.32 Uncertainty estimates for level in NMVOC emissions, 2005-2007. Tonnes and per cent.

Uncertainty in level	Negative (n)	Negative (n) (per cent of total emissions)	Positive (p)	Positive (p) (per cent of total emissions)
2005	2 288	4.58	1 437	2.88
2006	1 651	3.70	1 103	2.47
2007	1 299	2.79	1 168	2.51

Table 4.33 Uncertainty estimates for trend in NMVOC emissions, 2005-2007. Tonnes.

Uncertainty in trend	Negative (n)	Positive (p)	95% confidence interval for change
2005-2006	2 135	1 067	(-7 366, -4 164)
2006-2007	1 420	947	(407, 2 774)
2005-2007	1 882	1 076	(-5 286, -2 328)

Time series consistency

The activity data from the Norwegian Product Register is only available from 2005 onwards. For the years from 1990 to 2000, data from the previous solvent balance has been used. The two time series have been spliced by interpolation. This introduces a degree of time series inconsistency. However, the results from the previous solvent balance were evaluated and updated with new knowledge from the current model in Holmengen and Kittilsen (2009). Thus, overall time series consistency is deemed to be satisfactory.

4.5.3.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V. Large between-year discrepancies in the time series of substance quantities are routinely identified and investigated, in order to correct errors in consumption figures. Large within-year discrepancies between minimum and maximum quantities in simplified declarations are routinely identified and investigated, in order to prevent overestimation for substances where consumption figures are given in intervals. Large within-year discrepancies between totals for industrial sectors (NACE) and totals for products (UCN) are routinely identified and investigated, in order to detect erroneous or incomplete industrial sectoral and product type distribution.

4.5.3.7 Category-specific recalculations

Updated activity data (correction of error). An error was detected in activity data for 2012 and 2015. The indirect CO_2 emissions from NMVOC from solvent use (2D3a) increased by about 2 per cent both years.

Correction of error. Marginal reduction in indirect CO_2 emissions 2013-2015, due to the removal of erroneously included figures on NMVOC emissions for a plant that was closed down in 2012.

4.5.3.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.5.4 Road paving with asphalt, 2D3b

4.5.4.1 Category description

Indirect CO_2 emissions from NMVOC emissions from road paving with asphalt are included in the inventory.

4.5.4.2 Methodological issues

The emissions from road paving are calculated in accordance with a Tier 1 approach (EEA 2013).

$$E_{pollutant} = AR_{production} * EF_{pollutatnt}$$

where

E pollutant = the emission of the specified pollutant

AR production = the activity rate for the road paving with asphalt

EF pollutant = the emission factor for this pollutant

4.5.4.3 Activity data

The activity data used is the annual weight of asphalt used for road paving in Norway, collected by the Contractors Association - Building and Construction annually (EBA 2014).

4.5.4.4 Emission factors

The share of bitumen in the asphalt is set to be 0,05 for all years, based on information from a road technology Institute, a centre for research and development, quality control and documentation of asphalt (http://www.asfaltteknisk.no/).The emissions of NMVOC are calculated using an emission factor of 16 g NMVOC / tonne asphalt (EEA 2013).

4.5.4.5 Uncertainties and time series consistency

The activity data and emission factor used are uncertain. The annual emissions are however low. Activity data on asphalt used are available from 1995 onwards. For the years 1990-1994, the emission figure for 1995 is used. This introduces some degree of time series inconsistency in methodology. The annual variability in emissions throughout the entire time series is however insignificant, and this inconsistency is thus deemed acceptable.

4.5.4.6 Category-specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. See Annex V for the description of the general QA/QC procedure.

4.5.4.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.5.4.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.5.5 Other, 2D3d (use of urea as a catalyst)

4.5.5.1 Category description

Urea is used as a catalyst to reduce NO_X emissions, in Norway primarily from road transport and shipping. When urea is injected upstream of a hydrolysis catalyst in the exhaust line, the following reaction takes place:

$$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2$$

The ammonia formed by this reaction is the primary agent that reacts with nitrogen oxides to reduce them to nitrogen.

There were no emissions from the use of urea as a catalyst in 1990, and the use of urea and thus emissions have increased significantly the last few years.

4.5.5.2 Methodological issues

Emissions are calculated based on equation 3.2.2 of Volume 2 of the 2006 IPCC Guidelines:

*Emissions = Activity * 12/60 * Purity * 44/12*

where

Emissions = CO_2 emissions form urea-based additive in catalytic converters (Gg CO_2)

Activity = amount of urea-based additive consumed for use in catalytic converters

Purity = the mass fraction (= fraction of urea in the urea-based additive)

The fraction 12/60 converts the emission figure from urea ($CO(NH_2)_2$) to carbon (C), while 44/12 converts C to CO_2.

Emissions are calculated as the sum of emissions from each purity.

4.5.5.3 Activity data

No official statistics cover sale, production, or use of urea as a catalyst in Norway. There is no national production of urea used as a catalyst, as the urea produced in Norway is used for fertilizers only. There are many importers of urea used as a catalyst, and the urea is often imported in smaller containers, and not in bulk. Information from the largest importer of urea shows that urea is imported to Norway in at least three different purities: 32.5 per cent for use in road transport, 40 per cent for use in shipping, and 100 per cent for dilution before use. The statistics on external trade does not have a clear split on urea used for fertilizers and urea used as catalyst, nor does it split on different purities.

Based on these considerations, import data from the largest producer together with estimates of marked shares have been used to calculate the total consumption of urea used as a catalyst each year. The first year of activity is considered to be 2008, as very few vehicles had the technology prior to this year.

4.5.5.4 Emission factors

There are no emission factors used for this calculation. All carbon in the urea used is converted to CO_2.

4.5.5.5 Uncertainties and time series consistency

There are no emission factors as such in these calculations, and the purity of the different solutions are deemed to be reliable. However, the calculations are based on activity data where expert judgement is an important parameter, and there is a certain degree of uncertainty.

The same source of activity data and the same parameters have been used for all years, and the time series consistency is thus deemed to be satisfactory.

4.5.5.6 Category-specific QA/QC and verification

In the development of the emission estimates, activity data used (import data from the largest importer) were compared with import data from the statistics on external trade.

4.5.5.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.5.5.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.6 Electronics industry – 2E

Norway reports the source category integrated circuit or semiconductor under the category 2E, see Table 4.34 and Table 4.35.

Table 4.34 Electronics industry. Components emitted and included in the Norwegian inventory.

Source category	SF_6	HFCs	PFCs	NF_3	Tier	Key category
2E1. Integrated circuit or semiconductor	E	NO	NO	NO	1	No

R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated. NA = Not Applicable. NO = Not Occuring. IE = Included Elsewhere.

Table 4.35 Emission trends for 2E Electronics industry (kt CO_2 equivalents).

Source category	1990	1990, % of IPPU	2015	2016	2016, % of IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2E1. Integrated circuit or semiconductor	0.0	0.0	1.14	1.14	0.01		0.0

Source: Statistics Norway and Norwegian Environment Agency

4.6.1 Integrated circuit or semiconductor, 2E1

4.6.1.1 Category description

There are SF_6 emissions from the use in the manufacturing of semiconductors. There were no emissions from the production of integrated circuit or semiconductors in 1990, but the emissions in 2015 were 1 140 tonnes of CO_2-equivalents, see Table 4.35.

4.6.1.2 Methodological issues

The method is described in a report from SFT (1999c) and there have been emissions of SF_6 from this source since 1995. Data on sales to semiconductor manufacturers were collected for 1998, and total sales amounted to 90 kg. The report projected that sales would increase to 100 kg, but would then remain in that range in the next decade. No new data have been collected, and the projection from the 1999 report has been prolonged.

4.6.1.3 Activity data

The report from 1999 assumed that 50% of the gas reacts in the etching process and the remaining 50% are emitted. Hence 45 kg are reported as emissions until 1998 and 50 kg from 1999 onwards.

4.6.1.4 Emission factors

The leakage rate for the production of semiconductors is shown in Table 4.36.

Table 4.36 Yearly rate of leakage of SF6 from the production of semiconductors.

Emission source	Leakage rate (per cent of input of SF_6)
Production of semiconductors	50

Source: SFT (1999c)

4.6.1.5 Uncertainties and time series consistency

An uncertainty estimate is given in Annex II.

A general assessment of the time series consistency has not revealed any time series inconsistencies in the emission estimates for this source category.

4.6.1.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V. Since the emissions have been assumed to be constant since 1999, there is no specific QA/QC procedure for this source category.

4.6.1.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.6.1.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.7 Product uses as substitutes for ODS – 2F (key category for HFCs)

Norway reports the source category HFCs and PFCs from refrigeration and air conditioning and other applications under the category 2F. See Table 4.37 and Table 4.38 for details.

Table 4.37 Product uses as substitutes for ODS. Components included in the inventory, tier of method and key category.

Source category	HFCs	PFCs	SF_6	NF_3	Tier	Key category
2F1-2F6. Refrigeration and air conditioning, foam blowing agents, fire protection, aerosols, solvents, other applications.	E	E	NO	NO	*	Yes**

**Mainly estimated using Tier 2a (emissions calculated at a disaggregated level, emission factor approach). Exceptions are mobile air conditioning that is estimated using Tier 2b (b=mass balance approach) and fire protection, areosols and solvents that are estimated using Tier 1a (emissions calculated at an aggregated level, emission factor approach).*
***In the key category analysis, 2F1 and 2F6 have been aggregated.*
R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated. NA = Not Applicable. NO = Not Occuring. IE = Included Elsewhere.

Table 4.38 Emission trends for 2F Product uses as substitutes for ODS (kt CO_2 equivalents).

Source category	1990	1990, % of IPPU	2015	2016	2016, % of IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2F1-2F6. Refrigeration and air conditioning, foam blowing agents, fire protection, aerosols, solvents, other applications.	0.04	0.0	1 232.9	1 363.6	15.8	3106145.2	10.6

Source: Statistics Norway and Norwegian Environment Agency

Table 4.38 shows the emission trends for 2F as a whole. The GHG emissions from this sector category were a little less than 1.4 million tonnes in 2016, this is 15.8 per cent of the total emission from the IPPU-sector. The emissions were 44 tonnes CO_2-equivalents in 1990 and have increased substantially over the years. The emisisons increased by 10.6 per cent from 2015 to 2016. The majority of the emissions are reported in 2F1 and these include minor emissions of PFC-218 in the years 2010-2016.

HFCs and PFCs are mainly used as substitutes for ozone depleting substances (CFCs and HCFCs) that are being phased out according to the Montreal Protocol. They are used in varied applications, including refrigeration and air conditioning equipment, as well as in foam blowing, fire extinguishers, aerosol propellants and analysing purposes. There is no production of HFCs and PFCs in Norway. However, PFCs are emitted as a by-product during the production of aluminium. Due to, i.e., high taxation, the use of PFCs in product-applications has been very low. PFC-218 has been used as a commercial cooling agent.

The amounts of imported and exported gases are found in registers from the Norwegian Directorate of Customs and Excise. All import of F-gases is covered in these registers, as Norway lays a tax on the import of F-gases (Ministry of Finance 2014). 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. From 1st of January 2014, the tax increased by about 100 NOK to NOK 330 (approximately EUR 40) per tonne CO_2 equivalents of gas imported as of 2014. In May 2010, EU regulation (EC) No 842/2006 on certain fluorinated greenhouse gases was included in Norwegian legislation.

Also practically all export of F-gases is covered, as commodities with F-gases have their own commodity code (HS-code). The registered export of F-gases from Norway is very low, and any underestimation of the export of F-gases would thus be very slight and eventually lead to over-estimation (and not under-estimation) of the emissions.

The imported and exported gases are allocated to sectors based on commodity codes and information identifying each company. In some cases (sector 2F1) the type of gas is used as additional information. Uncertainties in the distribution by sector do not affect the total amount of F-gases to be emitted over time, as the emissions over time are determined by the total amount of F-gases to be distributed. Thus, under-estimation in one sector would eventually lead to an equivalent over-estimation in another sector at some point of time.

The HFC emisisons from 2F1 and 2F6 is defined as a key category according to the approach 2 analysis.

4.7.1 Refrigeration and air conditioning, 2F1

4.7.1.1 Category description

HFCs and PFCs are mainly used as substitutes for ozone depleting substances (CFCs and HCFCs) that are being phased out according to the Montreal Protocol. Emissions from refrigeration and air conditioning equipment are reported under this source category.

4.7.1.2 Methodological issues

Actual emissions of HFCs and PFCs are calculated using the Tier 2 methodology. This methodology takes into account the time lag in emissions from long lived sources, such as refrigerators and air-conditioning equipment. The chemicals slowly leak out from seams and ruptures during the lifetime of the equipment. The leakage rate, or emission factor, varies considerably depending on type of equipment and its maintenance.

An emission factor approach is used to estimate emissions from all categories except mobile air conditioning. For mobile air conditioning a hybrid of mass-balance and emission factor approach is used. There is no production of new cars in Norway; hence it is assumed that HFCs imported in bulk for use in mobile air conditioning is used to refill the systems after leakage. This is the mass-balance approach, and it leads to very high product life factors (up to 100 per cent) in the beginning of the time series because no bank of chemicals was yet accumulated. A restriction is however set in the model: Where the imported bulk is lower than 10 per cent of the bank, the emission factor approach is applied. This model assumption means that the product life factor will never be lower than 10 (using an emission factor of 10 per cent) and is occurring towards the end of the time series.

In the CRF, there are reported amounts of HFC-143 in 2005 and 2006 and of HFC-134 in 2004 and 2008 filled into new manufactured products in commercial refrigeration. According to an expert on refrigeration and HFCs, these two gases are not used regularly in Norway but is imported to be used

in equipment testing. For other years, NO is therefore considered to be the appropriate notation key for these two gases for amounts filled into new manufactured products. This is confirmed by our data, and any new import of these two gases will be reflected in the registers from the Norwegian Directorate of Customs and Excise as both gases are covered by the tax on HFCs.

The reported stock emissions for perfluoropropane (C_3F_8) consumed in commercial refrigeration in CRF table 2(II).B-H have a declining trend. The use of PFCs is being phased out and replaced by other gases and only small amounts of PFCs have been imported in bulk in the last few years. About the same amount of PFCs that are reported as imported are reported as collected for destruction, so there has not been a build-up of stock that would generate emissions (i.e. the entire amount of gas remained in stock from the previous year is assumed to be collected for destruction). Since 2014, the AD for annual average stock and stock emissions for C_3F_8 are therefore reported as "NO".

4.7.1.3 Activity data

There is no production of HFC or PFC in Norway. Hence all emissions of these chemicals originate from chemicals imported in *bulk* or in products. The methodology requires that annual imported amounts of each chemical are obtained by source category. Various data sources are used:

Amounts of chemicals imported in bulk were up to 2009 obtained from the Norwegian Climate and Pollution Agency (now Norwegian Environment Agency). After 2009, bulk data are collected from the Norwegian Directorate of Customs and Excise. Time series for imported and exported amounts of chemicals in *products* are based on collected data for some years and data prior to and between these years are estimated. For the years 1995-1997 data were collected through a survey performed in 1999 (SFT 1999b). Data on imports from customs statistics were collected for the years 2005-2006 and 2010-2012. They are collected annually after 2011.

Amounts of chemicals destructed after collection from retired equipment are annually reported to Statistics Norway from the company in charge of the collection. A more thorough description of the activity data is available in Bjønnes (2013). A provisional distribution of chemicals by application category was used for 2012, based on the 2011 distribution. The totals per gas, however, were collected from the Norwegian Directorate of Customs and Excise.

4.7.1.4 Emission factors

Leakage rates and product lifetimes used in the calculations are shown in Table 4.39.

Table 4.39 Emission factors[1] for HFCs and PFCs from 2F1 Refrigeration and Air conditioning.

Source category	Lifetime (years)	Production/initial emission (per cent of initial charge)	Lifetime emission (per cent of initial charge/year)
2.F.1.a. Commercial Refrigeration			
Stand-alone Commercial	10	NO	3.5
Medium and Large Commercial	15	2	10
2.F.1.b Domestic Refrigeration	15	NO	0.5
2.F.1.c Industrial Refrigeration	15	2	10
2.F.1.c. Transport Refrigeration	9	1	20
2.F.1.e Mobile Air-Conditioning	12	NO	10
2.F.1.f Stationary Air-Conditioning	15	1	4

[1]*IPCC (2006), IPCC (1997b)*

It is important to note that subapplication 2.F.1.a, Commercial refrigeration, is calculated at a more detailed level. Two groups of equipment that differs substantially in their life cycle and emission patterns, and hence emission factors, are taken into account:

- Stand-alone commercial applications includes equipment like vending machines and moveable refrigerators and freezers typically used for keeping beverages and ice cream cold in supermarkets, office buildings, schools etc. There is currently no production of this kind of equipment in Norway. All emissions take place during the operating phase (emissions from stocks/lifetime emissions) or at decommissioning. The IPCC 2006 Guidelines recommends an operation emission factor between 1 and 15 per cent for this application category, and between 0.1 and 0.5 per cent for domestic refrigeration. Because the units imported to Norway are small, sealed units and thus similar to the refrigerators and freezers for domestic use, an emission factor in the lower end of IPCCs recommendation is believed to best reflect the actual emissions.
- Medium and large commercial refrigeration equipment is normally built and filled with fluorinated substances on site. They will thus have emissions both in the production phase and from operation/use the subsequent years. The IPCC 2006 Guidelines recommends an operation emission factor between 10 and 35 per cent for this application category. The lower emission factor is used in the Norwegian calculations. The reasoning behind this is that the tax on imports of fluorinated substances is assumed to result in a high level of maintenance of the equipment and low leakage rates.

This means that the implied emission factor named “Product life factor” as calculated in the CRF, will vary for this group as the share of stock for the two groups of equipment are not constant over time. In order to provide better transparency, Table 4.40 provides information on the relative share of stock for the two categories, aggregated for all substances in CO_2 equivalents. For most fluorinated gases, the majority of stock is comprised by medium and large equipment, hence the product life factor is close to 10. Important exceptions are HFC-32 and HFC-134a.

Table 4.40 Relative share of emissions from imported and domestically filled commercial refrigeration applications.

Year	Share imported	Share domestically filled
1990	0.0	100.0
2000	0.6	99.4
2010	2.9	97.1
2011	3.8	96.2
2012	5.0	95.0
2013	6.6	93.4
2014	8.9	91.1
2015	9.1	90.9
2016	9.6	90.4

Source: Statistics Norway

4.7.1.5 Uncertainties and time series consistency

The uncertainties of the different components of the national greenhouse gas inventory have been evaluated in detail in 2006 by Statistics Norway (See annex II). Both the leakage rate (emission factor) and the stored amount of chemicals (activity data) are considered quite uncertain. The total uncertainties for the emission estimates by the consumption of halocarbons are estimated to be ±50 per cent for both HFC and PFC.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.7.1.6 Category-specific QA/QC and verification

In addition to the general QA/QC procedures described in Annex V, the activity data, emissions figures and the model used to estimate emissions are checked by several manual and automatic controls performed during and after the production of the figures.

Firstly, the activity data on imports and exports of chemicals undergo automatic checks before they are used as input for the emission calculations. Double counting and missing values are flagged and checked at a detailed level, i.e. for each observation of amount of chemical by importer/exporter and goods.

Aggregated figures for amount of chemical imported/exported for each year are then checked manually as they are entered into excel sheets containing time series for each CRF equipment/emission source. Potential errors like missing values or major differences in figures between years are checked and corrected if necessary. Aggregated figures on imports per gas are also compared with tables from the Norwegian Directorate of Customs and Excise, in order to check that our computerized coding has not altered the total amounts of import per gas. These controls would probably benefit from being automatic in the future.

Both activity data and emissions per chemical and type of equipment/emission source undergo controls in the excel sheets where the emissions calculations take place: Potential emissions are

compared with actual emissions and IEFs are calculated and checked. Currently, these controls are only applied to the most important emission sources. The controls would probably also benefit from being automatic in the future.

The estimated emissions are finally subjected to several controls in order to identify errors in activity data and/or the calculation model. This includes the flagging of:

- Emissions from combinations of industrial sector and type of chemical that have not occurred previous years
- Emissions from combinations of industrial sector and type of chemical that occurred the previous year, are not occurring this year
- Large or small emissions compared with the previous years:
    - By type of chemical and sector
    - By type of chemical and CRF/NFR emission source
    - Recalculations

4.7.1.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.7.1.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.7.2 Other applications, 2F6

4.7.2.1 Category description

Due to confidentiality restrictions, Norwegian emissions from categories 2.F.2 (foam blowing), 2.F.3 (fire extinguishers), 2.F.4 (aerosols/metered dose inhalers (MDI)) and 2.F.5 (solvents) are reported in the CRF tables using the notation key "IE" and aggregated under 2.F.6 (Other applications using ODS substitutes) and not disaggregated by substance. Note however, that the calculations are made for each subsector.

In response to a recommendation from the technical expert review team, more transparent information on the uses and the levels of emisisons per capita compared to other Parties was included in the NIR. This information is shown below.

More than 95 per cent of the Norwegian emissions reported in 2F6 since 1995, in terms of CO_2-equivalents[17], were from:

i. Foam blowing agents (2.F.2), i.e. emissions of HFC-134a and HFC-152a from the use of hard foam/ closed cells-products.
    i. For HFC-134a the per capita emissions were in the range of 0-1.9 kg CO_2-eq before 1998 and 2.0-3.9 kg CO_2-eq in the period 1998 to 2012. Per capita

[17] Note that the reported emissions in sector 2F6 are given in CO_2-eq.

emissions in comparable countries were in the range of 0-11.71 kg CO_2-eq in 2012.

ii. For HFC-152a the per capita emissions were in the range of 0-1.74 kg CO_2-eq in the period 1990-2012. Per capita emissions in comparable countries were in the range of 0-1.74 kg CO_2-eq in 2012.

ii. Areosol (2.F.4), i.e. emissions from the use of HFC-134a in metered dose inhalers (2.F.4.a). The per capita emissions have grown from 0-1.9 kg CO_2-eq per capita before 2011, to 2.0-3.9 kg CO_2-eq per capita in 2011 and 4.0 to 5.9 kg CO_2-eq per capita in 2012. Per capita emissions in comparable countries were in the range of 0.24-12.91 kg CO_2-eq in 2012.

iii. Fire extinguishers (2.F.3), both in use and in the waste phase, of the gases HFC-125, HFC-134a and HFC-227ea). The emissions have increased from 0-1.9 kg CO_2-eq per capita before 2011, to 2.0-3.9 kg CO_2-eq per capita in 2011 and 2012. Comparable countries had emissions in the range of 0.59-6.78 kg CO_2-eq per capita in 2012.

As can be seen from the list above, the Norwegian per capita emission for each of these three sectors in 2012 was well within the range of the selected comparable countries (Austria, Denmark, Finland, Ireland, Sweden, United Kingdom and United States). For the other categories included in the aggregated 2.F.6 amount, the emitted amounts were zero or close to zero. This explains the difference from the other comparable countries in the overall 2F2 to 2F6 amount. The increase in the *reported* Norwegian aggregated 2F6 emission since 2009 is due to 2F4 (metered dose inhalers, HFC-134a, from stocks).

4.7.2.2 Methodological issues

See description for source category 2F1.

4.7.2.3 Activity data

See description for source category 2F1.

4.7.2.4 Emission factors

Leakage rates and product lifetimes used in the calculations are shown in Table 4.41.

Table 4.41 Emission factors[1] for HFCs from products and lifetime of products.

Source category	Lifetime (years)	Production/initial emission (per cent of initial charge)	Lifetime emission (per cent of initial charge/year)
2.F.2 Foam			
2.F.2a Closed cells	20	5	4.5
2.F.2b Open cells	NO	NO	NO
2.F.3 Fire protection	15	2	5
2.F.4 Aerosols			
2.F.4.a Metered Dose Inhalers	2	NO	50
2.F.4.b Other aerosols	2	NO	50
2.F.5 Solvents	2	NO	50

[1]*IPCC (2006), IPCC (1997b)*

4.7.2.5 Uncertainties and time series consistency

See description for source category 2F1.

4.7.2.6 Category-specific QA/QC and verification

See description for source category 2F1.

4.7.2.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.7.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.8 Other product manufacture and use – 2G

Norway reports the source categories electric equipment, SF6 and PFCs from other product use, medical applications, propellant for pressure and aerosol cans and other use of N_2O under the category 2G, see Table 4.42.

Table 4.42 Other product manufacture and use. Components included in the inventory, tier of method and key category.

Source category	HFCs	PFCs	SF_6	NF_3	N_2O	Tier	Key category
2G1.Electric equipment	NO	NO	E	NO	NA	Tier 1	No
2G2. SF_6 and PFCs from other	NA	NO	E	NO	NA	Tier 1	No
2G3a. Use of N_2O in anaesthesia	NA	NA	NA	NA	E	Tier 1	No
2G3b.1. Propellant for pressure	NA	NA	NA	NA	E	Tier 1	No
2G3b.2. Other use of N_2O	NA	NA	NA	NA	E	Tier 1	No

R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated. NA = Not Applicable. NO = Not Occuring. IE = Included Elsewhere.

Table 4.43 shows the emission trends for 2G as a whole and for the various sub-categories. The GHG emissions from this sector category were about 85 kt in 2016, this is 1.0 per cent of the total emission from the IPPU-sector. The emissions from this sector decreased by 3.9 per cent from 1990 and the emissions decreased by 8.4 per cent from 2015 to 2016.

Table 4.43 Emission trends for 2G Other product manufacture and use (kt CO_2 equivalents).

Source category	1990	1990, % of IPPU	2015	2016	2016, % of IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2G1.Electric equipment	51.1	0.4	40.8	34.8	0.4	-31.9	-14.5
2G2. SF_6 and PFCs from other product use	2.2	0.0	27.9	27.7	0.3	1138.6	-0.9
2G3a. Use of N_2O in anaesthesia	34.2	0.2	21.2	19.7	0.2	-42.5	-7.2
2G3b.1. Propellant for pressure and aerosol cans	0.0	0.0	1.6	1.6	0.0		0.0
2G3b.2. Other use of N_2O	0.0	0.0	0.4	0.4	0.0		0.0
2G. Total	87.5	0.6	91.8	84.1	1.0	-3.9	-8.4

Source: Statistics Norway and Norwegian Environment Agency

As part of the transformation to new reporting guidelines, Norway has examined whether there are activities that would result in emissions of trinitrogenfluoride (NF_3). Our assessment is that here are no emissions of NF_3 in Norway.

4.8.1 Electric equipment, 2G1

4.8.1.1 Category description

SF_6 is used as an insulation medium in high tension electrical equipment including gas insulated switchgear (GIS) and circuit breakers. There is no production of SF_6 in Norway. In March 2002 a voluntary agreement was signed between the Ministry of Environment and the most important users and producers of GIS. According to this agreement emission from this sector should be reduced by 13 per cent in 2005 and 30 per cent in 2010 with 2000 as base year. For the following up of this agreement, the users (electricity plants and –distributors) and producer (one factory) report annually to the government. This voluntary agreement terminated successfully in 2010, but a continuation is being discussed. Although the voluntary agreement has terminated, the users still report annually to the government.

4.8.1.2 Methodological issues

The general methodology for estimating SF_6 emissions was revised in a SFT report (SFT 1999c), while the sector specific methodology for GIS has been revised in the 2010 reporting based on new information from the agreement.

Emissions from production of GIS (one factory) were included for the first time in 2003. The company has, as part of the voluntary agreement with the Ministry of the Environment, made detailed emission estimates back to 1985. These emissions constitute a significant part of national emissions of SF_6. In recent years emissions rates have been considerably reduced due to new investments and better routines. The company now performs detailed emission calculations based on accounting of the SF_6 use throughout the whole production chain.

Emissions from a small number of GIS users that are not part of the agreement are calculated with emission factors from Table 4.44. SF_6 emissions from manufacturing are included in emissions from stocks due to confidentiallity.

4.8.1.3 Activity data

Data is collected from companies that use SF_6 in various processes. The calculations take into account imports, exports, recycling, accumulation in bank, technical lifetimes of products, and different rates of leakage from processes, products and production processes. From 2003 onwards emission estimates reported directly from users and producers, according to the voluntary agreement, are important input.

4.8.1.4 Emission factors

Leakage rates and product lifetimes used in the calculations are shown in Table 4.44.

Table 4.44 Product lifetimes and leakage rates from products containing SF_6.

Product emission source	Yearly rate of leakage	Product lifetime (years)
Sealed medium voltage switchgear	0.1	30
Electrical transformers for measurements	1	30

Source: SFT (1999c)

4.8.1.5 Uncertainties and time series consistency

An uncertainty estimate is given in Annex II. The uncertainty of 60 per cent is an expert judgement (Rypdal & Zhang 2000).

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.8.1.6 Category-specific QA/QC and verification

The current methodology was established in the SFT report (SFT 1999c), with emissions from GIS calculated from stock data estimates and leakage factors. It was revised in 2004 when data from the voluntary agreement on GIS became available, with emissions estimated from reported data on refilling (Hansen 2007).

4.8.1.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.8.1.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.8.2 SF_6 and PFC from other product use, 2G2

4.8.2.1 Category description

This source category includes SF_6 emissions from other product use.

4.8.2.2 Methodological issues

The method for other sources is described in a SFT report (SFT 1999c). For tracer gas, medical use, and other minor uses, the activity data are annual consumption as estimated in the SFT report. However, for tracer gas some major research projects expired in 2001 and 2006, respectively, and the consumption has been reduced. For sound-insulating windows and footwear, the emissions are calculated from estimated stock of SF_6 in the products, and from production of windows. Footwear with SF_6 was imported, and the use ended in 2001. There was no production of sound-insulting windows from 2008.

4.8.2.3 Activity data

Data is collected from direct consultations with importers and exporters of bulk chemicals and products containing SF_6.The activity data are annual additions of SF_6 to the product stock, as estimated by SFT (1999c). 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.

4.8.2.4 Emission factors

Leakage rates and product lifetimes used in the calculations are shown in Table 4.45 and Table 4.46.

Table 4.45 Yearly rate of leakage of SF_6 from different processes.

Emission source	**Leakage rate (per cent of input of SF_6)**
Secondary magnesium foundries	100
Tracer gas in the offshore sector	0
Tracer gas in scientific experiments	100
Medical use (retinal surgery)	100
Production of sound-insulating windows	2[1]
Other minor sources	100

[1] *1 per cent after 2002*

Source: SFT (1999c)

Table 4.46 Product lifetimes and leakage rates from products containing SF_6.

Product emission source	**Yearly rate of leakage**	**Product lifetime (years)**
Sound-insulating windows	1	30
Footwear (trainers)	25	9
Other minor sources	..	..

Source: SFT (1999c)

4.8.2.5 Uncertainties and time series consistency

An uncertainty estimate is given in Annex II. The uncertainty of 60% is an expert judgement (Rypdal & Zhang 2000).

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.8.2.6 Category-specific QA/QC and verification

The current methodology was established in a SFT report (SFT 1999c), with emissions from GIS calculated from stock data estimates and leakage factors. It was revised in 2004 when data from the voluntary agreement on GIS became available, with emissions estimated from reported data on refilling (Hansen 2007).

4.8.2.7 Category-specific recalculations

Updated activity data (change in assumption) 2003-2015. According to the industry, the production of sound isolated windows with SF6 stopped in 2002/2003, thus the amount of gas used for

production has been set to zero from 2003 and forward. This results in significantly lower (between 6 and 36 per cent) emissions of SF6 from this source (2G2) for all years (2003 and onward).

Updated activity data (change in assumption) 2015. Emissions from decomissioning of sound insulated windows produced in 1985 (first year of production) is now included. This leads to an increase in the emissions of SF6 from this source (2G2) in 2015 of about 100 percent.

4.8.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.8.3 Use of N_2O in anaesthesia, 2G3a

4.8.3.1 Category description

N_2O is used in anaesthesia procedures in hospitals, by dentists and by veterinarians.

4.8.3.2 Methodological issues

N_2O is used in anaesthesia procedures and will lead to emissions of N_2O. For the years 1998 and 2000-2013, the emissions are given by data on sales of N_2O for medical uses from the three major producers and importers in this period. The data include N_2O used as anaesthesia in hospitals, by dentist and by veterinarians. For the year 1999, sales figures have been interpolated between 1990 and 2000. For the years prior to 1998, annual consumption is estimated on basis of sales figures for 1998 and the number of births and number of bednights in hospitals for each year to estimate consumption. For the years 1990-1998, no N_2O is assumed used by dentists and veterinarians as the amounts they used in 2000 were very small.

4.8.3.3 Activity data

For this source actual sale of N_2O is used for the year 1998, 2000-2013. For the calculations of use prior to 1998, annual number of births and bednigths in hospitals are taken from the Statistical yearbook of Norway.

4.8.3.4 Emission factors

The figures are based on sales of N_2O.

4.8.3.5 Uncertainties and time-series consistency

The figures are uncertain. There may be small importers not included in Statistics Norway's telephone survey with 2000 and the investigation done by the Norwegian Environment Agency in 2014, but the emissions are small, so it is believed that the uncertainty is at an acceptable level.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.8.3.6 Category-specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. See Annex V for the description of the general QA/QC procedure.

4.8.3.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.8.3.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.8.4 Propellant for pressure and aerosol products, 2G3b.1.

4.8.4.1 Category description

N_2O is used as a propellant in spray boxes and this use will lead to emissions of N_2O. It is also used in research work, for instance in the food industry and at universities. There is no production of N_2O for these purposes in Norway.

4.8.4.2 Methodological issues

Information on sale volumes has been reported by the plants to Statistics Norway. It is assumed that all propellant is released to air.

4.8.4.3 Activity data

Information has been gathered from the plants indicating that there is no production or sale of N_2O for use as a propellant in Norway. The N_2O is already in the spray cans when imported. There was no import of these spray cans prior to 1993. For the years 1994-2002 the number of cans imported in 1994 have been used as activity data, while the number of cans imported in 2003 has been used as activity data for all years since.

4.8.4.4 Emission factors

Not relevant.

4.8.4.5 Uncertainty and time-series consistency

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.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.8.4.6 Category-specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. See Annex V for the description of the general QA/QC procedure.

4.8.4.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.8.4.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.8.5 Other use of N_2O, 2G3b.2

4.8.5.1 Category description

Small amounts of N_2O are used for research work and for drag-racing.

There were no emissions of N_2O from use in research and for drag racing in 1990. The use has been estimated to 407 tonnes CO_2 equivalents from the year 1993 and onwards.

4.8.5.2 Methodological issues

Data on imported amounts in 2002 has been used for all years and it is assumed that all propellant is released to air.

4.8.5.3 Activity data

Data on imported amounts in 2002 has been used for all years.

4.8.5.4 Emission factors

Not relevant.

4.8.5.5 Uncertainty and time-series consistency

The figures for one year are used for all years. A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.8.5.6 Category-specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. See Annex V for the description of the general QA/QC procedure.

4.8.5.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.8.5.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.9 Other – 2H

Under Other production, Norway reports the two source categories pulp and paper and food and beverages industry, see Table 4.47.

Table 4.47 Other production. Components included in the inventory, tier of method and key category.

Source category	CO_2	NMVOC	Tier	Key category
2H1. Pulp and paper	R	NA	Tier 2	No
2H2. Food and beverages industry	R	E	Tier 2	No

R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated. NA = Not Applicable. NO = Not Occuring. IE = Included Elsewhere.

Table 4.48 shows the emission trends for 2H as a whole and for the various sub-categories. The GHG emissions from this sector category were about 115 kt in 2016, this is 1.3 per cent of the total emission from the IPPU-sector. The emissions from this sector increased by 269.6 per cent from 1990 and the emissions increased by 6.5 per cent from 2015 to 2016.

Table 4.48 Emission trends for 2H Other (kt CO_2 equivalents).

Source category	1990	1990, % of IPPU	2015	2016	2016, % of IPPU	Trend 1990-2016 (%)	Trend 2015-2016 (%)
2H1. Pulp and paper	10.5	0.1	8.8	10.2	0.1	-2.3	16.3
2H2. Food and beverages industry	20.8	0.1	99.7	105.3	1.2	406.8	5.6
2H. Total	31.3	0.2	108.6	115.6	1.3	269.6	6.5

Source: Statistics Norway and Norwegian Environment Agency

4.9.1 Pulp and paper, 2H1

4.9.1.1 Category description

There are CO_2 emissions from non-combustion from two plants in this sector and they are covered by the EU ETS. The emissions originate from the use of limestone. Emissions from combustion are included in Chapter 3.

4.9.1.2 Methodological issues

The CO_2 emissions are calculated by multiplying the amount of limestone by an emission factor. For the years 1990-97 the emissions are calculated by the Norwegian Envionment Agency based upon activity data reported to the agency by the plants and emission factor. The emissions in the period 1998-2004 are reported in the plants' application for CO_2-permits within the Norwegian emissions trading scheme. From 2005 and onwards, the plants report the emissions through the annual reporting under the emissions trading scheme.

4.9.1.3 Activity data

Activity data is reported by the plants to the agency. The amount of limestone is calculated from purchased amount, adjusted for the amount of limestone in storage in the beginning and end of the year. The aggregate amounts of limestone used by the plants included in 2H1 are reported in the CRF Table 2(I).A-Hs2 and are shown in Table 4.5 for some selected years in the time series.

4.9.1.4 Emission factors

The emission factor used in the calculation is 0.44 tonne CO_2 per tonne limestone.

4.9.1.5 Uncertainties and time-series consistency

Uncertainty estimates are given in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.9.1.6 Category-specific QA/QC and verification

The general QA/QC methodology is given in Annex V and the specific QA/QC carried out for Industrial processes is described in Annex VIII. The plants are covered by the EU ETS and their emissions are verified annually. In addition, the emissions are checked both by the case handler and by the agency's inventory team.

4.9.1.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.9.1.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

4.9.2 Food and beverages industry, 2H2

4.9.2.1 Category description

This source category includes NMVOC emissions from production of bread and beer, CO_2 from carbonic acid mainly used in breweries, domestic use of captured CO_2, imported CO_2 and CO_2 from production of bio protein.

Some CO_2 from the production of ammonia (2B1) is captured and in Norway mainly used as carbonic acid in carbonated beverages. The emissions reported here in 2H2 include CO_2 bound in products and imported CO_2. The emissions are reported in this source category, although the largest part of the emissions takes place after the bottles is opened and not in the breweries. Exported CO_2 from this source is not included in the Norwegian emission inventory.

One plant produced bio protein in the years 2001-2005. Natural gas was used to feed the bacteria cultures that produced the bio protein and this was used as animal fodder.

4.9.2.2 Methodological issues

CO_2

For carbonic acid, the CO_2 figures are based on the sales and export statistics from the ammonia producing plant and import statistics from Statistics Norway's External trade in goods statistics.

For the production of bio protein, the plant reported emissions of about 2 000 – 11 000 tonnes CO_2 and these are included in the national inventory.

NMVOC

Production of bread and beer (and other similar yeast products) involves fermentation processes that lead to emission of NMVOC (ethanol). Emissions are calculated based on production volumes and emission factors.

4.9.2.3 Activity data

NMVOC

Production volumes of bread and beverage are annually reported to Statistics Norway.

CO_2

For carbonic acid, the CO_2 figures are based on the sales and export statistics from the ammonia producing plant and import statistics from Statistics Norway's External trade in goods statistics, see Table 4.49.

Table 4.49 Sold CO_2 (minus exports) and imported CO_2 (tonnes).

Year	Sold CO_2 (minus exports)	Imported CO_2	Domestic use of CO_2 (2H2)
1990	20 000	787	20 787
1995	34 000	2 374	36 374
2000	50 000	2 597	52 597
2005	52 974	18 433	71 407
2007	50 676	28 512	79 188
2008	63 636	13 974	77 610
2009	61 414	13 664	75 078
2010	76 000	8 675	84 675
2011	76 557	14 750	91 307
2012	81 399	13 560	94 959
2013	78 000	13 249	91 249
2014	83 680	7 712	91 392
2015	88 602	11 144	99 746
2016	80 436	24 912	105 348

Sources: Statistics Norway and the Norwegian Environment Agency

For the production of bio protein, the activity data is the amount of natural gas used in the process.

4.9.2.4 Emission factors

NMVOC

The emission factors in are shown in Table 4.50.

Table 4.50. 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)

4.9.2.5 Uncertainties and time-series consistency

NMVOC

The emission factors used are not specific for Norwegian conditions (EEA 1996).

CO_2

See the uncertainty in the activity data for the ammonia plant (2B1) in Annex II.

A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

4.9.2.6 Category-specific QA/QC and verification

NMVOC and CO_2

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

4.9.2.7 Category-specific recalculations

There have been no recalculations performed for this source category this year.

4.9.2.8 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

5 Agriculture (CRF sector 3)

5.1 Overview

About 8.5 per cent of the total Norwegian emissions of greenhouse gases (GHG) originated from agriculture in 2016. This corresponds to 4.52 million tonnes CO_2-eq. Emissions from agriculture were in 2016 about 6.0 per cent lower than in 1990, and about 0.6 per cent higher than in 2015.

The sector's clearly biggest sources of GHG's were enteric fermentation (CH_4) from domestic animals contributing with 51 per cent of the sector's emissions, and N_2O from agricultural soils contributing with 37 per cent. Manure management contributed with about 10 per cent. CO_2 emissions in the agriculture sector, mainly from liming and a minor part from urea application, contributed with 2 per cent. There are also some minor emissions of the greenhouse gases N_2O and CH_4 arising from the burning of crop residues on the fields.

Table 5.1 Emissions from Agriculture categories in 1990, 2015 and 2016 (ktonnes CO_2-equivalents).

Category	1990	1990, % of Agriculture	2015	2016	2016, % of Agriculture	Trend 1990-2016 (%)	Trend 2015-2016 (%)
3A Enteric fermentation	2 415	50 %	2 265	2 305	51 %	-5 %	2 %
3B Manure management	402	8 %	435	439	10 %	9 %	1 %
3D Agricultural soils	1 724	36 %	1 700	1 689	37 %	-2 %	-1 %
3F Field burning of agricultural residues	36	1 %	4	4	0 %	-90 %	-11 %
3G Liming	231	5 %	86	82	2 %	-65 %	-5 %
3H Urea application	0.6	0 %	0.2	0.2	0 %	-66 %	-12 %
Total	4 809	100 %	4 491	4 518	100 %	-6 %	1 %

Source: Statistics Norway and the Norwegian Environment Agency

Agriculture contributes particularly to CH_4, N_2O and NH_3 emissions. Domestic animals are the major source of CH_4 emissions from agriculture. Both enteric fermentation and manure management contribute to emissions of CH_4. Manure management also generates emissions of N_2O.

Microbiological processes in soil lead to emissions of N_2O. Both direct and indirect N_2O from soil processes are described in the IPCC methodology and are included in the Norwegian inventory. Direct N_2O emissions arising from the use of fertiliser (manure, synthetic fertilizer, sewage sludge and other organic fertilisers applied to soils), emissions from pastures, crop residues and cultivation of organic soils are included. Indirect N_2O emissions from atmospheric deposition and nitrogen leaching and run-off from both the manure management systems and from agricultural soils are also included.

Manure storage and the use of fertiliser (manure, synthetic fertiliser, sewage sludge and other organic fertilisers applied to soils) also generate emissions of ammonia (NH_3) and NO_X that gives indirect N_2O from atmospheric deposition. NH_3 volatilized from grazing animals are also included in the estimations of indirect N_2O.

As indicated in chapter 1.5, the Tier 2 key category analysis performed in 2018 for the years 1990 and 2016 has revealed key categories in terms of total level and/or trend uncertainty in the agriculture sector as shown in Table 5.2. The key categories according to tier 1 key category analysis are also provided in Table 5.2.

Table 5.2 Key categories in the sector Agriculture.

IPCC	Source category	Gas	Key category according to tier	Method
3A	Enteric fermentation	CH_4	Tier 2	Tier 1/2
3B1	Manure management - Cattle	CH_4	Tier 1	Tier 2
3B	Manure management	N_2O	Tier 2	Tier 1/2
3Da1	Direct emissions from managed soils - Inorganic N fertilizers	N_2O	Tier 2	Tier 1
3Da2	Direct emissions from managed soils - Organic N fertilizers	N_2O	Tier 2	Tier 1
3Da3	Direct emissions from managed soils – Urine and dung deposited by grazing animals	N_2O	Tier 2	Tier 1
3Da4	Direct emissions from managed soils - Crop residues	N_2O	Tier 2	Tier 1
3Da6	Direct emissions from managed soils - Cultivation of organic soils	N_2O	Tier 2	Tier 1
3Db1	Indirect emissions from managed soils – Atmospheric deposition	N_2O	Tier 2	Tier 1
3Db2	Indirect emissions from managed soils – Nitrogen leaching and run-off	N_2O	Tier 2	Tier 1
3G	Liming	CO_2	Tier 1	Tier 1

5.2 Livestock population characterisation

5.2.1 Data sources

The animal population data used in the estimations on a disaggregated level are provided in Annex IX, Table AIX-1. The same data for number of animals of the various animal groups is used in all the different calculations of emissions.

The main sources of the livestock statistics are the register of production subsidies (sheep for breeding, goats, breeding pigs, poultry for egg production and beef cows), statistics of approved carcasses (animals for slaughter) and the Cow Recording System at TINE BA[18] (TINE BA Annually) (heifers for breeding and dairy cows). These sources cover 80-100 per cent of the animal populations. The estimated shortage of coverage is compensated in the total number of animals used in the emission estimates. The coverage in the data sources is shown in Table 5.3.

[18] TINE BA is the sales and marketing organisation for Norway's dairy cooperative and covers most of the milk production and the meat production induced by milk production.

Table 5.3 Estimated coverage of animal populations in the the data sources used. 2016

	Statistics Norway, production subsidies	**Statistics Norway, statistics of approved carcasses [4]**	**TINE**	**Other**
Dairy cows		100[2]	98.6[1]	
Heifers for breeding			98.6[1]	
Young cattle for slaughter		100	100[3]	
Beef cows	99.8	100[2]		
Sheep	99.8	100		
Goats	100			
Laying hens	99.5			
Chics for breeding	84.5			
Chicken for slaughter		100		
Other poultry for breeding	96.5			
Other poultry for slaughter		100		
Sows	98.2			
Young pigs for breeding	100			
Pigs for slaughter		100		
Horses	Unkown[5]			Unkown [5]
Fur-bearing animals	100			
Deer	100			
Reindeer				100[6]

Source: Estimations by Statistics Norway and the Cow Recording System (dairy cows and heifers).

[1] Share of livestock herds.

[2] Data source only for slaughter weight

[3] Data source only for slaughter age

[4] Figure refers to share of slaughtered animals, excluding home slaughter. Animals dead from other causes also excluded

[5] Total number of horses used in the inventory is based on data from productions subsidies (roughly 50 per cent of total number) and an additional estimation of number of horses outside agriculture by NIBIO.

[6] Norwegian Agriculture Agency

The statistics of approved carcasses covers close to 100 per cent of all slaughtered animals. Home slaughter is not included, but the extent of home slaughter is very low due to legal restrictions. Even animals consumed by producers are in most cases registered at the slaughterhouses. The number of dairy cows and heifers for breeding derive from the Cow Recording Systems. Between 98 and 99 per cent of all dairy cows are assumed to be registered here.

The registers are updated annually. In addition to the animals included in these registers, an estimate of the number of other horses is obtained from the Norwegian Institute of Bioeconomy Research (NIBIO)[19]. The number of reindeer is obtained from the Norwegian Reindeer Husbandry Administration.

For the categories of animals living shorter than a full year or two, generally animals for slaughter, lifetime is taken into account to get a yearly average for the number of animals.

5.2.2 Method for estimating number of cattle

For dairy cows, additional information from the Cow Recording System concerning annual milk production and proportion of concentrate in the diet is used (TINE BA Annually). The Cow Recording System also supplies annual information about slaughter age for heifers and bulls and data for estimating live weight of dairy cows and heifers for breeding, and also the age of young cows at their first calving. (Moen, *pers. comm.*[20]).

For heifers and bulls for slaughter, animal numbers are based on data from statistics of approved carcasses which provide data on numbers slaughtered and slaughter weights. Combined with slaughter age from the Cow Recording System (TINE BA Annually), this gives a precise estimation of animal life time for each animal slaughtered. One principal draw-back of this method for estimating animal population is that emissions in all stages of these animals' lives will be accounted for in the year of slaughter, even though the emissions in the early stages of the lives of these animals to a large extent took place in the previous year. In a stable population of animals, this error is automatically adjusted for. Since animal populations are relatively stable, this error is considered much smaller compared to errors related to estimating animal year based on animal populations in the register of production subsidies which was previously used. The data sources used also ensure a better coherence between animal numbers, life time and weight. Estimated animal years for cattle are provided in Table 5.4.

The number of milk cows calving for the first time (=heifers for replacement) and their average age at time of calving is reported by the Cow Recording System (TINE BA Annually) on request from Statistics Norway. These data date back to 2004. For the years 1990-2003, average fraction (number of heifers)/(number of milk cows) for the years 2004-2011 is used to estimate number of heifers based on number of milk cows. Number of heifers for replacement in beef production is collected from annual reports from Animalia (Norwegian Meat and Poultry Research Center

[19] Former named the Agricultural Economics Research Institute (NILF).

[20] Moen, O. (*annually*): Personal information, email from Oddvar Moen, Tine Rådgivning annually.

(www.animalia.no)). Figures exist from 2007. For previous years, the number is estimated with the same method as for heifers for milk production.

Table 5.4 Estimated animal years for cattle

	Heifer for replacement	Heifers for slaughter	Bulls for slaughter	Beef cows[1]	Dairy cows
1990	311 279	47 020	289 945	8 193	325 896
1995	299 284	47 103	284 237	20 334	310 346
2000	280 121	63 512	285 349	42 324	284 880
2005	255 862	57 619	263 170	54 841	255 663
2006	246 711	58 446	255 963	55 706	250 903
2007	235 282	56 607	247 578	57 609	246 624
2008	240 399	54 831	238 111	60 401	238 550
2009	247 902	53 397	235 689	63 803	235 480
2010	239 839	53 410	230 872	67 110	232 294
2011	239 007	48 778	223 536	68 539	224 721
2012	235 891	42 863	217 050	71 834	229 767
2013	239 386	47 294	220 401	70 969	225 163
2014	244 601	67 624	208 979	73 894	221 032
2015	238 485	634 8154	206 328	77 408	217 576
2016	238 551	64 361	217 885	84 372	215 015

[1] *Counted animals*

Source: Cow Recording System (TINE BA Annually)(dairy cows), slaughter statistics and estimations by Statistics Norway

5.2.3 Method for estimating number of sheep

In the estimations of emissions from manure management, the sheep population is divided between sheep > one year, and sheep < one year. Data from both the register of production subsidies and slaughter statistics is used in estimating the number of animals.

Sheep more than one year old is estimated as the number of sheep registered 1. of January deducted for the number of sheep slaughtered Jan.-May the same year. The sheep slaughtered later in the year are counted as living the whole year.

Sheep less than one year old is estimated as number of sheep under one year registered 1. of January + number of lambs slaughtered June-December *143/365. Lambs slaughtered before June

are assumed to be registered as sheep under one year 1. of Jan. Practically all lambs slaughtered after June are born in the spring. An expert judgment suggests an average lifetime of 143 days for slaughtered lambs born in the spring (UMB, *pers. comm*[21]).

In the estimations of enteric methane, sheep is split in four categories: sheep > 1 year, sheep < 1 year for breeding, lambs slaughtered June-Dec. and lambs slaughtered Jan.-May. Sheep over one year is estimated as explained above. Sheep under one year for breeding is estimated as the number of sheep under one year registered 1. of January deducted for the number of lambs slaughtered Jan.-May. For the numbers of slaughtered lambs, slaughter statistics are used. The numbers of slaughtered lambs were previously estimated.

5.2.4 Deviations from FAO statistics

There are some differences between the number of animals used in these calculations and the FAO statistics. The general reason that animal statistics used in the emission inventory differ from the statistics delivered to FAO is that the statistics are used for different purposes. Animal statistics used in the inventory has to be categorized so that the categories fit the recommended methodology and the various emission factors used in the emission estimations. The figures reported to the FAO are provided by the Norwegian Institute of Bioeconomy Research (NIBIO)[22]. NIBIO makes an overall estimation for the agricultural sector, which is the basis for the annual negotiations for the economic support to the sector. This estimate includes a grouping of all agricultural activities, comprising area, number of animals and production data. Differences include:

- Different emphasis on the dates for counting, 31.07 and 31.12
- NIBIO does not register pigs under 8 weeks, whilst Statistics Norway does. For the number of animals for slaughter, Statistics Norway uses the statistics of approved carcasses, which together with data on slaughter age gives a far better figure on estimated animal years (average population through the year) compared to figures for registered animals at specific dates which is used in the FAO statistics.
- For the number of dairy cows and heifers for replacement, Statistics Norway uses statistics from the Cow Recording System (TINE BA Annually), which is presumed to give a more accurate figure on number of animal years of dairy cows than the figures from Statistics Norway.

Emissions from other animal groups than included in the estimations (ostrich, donkey, lama and alpaca) are expected to be very small and decreasing. Emissions from ostrich have earlier been included in the estimations, but the number of ostrich has had a decreasing trend and are now very limited (39 in 2013). At the most the number of ostrich was 2113 in 1999. The total emissions from ostrich were less than 500 tonnes of CO_2 equivalents when the animal population was at its highest.

[21] UMB (2001): Expert judgement by Department of Animal Science, Ås: Norwegian University of Life Sciences.

[22] Former named the Agricultural Economics Research Institute (NILF).

5.3 Nitrogen in animal manure as basis for emission estimates

Access to nitrogen is vital for all plant growth; hence nitrogen is added to the soil from i.a. animal manure. This causes emissions to air at various points of compounds containing nitrogen. Of the nitrogen compounds emitted to air from animal manure, N_2O, NO_X and NH_3 are estimated.

According to the IPPC and LRTAP guidelines, process emissions of nitrogen compounds from use of animal manure are calculated from the following sources:

1. Manure management systems (N_2O, NH_3 and NO_X)
2. Application of manure on soil (N_2O, NH_3 and NO_X)
3. Droppings from animals on pastures (N_2O and NH_3)
4. Leakage of nitrogen through manure management systems and soils (N_2O)
5. Deposition of nitrogen from emissions of NH_3 and NO_X (N_2O)

Though the nitrogen flow is continuously depending on its surroundings (soil characteristics, temperature, moisture etc.) and the preceding supplies and losses of N, the emission estimates of each of the sources above are generally done independently of emissions from the other sources mentioned. Figure 5.1 gives an overview of the manure nitrogen flows in the Norwegian greenhouse gas inventory.

The following decides the amounts of N that are used as the basis for the respective emission calculations:

- The amount of N in manure systems is calculated as total N in manure adjusted for the N that is dropped on pastures.
- N_2O emitted during spreading is calculated from the amounts of N in manure storage. This means that N lost through leaching in manure storage and as N_2O, NH_3 and NO_X in manure storage and during spreading is not deducted.
- NH_3 emitted during and after spreading of manure is based on the amounts of N in manure storage minus N lost as NH_3 volatilization in manure storage. NO_X emitted during and after spreading of manure is based on the amounts of N in manure storage, and *not* deducting N lost as NH_3 or NO_X volatilization in manure storage. Losses of N through leaching and N_2O emissions in manure storage are not deducted.
- Emissions of N_2O and NH_3 from pasture are calculated independently of each other, and are based on the amounts of N estimated in manure dropped during grazing. NO_X emissions from pastures is not estimated.
- N_2O lost through leaching due to spreading and grazing is based on total N in manure storage and N dropped on pastures. This means that N emitted as N_2O, NH_3 and NO_X or lost in other ways is not deducted. N_2O lost through leaching during storage of manure is based on the amounts of N estimated for the particular management systems that are susceptible to leaching.

- The nitrogen in NH_3 and NO_X volatilised both during storage, pasture and spreading of manure is the basis for the calculation of N_2O emissions from atmospheric deposition. How the amounts of N are estimated in the various emission estimates, is described in more details in the respective chapters below.

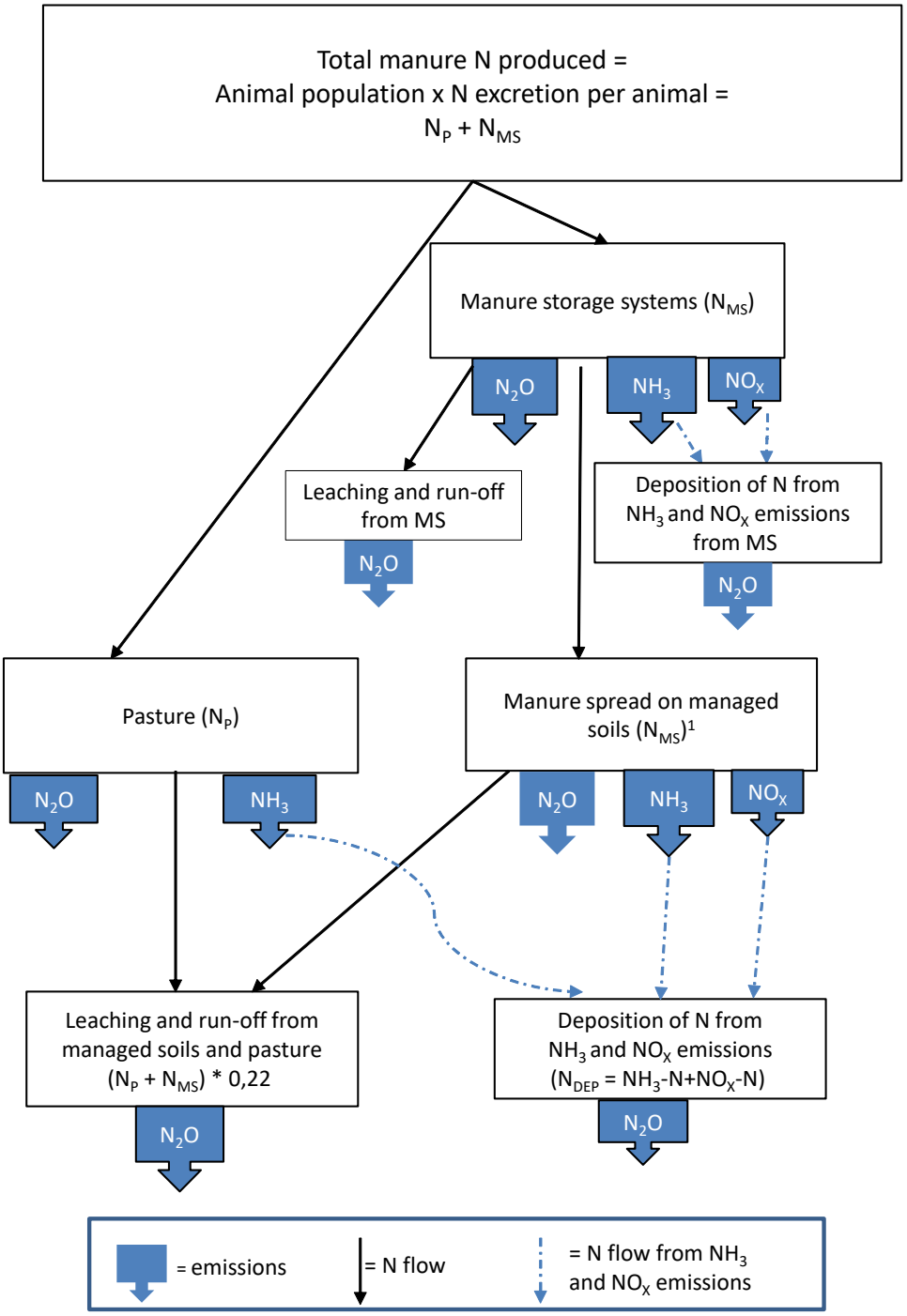


Figure 5.1 Overview of the manure nitrogen flows in the Norwegian greenhouse gas inventory.

[1] N_{MS} is the N basis for the N_2O and NO_X emission estimations, while (N_{MS} - N lost as NH_3 in manure storage systems) is the N basis for the NH_3 emission estimations.

5.4 Emissions from enteric fermentation in domestic livestock - 3A (Key category for CH_4)

5.4.1 Category description

An important end product from the ruminal fermentation is methane (CH_4). The amount of CH_4 produced from enteric fermentation is dependent on several factors, like animal species, production level, quantity and quality of feed ingested and environmental conditions. According to IPCC the method for estimating CH_4 emissions 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_4 per animal per year.
- Multiply the subgroup emission factors by the subgroup populations to estimate subgroup emissions, and sum across the subgroups to estimate total emission.

Enteric fermentation is a key category both for level and trend assessment.

Enteric fermentation contributed with 2 305 ktonnes CO_2 equivalents in 2016, which is 51 percent of the GHG emissions from this sector. Emissions decreased by 5 per cent in the period 1990-2016 and increased by 2 per cent in 2015-2016.

5.4.1.1 Methodological issues

A Tier 2 methodology is used for calculating CH_4 from enteric fermentation for the main emission sources cattle and sheep. The Tier 2 methodology used is described more in detail in Annex IX, section 2. The methodology for calculating CH_4 from enteric fermentation for the other animal categories is in accordance with the Tier 1 method from the IPCC guidelines (IPCC 2006). The numbers of animals of each category and average emission factors of tonnes CH_4 per animal and year for each category of animals are used to calculate the emissions.

5.4.1.2 Activity data

Emissions are estimated from the animal population. How the animal population is estimated is described in Section 5.2 and Annex IX.

The Tier 2 method of calculation which is implemented for cattle and sheep requires subdividing the cattle and sheep populations by animal type, physiological status (dry, lactating or pregnant) live weight and age. Table 5.5 describes the animal categories used for cattle and sheep in the calculations. Table 5.6 and Table 5.7 gives important input parameters in the estimations of enteric methane from cattle.

Table 5.5 Categories of cattle and sheep used in the Norwegian calculations of methane emission from enteric fermentation.

Categories of cattle and sheep
Dairy cows
Beef cows
Replacement heifers
Finisher heifers, < one year at time of slaughter
Finisher heifers, > one year at time of slaughter
Finisher bulls, < one year at time of slaughter
Finisher bulls, > one year at time of slaughter
Breeding sheep, > one year
Breeding sheep, < one year
Slaughter lamb, < one year. Jan- May
Slaughter lamb, < one year. Jun- Dec

Average daily weight gain (ADG), which is utilised in the calculations for growing cattle, was taken from the Cow Recording System (TINE BA Annually) when the Tier 2 model was developed (Storlien & Harstad 2015).

Table 5.6 Important parameter inputs in the calculations of methane emissions from cattle over 1 year.

	Annual milk production, dairy cows. kg/animal/year	**Proportion of feed concentrate in the rations of mature dairy cows. Per cent**	**Carcass weight at time of slaughter, heifer> 1 year. kg**	**Age at time of slaughter, heifers > 1 year. Months**	**Carcass weight at time of slaughter, bulls > 1 year. Kg**	**Age at time of slaughter, bulls > 1 year. Months**
1990	6 320	39.1	185	21.6	255	19.7
1995	6 326	36.8	200	22.2	276	19.7
2000	6 156	36.4	202	22.3	269	18.8
2005	6 723	37.7	216	22.8	296	19.0
2006	6 742	38.5	213	22.8	297	18.7
2007	6 961	39.4	212	22.4	296	18.3
2008	7 144	39.8	213	22.5	298	18.2
2009	7 276	40.1	219	22.8	301	18.0
2010	7 373	41.0	221	22.8	302	18.0
2011	7 309	41.9	210	22.5	297	17.7
2012	7 475	42.9	205	22.7	294	17.7
2013	7 691	43.4	209	22.8	298	17.5
2014	7 711	43.4	244	22.8	302	17.3
2015	7 958	43.6	256	23.2.8	310	17.4
2016	8 062	43.6	260	23.2	317	18.2

Source: Cow Recording System (TINE BA Annually) (dairy cows) and estimations by Statistics Norway

Table 5.7 Important parameter inputs in the calculations of methane emissions from cattle under 1 year.

	Heifers < 1 year. Carcass weight	Heifers < 1 year. Average age, months	Bulls < 1 year. Carcass weight	Bulls < 1 year. Average age, months
1990	56.30	6.46	75.81	6.43
1995	69.65	7.00	93.79	6.94
2000	65.00	6.05	82.05	5.88
2005	92.87	7.86	115.60	7.46
2006	92.01	7.83	116.34	7.57
2007	93.23	7.99	117.27	7.63
2008	92.49	7.89	116.49	7.53
2009	93.28	8.02	118.42	7.56
2010	93.23	8.09	116.05	7.50
2011	94.71	8.15	117.61	7.50
2012	95.88	7.92	119.66	7.56
2013	101.58	8.15	122.50	7.59
2014	106.02	8.18	124.47	7.52
2015	108.90	8.125	125.19	7.52
2016	106.89	7.86	126.29	7.52

Source: Cow Recording System (TINE BA Annually) and estimations by Statistics Norway

For beef cattle, average GE and Y_m factors per animal is estimated based on feeding data from representative Norwegian herds. For sheep and lamb the parameters used in the calculations, apart from the number of animals and slaughter weight, are fixed due to lack of annual data (Table 5.8). More information is provided in Annex IX, section 2.

Table 5.8 Important parameter inputs in the calculations of methane emissions from sheep. 2016

	Carcass weight. kg	Age at slaughter. Months	Conversion factor for methane. Per cent
Breeding sheep > 1 year	31.17	NA	6.5
Breeding sheep < 1 year	29	NA	4.5
Lamb for slaughter, Jan.-May	18.62	11	4.5
Lamb for slaughter, June-Dec.	18.44	4.7	4.5

Source: Carcass weight from slaughter statistics, Statistics Norway, and age at slaughter and conversion factors from Volden and Nes, 2006, see Annex IX section 2.

5.4.1.3 Emission factors

For cattle and sheep, the following basic equation is used to calculate the CH_4 emission factor for the subgroups (Tier 2):

$EF = (GE \cdot Y_m \cdot 365 \text{ days/yr}) / (55.65 \text{ MJ/kg } CH_4)$

Where:
EF = emission factor, kg CH_4/head/yr
GE = gross energy intake, MJ/head/day
Y_m = CH_4 conversion rate, which is the fraction of gross energy in feed converted to CH_4.

This equation assumes an emission factor for an entire year (365 days). In some circumstances the animal category may be alive for a shorter period or a period longer than one year and in this case the emission factor will be estimated for the specific period (e.g., lambs living for only 143 days and for beef cattle which are slaughtered after around 540 days, varying from year to year). Further description of the determination of the variables GE and Y_m for the different animal categories and the values used in the calculations are given in Annex IX.

The emissions from hens and pullets, domestic reindeer, deer and fur-bearing animals are also included in the Norwegian calculations. The Norwegian University of Life sciences has investigated and documented the national emission factors for poultry. Only hens and pullets have emissons of significance (Svihus 2015). For reindeer the emission factor 14.0 kg/animal/year is used and for deer 20.0 kg/animal/year. Both factors are expert judgments from the University of Life Sciences (Karlengen et al. 2012) and have been estimated based on the methodology described for cervidae in IPCC (2006). Danish emission factors are used for goat since they are considered to reflect Norwegian feed intake and circumstances (Karlengen et al. 2012). Emission factor for fur-bearing animals has been developed by scaling emission factor for pigs, which are assumed most similar with regard to digestive system and feeding. The scaling is done by comparing average weights for fur-bearing animals and pigs and the factor is set to 0.1 kg/animal/year.

For the other animal categories the Tier 1 default emission factors for each kind of animal (IPCC 2006) is used. The factors used are shown in Table 5.9.

Table 5.9 Emission factors for CH_4 from enteric fermentation and different animal types estimated with the Tier 1 method

Animal	**Emission factor (Tonnes/animal/year)**	**Source**
Horses	0.018	(IPCC 2006)
Goats	0.013	(Karlengen et al. 2012)
Pigs	0.0015	(IPCC 2006)
Hens	0.00002	(Svihus 2015)
Pullets	0.0000036	(Svihus 2015)
Reindeer	0.014	(Karlengen et al. 2012)
Deer	0.02	(Karlengen et al. 2012)
Fur-bearing animals	0.0001	Estimate by Statistics Norway

Source: IPCC (2006), Karlengen et al. (2012), Svihus (2015).

5.4.2 Uncertainties and time-series consistency

Activity data

The data is considered to be known within ±5 per cent. There is also uncertainty connected to the fact that some categories of animals are only alive part of the year and the estimation of how long this part is.

Emission factors

Although the emissions depend on several factors and therefore vary between different individuals of one category of animal, average emission factors for each category are used in the tier 1 methodology for all animal categories except cattle and sheep, where a tier 2 methodology is used.

The standard deviation of the emission factors is considered to be ±40 per cent, which is the estimate from the IPCC guidelines (IPCC 2006). An uncertainty estimate of ±25 per cent is used for the emission factors for cattle and sheep in the Tier 2 methodology (Storlien & Harstad 2015).

5.4.3 Category specific QA/QC and verification

In 2001, a project was initiated to improve the estimate of the exact number of animal populations. This was completed in 2002. In 2012, a further revision of the numbers of bulls and heifers was implemented. 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 2015, the equations of this model were updated for cattle based on Norwegian data from the Cow recording system/NorFor (Storlien & Harstad 2015).

The Norwegian University of Life sciences has further investigated and documented the national emission factor of 20 g CH_4 per head used for laying hens in a project in 2015 (Svihus 2015). New emission factors for poultry in Norway were estimated in Svihus (2015). Only hens and pullets have measurable emissions. In the previous submissions, only hens and turkeys were considered. The new emissions factors have increased total emissions from poultry between 1 and 10 tonnes of CH_4 per year. Total emissions were 98 tonnes in 2015, which shows this an insignificant source of CH_4 emissions.

In 2015, a project at the Norwegian University of Life sciences NMBU investigated the basic equations used to calculate the emission factors for enteric methane for cattle in the tier 2 methodology. The results of this project were implemented in the 2016 submission.

5.4.4 Category-specific recalculations

The emission factor for enteric CH_4 for beef cows was updated in 2017. The previous calculation of enteric CH_4 emissions from beef cows were based on a country-specific Tier 2 method from 2015 described in Annex IX, section 2.2.1 in NIR 2017. They developed prediction equations for gross energy intake and Y_m as a function of milk yield and concentrate %, based on data from experiments on dairy cows. Data for these factors are scarcely recorded for beef cows and was based on expert

opinions. Additionally, feed evaluation systems for dairy cows applied to beef cows leads to an overestimation of the emission factor, as beef breeds have a lower maintenance requirement compared to dairy breeds (e.g., (Refsgard Andersen 1990)). Since 2016, new data on the practical feeding regime of Norwegian beef cows have become available, and based on these data, new emission factors was estimated. The methodology is documented in Annex IX and in Aspeholen Åby et al. (2017). Due to this revision, the emission per animal is reduced from 110 kg to 82 kg per animal and year.

See chapter 10 for more details.

5.4.5 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

5.5 Emissions from manure management - 3B (Key categories for CH_4 and N_2O)

5.5.1 Category description

The relevant greenhouse gases emitted from this source category are CH_4 (IPCC 3Ba) and N_2O (IPCC 3Bb). Emissions from cattle are most important in Norway for both components.

N_2O emissions from manure management is key category according to Tier 2 key category analysis and CH_4 emissions from cattle manure management is key category according to Tier 1 key category analysis.

CH_4 emissions due to manure management amounted to 264 ktonnes CO_2 equivalents in 2016 whilst N_2O emissions amounted to 175 ktonnes CO_2 equivalents.

Manure management emitted 439 ktonnes of CO_2 equivalents in 2016, which are approximately 10 per cent of the GHG emissions from agriculture.

Emissions of GHGs from manure management increased by 9 per cent in the period 1990-2016, and by 1 per cent from 2015 to 2016.

Organic material in manure is transformed to CH_4 in an anaerobic environment by microbiological processes. Emissions from cattle (manure) are most important in Norway. The emissions from manure depend on several factors; type of animal, feeding, manure management system and weather conditions (temperature and humidity).

During storage and handling of manure (i.e. before the manure is added to soils), some nitrogen is converted to N_2O. The fraction converted to N_2O depends on the system and duration of manure management. Liquid system is the most widespread storage system, and consequently the most important source. Indirect emissions of N_2O (atmospheric deposition and leaching) from manure storage are also estimated.

Emissions of NH_3 from manure depend on several factors, e.g. type of animal, nitrogen content in fodder, manure management, climate, time of spreading of manure, cultivation practices and characteristics of the soil. In the IPCC default method, a NH_3 volatilisation fraction of 20 per cent is used for the total N excretion by animals in the country. However, in the Norwegian emission inventory, yearly updated NH_3 volatilisation estimations are used, because this is expected to give more correct values for Norway. The estimated national volatilization fractions from spreading of manure ($frac_{gasm}$) have differed between 13-14 per cent since 1990.

Like for NH_3, emissions from NO_X from animal manure lead to indirect emissions of N_2O from deposition. The amounts of N from NO_X emissions from manure management systems, spreading of manure and droppings on pastures are however small.

Section 5.3 gives more information about nitrogen in animal manure as basis for emission estimates and an overview of the manure nitrogen flows in the Norwegian greenhouse gas inventory.

5.5.1.1 Methodological issues

CH_4

For sheep, goat, horse, deer, reindeer, mink and fox, IPCC Tier 1 methods are used for the estimations of emission of CH_4 from manure management (IPCC 2006). The emission factors used are based on country specific expert judgements (Karlengen et al. 2012) where such exists (horse, mink and fox, deer and reindeer), while for sheep and goat the IPPC default emission factors are used.

For cattle, swine and poultry, emissions of methane from manure are estimated using the following equations, in accordance with the IPCC Tier 2 method (IPCC 2006).

$$CH_4 \text{ Emissions} = EF * \text{Population}$$

$$EF_i = VS_i * 365 \text{ days/year} * Bo_i * 0.67 \text{ kg/m}^3 * \sum_{(jk)} MCF_{jk} * MS_{ijk}$$

EFi = annual emission factor for defined livestock population *i*, in kg

VSi = daily VS excreted for an animal within defined population *i*, in kg

Boi = maximum CH_4 producing capacity for manure produced by an animal within defined population *i*, m^3/kg of VS

MCFjk = CH_4 conversion factors for each manure management system *j* by climate region *k*

MSijk = fraction of animal species/category *i*'s manure handled using manure system *j* in climate region *k*

The factors VS, B_0 and MCF are average factors meant to represent the whole country. The populations of animals are consistent with the animal data used elsewhere in the inventory (see chapter 5.2 and Annex IX for further details). For young cattle, this implies that the VS production is estimated for the whole average life time/time until first calving and not per animal year. The amount of volatile solids (VS) for other cattle is estimated directly as kg/animal/year. The VS factors are based on the same data sources used in the estimations of nitrogen excretion factors, that are used in estimations of N_2O from manure (Karlengen et al. 2012). For swine and poultry, country specific estimates of the University of Life Sciences (NMBU) for the percentage of the manure in dry matter that are volatile solids are used. Background data used for the estimations of VS are given in Table 5.10 and in Annex IX.

The factor B_0 represents the maximum potential production of methane under optimum conditions. For dairy cows, the B_0 factors are based on Norwegian research and for pigs the factor is based on literature studies (Morken et al. 2013), for other cattle and poultry the default IPCC factors are used.

Table 5.10 Norwegian factors for amount of manure (in dry matter - d.m.), VS and Bo used to estimate CH_4 from manure management with the IPCC Tier 2 method. 2016.

	Manure (kg dry matter per animal)	VS %	VS, kg per animal	VS, total, tonnes	Bo
Non-Dairy Cattle					
Beef cows			970	75 036	0.18
Replacement heifer			965	106 575	0.18
Finisher heifer			766	26 418	0.18
Finisher bulls			718	107 452	0.18
Dairy cows			1 541	331 357	0.23
Poultry					
Hens	13.15	0.9	11.84	51 325	0.39
Chicks bred for laying hens, animal places	3.10	0.9	2.79	3 039	0.36
Chicks for, slaughter animal places	4.08	0.9	3.67	37 227	0.36
Ducks for breeding	30.00	0.9	27.00	79	0.36
Ducks for slaughter, animal places	8.12	0.9	7.31	425	0.36
Turkey and goose for breeding	30.00	0.9	27.00	448	0.36
Turkey and goose for slaughter, animal places	17.23	0.9	15.51	7 316	0.36
Swine					
Piglets 4-10 weeks	18.41	0.9	16.57	4 546	0.30
Young pigs for breeding	113.00	0.9	101.70	4 239	0.30
Pigs for slaughter, animal places/årsdyr	131.34	0.9	118.21	57 001	0.30
Sows	307.90	0.9	393.57	13 286	0.30
Boar	307.90	0.9	393.57	221	0.30

Sources:
Manure, dry matter poultry and swine: Karlengen et al. (2012)
VS%, poultry: expert estimate Birger Svihus NMBU, email 03.01.2013
VS%, swine: expert estimate Nils Petter Kjos, NMBU, email 03.01.2013.
VS per animal, cattle: Estimates based on Karlengen et al. (2012)
B_0: Morken et al. (2013) for dairy cattle and swine and IPCC (2006) for other animal groups.

For MCF, standard IPCC factors from 2006 IPCC Guidelines (IPCC 2006) are used for the different manure management systems.

Table 5.11 Norwegian factors for MCF used to estimate CH_4 from manure management with the IPCC Tier 2 method

	MCF
Pit storage below animal confinement>1month [1]	0.17
Pit storage below animal confinement<1month [1]	0.03
Liquid / slurry without cover	0.17
Liquid / slurry with cover	0.1
Solid storage	0.02
Cattle and swine deep bedding	0.17
Dry lot	0.01
Poultry manure	0.015
Pasture range and paddock, cattle	0.02
Pasture range and paddock, horses, goats and sheep	0.01

[1]The share of the manure stored over and under one month before spreading is based on expert judgement by J. Morken, Norwegian University of Life Sciences, 06.08.14.

Sources: IPCC (2006)

N_2O

In Norway, all animal excreta that are not deposited during grazing are managed as manure. N_2O emissions from manure are estimated in a N_2O side model. The estimations are made in accordance with the IPCC tier 2 method (IPCC 2006), using Norwegian values for N in excreta from different animals according to Table 5.12. The rationale for the Norwegian values for N in excreta is provided in Karlengen (2012). The N-excretion factors for cattle, poultry and pigs have been scientifically investigated, while the remaining categories have been given by expert judgements (Karlengen et al. 2012). Based on typical Norwegian feedstock ratios, the excretion of nitrogen (N) were calculated by subtracting N in growth and products from assimilated N. Comparisons have also been made with emission factors used in other Nordic countries and IPCC default factors.

The factors for cattle are based on equations using animal weight, production (milking cows), life time (young cattle) and protein content in the fodder as activity data.

The Nordic feed evaluation system (NorFor) was used to develop the nitrogen factors for cattle. Excretions of N in the manure were calculated as the difference between their intake, and the sum of what is excreted in milk, fetus and deposited in the animal itself. The procedure used for calculating the excretion of faeces and N consisted of two steps:

1. Simulations in ”NorFor” were conducted to gain values for the faeces/manure characteristics covering a wide variation of feed characteristics (N content) and production intensities (milk yield/meat production)
2. The results from the simulations were used to develop regression equations between faeces/manure characteristics and parameters related to the diet (N content) and animal characteristics (milk yield, weight, age etc).

Calculations of N-factors based on these equations have been made back to 1990 for cattle. For poultry and pigs, N-factors have been estimated for 2011 in Karlengen et al. (2012). The factors used until this update were estimated in 1988 (Sundstøl & Mroz 1988), and are regarded as still valid for 1990. A linear interpolation has been used for the years between 1990 and 2011. For the remaining animal categories, N in excreta is considered constant throughout the time series. More background data for the calculations is provided in Annex IX, Section 3.1. The factors are shown in Table 5.12. The factors for total N are used in the estimations of N_2O emissions, whilst ammonium N is used in the estimations of NH_3 and NO_X emissions.

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 provided in Table 5.14. This is described in section 5.5.1.2.

Table 5.12 N in excreta from different animal categories[1]. 2016. kg/animal/year unless otherwise informed in footnote.

	Total N	**Ammonium N**
Dairy cow	129.9	73.9
Beef cow	65.0	36.4
Replacement heifer[2]	86.7	47.7
Bull for slaughter[2]	72.7	44.1
Finishing heifer[2]	68.1	41.4
Young cattle[3]	43.87	25.59
Horses	50.0	25.0
Sheep < 1 year	7.7	4.3
Sheep > 1 year	11.6	6.38
Goats	13.3	7.9
Pigs for breeding	23.5	15.7
Pigs for slaughtering[4]	3.2	2.13
Hens	0.670	0.29
Chicks bred for laying hens[4]	0.046	0.017
Chicks for slaughtering[4]	0.030	0.011
Ducks, turkeys/ goose for breeding	2.0	0.8
Ducks, turkeys/ goose for slaughtering[4]	0.4	0.18
Mink	4.3	1.7
Foxes	9.0	3.6
Reindeer	6.0	2.7
Deer	12.0	5.4

[1] Includes pasture.

[2] Factors for excreted nitrogen apply for the whole life time of animals, and nitrogen is calculated when animals are slaughtered/replaced.

[3] Average factor for all heifers for slaughter and replacement and bulls for slaughter, per animal and year.
[4] Per animal. For these categories, life time is less than a year. This means that the number of animals bred in a year is higher than the number of stalls (pens).
Source: Karlengen et al. (2012) and estimations by Statistics Norway.

NH_3

Ammonia volatilised from manure storage represents, together with NO_X, the activity data in the estimations of indirect N_2O emissions from atmospheric deposition, source 3Bb5 (atmospheric deposition from manure storage). A model is used for calculating the emissions of ammonia from manure management. The principle of the model is illustrated in Figure 5.2.

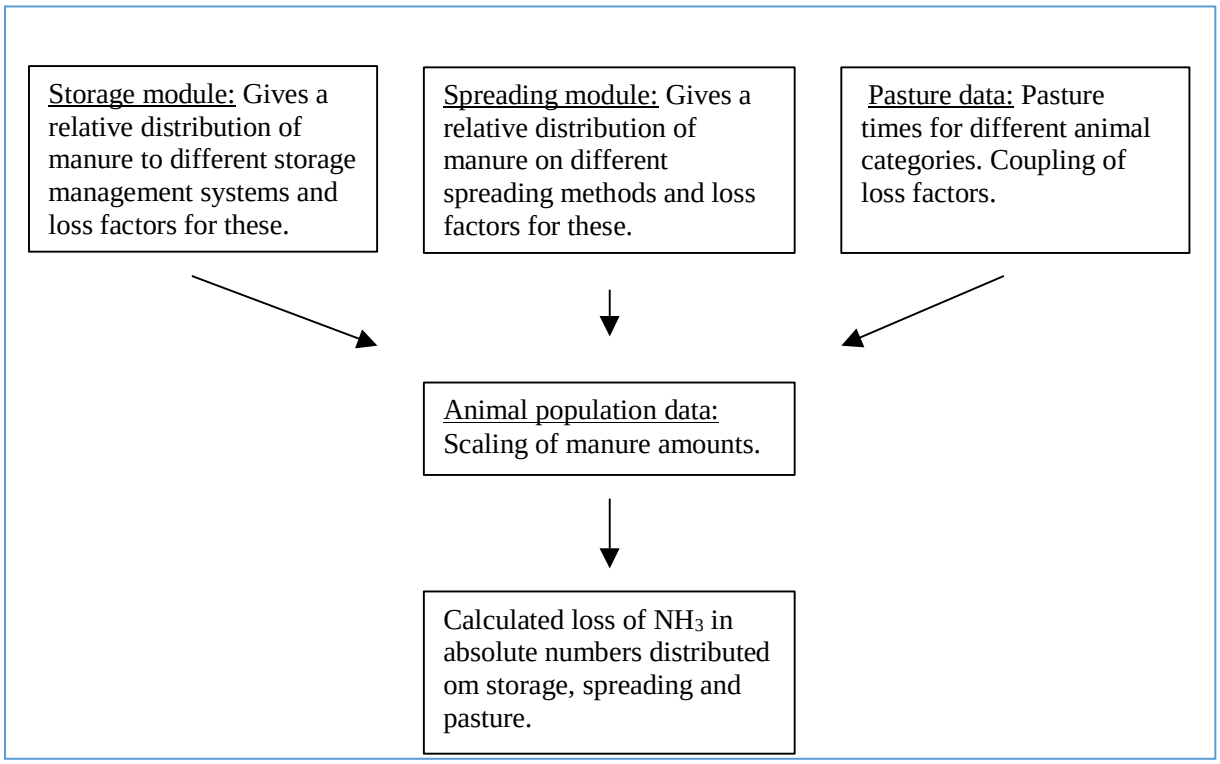


Figure 5.2 The principle of the NH_3 model

The storage module in the NH_3 model determines the relative distribution of manure nitrogen to the different storage management systems. Total NH_3 emissions from storage are estimated by multiplying the different emission factors for the storage systems by the amount of manure nitrogen (ammonium N) for each storage system and summarizing the results. The amount of ammonium nitrogen in the manure is estimated by the number of animals and ammonium nitrogen excretion factors for each type of animal (see Table 5.12).

NO_X

Nitrous oxide volatilised from manure storage represents, together with NH_3, the activity data in estimations of indirect N_2O emissions from atmospheric deposition, source 3Bb5 (atmospheric deposition from manure storage).

NO_X emissions from manure management systems are estimated according to the methodology in EEA (2016). In Norway, all animal excreta that are not deposited during grazing are managed as manure. Norwegian values for N in excreta from different animals according to Table 5.12 are used.

Norwegian values are also used for the fraction of total excretion per species for each management system (MS) and for pasture, see Table 5.14. The fractions are updated every year.

Indirect N_2O from manure management, 3Bb5

Deposition of nitrogen from manure management is assumed to correspond to the amount of nitrogen in the NH_3 and NO_X that volatilises from manure storage systems. The N_2O emissions are calculated by multiplying the amount of N from deposition with the IPCC default emission factor of 0.01 kg N_2O-N/(kg NH_3-N+NO_X-N volatilized) (IPCC 2006).

Storage systems that are not watertight may cause leaching of manure nitrogen. It is assumed that leaching occurs from the storage systems solid storage (not including dry manure in manure cellars), cattle and swine deep bedding, dry lot and poultry manure. The fractions that are assumed leached are based on expert judgement, see Table 5.13.

Table 5.13 $Frac_{leach}$ for storage systems that are assumed to have leaching.

	$Frac_{leach}$, per cent
Solid storage [1]	25
Cattle and swine deep bedding	15
Dry lot	25
Poultry manure	25

[1] Solid manure stored in manure cellars are not assumed to have leaching.
Source: Expert judgement by Statistics Norway and the Norwegian Agricultural Agency[23].

The IPCC default emission factor of 0.075 kg N_2O-N/kg N lost to leaching/runoff is used (IPCC 2006).

5.5.1.2 Activity data

CH_4, N_2O, NO_X and NH_3

Emissions are estimated from the animal population. How the animal population is estimated is described in Section 5.2 and Annex IX.

Surveys for assessing use of manure management systems (MMS) have been carried out in 2000, 2003 and 2013. The distribution of manure systems according to the IPCC terms used in the CRF reporting are given in Table 5.14 (used in the CH_4, N_2O and NO_X emission estimations) and according to the terms used in the NFR reporting in Table 5.15 (used in the NH_3 emission estimations).

Norway has developed calculation models for estimating N_2O and NH_3 emissions. The basic data from the 2013 Manure Survey is however treated a little differently in the two models, and different manure storage categories are used. For estimating NO_X emissions, the setup for the N_2O estimations was more suitable to use than the NH_3 model. This means that the NO_X estimations are in better

[23] Email from Jon Magnar Haugen, the Norwegian Agricultural Agency, 25.11.2015.

coherence with the calculations for the N_2O emissions than with the NH_3 calculations regarding the use of the data from the manure surveys.

Table 5.14 Fraction of total excretion per specie for each management system and for pasture (MS) used in the estimations of CH_4, N_2O and NO_X. 2016

	Pit storage below animal confine-ment	**Liquid / slurry without cover**	**Liquid / slurry with cover**	**Solid storage**	**Cattle and swine deep bedding**	**Dry lot**	**Pasture range and paddock**	**Poultry manure**
Dairy cattle	0.01	0.15	0.68	0.00	0.00	0.00	0.17	
Mature non dairy cattle	0.01	0.09	0.38	0.08	0.03	0.10	0.31	
Young cattle	0.01	0.10	0.54	0.02	0.01	0.02	0.31	
Swine	0.01	0.20	0.74	0.02	0.00	0.03	0.00	
Sheep	0.41	0.01	0.00	0.07	0.02	0.04	0.45	
Goat	0.32	0.00	0.00	0.03	0.03	0.25	0.37	
Horse	0.38	0.00	0.00	0.04	0.03	0.30	0.25	
Poultry								1.00
Fur bearing animals				1.00				
Reindeer, deer and other animals							1.00	

Source: Data for storage systems from Statistics Norway (Gundersen & Heldal 2015), data for pasture times from TINE BA (Annually) (Dairy cattle, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002) (non-dairy cattle, sheep) and expert judgements (poultry, fur bearing animals and other).

Table 5.15 Fraction of total excretion per animal category for each management system and for pasture (MS) used in the estimations of NH_3. 2016. [IPCC categories, ref. table 3.13 in (EEA 2016), 3B Manure management]

	In-house slurry pit [pit storage below animal confinements]	Tank without cover [Liquid/ slurry]	Tank with cover [Liquid/ slurry]	Heaps [solid storage]	In-house deep litter [Cattle and swine deep bedding]	Dry lot	Pasture range and paddock
Dairy cattle	0.60	0.05	0.12	0.03	0.02	0.01	0.17
Other cattle	0.50	0.04	0.10	0.02	0.02	0.01	0.31
Swine	0.63	0.11	0.20	0.04	0.02	0.00	0.00
Sheep	0.29	0.00	0.00	0.18	0.07	0.01	0.45
Goat	0.16	0.00	0.00	0.43	0.03	0.02	0.37
Horse	0.19	0.00	0.00	0.51	0.03	0.03	0.25
Poultry	0.03	0.00	0.00	0.97	0.00	0.00	0.00
Fur bearing animals	0.25	0.00	0.00	0.68	0.04	0.03	0.00
Reindeer, deer and other animals							1.00

Source: Data for storage systems from Statistics Norway (Gundersen & Heldal 2015), data for pasture times from (TINE BA Annually) (Dairy cattle, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002)

Data on storage systems for other years is not available. Separate estimations of the effects on emissions of the assumed changes in storage systems since 1990 show that these assumed changes do not significantly impact the emissions. For the intermediate years 2004-2012 between the surveys of 2003 and 2013, the distribution of management system has been estimated using a linear interpolation of changes between 2003 and 2013, for each system. The surveys on management systems do not include pasture. Data for pasture times for dairy cattle and dairy goat has however been annually updated in the Cow Recording System (TINE BA Annually) until 2013, while for the other animals, data from Sample survey of agriculture and forestry for 2001 at Statistics Norway (2002) is used.

In the CH_4 estimations, the share of the manure stored more respective less than one month in pit storage below animal confinement before spreading is based on expert judgement[24]. It is assumed that 1/6 of the manure is stored less than 1 month, the rest more than 1 month.

In the manure surveys of 2000 and 2013, the manure of each management system is distributed by all combinations of the following regions and productions:

Regions:

- South-Eastern Norway
- Hedmark and Oppland
- Rogaland
- Western Norway

[24] Personal communication John Morken, NMBU, 6.8.2014

- Trøndelag
- Northern Norway

Production[25]:

- Cattle
- Swine
- Sheep
- Goats and horses
- Poultry

5.5.1.3 Emission factors

CH_4

The calculated average emission factors for different animal types are shown in Table 5.16 and Table 5.17. Except for sheep and goats, they are country specific factors which may deviate from the IPCC default values.

Table 5.16 CH_4 emission factors for manure management used in the IPCC tier 1 method. kg/animal/year.

	Emission factor[1]	**Source**
Sheep > 1 year	0.19	IPCC (2006)
Sheep < 1 year	0.19	IPCC (2006)
Dairy goats	0.13	IPCC (2006)
Other goats	0.13	IPCC (2006)
Horses	2.95	(Karlengen et al. 2012)
Mink, males	0.27	(Karlengen et al. 2012)
Mink, females	0.54	(Karlengen et al. 2012)
Fox, males	0.43	(Karlengen et al. 2012)
Fox, females	0.87	(Karlengen et al. 2012)
Reindeer	0.36	(Karlengen et al. 2012)
Deer	0.9	(Karlengen et al. 2012)

[1] *Includes pasture.*

[25] The grouping of animals is different in the two surveys. Cattle is one category in the 2000 survey and three categories in the 2013 survey. Goats are grouped with sheep in the 2000 survey, but with horses in the 2013 survey. Horses are grouped with other animals in the 2000 survey. Fur bearing animals are not included in the 2013 survey

Table 5.17 Average CH_4 emission factors for manure management used in the IPCC tier 2 method. kg/animal/year. 2016

	Emission factor[1]
Dairy cows	22.54
Bulls[2]	6.61
Heifers[2] for slaughter	7.01
Heifers for breeding[2]	8.89
Beef cows (mature non-dairy cattle)	7.67
Sows	6.17
Young pigs for breeding	2.26
Pigs for slaughter[3]	2.63
Hens	0.046
Chicks bred for laying hens	0.01
Chicks for slaughter[3]	0.013
Ducks for breeding	0.098
Ducks for slaughter[3]	0.026
Turkey and goose for breeding	0.098
Turkey and goose for slaughter[3]	0.056

[1] Includes pasture.

[2] Factors apply for the whole life time of animals.

[3] Per animal place. This means that the factor includes all animals bred in on place (pen) during the year

Source: Karlengen et al. (2012), IPCC (2006), Morken et al. (2013) and estimations by Statistics Norway.

N_2O

The IPCC default values for N_2O emission factors from manure management are used (Table 5.18). These are consistent with the 2006 IPCC Guidelines (IPCC 2006).

Table 5.18 Emission factors for direct N_2O emissions from manure management per manure management system

Manure management system	**Emission factor, kg N_2O-N/kg N**
Pit storage below animal confinement	0.002
Liquid / slurry without cover	0
Liquid / slurry with cover	0.005
Solid storage	0.005
Dry lot	0.02
Cattle and swine deep bedding	0.01
Dry lot	0.02
Poultry manure	0.001
Pasture range and paddock (cattle, pigs and poultry)	0.02
Pasture range and paddock (other animals)	0.01

Source: IPCC (2006)

NH_3

Emission factors vary with production and storage system; in the model there is no variation between regions. The factors used are shown in Table 5.19. The factors in Table 5.19 are based on data from Denmark, Germany and Netherlands, since measurements of NH_3 losses in storage rooms have so far not been carried out in Norway.

Table 5.19 NH_3 emissions factors for various storage systems and productions. Per cent losses of N of ammonium N.

	Storage system						
	Manure cellar for slurry	**Open manure pit for slurry**	**Manure pit for slurry with lid**	**Open flagstones**	**Indoor built up/deep litter**	**Outdoor built up/enclosure**	**Storage for solid dung and urine**
	Gutter	Gutter		Drainage to gutter			
Cattle, milking cow:							
Loss from animal room	5	5	5	5	8	8	5
Loss from storage room	2	9	2	2	15	15	15
Total loss	7	14	7	7	23	23	20
Pigs:							
Loss from animal room	15	15	15	15	15	15	20
Loss from storage room	4	6	2	2	25	25	30
Total loss	19	21	17	17	40	40	50
Sheep and goats:							
Loss from animal room	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
Poultry:							
Loss from animal room	12	10	12	12	25	25	25
Loss from storage room	15	15	15	15	25	25	25
Total loss	27	25	27	27	50	50	50
Other animals:							
Loss from animal room	5	NO	NO	NO	15	15	15
Loss from storage room	10	NO	NO	NO	15	15	15
Total loss	15	NO	NO	NO	30	30	30

Source: Morken (pers. Comm.) Morken, J. (2003): Personal information, Ås: Department of Agricultural Engineering, Norwegian University of Life Sciences.

The factors are combined with activity data in the Statistics Norway survey of different storage systems in 2000 (Gundersen & Rognstad 2001), the Sample survey of agriculture and forestry 2003 (Statistics Norway 2004) and data from the report *Use of inorganic and organic fertilisers in agriculture 2013* (Gundersen & Heldal 2015), and emission factors for NH_3 emissions from storage of manure and stalled animals are calculated for production and region (Table 5.20). To estimate losses, these emission factors are in turn multiplied with the amount of manure (based on number of animals and N-factors per animal). The changes in storage systems from 2003 to 2013 have been

linearly interpolated in the intermediate years. From 1990-2002 and from 2013, the number of animals is the only activity data that differs from year to year.

Table 5.20. Average emission factors for the manure storage systems used, distributed on type of animal production and region. Per cent losses of N of ammonium N.

	South-Eastern Norway	Hedmark/ Oppland	Rogaland	Western Norway	Trøndelag	Northern Norway
Cattle	8.3	10.7	9.0	7.8	7.6	7.8
Swine	20.8	23.4	22.0	19.2	19.1	20.2
Sheep	11.2	13.3	12.6	8.9	10.7	11.3
Poultry	49.2	50.0	48.5	49.1	49.9	48.9
Goats, horses and fur-bearing animals	26.3	29.4	27.6	29.8	24.7	29.7

Source: Statistics Norway, NH_3-model estimations

NO_X

The emissions factors used for NO_X emissions in manure management systems are shown in Table 5.21.

Table 5.21 NO_X emission factors for manure management per manure management system.

	EF (AWMS) (kg NO-N/kg of Nex in AWMS
Pit storage below animal confinement	0.01
Liquid / slurry without cover	0.0001
Liquid / slurry with cover	0.0001
Solid storage	0.01
Cattle and swine deep bedding	0.01
Dry lot	0.01
Poultry manure	0.01
Pasture range and paddock	0

Source: EEA (2016)

N excretions is estimated as urine-N, which is the same N excretion factor that is used in the estimations of NH_3 from manure management systems.

5.5.2 Uncertainties and time-series consistency

Uncertainties estimates are provided in Annex II.

Activity data

CH_4

The data for the number of animals is considered to be known within ±5 per cent. Other activity data are the different kinds of manure treatment (which will determine the emission factor), which have been assessed by expert judgments. This will contribute to the uncertainty.

N_2O and NH_3

The data for the number of animals is considered to be known within ±5 per cent.

For the emissions from manure management, Norwegian data for N in excreta is used (Table 5.12). The nitrogen excretion factors are uncertain, but the range is considered to be within ±15 per cent (Rypdal 1999). The uncertainty has not been estimated for the revised nitrogen excretion factors from Karlengen et al (2012), and in the key category analysis is the uncertainty estimate for the country specific nitrogen excretion factors from 1999 still used as the best available estimate. This can be considered as a conservative estimate of the uncertainty since it is expected that the new nitrogen excretion factors have a lower uncertainty. The uncertainty is connected to differences in excretion between farms in different parts of the country, the fact that the survey farms may not have been representative, general measurement uncertainty and the fact that fodder and fodder practices have changed since the factors were determined.

There is also an uncertainty connected to the division between different storage systems for manure, which is considered to be within ±10 per cent, and the division between storage and pasture, which is considered to be within ±15 per cent.

Emission factors

CH_4

The emission factors are considered to have the uncertainty range ±20 per cent for cattle, poultry and pigs (Tier 2) and ±30 per cent for other animals (Tier 1) (IPCC 2006).

N_2O

For the emission of N_2O from different storage systems, IPCC default emission factors are used. They have an uncertainty range of a factor of 2 (IPCC 2006).

NH_3

Ammonia emissions from agriculture are estimated based on national conditions. There are uncertainties in several parameters as fraction of manure left on pastures, amount of manure, conditions of storage, conditions of spreading and climate conditions. Uncertainty analyses have not been made for the revised NH_3 model, which has been in use since 2003. The revision of the model is however supposed to have reduced the uncertainty. Also the new estimations of nitrogen excretion from animals (Karlengen et al. 2012) are believed to have reduced uncertainty further.

NO_X

Uncertainty has not been assessed. According to EEA (2016), uncertainty is high, ranging between -50 per cent to + 100 per cent.

5.5.3 Category specific QA/QC and verification

In a Nordic project in 2002, the results for both CH_4 and N_2O emissions 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 & 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 (NMBU), made improvements in 2003 in the calculation model for ammonia emissions from the agricultural sector. Data sources used for the recalculations in the revised NH_3 model are coefficients from the Norwegian University of Life Sciences, and three surveys from Statistics Norway; two manure surveys (Gundersen & Rognstad 2001) and (Gundersen & Heldal 2015) and the sample survey of agriculture and forestry (Statistics Norway 2002).

In 2011, the Norwegian University of Life Sciences (NMBU) published a comparison of the methodologies used for calculating CH_4 emissions from manure management in Sweden, Finland, Denmark and Norway (Morken & Hoem 2011).

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

A project with the aim to revise the Norwegian CH_4 conversion factors (MCF) for the manure storage systems in use was conducted at the Norwegian University of Life Sciences (NMBU) in 2013. The maximum CH_4 producing capacity (B_o) was also revised for cattle manure.

The methodology for estimating methane from manure management was revised in the 2014 submission. The emissions of methane from manure for cattle, pigs and poultry were estimated with tier 2 method in accordance with IPCC GPG (IPCC 2000). The population of animals was brought into consistency with the animal data used elsewhere in the inventory.

In 2014, a new manure survey for 2013 was carried out by Statistics Norway (Gundersen & Heldal 2015). The results are implemented in the estimations of CH_4 and N_2O emissions from manure. Statistics Norway's detailed manure survey gave more extended activity data which is better related to emission source categories, for manure management and spreading. New loss factors for different manure management categories are also used in the revised NH_3-model. These factors are closer connected to specific activities.

5.5.4 Category-specific recalculations

Last year the storage categories used in the manure survey from Statistics Norway in 2013 (Gundersen & Heldal 2015) were redefined with regard to how they match the IPCC categories of manure management systems. This defined the part of the manure stored in manure cellars as

"liquid systems with cover", at the expense of "pit storage below animal confinement". This year, this has been changed back again for the animal categories sheep, goat and horses since the manure from these animals that is stored in manure cellars normally should not be considered as "liquid". This redefinition is connected only to the 2013 survey, and thus affects fully the emission estimates in 2013 and after, while the effect gradually diminishes towards 2003 when data from the former manure survey was used. The redefinition from liquid systems to pit storage of manure management system categories reduce the N_2O emissions.

See Chapter 10 for more details.

5.5.5 Category-specific planned improvements

The emission estimation methodology for this source category is currently undergoing improvement, see Table 10.9.

Norway uses a country-specific model to calculate NH_3 emissions from manure management. The model calculates emissions at county level and is complicated to update. There is a need to review the model to make it better fit the requirements for inventory reporting purposes, and to be able to keep the time series updated and consistent. There is also a need to review the emission factors used in the model. Changes in the calculation model for NH_3 are expected to also result in some changes in the estimations of indirect N_2O from atmospheric deposition.

5.6 Direct and indirect N_2O emissions from agricultural soils - 3D (Key categories for N_2O)

5.6.1 Category description

The emissions of N_2O from agricultural soils in Norway in 2016 amounted to 1.7 Mtonnes calculated in CO_2-equivalents. They accounted for about 37 per cent of the total Norwegian GHG emissions from agriculture in 2016.

The emissions had minor fluctuations in the period 1990-2016. During the period 1990-2016, emissions decreased by 2 per cent. From 2015 to 2016, the emissions decreased by 0.7 per cent.

Table 5.22 Emission trends for 3D Direct and indirect N_2O emissions from agicultural soils (kt CO_2 equivalents).

Source category	1990	1990, % of Agriculture	2015	2016	2016, % of Agriculture	Trend 1990-2016 (%)	Trend 2015-2016 (%)
3Da1. Inorganic N fertilizers	516	11 %	488	479	11 %	-7 %	1 %
3Da2. Organic N fertilizers	287	6 %	326	327	7 %	14 %	0 %
3Da3. Urine and dung deposited by grazing animals	186	4 %	165	169	4 %	-9 %	2 %
3Da4. Crop residues	105	2 %	76	72	2 %	-31 %	-6 %
3Da6. Cultivation of organic soils	376	8 %	394	393	9 %	4 %	0 %
3Db1. Indirect N_2O Emissions from managed soils - Atmospheric deposition	86	2 %	87	87	2 %	1 %	0 %
3Db2. Indirect N_2O Emissions from managed soils - Nitrogen leaching and run-off	168	4 %	164	162	4 %	-4 %	-1 %
3D. Total	1 724	36 %	1 700	1 689	37 %	-2 %	-1 %

Source: Statistics Norway and Norwegian Environment Agency

Different sources of N_2O from agricultural soils are distinguished in the IPCC methodology, namely:

- Direct emissions from agricultural soils (from use of synthetic fertilisers, animal excreta nitrogen, sewage sludge and other organic fertilisers applied to soils, droppings from grazing animals, crop residues and cultivation of soils with a high organic content);
- N_2O emissions indirectly induced by agricultural activities (N losses by volatilization, leaching and run-off).

The use of synthetic fertilisers, animal excreta nitrogen and sewage sludge used as fertiliser, and other organic fertilisers applied to soils also results in emissions of NH_3 and NO_X that gives indirect N_2O emissions from volatilization. NH_3 volatilized from grazing animals are also included in the estimations of indirect N_2O.

Section 5.3 gives more information about nitrogen in animal manure as basis for emission estimates and an overview of the manure nitrogen flows in the Norwegian greenhouse gas inventory.

Emissions of N_2O from agricultural soils are key categories because of uncertainty, both in level and trend.

5.6.1.1 Inorganic N fertilisers, 3Da1

Methodological issues

N_2O

IPCC Tier 1 methodologies and default emission factors (IPCC 2006) are used for estimating direct N_2O emissions from managed soils.

The direct emissions of N_2O from use of synthetic fertilisers are calculated from data on total annual amount of fertiliser sold in Norway and its nitrogen content, subtracting the amount of synthetic fertiliser applied in forest. The resulting amount that is applied on agricultural fields is multiplied with the IPCC default emission factor (IPCC 2006).

NH_3

The calculations of NH_3 emissions from the use of synthetic fertiliser are based on the amounts of nitrogen supplied and emission factors for the percentage of nitrogen emitted as NH_3 during spreading.

NO_X

The sum of all nitrogen applied to soil has been multiplied with the default tier 1 emission factor to estimate the nitric oxide (NO) emission from crop production. Thereafter the amount of NO is translated to amount of NO_2.

Activity data

N_2O

The Norwegian Food Safety Authority calculates a total value for annual consumption of synthetic fertilisers in Norway based on sale figures (Norwegian Food Safety Authority Annually). This data is corrected for the amount fertiliser used in forests which is provided yearly by the Norwegian Institute of Bioeconomy Research (NIBIO).

The calculation of emissions from use of nitrogen fertiliser is based on sales figures for each year. A strong price increase for nitrogen fertiliser caused a stock building in 2008 and corresponding lower sales in 2009. In addition, new fertilisation standards may have brought about a reduction of the use of fertilisers. To correct for this, a transfer of fertiliser use has been made from 2008 to 2009.

NH_3

For the calculation of the emission of NH_3, the amount of total N in the fertilizer is used (the same as for estimating N_2O). For the calculation of the emission of NH_3, we need a specification of the use of different types of synthetic fertiliser since the NH_3 emission factor vary between the different types. 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.

NO_X

For the calculation of the emission of NO_X, the amount of total N in the fertilizer is used (the same as for estimating N_2O).

Emission factors

N_2O

The IPCC default emission factor of 0.01 kg N_2O-N/kg N applied (IPCC 2006) has been used.

NH_3

The percentage of nitrogen emitted as NH_3 during spreading ($frac_{gasf}$) are used as emission factor. More information about the calculation of $frac_{gasf}$ and the NH_3 emission factors (g NH_3/kg N applied) for the different types of fertilisers is provided in Annex IX, section 3.3.

NO_X

The tier 1 default emission factor of 0.04 kg NO_2/ kg fertilizer-N applied (EEA 2016) has been used.

5.6.1.2 Animal manure applied to soils, 3Da2

Methodological issues

N_2O

IPCC Tier 1 methodologies and default emission factors (IPCC 2006) are used for estimating direct N_2O emissions from animal manure applied to managed soils.

In Norway, all animal excreta that are not deposited during grazing are used as manure and applied to soils. Further, it is assumed that animals do not emit N_2O themselves. NH_3 emissions in storage, and N_2O emissions in storage and manure application are all estimated individually and the emission estimates are based on the same nitrogen pool.

The emission of N_2O from manure used as fertiliser is calculated by multiplying the total amount of N in manure used as fertiliser with the IPCC default emission factor (IPCC 2006). This amount is equivalent to total N excreted from the animals deducted for the amount dropped during grazing.

NH_3

NH_3 emissions from spreading of manure depend on several factors, e.g. climate and time of spreading of manure, type of cultivation and cultivation practices and characteristics of the soil.

Emissions of ammonia are calculated for spreading of manure on cultivated fields and meadow. The total amount of manure nitrogen that is spread is estimated by the number of animals and nitrogen excretion factors for each type of animal, and is thereafter distributed on different spreading methods based on national data. The nitrogen basis for the estimated amounts of nitrogen that volatilises as NH_3 during spreading has been corrected for the amount of nitrogen in the NH_3 that volatilises during storage, unlike the method used in the N_2O estimations. N lost as N_2O and leaching during storage is however not deduced from the N basis. Total emissions from spreading are estimated by emission factors for each different spreading method used multiplied by the amount of manure nitrogen spread with the respective method.

NO_X

The sum of all nitrogen applied to soil has been multiplied with the default tier 1 emission factor to estimate the nitric oxide emission from crop production. Thereafter the amount of NO is translated to amount of NO_2.

Activity data

N_2O, NH_3 and NO_X

The amount of N in manure systems is calculated as total N in manure adjusted for the N that is dropped on pastures.

N_2O emitted during spreading is calculated from the amounts of N in manure storage. This means that N lost through leaching in manure storage and as N_2O, NO_X and NH_3 in manure storage and during spreading is not deducted.

NH_3 emitted during and after spreading of manure is based on the amounts of N in manure storage minus N lost as NH_3 volatilization in manure storage. Other losses of N, such as leaching, N_2O and NO_X is not deducted.

NO_X emitted during and after spreading of manure is based on the amounts of N in manure storage, and *not* deducting N lost as NH_3 or NO_X volatilization in manure storage. Losses of N through leaching and N_2O emissions in manure storage are not deducted.

There are several sources of activity data on spreading of manure. The main sources are manure surveys performed in 2000 and in 2013 by Statistics Norway (Gundersen & Rognstad 2001) and (Gundersen & Heldal 2015), various sample surveys of agriculture and forestry 1990-2007 and the annual animal population.

Data from the manure survey only exists for 2000 and 2013, while the data from the sample surveys has been updated for several, but not all, years. The manner of spreading the manure affects the NH_3 emissions estimates, while the N_2O emission estimations are insensitive to methods of spreading.

How the amount of nitrogen in animal manure is estimated is further described in section 5.3 and 5.5.1.1. How the animal population is estimated is described in Section 5.2 and Annex IX.

Nitrogen factor are estimated by Karlengen et al (2012). In the estimations of NH_3 losses, the factors of N excretion correspond to the estimated nitrogen excreted in the urine.

Table 5.23 Sources for activity data for emissions from animal manure applied to soils.

	Sources
Number of animals	Statistics Norway (applications for productions subsidies, no. and weight of approved carcasses), The Cow Recording System (TINE BA Annually)
Nitrogen factors for manure, Annex IX, section 3.	Karlengen et al (2012), various sources, compiled by Statistics Norway
Distribution between manure storage systems	Sample Survey of agriculture and forestry 2003 (Statistics Norway 2004), manure survey in 2000 and 2013 (Gundersen & Rognstad 2001) and (Gundersen & Heldal 2015)
Pasture times for different animal categories	TINE BA (Annually) (Dairy cows, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002) (non-dairy cattle, sheep), expert judgements.

Table 5.24 Parameters included in the estimation of NH_3 emissions from manure.

	Sources
Area where manure is spread, split on cultivated field and meadow	Statistics Norway (Sample Surveys of Agriculture, various years), (Gundersen & Rognstad 2001) (Gundersen & Heldal 2015)
Area and amount where manure is spread, split on spring and autumn	Gundersen and Rognstad (2001) and Gundersen and Heldal (2015)
Addition of water to manure	(Gundersen & Rognstad 2001), and Gundersen and Heldal (2015), expert judgements, Statistics Norway's Sample Survey 2006 (Statistics Norway 2007)
Spreading techniques	(Gundersen & Rognstad 2001), Gundersen and Heldal (2015), expert judgements
Usage and time of harrowing and ploughing	(Gundersen & Rognstad 2001), Gundersen and Heldal (2015), expert judgements, Statistics Norway's Sample Surveys of Agriculture

Emission factors

N_2O

The IPCC default emission factor of 0.01 kg N_2O-N/kg N applied (IPCC 2006) has been used.

NH_3

Emission factors for spreading of stored manure vary with spreading method (Gundersen & Rognstad 2001; Gundersen & Heldal 2015), water contents (Statistics Norway 2007), type and time of treatment of soil (Gundersen & Rognstad 2001; Gundersen & Heldal 2015), time of year of spreading (Gundersen & Rognstad 2001; Gundersen & Heldal 2015; Statistics Norway 2007), cultivation and region. The basic factors used are shown in Table 5.25.

Table 5.25 Emissions factors for NH_3-N for various methods of spreading of manure. Per cent of ammonium N.

			Western and northern Norway			Southern and eastern Norway		
			Spring	**Summer**	**Autumn**	**Spring**	**Summer**	**Autumn**
Meadow								
Surface spreading			0.5	0.6	0.4	0.5	0.6	0.4
Injection			0.1	0.1	0.05	0.1	0.1	0.05
Water mixing			0.3	0.3	0.2	0.3	0.3	0.2
Dry manure			0.04	0.1	0.1	0.04	0.1	0.1
Open fields								
Method	Time before down-moulding	Type of down-moulding						
Surface spreading	0-4 hrs	plow	0.2		0.2	0.15		0.3
Surface spreading	+ 4 hrs	plow	0.5		0.35	0.4		0.4
Surface spreading	0-4 hrs	harrow	0.4		0.35	0.35		0.35
Surface spreading	+ 4 hrs	harrow	0.5		0.45	0.45		0.45
Water mixing	0-4 hrs	plow	0.1		0.1	0.1		0.15
Water mixing	+ 4 hrs	plow	0.25		0.2	0.2		0.25
Water mixing	0-4 hrs	harrow	0.2		0.2	0.2		0.2
Water mixing	+ 4 hrs	harrow	0.3		0.25	0.25		0.25
Dry manure			0.04		0.1	0.04		0.1

Source: Morken and Nesheim (2004)

The factors in Table 5.25 are combined with data from the Sample survey of agriculture and forestry 2006 (Statistics Norway 2007) 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 5.26). These factors are, in turn, connected to activity data that is 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 culvation of the areas where the manure is spread.

Table 5.26 Average NH_3 emission factors for cultivated fields and meadows after time of spreading and region. 2016. Per cent of ammonium N.

	South-Eastern Norway		**Hedmark/ Oppland**		**Rogaland**		**Western Norway**		**Trøndelag**		**Northern Norway**	
	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow
Spring	15.9	40.0	21.0	42.3	4.0	38.6	4.0	43.2	21.6	42.4	7.7	42.6
Autumn	17.6	28.9	20.3	30.7	10.0	27.8	10.0	31.4	25.3	30.8	13.2	31.0

Source: Statistics Norway, NH_3 estimations.

NO_X

The tier 1 default emission factor of 0.04 kg NO_2/kg fertilizer-N applied ((EEA 2016)) has been used.

5.6.1.3 Sewage sludge applied to soils, 3Da2

Methodological issues

N_2O

IPCC Tier 1 methodologies and default emission factors (IPCC 2006) are used for estimating direct N_2O emissions from managed soils.

Data for the N_2O emission arising from sewage sludge applied on fields has been calculated by multiplying the amount of nitrate in the sewage sludge applied with the IPCC default emission factor.

NH_3

To calculate NH_3 emissions from sewage sludge used as fertiliser, the total N in sewage sludge is multiplied by $frac_{gasm}$. $Frac_{gasm}$ is volatilised N in animal manure applied and dung and urine deposited by grazing animals as fraction of total N in the manure applied and dung and urine deposited (kg NH_3–N + NO_X–N)/(kg N applied or deposited).

NO_X

The sum of all nitrogen applied to soil has been multiplied with the default tier 1 emission factor to estimate the nitric oxide emission from crop production. Thereafter the amount of NO is translated to amount of NO_2.

Activity data

N_2O, NH_3 and NO_X

Statistics Norway (waste water statistics) annually gives values for the amount of sewage sludge, and the fraction of the sewage sludge that are applied on fields. The N-content in the sludge is given in Statistics Norway (2001), and the same value of 2.82 per cent is used for all years.

Emission factors

N_2O

The IPCC default emission factor of 0.01 kg N_2O-N/kg N applied (IPCC 2006) has been used.

NH_3

The estimated national volatilization fractions ($frac_{gasm}$) have differed between 14-15 per cent since 1990.

NO_X

The tier 1 default emission factor of 0.04 kg NO_2/kg fertilizer-N applied (EEA 2016) has been used.

5.6.1.4 Other organic fertilizers applied to soils, 3Da2

Methodological issues

N_2O

Emissions of N_2O from other organic fertilisers applied to soils are estimated by multiplying estimated amounts of N in organic fertilisers with the IPCC default emission factor for N applied to agricultural soils.

NH_3

Emissions of NH_3 from other organic fertilisers applied to soils are estimated by multiplying estimated amounts of N in organic fertilisers with the $frac_{gasm}$ -factor. $Frac_{gasm}$ is volatilised N in animal manure applied and dung and urine deposited by grazing animals as fraction of total N in the manure applied and dung and urine deposited (kg NH_3–N + NO_X–N)/(kg N applied or deposited)

NO_X

The amount of nitrogen in other organic fertilisers applied to soil has been multiplied with the default tier 1 emission factor to estimate the nitric oxide emission from crop production. Thereafter the amount of NO is translated to amount of NO_2.

Activity data

N_2O, NH_3 and NO_X

The annual amount of nitrogen in other organic fertilisers applied in agriculture during the period 1990-2013 was assessed in 2014 (Aquateam COWI AS 2014). Other organic fertilizer consists of compost and organic fertilizer from composting and biogas plants based on food waste, in addition of meat and bone meal (PAP) and sludge from land based aquaculture facility in agriculture. This was a practically non-existent source of nitrogen before 2000. Since then, it has varied over the years. One important reason for the inter-annual variations is changes in regulations for the usage of meat and bone meal as fertilizer on agriculture land, which has resulted in significant inter-annual variations.

This is a small emission source, emissions in 2015 were estimated to less than 0.01 ktonnes N_2O, or approx. 0.005 % of total GHG emissions.

Emission factors

N_2O

The IPCC default emission factor of 0.01 kg N_2O-N/kg N applied (IPCC 2006) has been used.

NH_3

The estimated national volatilization fractions have differed between 14-15 per cent since 1990.

NO_X

The tier 1 default emission factor of 0.04 kg NO_2/kg fertilizer-N applied (EEA 2016) has been used.

5.6.1.5 Urine and dung deposited by grazing animals, 3Da3

Methodological issues

N_2O

The fraction of the total amount of animal manure produced that is droppings on pastures is given by national data for the distribution of manure to different storage systems and data for pasture times (Table 5.14). The amount of N deposited during grazing is multiplied with the IPCC default emission factor (IPCC 2006).

NH_3

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.

Activity data

N_2O and NH_3

Data for time on pasture and share of animals on pasture are collected from the Sample Survey in Statistics Norway 2001 (Statistics Norway 2002) and from TINE BA (TINE BA Annually). The data from TINE BA comprises pasture data for goats and milking cows. All other pasture data is from the Sample survey 2001 (Statistics Norway 2002).

How the amount of nitrogen in animal manure and the fraction of nitrogen amount that goes to pasture is estimated is further described in section 5.3 and 5.5.1. How the animal population is estimated is described in Section 5.2 and Annex IX.

Emission factors

N_2O

The emissions of N_2O from animals on pastures are calculated using the IPCC default emission factors of 0.02 kg N_2O-N/kg N for cattle, poultry and pigs, and of 0.01 kg N_2O-N/kg N for other animal groups (IPCC 2006).

NH_3

The emission factors used for the calculation of the NH_3 emissions from grazing animals are shown in Table 5.27. These are the same as the emission factors used in Germany (Dämmgen et al. 2002) and Denmark (Hutchings et al. 2001).

Table 5.27 Ammonia emission factors from droppings from grazing animals on pasture. Per cent of ammonium N.

	N-loss/N applied
Cattle	7.5
Sheep and goats (from 2013 sheep only[1])	4.1
Reindeer	4.1
Other animals (from 2013 including goat[1])	7.5

[1] Goats are grouped with sheep in the 2000 survey, and with horses in the 2013 survey

Source: Dämmgen et. al.(2002), Hutchings et. al. (2001)

5.6.1.6 N_2O from crop residues, 3Da4

Methodological issues

N_2O emissions associated with crop residue decomposition are estimated using the IPCC tier 1 approach (IPCC 2006) but with some national factors. Some country specific factors are given for fraction of dry matter, fraction of total area that is renewed annually, ratio of above-ground and below ground residues to harvested yield, N content of above-ground and below-ground residues and fraction of above ground residues removed from the field. The national factors are documented in Grønlund et al. (2014). In the development of national factors, residues from perennial grass and grass-clover mixtures were prioritized, in addition to the cereal species; wheat, barley and oats, which combined constitute about 85 percent of the total agricultural crop residues. For other productions, the IPCC default factors (IPCC 2006) are assumed to be sufficiently representative.

The factors were calculated from the sale statistics for clover seeds, area statistics of meadows of different age classes, area statistics of renewed meadow, and research results on clover and N content in meadow, and yield and N content of straw in Norway.

Based on area statistics on renewed meadows the $Frac_{Renew}$ has been estimated to 0.1.

About 75 percent of the meadows have been renewed with a mixture of grass and clover seeds, but only about 55 percent of 1 and 2 year old meadow areas can be considered as grass-clover mixtures with more than 5 percent clover. The mean clover share in the grass-clover mixtures has been estimated to about 20 percent. The clover share is lower in older meadow, but the content in the first years is more representative for the total crop residues produced during the lifetime of the meadow.

Above-ground crop residues contain both leaves and stubbles, while below ground residues are assumed to contain only roots. The N contents of above-ground and below-ground crop residues (N_{AG} and N_{BG}) have been estimated to 0.015 and 0.011 respectively for meadow without clover and 0.019 and 0.016 respectively for meadow with 20 percent clover share. A possible higher clover share in the beginning of the 1990s has not had a significant influence on N fractions of grass-clover mix in meadows.

Straw harvested for purposes as feed, beddings and energy ($FRAC_{Remove}$) has been estimated to 0.13 of the total straw production.

For wheat, barley and oats the ratio of above-ground residues (straw) to harvested grain yield (R_{AG}) has been estimated to 0.95, 0.76 and 0.92 respectively, and the N fraction in the straw (N_{AG}) has been estimated to 0.0042, 0.005 and 0.033 respectively (Grønlund et al. 2014). The fraction of crop residue burned on field was updated in 2012 by the Norwegian Agricultural Authorities[26]. This reduced the fraction for 2011 from 7.5 to 4 per cent.

$$F_{CR} = \sum_T \left[Crop_{(T)} * Frac_{DM(T)} * \left(1 - Frac_{BURN(T)}\right) * Frac_{RENEW(T)} * \left[R_{AG(T)} * N_{AG(T)} * (1 - Frac_{REMOVE(T))}) + R_{BG(T)} * N_{BG(T)} \right] \right]$$

F_{CR} = N in crop residue returned to soils (tonnes)

$Crop_T$ = Annual crop production of crop (tonnes)

$Frac_{DM}$ =Dry matter content

$Frac_{BURN}$ = Fraction of crop residue burned on field

$Frac_{RENEW}$ (T) = fraction of total area under crop T that is renewed annually

RAG(T) = ratio of above-ground residues dry matter (AGDM(T)) to harvested yield for crop T (kg d.m.)$^{-1}$,

NAG(T) = N content of above-ground residues for crop T, kg N (kg d.m.) $^{-1}$

[26] Johan Kollerud, Norwegian Agricultural Authorities, unpublished material 2012.

$Frac_{REMOVE}$ = Fraction of crop residue removed for purposes as feed beddings and energy

RBG(T) = ratio of below-ground residues to harvested yield for crop T, kg d.m. (kg d.m.)$^{-1}$

NBG(T) = N content of below-ground residues for crop T, kg N (kg d.m.)$^{-1}$

Table 5.28 Factors used for the calculation of the nitrogen content in crop residues returned to soils.

	Share of meadows	**$Frac_{DM}$**	**$Frac_{RENEW}$**	**R_{AG}**	**N_{AG}**	**$Frac_{REMOVE}$**	**R_{BG}**	**N_{BG}**
Perennial grasses	0.45	0.9	0.1	0.3	0.015	0	1.04	0.011
Grass-clover mixtures	0.55	0.9	0.1	0.3	0.019	0	1.04	0.013
Wheat		0.85	1	0.95	0.0042	0.13	0.47	0.009
Rye		0.85	1	1.1	0.005	0.13	0.46	0.011
Rye wheat		0.85	1	1.09	0.006	0.13		0.009
Barley		0.85	1	0.76	0.005	0.13	0.39	0.014
Oats		0.85	1	0.92	0.0033	0.13	0.48	0.008
Rapeseed		0.85	1	1.1	0.006	0.15	0.46	0.009
Potatoes		0.22	1	0.1	0.019	0	0.22	0.014
Roots for feed		0.22	1	0.1	0.019	0		0.014
Green fodder (non-N fix)		0.9	1	0.3	0.015	0	0.70	0.012
Vegetables		0.22	1	0.1	0.019	0	0.22	0.014
Peas		0.91	1	1.1	0.008	0	0.40	0.008
Beans		0.91	1	1.1	0.008	0	0.40	0.008

Source: Grønlund et al. (2014)

Activity data

As activity data for the estimations of emissions of N_2O from crop residues are annual crop yield statistics from Statistics Norway used.

Emission factors

The IPCC default emission factor of 0.01 kg N_2O-N/kg N applied (IPCC 2006) has been used.

5.6.1.7 N_2O from mineralization/immobilization associated with loss/gain of soil organic matter, 3Da5

Methodological issues

Cropland remaining cropland result in positive SOC stock changes in the mineral soil pool; thus no N_2O emissions are reported from this sub-category. For more information, see NIR Chapter 6.13 Direct N_2O from N mineralization and immobilization – 4(III).

5.6.1.8 N_2O from cultivation of organic soils, 3Da6

Methodological issues

Large N_2O emissions occur as a result of cultivation of organic soils (histosols) due to enhanced mineralization of old, N-rich organic matter (IPCC 2006). The emissions are calculated using the IPCC default emission factors, and an estimation of the area of cultivated organic soil in Norway.

Activity data

The area estimate of cultivated organic soils is given from the Norwegian Institute of Bioeconomy Research (NIBIO) and are consistent with the area used in the LULUCF sector and includes all areas with organic soils of cropland remaining cropland, grassland remaining grassland, land converted to cropland and land converted to grassland. More information about the methodology used for estimation of this area is given in the LULUCF Chapter 6.3.2.

Emission factors

Emissions occurring as a result of cultivation of organic soils are calculated using the IPCC default emission factor of 13 kg N_2O-N/ha per year for cropland and 9.5 kg N_2O-N/ha per year for grassland (IPCC 2014b).

5.6.1.9 Indirect N_2O emissions from atmospheric deposition, 3Db1

Methodological issues

Atmospheric deposition of nitrogen compounds fertilises soils and surface waters, and enhances biogenic N_2O formation. Deposition of nitrogen are assumed to correspond to the amounts of NH_3 and NO_X that volatilises during the spreading of synthetic fertilisers, manure, sewage sludge and other organic fertilisers, and NH_3 volatilisation from pastures. The N_2O emissions are calculated by multiplying the amount of N from deposition with the IPCC default emission factor (IPCC 2006).

Activity data

Information about the estimation of NH_3 and NO_X from spreading of synthetic and organic fertilisers and the estimation of NH_3 volatilisation from pastures are given in NIR section 5.6.1.1- 5.6.1.5.

Emission factors

N_2O

The IPCC default emission factor of 0.01 kg N_2O-N/(kg NH_3-N+NO_X-N volatilized) (IPCC 2006) is used to calculate indirect emissions of N_2O from volatilized NH_3 and NO_X.

5.6.1.10 Indirect N_2O emissions from leaching and run-off, 3Db2

Methodological issues

A considerable amount of fertiliser nitrogen is lost from agricultural soils through leaching and run-off. Fertiliser nitrogen in ground water and surface waters enhances biogenic production of N_2O as the nitrogen undergoes nitrification and denitrification. The fraction of the fertiliser and manure nitrogen lost to leaching and surface runoff may vary depending on several factors. A default value of 30 per cent is proposed (IPCC 2006), but in the Norwegian inventory a national factor of 22 per cent

is used as that is believed to give better results under Norwegian conditions (Bechmann et al. 2012). This estimation was based on data from the Agricultural Environmental monitoring program (JOVA). The overall $Frac_{leach}$ estimated in this study was 22 % of the N applied. This value is a median of $Frac_{leach}$ for every year during the monitoring period and for each of eight catchments with different production systems. The JOVA-program includes catchment and field study sites representing typical situations in Norwegian agriculture with regard to production system, management, intensity, soil, landscape, region and climate. Data from plot-scale study sites confirmed the level of N leaching from the agricultural areas within the JOVA catchments. The amount of nitrogen lost to leaching is multiplied with the IPCC default emission factor to calculate the emission of N_2O (IPCC 2006).

Nitrogen sources included are inorganic fertilisers, manure, sewage sludge and other organic fertilisers spread on fields, crop residues, and droppings from grazing animals.

Activity data

Information about the estimation of the nitrogen amounts from spreading of synthetic and organic fertilisers and from pastures and crop residues are given in NIR section 5.6.1.6.

Emission factors

N_2O

The IPCC default emission factor of 0.075 kg N_2O-N/kg N lost to leaching/runoff is used (IPCC 2006).

5.6.2 Uncertainties and time-series consistency

5.6.2.1 Activity data

There are several types of activity data entering the calculation scheme:

Sales of nitrogen fertiliser: The data is based on sales figures during one year (The Norwegian Food Safety Authority). The uncertainty in the sales figures is within ±5 per cent (Rypdal & Zhang 2000). In addition, there is a possible additional 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.

Amount of nitrogen in manure: The figures are generated for each animal type, by multiplying the number of animals with a nitrogen excretion factor. The nitrogen excretion factors are uncertain. However, due to monitoring of nitrogen leakage in parts of Norway, the certainty has been improved over time. The range is considered to be within ±15 per cent (Rypdal & Zhang 2000). 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 NH_3 emissions: The data is based on national figures for NH_3 emission from agriculture. These are within ±30 per cent (Rypdal & Zhang 2000)

Leakage of nitrogen: The upper limit for the leakage is the applied nitrogen. The uncertainty is roughly about ±70 per cent (Rypdal & Zhang 2000).

5.6.2.2 Emission factors

N_2O

Uncertainty estimates used for the N_2O emission factors are given in Annex II.

NH_3

The uncertainty in the estimate of NH_3 emissions from use of fertiliser is assessed to be about ±20 per cent (Rypdal & Zhang 2001). This uncertainty could be lower if better data on fertiliser composition were obtained. The uncertainty is higher for animal manure, ±30 per cent (Rypdal & Zhang 2001). This is due to uncertainties in several parameters including fraction of manure left on pastures, amount of manure, conditions of storage, conditions of spreading and climate conditions (Rypdal & Zhang 2001). Other factors that could lead to uncertainness are variation in storage periods, variation in house types and climate, and variation in manure properties.

5.6.3 Category-specific QA/QC and verification

In a Nordic project in 2002, the estimates for emissions of direct and indirect N_2O from agricultural soils in the national emission inventories have been compared with the results using the IPCC default methodology and the IPCC default factors. The results for the Nordic countries are presented in a report (Petersen & Olesen 2002).

Statistics Norway, in cooperation with the Norwegian University of Life Sciences (NMBU), made in 2003 improvements in the calculation model for ammonia emissions from the agricultural sector. Data sources used for the recalculations in the revised NH_3 model are coefficients from the Norwegian University of Life Sciences, and two surveys from Statistics Norway; a manure survey (Gundersen & Rognstad 2001) and the sample survey of agriculture and forestry 2001 (Statistics Norway 2002). Data from the manure survey of 2013 was implemented in the estimations of N_2O and CH_4 emissions from manure in the 2015 submission (Gundersen & Heldal 2015).

In 2006, the methodology used for estimating N_2O 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 2014, the methodology was further enhanced with emphasis on nitrogen in residues in grass and in grain production (Grønlund et al. 2014).

In the 2015 submission, the area of cultivated organic soils has been revised back to 1990 based on an assessment by the Norwegian Institute of Bioeconomy Research. The new area estimates better reflect the land use changes measured in the national forest inventory. In connection with the implementation of the 2006 IPCC guidelines in the 2015 submission, the emission factor was

reassessed and the Nordic factor of 13 kg N_2O-N/ha cropland and 9.5 kg N_2O-N/ha grassland was implemented.

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_2O emissions from use of nitrogen fertiliser is based on sales figures for each year. To correct for this, a transfer of fertiliser from 2008 to 2009 was made in the calculations.

New factors for nitrogen excretion from animals and a revision of animal statistics has been made in 2012, to better reflect the actual nitrogen excretion from each animal category and to have a more correct linkage between the nitrogen excretion factors used and the different animal categories.

In the project in 2012, when the Norwegian University of Life Sciences (NMBU) updated the Norwegian nitrogen excretion factors for the different animal species, comparisons were made with the corresponding factors used in Sweden, Denmark and Finland and with IPCC default factors as a verification of the Norwegian factors (Karlengen et al. 2012).

A new $Frac_{leach}$ factor was estimated in a study by Bioforsk (Norwegian Institute for Agricultural and Environmental Research) in 2012 (Bechmann et al. 2012). The updated factor is based on data from the Agricultural Environmental monitoring program (JOVA).

A project with the aim to revise the Norwegian CH_4 conversion factors (MCF) for the manure storage systems in use was conducted at the Norwegian University of Life Sciences (NMBU) in 2013. The maximum CH_4 producing capacity (B_o) was also revised for cattle manure.

An update of the manure distribution between different manure management systems has been made for the N_2O emissions estimates based on the results of a survey conducted by Statistics Norway in 2013-2014 (Gundersen & Heldal 2015). Data from the manure survey of 2013 was implemented in the estimations of N_2O and CH_4 emissions from manure in the 2015 submission, and in the 2016 submission for NH_3.

5.6.4 Category-specific recalculations

In the 2017 submission, the interpretation of the how the categories in the Norwegian manure survey of 2013 complies with the IPCC categories of MMS was revised. A large fraction of the manure was therefore redefined from “Pit storage below animal confinement” to “Liquid / slurry with cover”. Due to different emission factors for these categories of MMS, the emissions of N_2O increased, while the emissions of CH_4 decreased. Measured as CO_2 eq., the total change was very little. In the 2018 submission, the same fraction that was redefined in 2017 for horses, sheep and goat was changed back to “pit storage” since the manure from these animals should be considered dry rather than liquid.

See chapter 10 for more details.

5.6.5 Category-specific planned improvements

The emission estimation methodology for this source category is currently undergoing improvement, see Table 10.9.

Norway uses a country-specific model to calculate NH_3 emissions from manure management. The model calculates emissions at county level and is complicated to update. There is a need to review the model to make it better fit the requirements for inventory reporting purposes, and to be able to keep the time series updated and consistent. There is also a need to review the emission factors used in the model. Changes in the calculation model for NH_3 are expected to also result in some changes in the estimations of indirect N_2O from atmospheric deposition.

5.7 Emissions from field burning of agricultural residues – 3F

5.7.1 Category description

Burning of agricultural residues gives emissions of standard non-fossil combustion products. The source contributes with 0.1 per cent of the agricultural greenhouse gas emissions, and the trend has been decreasing with 90 per cent since 1990.

5.7.1.1 Methodological issues

CH_4, N_2O

Emissions from the burning of crop residues are being calculated in accordance with a Tier 1 approach (EEA 2013):

$E_{Pollutant} = AR_{residue\_burnt} * EF_{Pollutant}$

$E_{Pollutant}$ = emission (E) of pollutant

$AR_{residue\_burnt}$ = activity rate (AR), mass of residue burnt (dry matter)

$EF_{Pollutant}$ = emission factor (EF) for pollutant

5.7.1.2 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 ($Frac_{BURN}$) made by the Norwegian Crop Research Institute and Statistics Norway (chapter 5.6.1.6). For cereals, a water content of 15 per cent is used (Statistics Norway). The activity data is consistent with the data used in the estimations of N_2O from crop residues.

5.7.1.3 Emission factors

Table 5.29 Emission factors for agricultural residue burning.

Components	Emission factors	Unit	Source
CH_4	2.7	kg/ tonnes crop residue (d.m.) burned	(IPCC 2006)
N_2O	0.07	kg/ tonnes crop residue (d.m.) burned	(IPCC 2006)

5.7.2 Uncertainties and time-series consistency

Uncertainty estimates are given in Annex II.

5.7.3 Category-specific QA/QC and verification

In 2002, the emissions of CH_4 and N_2O, from agricultural residual burning were included in the Norwegian inventory. The time series were included, but it should be noted that the figures for the earlier years have a higher uncertainty than the more recent years. The amount of crop residues burned in Norway has been investigated by questionnaires in 2004 and 2012.

5.7.4 Category-specific recalculations

There have been no recalculations performed for this source category this year.

5.7.5 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

5.8 Emissions from liming – 3G (Key category for CO_2)

5.8.1 Category description

Liming of agricultural soils and lakes gives emissions of CO_2. The source contributed with about 2 per cent of the agricultural greenhouse gas emissions in year 2016, and the emissions has decreased with 65 per cent since 1990.

CO_2 emissions from liming is key category according to Tier 1 key category analysis.

It is common to lime Norwegian soils because of the low buffer capacity of most soils. The use of limestone is more popular than dolomite. Also, for several years many lakes in the southern parts of Norway have been limed to reduce the damages from acidification. Estimated emissions from liming on agricultural lands have reduced since 1990, whereas liming of lakes has been relatively constant.

5.8.1.1 Methodological issues

A Tier 1 method was used with specific emission factors for limestone and dolomite.

5.8.1.2 Activity data

Statistics on consumption of liming applied to agricultural soils are derived from the Norwegian Food Safety Authority. The statistics are based on reports from commercial suppliers of lime. The amount of lime applied to lakes was collected from the Norwegian Environment Agency. It was not possible to separate the amount of lime originating as limestone or dolomite for lakes for the whole time-series.

5.8.1.3 Emission factors

The default emission factor values provided by IPCC are 0.12 Mg CO_2-C Mg^{-1} for limestone and 0.13 Mg CO_2-C Mg^{-1} for dolomite. For limestone this is equal to emissions of 0.44 Mg CO_2 per Mg $CaCO_3$ applied. The emission factors are based on the stoichiometry of the lime types.

For emissions estimates for liming on lakes, the emissions factor for limestone is used (0.12 Mg CO_2-C Mg^{-1}), as only the total amount of lime was available.

5.8.2 Uncertainties and time-series consistency

The amount of limestone and dolomite used is expected to be known with an uncertainty on ±5 percent and the emission factor with an uncertainty of ±10%.

5.8.3 Category-specific recalculations

There have been no recalculations performed for this source category this year.

5.8.4 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

5.9 Emissions from urea application – 3H

5.9.1 Category description

Urea application on agriculture soils is a minor source of CO_2 emissions in the inventory and contributes with less than 0.01 per cent of the agriculture greenhouse gas emissions in 2016.

5.9.1.1 Methodological issues

Application of urea results in an emission of CO_2. Norway uses a Tier 1 methodology.

Annual CO_2 emissions from urea fertilisation are estimated according to equation 11.13 (IPCC 2006):

CO_2–C Emission = M • EF,

where:

CO_2–C Emission = annual C emissions from urea application, tonnes C yr^{-1}

M = annual amount of urea fertilisation, tonnes urea yr^{-1}

EF = emission factor, tonne of C (tonne of urea)$^{-1}$

5.9.1.2 Activity data

Amount of urea used is received from Norwegian Food Safety Authority annually; total sale of synthetic fertiliser, and is the same figure for the amount of urea used in the estimations of NH_3 from use of synthetic fertilisers. The amount used is very small, and consequently this is a very small source of CO_2 emissions.

5.9.1.3 Emission factors

The default emission factor of 0.20 is used (IPCC 2006).

5.9.2 Uncertainties and time-series consistency

Activity data

The uncertainty that applies to use of mineral fertilisers on ±5 percent are used.

Emission factor

Using the Tier 1 method, it is assumed all C in the urea is lost as CO_2 from the atmosphere. This is a conservative approach (IPCC 2006). No uncertainty estimate is found, and Norway uses an uncertainty of ±10%.

5.9.3 Category-specific recalculations

There have been no recalculations performed for this source category this year.

5.9.4 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6 Land-use, land-use change and forestry (CRF sector 4)

This chapter provides estimates of emissions and removals from Land Use, Land-Use Change and Forestry (LULUCF), documentation of the implementation of guidelines given in *2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006)* (hereinafter referred to as IPCC 2006 Guidelines), the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014a), and selected parts of the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands* (IPCC 2014b) (hereinafter referred to as IPCC 2013 Wetlands supplement).

All analyses in this chapter, except the key category analysis (Table 6.6), have been conducted by the Norwegian Institute of Bioeconomy Research (NIBIO).

6.1 Sector Overview

6.1.1 Emissions and removals

The LULUCF sector is unique compared to the other reported sectors in that it can function as both a source of atmospheric emissions through disturbance and decomposition of organic matter and a sink of emissions through the removal of atmospheric CO_2 by plants, fungi, and bacteria. The balance of the two is net emissions or removals in the LULUCF sector.

The LULUCF sector had a net removal of 24 356 kt CO_2-equivalents in 2016. These removals are substantial, and equal to approximately half of the total emissions from all other sectors than LULUCF in the Norwegian GHG accounting. The average annual net sequestration from the LULUCF sector was about 22 175 kt CO_2-equivalents per year for the period 1990-2016.

Forest land is responsible for the vast majority of the CO_2 removals in the sector. In 2016 the net removals were 28 827 kt CO_2-equivalents (Figure 6.1). Wetlands also serve as a net sink in some years, due to biomass sequestration in trees on such areas. However, in 2016, there were net emissions from wetlands of 21 kt CO_2-equivalents. Cropland was the land use category with the largest emissions in the beginning of the inventory period, with 1 828 kt CO_2-equivalents in 1990, and the emissions have increased to 2 039 kt CO_2-equivalents in 2016. The main source of emissions in the grassland category is organic soils, and the emissions are estimated to be 46 kt CO_2-equivalents in 1990 increasing to 196 kt CO_2-equivalents in 2016. Emissions from settlements have become about three times greater during the inventory period, with an increase from 688 kt CO_2-equivalents in 1990 to 2 113 kt CO_2-equivalents in 2016. This land use category is now responsible for the largest emissions of the six land use categories in the LULUCF sector. Emissions from other land were 0.95 kt CO_2-equivalents in 2016. The decay from the harvested wood products (HWP) pool has been larger than the input to the pool since 2009. In 2016, the emissions from HWP were 85 kt CO_2, a reduction by 127 kt CO_2 since last year.

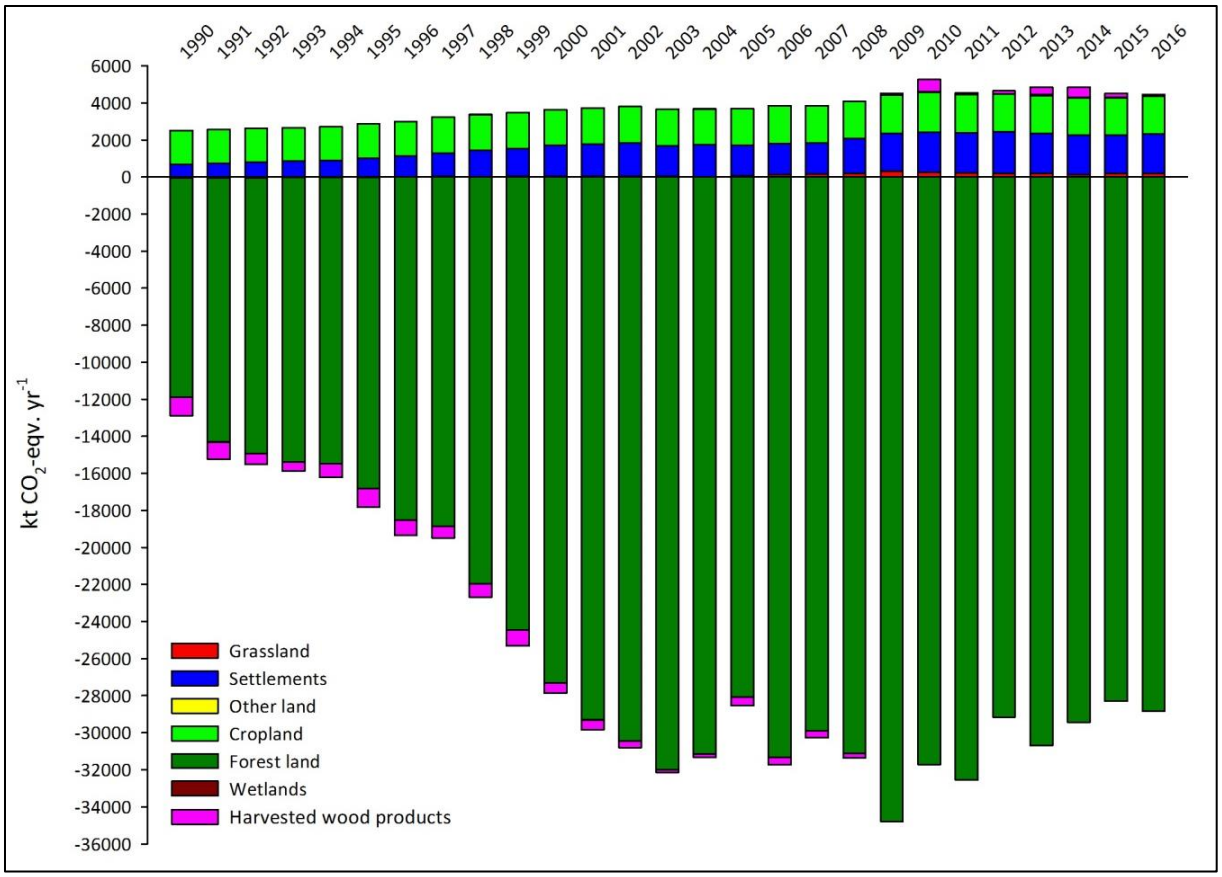


Figure 6.1 Net CO_2 emissions and removals (kt CO_2-equivalents per year) from the LULUCF sector by land-use category (forest land, cropland, grassland, wetlands, settlements, other land, and harvested wood products) from 1990 to 2016, including emissions of N_2O and CH_4. Source: Norwegian Institute of Bioeconomy Research.

Forest land was the major contributor to the net sequestration of CO_2 in the sector. In 2016, the total net removals from forest land were 29 226 kt CO_2 (Figure 6.2). Emissions from forest land occurred primarily from organic soils (734 kt CO_2 from organic soils on forest land remaining forest land and land converted to forest land). Mineral soil constituted a removal of 61 kt CO_2. Living biomass was the primary contributor to sequestration with 74 % (21 519 kt CO_2) of the total removals for forest land remaining forest land. The dead wood and litter pools contributed 5 % (1 332 kt CO_2) and 24 % (7 049 kt CO_2) to the total C sequestration on forest land remaining forest land, respectively. Land converted to forest land contributed with removals of 524 kt CO_2, primarily due to sequestration in living biomass and the litter pool.

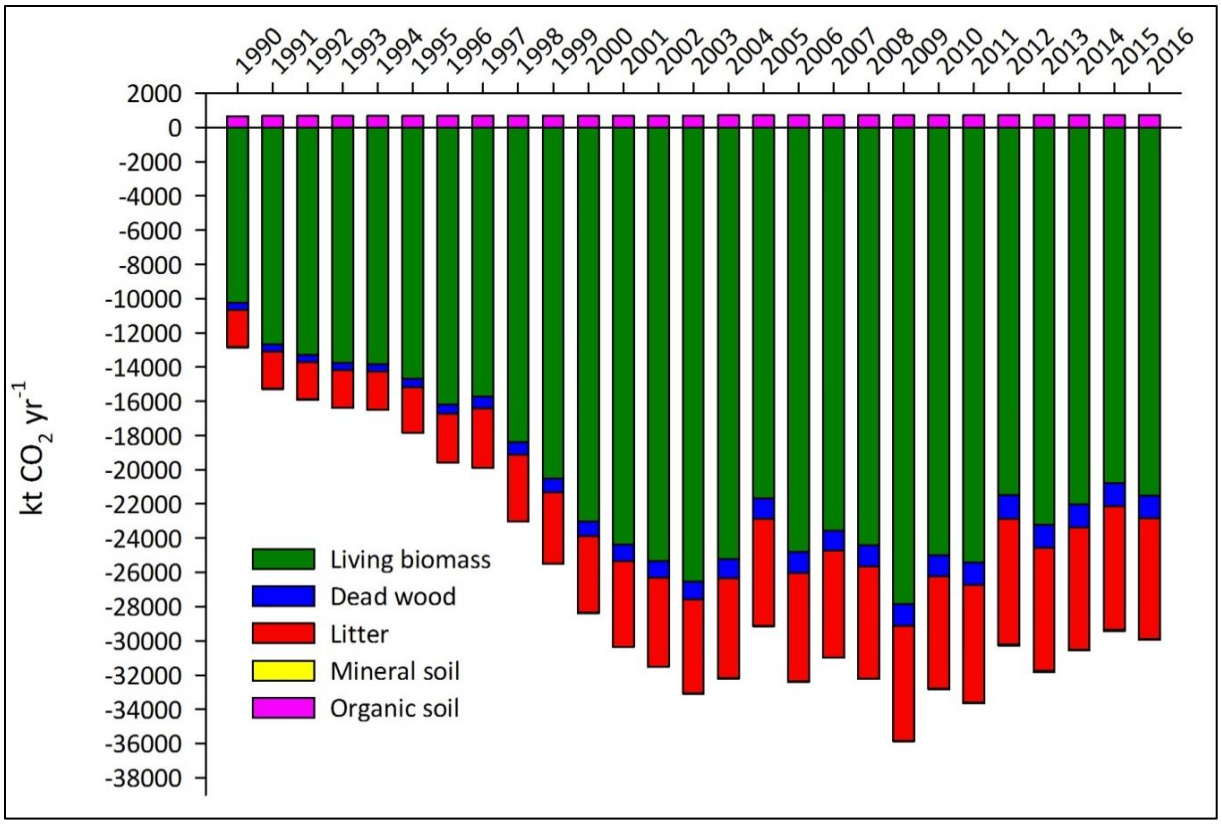


Figure 6.2 Emissions and removals of CO_2 on forest land from organic and mineral soil, dead wood, litter, and living biomass, 1990–2016. Source: Norwegian Institute of Bioeconomy Research.

Since 1989, the carbon stocks in living biomass in the LULUCF sector have increased significantly by around 40 % (Table 6.1). This increase is mainly due to the increase in the growing stock on forest land (Figure 6.3).

Table 6.1 Carbon stocks in 1989 and 2014 and differences in C stocks compared to 1989 as a total for all land-use categories, including associated uncertainties. The estimates are based on the sample plots in the lowlands outside Finnmark (>16 000 plots). SE = standard error.

Year	C stock (kt)	C stock difference to 1989 (kt)	2 SE (%) of C stock difference to 1989
1989	316 823	-	-
2014*	444 198	127 375	6

**The estimates are based on the last five years sampled in the National Forest Inventory (2012-2016). The estimate is therefore valid for the mid-year 2014.*

Annual variation in CO_2 removals on Forest land

Forest land covers around one third of the mainland area of Norway, and is the largest land-use category that is considered managed. Other land is the largest land-use category irrespective of management status. The carbon stock in living biomass on forest land has increased throughout the inventory period (Figure 6.3).

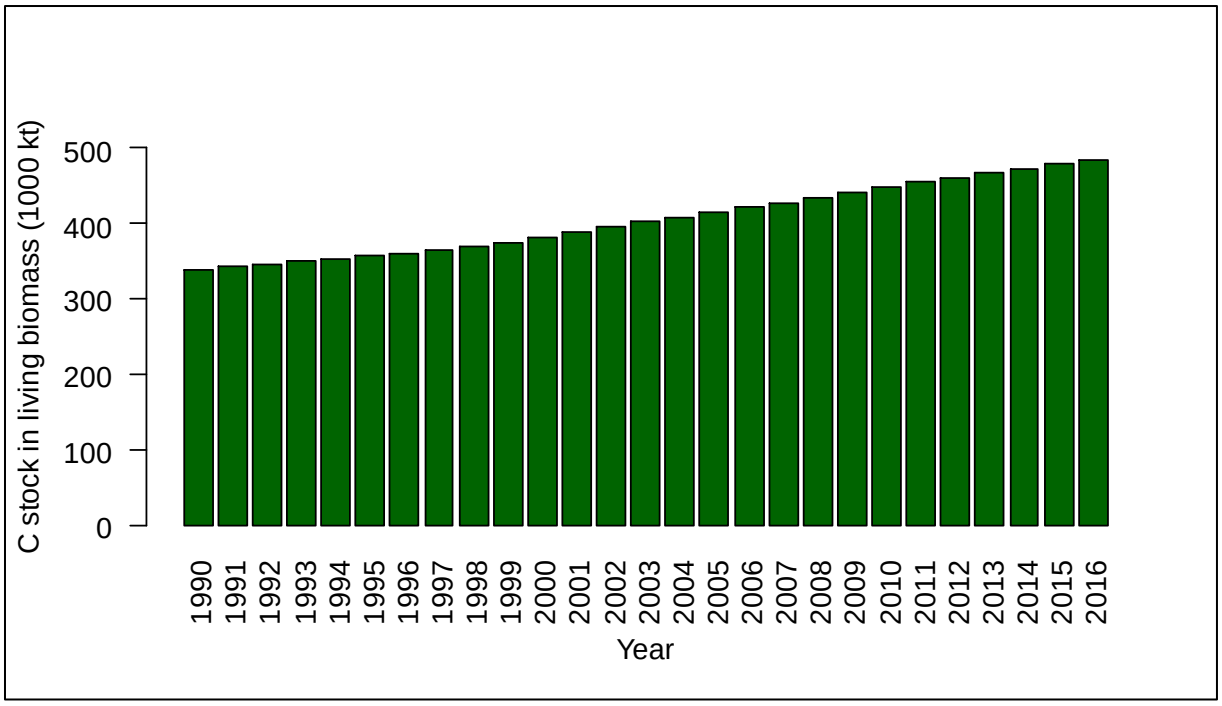


Figure 6.3 Development of the carbon stock in living biomass on forest land remaining forest land from 1990–2016. Source: Norwegian Institute of Bioeconomy Research.

The steady increase in carbon stock in living biomass is caused by several factors. One main factor is an active forest management policy over the last 60–70 years which resulted in increasing increment of timber volume (and biomass). The combination of the policy to rebuild the country after World War II and the demand for timber, led to a large national 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 a peak of more than 100 million planted annually in the 1960s. These trees are now at their most productive age and contribute to the increase in living biomass and hence the carbon stock. At the same time, levels of annual fellings are much lower than the annual increment, causing an accumulation of tree biomass (Figure 6.4). The number of planted trees has been decreasing since 1992, and since 2003, only about 20 million trees have been planted annually. The last few years, the number of planted trees has slightly increased, and in 2015 31 million trees were planted (Landbruksdirektoratet, 2017). The lower number of planted trees compared to the post-war decades, together with a changed age structure of the forest, may result in a relative decrease in biomass accumulation, and hence a decrease in the future carbon sequestration.

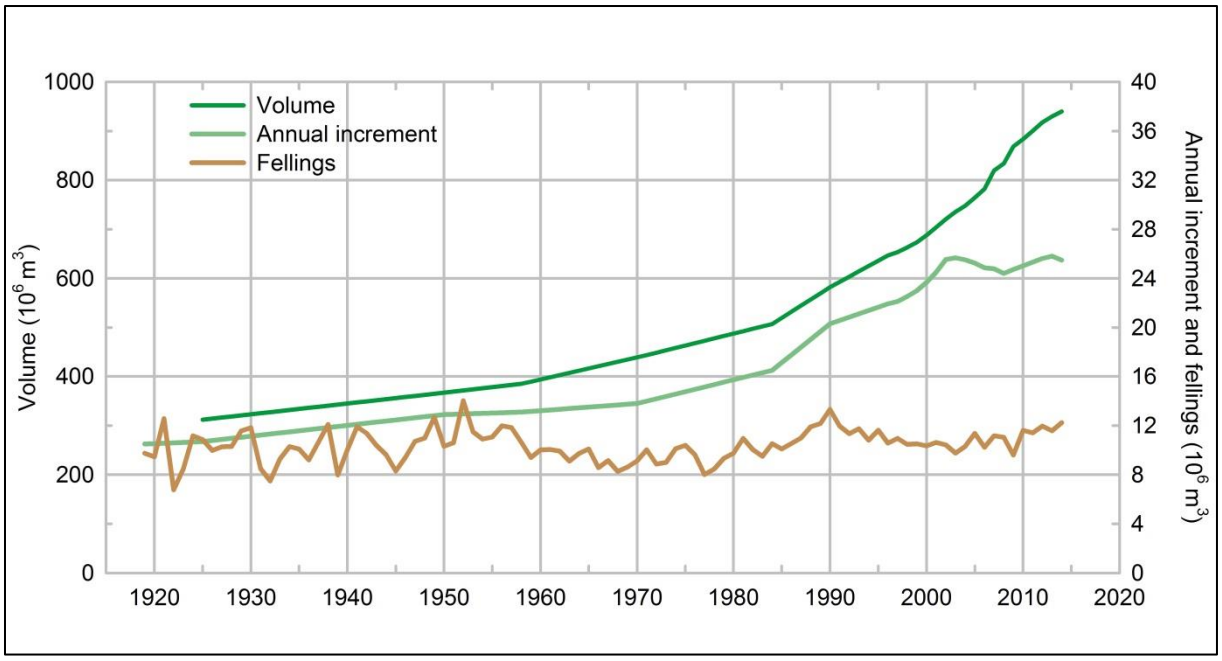


Figure 6.4 Forest fellings, annual increment and volume, 1919–2014. The 2014 value is the middle year in the National Forest Inventory cycle (2012-2016) for volume (without bark) and annual increment. Source: Norwegian Institute of Bioeconomy Research and Statistics Norway.

6.1.2 Activity data

The main data source used for the LULUCF sector is the National Forest Inventory (NFI). Data from the NFI is used to estimate the total areas of forest land, cropland, wetlands, settlements and other land, as well as the land-use transitions between these categories. Land area accounting for the inventory has been done according to an Approach 2, as described in chapter 3 of the IPCC Guidelines (IPCC 2006). The NFI data are also used to calculate changes of carbon stocks in living biomass and as input values for modeling changes in the carbon stock in dead organic matter (DOM) and mineral soil for forest land remaining forest land. DOM is the combined pool of litter and dead wood.

The NFI utilizes a 5-year cycle based on re-sampling of permanent plots. The sample plots are distributed across the country in order to reduce the periodic variation between years, and each year 1/5 of the plots are inventoried. The same plots are inventoried again after five years, and all plots are assessed during a 5 year period. The current system with permanent plots was put in place between 1986 and 1993, and made fully operational for the cycle covering the years 1994 through 1998. Because the re-sampling method was not fully implemented before 1994, the method used to calculate annual emissions and removals is not the same throughout the time-period, and the methods have been bridged. See section 6.3.1 for a detailed description of the method.

The annual changes in the C stock depend upon several factors, such as harvest levels and variable growing conditions due to temperature and precipitation. All these factors influence the reported annual changes of CO_2 removals from the atmosphere, but among these the harvest level is the most important.

The annual fluctuation seen in CO_2 sequestered from dead organic matter and soil are influenced by annual variation in the C input data to the Yasso07 model. Carbon input to the Yasso07 model is from standing biomass, dead organic matter from natural mortality, and harvest residues including stumps and roots from harvested trees. All these factors are influenced by the same natural and man-made factors as stated for living biomass and all cause annual changes.

The NFI data are complemented with auxiliary data for several other sink/source categories, e.g. horticulture, arable crop types, grassland management, synthetic N fertilization, drainage of forest soil, and forest fires. These data are acquired from Statistics Norway, the Norwegian Agricultural Authority, the Norwegian Food Safety Authority, the Norwegian Environment Agency, and The Directorate for Civil Protection and Emergency Planning. Detailed descriptions of these data are provided under their relevant emission categories.

6.1.2.1 Land-use changes 1990–2016

Net land-use changes in Norway from 1990 to 2016 have been very small. Only the area of settlements has increased slightly, while the other land-use categories have decreased or remained constant (Figure 6.5).

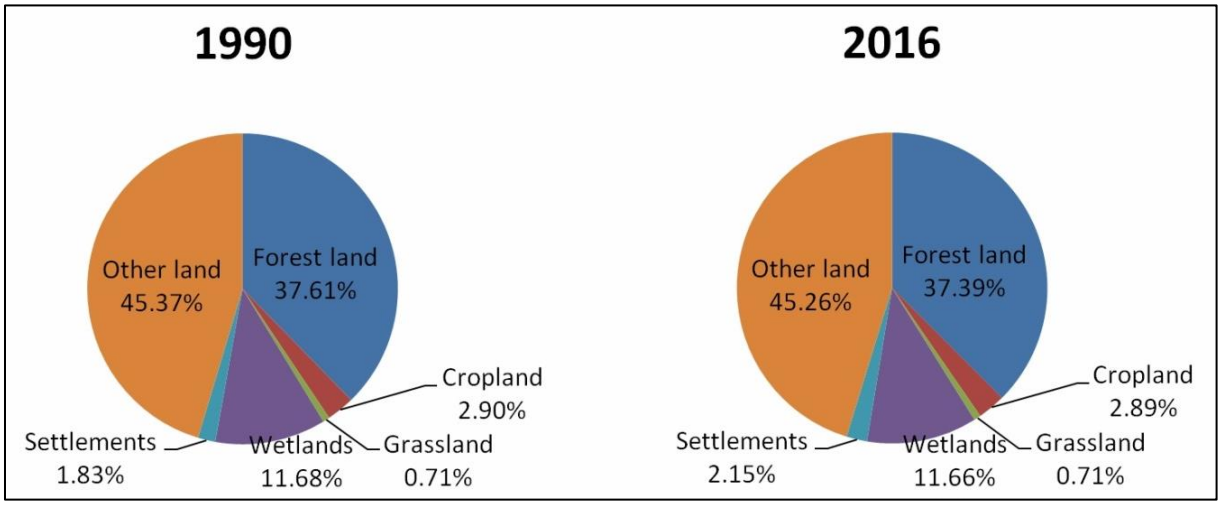


Figure 6.5 Area distribution of the IPCC land-use categories for 1990 and 2016.
Source: Norwegian Institute of Bioeconomy Research

The small land-use changes are also illustrated by the land-use conversion matrix for the whole inventory period from 1990 to 2016 (Table 6.2). A key finding from these data is that the changes in land-use from 1990 to 2016 are quite small; with approximately 0.8 % of the total land in a "land-conversion" category and the rest in a "remaining" category. The largest changes were in forest land and settlements. There have been land-use conversions from all categories to forest land and to settlements. Whereas the net area of settlements increased, the net area of forest land decreased. The classification of land-use change is almost directly transferable to the activities reported under the Kyoto Protocol, which is illustrated by the land-use matrix in Table 6.2. More details about the activities reported under the Kyoto Protocol, as well as the definition of human-induced land-use change, are given in chapter 11. Under the convention reporting we apply a 20-year transition

period, which means that areas reside in conversion classes for 20 years before they are transferred to the remaining class.

Table 6.2 Land-use change matrix for the IPCC land-use categories from 1990 to 2016. The 20 year transition period is ignored in this table, in order to give a full picture of all conversions that happened in the period. This results in differences to the specific area estimates in the CRF. The column Total here are nonetheless the same as the sum of lands to and remaining in a category reported in the CRF.*

	Land-use (kha)							
Year		**2016**						
	Land-use	**Forest land**	**Cropland**	**Grassland**	**Wetlands**	**Settlements**	**Other land**	**Total***
1990	**Forest land**	12052	20	28	4	100	0	12203
	Cropland	13	908	0	0	19	0	940
	Grassland	16	3	202	0	8	1	230
	Wetlands	11	5	1	3714	1	0	3731
	Settlements	22	2	1	0	561	0	586
	Other land	28	0	0	1	3	14656	14688
	Total*	12141	937	231	3719	691	14658	32378

**Differences of totals and column or row sums are due to rounding.*

6.1.3 Uncertainties

Uncertainties of area estimates are based on standard sampling methodology. The areas of the largest land-use categories, other land remaining other land and forest land remaining forest land, can be estimated with a precision (2 standard errors) of < 2 % (Table 6.3). Land-use changes are generally small in Norway. The largest change category is forest land converted to settlements. The uncertainty estimate for this area estimate is approximately 18 %. Due to the small number of NFI sample plots in several of the other land-use conversion categories, the relative size of the uncertainty estimates can be quite large. However, the absolute size of the uncertainty in those classes is nonetheless small.

The uncertainties of carbon stock change (CSC) estimates in living biomass in forest land, grasslands, wetlands, and other lands, were estimated as described in section 6.3. Estimated uncertainties are based on the sampling error. As for area estimates, the relative uncertainty estimates for CSC were quite large for small land-use categories, whereas their absolute size was comparably small (Table 6.3). For living biomass on cropland converted to settlements and settlements converted to croplands, the uncertainty was based on Tier 1 defaults. Uncertainty estimates for CSC estimates for the dead organic matter (DOM) pool were based on expert judgement by considering the uncertainty in the living biomass estimates.

Table 6.3 Uncertainties of living biomass and dead organic matter (DOM) pools shown as total aggregated uncertainty (U_{total}) based on the uncertainties of the carbon stock change (CSC) per hectare and the area estimates. Area uncertainty is for combined mineral and organic soils. See Table 6.4 for area uncertainty of mineral soils which is used to obtain the total uncertainty of DOM. 2 SE means two times the standard error.

Code	Land-use class	Area [a]	CSC	U_{total}	CSC	U_{total}
		2 SE %	Living biomass (2 SE %)		DOM (2 SE %)	
4A1	Forest land remaining forest land[b]	2	12	13	14	15
4A2	Cropland to forest land	51	70	87	100	117
4A2	Grassland to forest land	51	88	90	200	201
4A2	Other land to forest land	69	90	114	135	152
4A2	Settlements to forest land	40	67	78	100	108
4A2	Wetlands to forest land	55	108	121	100	136
4B1	Cropland remaining cropland[c]	0	75	75	NA	NA
4B2	Forest land to cropland	44	190	195	128	136
4B2	Grassland to cropland	125	NA	NA	NA	NA
4B2	Settlements to cropland	200	75	201	NA	NA
4B2	Wetlands to cropland	88	NA	NA	NA	NA
4C1	Grassland remaining grassland	13	115	116	NA	NA
4C2	Forest land to grassland	36	144	149	107	113
4C2	Wetlands to grassland	200	150	201	NA	NA
4D1	Wetlands remaining wetlands	5	39	39	NA	NA
4D2	Forest land to wetlands	101	134	168	182	201
4D2	Other land to wetlands	200	NA	NA	NA	NA
4E2	Cropland to settlements	46	75	88	NA	NA
4E2	Forest land to settlements	17	48	51	100	102
4E2	Grassland to settlements	71	150	168	NA	NA
4E2	Other land to settlements	136	NA	NA	NA	NA
4E2	Wetlands to settlements	123	150	195	19	200
4F2	Grassland to other land	201	NA	NA	NA	NA

[a] The area uncertainty is the same for living biomass and DOM. [b] Includes a safety margin for model errors of 1 percentage-points. [c]Area uncertainty of 0 % is based on SSB data and pertains to orchards. Total area uncertainty for cropland remaining cropland is 7% based on NFI estimates.

Uncertainties for mineral soil CSC factors on land-use conversion categories were assumed to be 50 % for conversions between forest land, cropland, and grassland. We assumed a lower uncertainty for these conversions than for the others because the SOC stocks were based on national measurements or national data of soil types applied to IPCC default values. For conversions to and from land-use classes, where SOC stock measurements were not available, we assumed the uncertainty to be 100 % (Table 6.4). Uncertainties in the C loss from drained organic soils were calculated using the error ranges supplied in the IPCC 2013 Wetlands supplement (IPCC 2014b) for all drained organic soils on cropland, grassland, forest land, and land under peat extraction. The uncertainty of the emission factors was then combined with the uncertainty of the area estimates determined by the sampling error. For two smaller classes (managed wetlands – peat extraction and orchards on croplands), the uncertainty of the area estimates is based on expert judgement as their

areas are not estimated by the NFI. The uncertainty in the soil type classification method, i.e. the inaccuracy of the soil maps, was ignored.

Table 6.4 Uncertainties of the mineral soil and drained organic soil pools shown as total aggregated uncertainty (U_{total}) based on the uncertainties of the carbon stock change (CSC) and the area estimates. 2 SE means two times the standard error.

Code	Land-use class	CSC	Area	U_{total}	CSC	Area	U_{total}
		Mineral soil (2 SE %)			Drained organic soil (2 SE %)		
4A1	Forest land remaining forest land [a]	16	2	19	41	50	65
4A2	Cropland to forest land	50	60	78	40	107	114
4A2	Grassland to forest land	50	50	71	NA	NA	NA
4A2	Other land to forest land	100	67	121	NA	NA	NA
4A2	Settlements to forest land	100	41	108	40	200	201
4A2	Wetlands to forest land	90	92	129	40	69	80
4B1	Cropland remaining cropland	50	7	51	19	25	32
4B2	Forest land to cropland	50	46	68	19	141	142
4B2	Grassland to cropland	50	125	135	NA	NA	NA
4B2	Settlements to cropland	100	200	201	NA	NA	NA
4B2	Wetlands to cropland	NA	NA	NA	19	88	90
4C1	Grassland remaining grassland	91	14	92	50	125	135
4C2	Forest land to grassland	50	36	62	NA	NA	NA
4C2	Wetlands to grassland	NA	NA	NA	50	200	201
4D1	Wetlands remaining wetlands [b]	NA	NA	NA	NA	NA	110
4D2	Forest land to wetlands	90	144	170	40	142	148
4D2	Other land to wetlands	100	200	201	NA	NA	NA
4E2	Cropland to settlements	100	46	110	NA	NA	NA
4E2	Forest land to settlements	100	18	102	19	66	70
4E2	Grassland to settlements	100	76	126	100	200	201
4E2	Other land to settlements	100	136	168	NA	NA	NA
4E2	Wetlands to settlements	90	151	176	19	200	201
4F2	Grassland to other land	100	201	201	NA	NA	NA

[a] Uncertainty for mineral soil on forest remaining forest is combined for litter, dead wood, and mineral soil.

[b] The sub-category peat extraction includes on-site and off-site emissions; specific uncertainties for areas and CSC are therefore not given.

Default uncertainty estimates were also used for N_2O and CH_4 emissions from drained organic soils, for direct and indirect N_2O emissions, and for biomass burning.

Table 6.5 Uncertainties of N_2O and CH_4 emissions for direct and indirect N_2O emissions and for drained organic soils shown as total uncertainty (U_{total}) based on the uncertainties of the emission factor (EF) and the activity data (AD). 2 SE means two times the standard error.

Code	Source	Land-use class	Gas	U_{total}	EF	AD
			2SE (%)			
4(I)	Direct N_2O from inorganic N inputs	Forest land	N_2O	201	200	20
4(I)	Direct N_2O from organic N inputs	Forest land	N_2O	206	200	50
4(I)	Direct N_2O from organic N inputs	Settlements	N_2O	201	200	20
4(II)	Drained organic soils	Forest land	N_2O	64	41	50
4(II)	Drained organic soils	Wetlands - Peat extraction	N_2O	151	113	100
4(II)	Drained organic soils	Cropland	CH_4	74	70	23
4(II)	Drained organic soils	Forest land	CH_4	180	173	50
4(II)	Drained organic soils	Grassland	CH_4	117	48	107
4(II)	Drained organic soils	Wetlands - Peat extraction	CH_4	128	NA	NA
4(III)	Direct N_2O	N mineralization/ immobilization	N_2O	224	200	100
4(IV)	Indirect N_2O from managed soils	Atmospheric deposition	N_2O	447	400	200
4(IV)	Indirect N_2O from managed soils	Leaching and runoff	N_2O	300	233	167
4(V)	Biomass burning	Wildfires in forest	N_2O	75	70	27
4(V)	Biomass burning	Wildfires in forest	CH_4	75	70	27

In the cases where the uncertainty of the activity data estimate was not derived from the NFI and the uncertainty of the CSC was based on expert judgment, the total uncertainty was derived by combining the two uncertainties. The specific methods and assumptions are described further for each of the sinks/sources under the sections of the individual land-use categories.

6.1.4 Key categories

A sink or source can be a key category either with respect to the level (size of the emission) or the trend (change in the size between 1990 and 2015). The key category analysis for the Norwegian inventory is performed by Statistics Norway. All of the reported sinks and sources were included in the analysis for the LULUCF sector. The CSC estimates for living biomass, dead organic matter (DOM), mineral soils and organic soils, were considered for each specific land-use conversion (e.g. forest land converted to cropland). The key category analysis was performed using an Approach 1 and Approach 2 approach for the whole greenhouse gas inventory.

From the analyses, 30 key categories were identified by both the Approach 1 and Approach 2 level analyses (Table 6.6). Forest land remaining forest land (FF) is the most important category in the LULUCF sector. Living biomass in FF is identified as the largest key category; followed by litter + dead wood + mineral soil; forest land converted to settlements DOM; and organic soil. Living biomass was also a key category for forest land converted to settlements, grassland or cropland, and for grassland converted to forest land. Carbon stock change estimates for dead organic matter (DOM) on all lands

converted from forest land, except for other land and wetlands, were also identified as key categories. CO_2 emissions from drained organic soils were a key category for the remaining categories for cropland, forest land, settlements, and peat extraction on-site and off-site emissions combined; N_2O and CH_4 emissions from drained organic soils on forest land, and CH_4 emissions from croplands were also key categories. For the mineral soil pools on land in conversions, forest conversion to grassland, settlements, and cropland were key categories, as were grassland converted to forest land and cropland converted to settlements. Forest land converted to settlements is an important land use change category (largest area change), and all four sources were determined as key categories. N_2O emission from mineralization and immobilization due to soil management is also a key category due to the inclusion of all land-use conversions. The sources that became key categories this year were dead organic matter on cropland, grassland, and settlements converted to forest land and living biomass on grassland remaining grassland. The sources no longer classified as key categories this year are living biomass on cropland converted to forest land and mineral soils on grassland remaining grassland.

Table 6.6 Approach 2 key category analysis results for the LULUCF sector showing level assessments for 1990 and 2016, and the trend assessment for 1990–2016. Key categories are indicated by bold values and the larger the value the more important is the key category.

Code	Sink/source category	Gas	Level assess 1990	Level assess 2016	Trend assess 1990–2016
4.A.1	Forest remaining forest - Living biomass	CO_2	**9.30**	**13.54**	**14.69**
4.A.1	Forest remaining forest - Litter + dead wood + Mineral soil	CO_2	**2.75**	**5.89**	**7.41**
4.E.2.1	Forest to Settlement - DOM	CO_2	0.30	**4.53**	**7.13**
4.B.1	Cropland remaining cropland - Organic soil	CO_2	**3.83**	**2.53**	**1.09**
4.A.1	Forest remaining forest, drained organic soils - Organic soil	CO_2	**2.97**	**2.17**	**1.19**
4.C.2.1	Forest to Grassland - DOM	CO_2	0.02	**1.87**	**3.03**
4.A.2.2	Grassland to Forest - DOM	CO_2	0.08	**1.48**	**2.35**
4.E.2.1	Forest to Settlement - Living biomass	CO_2	**1.48**	**1.30**	**0.95**
4.B.2.1	Forest to Cropland - DOM	CO_2	0.03	**1.26**	**2.02**
4.A.2.4	Settlement to Forest - DOM	CO_2	0.05	**1.13**	**1.81**
4.B.2.1	Forest to Cropland - Living biomass	CO_2	**0.70**	**1.05**	**1.16**
4(II)Forest	Forest remaining forest- drained organic soils (SSB)	N_2O	**1.26**	**0.98**	**0.59**
4.E.2.1	Forest to Settlement - Mineral soil	CO_2	0.05	**0.78**	**1.23**
4.C.2.1	Forest to Grassland - Living biomass	CO_2	0.32	**0.69**	**0.87**
4.E.2.1	Forest to Settlement - Organic soil	CO_2	.	**0.69**	.
4.C.2.1	Forest to Grassland - Mineral soil	CO_2	0.01	**0.64**	**1.03**
4.E.1	Settlements remaining settlements - Organic soil	CO_2	**0.91**	**0.61**	0.27
4.B.2.3	Wetland to Cropland - Organic soil	CO_2	.	**0.61**	.
4.C.1	Grassland remaining grassland - Living biomass	CO_2	**0.82**	**0.50**	0.17
4(II)Forest	Forest land drained organic soils	CH_4	**0.61**	**0.46**	0.27
4.A.2.1	Cropland to Forest - DOM	CO_2	0.04	**0.42**	**0.65**
4.B.2.1	Forest to Cropland - Organic soil	CO_2	0.05	**0.40**	**0.61**
4(III)	Direct N_2O from N mineralization/immobilization	N_2O	0.02	**0.38**	**0.60**
4.A.2.2	Grassland to Forest - Mineral soil	CO_2	0.02	**0.35**	**0.55**
4(II)Crop	Cropland - drained organic soil - Organic soil CC + LC	CH_4	0.45	**0.33**	0.18
4.D.1	Wetland Peat extraction - on+off-site - Organic soil	CO_2	**0.55**	0.33	0.09
4.A.2.2	Grassland to Forest - Living biomass	CO_2	0.02	0.31	**0.49**
4.E.2.2	Cropland to Settlement - Mineral soil	CO_2	0.02	0.25	**0.39**
4.B.2.1	Forest to Cropland - Mineral soil	CO_2	0.01	0.25	**0.40**
4G	Harvested wood Products - HWP	CO_2	**3.51**	0.21	**3.11**

6.1.5 Completeness

The following sources were not reported because they are not mandatory: carbon stock change in living biomass, DOM, and net carbon stock change in soils on flooded land remaining flooded land (CRF table 4.D.1.2) and CO_2, N_2O, and CH_4 emissions from rewetting of organic soils on forest land, cropland, grassland, and wetlands (CRF table 4(II)). Furthermore, the following sources were not reported because emissions are considered negligible: N_2O and CH_4 from controlled burning on forest land and from wild fires on grasslands (CRF table 4(V)), and the area of organic soil and net carbon stock change in organic soils on land converted to peat extraction (CRF table 4.D.2.1). For sources that were not reported, the notation key NE is used in the CRF.

6.1.6 Quality assurance and quality control (QA/QC) for LULUCF

NIBIO implements the QA/QC plan described for the National Inventory System in Annex V. In addition, a LULUCF-specific plan for QA/QC was developed internally at NIBIO. The LULUCF-specific plan has two objectives: 1) to ensure that emission estimates and data contributing to the inventory are of high quality, and 2) to facilitate an assessment of the inventory in terms of quality and completeness. These objectives are in accordance with chapter 6 of the 2006 IPCC guidelines for quality assurance and quality control.

The QA/QC plan for the LULUCF sector is based on the general Tier 1 QC procedures and includes two check lists (one for the source-category compiler and one for the LULUCF inventory compiler), an annual timeframe of the outlined QC activities, and a target for when to elicit QA reviews. Specifically, the QC is performed on the following 12 points:

1. Documentation of assumptions and selection criteria
2. Transcription errors
3. Emission calculations
4. Labeling of parameter units, conversion factors, and unit transfers
5. Database integrity
6. Consistency within sectors and source categories
7. Transfer of estimated emissions between inventory staff
8. Uncertainty estimation and calculations
9. Review of internal documentation
10. Time-series consistency
11. Completeness
12. Comparison to previous estimates

Several QA projects have been undertaken for the LULUCF reporting. In general, QA is initiated if a new method or model is implemented. Below are some examples of previously elicited QA activities.

Two external quality-assurance actions were undertaken in 2012. First, elicitation by the Norwegian Institute for Forest and Landscape (now NIBIO) of a qualified researcher to evaluate and improve the methodologies applied for emission estimates from cropland and grassland. This work resulted in substantial method revisions for most source categories due to the lack of methods evaluation since their development documented by (Rypdal et al. 2005). Moreover, a detailed documentation and justification of the new methods are provided in the report *Emissions and methodologies for cropland and grassland used in the Norwegian national greenhouse gas inventory* (Borgen & Hylen 2013). The second external QA was a smaller task performed on the final emission estimates for mineral soil on grassland remaining grassland, which was elicited from an expert at Colorado State University. This task provided a review of the emission calculations (the application of the new Tier 1 method) and of the method and activity data documentation. The methods were developed in accordance with the 2006 IPCC guidelines and implemented in the National GHG inventory in 2013.

Work was done to make a QA of the Yasso07-model estimates for mineral soil on forest land in 2014 – 2015. In this project, modelled and measured soil C stocks were compared on two field sites over time. Results from these sites and the overall estimation methodology for the relevant pools on forest land were discussed at two seminars with three contracted external experts from Finland, Denmark, and Norway (Dalsgaard, L. et al. 2017). In addition, a comparison of Yasso07 (current methodology) and field estimates of soil C stocks was carried out (Dalsgaard, L et al. 2016).

With the implementation of the IPCC 2006 guidelines, an external QA was elicited on the HWP calculations. The QA was performed by an expert from the Swedish University of Agricultural Sciences before the NIR 2015 submission.

Internal structures at NIBIO for the work on the LULUCF reporting have changed slightly every year. One important aim of the changes is to improve the QC procedures and to ensure that methods and calculations are put through an internal QC before reporting. The CRF tables went through internal QC by more than one person before the database was submitted to the national focal point. Furthermore, after the overall compilation of estimates from all sectors, there was an exchange of CRF tables from the focal point to NIBIO, and an additional QC was performed. Improving the QA/QC procedures is an ongoing process that will be further improved in future submissions.

6.2 Land-use definitions and classification system

6.2.1 Land-use definitions

National Forest Inventory (NFI) data are used to estimate total area of forest land, cropland, grassland, wetlands, settlements, and other land, and the land-use transitions between these. The rationale of using the NFI as activity data for all land-use categories is that it covers the whole country by sample plots. In addition, the NFI is the the most reliable data set available that can be used to determine transitions between different land-use categories during the whole reporting period in a consistent manner. The land-use categories are defined in accordance with the IPCC guidelines (IPCC 2003; IPCC 2006). They are described below, using the national terminology. In order for a unit to be classified as separate from an adjacent land-use category, it must have a minimum area and width of 0.1 ha and 4 m, which is consistent among all land-use categories in Norway. The NFI land cover and land-use categories and their transcription into IPCC land-use categories are illustrated in Table 6.7. All forest land, cropland, grassland (and settlement), are managed lands. A very small part of wetlands is managed for peat extraction. The vast majority of wetlands (and all of other lands) are unmanaged. Because managed and unmanaged lands are reported for the specific categories, total unmanaged lands are reported as IE.

Table 6.7 NFI land cover and land-use categories and their correspondence to the UNFCCC land-use categories.

Land use Land cover	Forestry (no other use or restrictions)	City, urban area Settlements of different kinds	Cabin area	Recreation area	Military training field	Protected Area, Nature Reserve	Roads/Railroad Airport	Power line	Other
Productive forest land (1)	Forest land	Settlements	Forest land	Forest land	Forest land	Forest land	Settlements	Settlements	Settlements
Non-productive forest land (2)	Forest land	Settlements	Forest land	Forest land	Forest land	Forest land		Settlements	Settlements
Other wooded land, Crown cower 5-10% (3)	Other land		Other land	Other land	Other land	Other land		Other land	
Wooded mire, Crown cover 5-10%	Wetlands					Wetlands			
Coastal calluna heath	Other land	Settlements				Other land	Settlements		
Bare rocks, shallow soil	Other land		Other land	Other land	Other land	Other land			Other land
Mire without tree cover	Wetlands					Wetlands			
Lakes and rivers (not sea)					Wetlands	Wetlands			Wetlands
Grazing land, not regularly cultivated									Grassland
Arable land, regularly cultivated						Cropland			Cropland
Other areas, gravel pits, mines, gardens, halting places, skiing slopes, forest roads etc.	Settlements	Settlements		Settlements	Settlements		Settlements	Settlements	Settlements

1) Productive forest land is defined as forest with crown cover that exceeds 10 % and that hosts a potential yield of stem-wood including bark of > 1 m^3 ha^{-1} yr^{-1}.

2) Non-productive forest land is defined as forest with crown cover that exceeds 10 % and that hosts a potential yield of stem-wood including bark of < 1 m^3 ha^{-1} yr^{-1}.

3) Other wooded land is defined as land with sparse tree cover with crown cover between 5 and 10 % and hosts trees that have the potential to reach a height of 5 m, or with a combined cover of shrubs, bushes, and trees above 10 %. It is classified as other wooded land when found on mineral soil (organic layer < 40 cm deep) and as wooded mire if found on organic soil (organic layer > 40 cm deep).

Forest land (4A) is defined in the National Forest Inventory (NFI). The values used in the NFI are in accordance with the range of parameters in the definition from the Global Forest Resources Assessment (FRA) 2005. Forest land is land with tree crown cover > 10 %. The trees have to be able to reach a minimum height of 5 m at maturity in situ. Minimum area and width for forest land considered in the Norwegian inventory is 0.1 ha and 4 m. Forest roads are considered as settlements. The minimum area and width is consistent among all land-use categories in Norway. Young natural stands and all plantations established for forestry purposes, as well as forest land, which is temporarily unstocked as a result of e.g. harvest or natural disturbance, are included under forest land. All forest in Norway is managed either for wood harvesting, protection and protective purposes, recreation, and/or to a greater or lesser extent, hunting and berry picking. On more marginal and less productive forest land the various management practices may be less intense, but still be present. Hence, all forest in Norway is considered managed.

Cropland (4B) is defined as lands that are annually cropped and regularly cultivated and plowed. Both annual and perennial crops are grown. It also encompasses grass leys that are in rotations with annual crops, which may include temporarily grazed fields that are regularly cultivated. This category includes arable land that was previously annually cropped and regularly plowed, but has since been abandoned. These areas remain in the cropland category until they have a regrowth of trees that make them unsuitable for plowing. All cropland is considered managed.

Grassland (4C) is defined as areas utilized for grazing on an annual basis. More than 50 % of the area should be covered with grass and it may be partly covered with trees, bushes, stumps, rocks etc. The grass may be mechanically harvested but the soil cannot be plowed. Land with tree cover may be classified as grassland if grazing is considered more important than forestry, even if it meets the forest definition. According to the agricultural statistics that are used for determining grassland management practices, grasslands include two categories; grazing lands and surface-cultivated grass. All grassland is considered managed according to these categories.

Wetlands (4D) are defined as lakes, rivers, mires, and other areas regularly covered or saturated by water for at least part of the year. Mires may be stocked by trees but with a tree coverage that do not meet the forest definition. Most wetlands are assumed to be unmanaged. Wetlands used for peat extraction and flooded lands caused by human constructed dams are considered managed.

Settlements (4E) include all types of built-up land: houses, gardens, villages, towns, cities, parks, golf courses, sport recreation areas, power lines within forests, areas close to cabins (< 5m), industrial areas, gravel pits and mines. All settlements are considered managed.

Other land (4F) is defined in the NFI as waste land, such as bare rocks, ice, and shallow soils that may have particularly unfavorable climatic conditions. In accordance with the IPCC definition, other land can also include unmanaged land areas that do not fall into any of the other five land-use categories, for example, heath lands, other wooded land (i.e. land with sparse tree cover on mineral soil), and open areas.

Table 6.8 Management status of different land-use categories. An area is only classified as belonging to one land-use category. The predominant national land cover and land use determines the assigned category.

Land-use category	Management status
Forest land	Managed
Cropland	Managed
Grassland	Managed
Wetlands	Unmanaged and managed (small area)
Settlements	Managed
Other land	Unmanaged

6.2.2 Consistency in areas and reporting categories

6.2.2.1 Area consistency

Up to the 2010 submission, the area of the different land-use categories were based on sample plots below the coniferous limit. In order to determine the land use at higher altitudes and in Finnmark county, the NFI included the first complete set of sample plots for these areas in the period 2005–2010. This allows for assessment of the extent of forest area, other wooded land, and other land uses in these areas. The plots are incorporated in the ordinary management plan for the NFI. On plots without previous measurements, land use and biomass development was estimated back to 1990 (back-casting) using data from the NFI (Anton-Fernandez & Astrup 2012), maps and aerial photographs for settlements, grassland, and cropland. This was done to improve the area estimates of 1990 for all new plots included in the system.

The definitions of land cover and land-use categories have been consistent for most categories since the permanent plots were established in the period 1986-1993. There have, however, been some changes in definitions throughout this period that have affected the land-use change matrix. The most important change relates to the forest definition. In 2005, the NFI forest definition was adjusted to the (IPCC 2003) definition for forest land, replacing a similar but not identical definition. The change of the forest definition did not result in an inconsistency, however, because the new forest definition was also applied to NFI data acquired before 2005. Also the category grassland had not been defined in the land-use classification in the first cycle of the NFI with permanent sample plots (6^{th} NFI, 1986 - 1993). The land-use classes assessed in the 7^{th} NFI (1994-1998) have been utilized for the corresponding plots in the 6^{th} NFI. The Norwegian Mapping Authority provided the value for the total land area of Norway.

6.2.2.2 Land-use changes prior to 1990

The NFI was not designed to assess land use change categories prior to 1990, and the forest inventory at that time did not cover the whole country. To be able to make a rough indication of the overall trend in forest area, the areas of productive forest land according to national classification is presented in Table 6.9. 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 on forest land, we have chosen not to take into account land-use changes that may have occurred prior to 1990. This implies that CSC in living biomass on land

converted to forest land may be underestimated, but the potential changes in living biomass are included in forest land remaining forest land.

Table 6.9 Area estimates of productive Forest land (kha) in the years 1967, 1979, and 1989.

Region	**1967**	**1979**	**1989**
Eastern and Southern Norway	3 903	4 085	4 289
Western Norway	689	770	895
Mid-Norway (Trøndelag)	974	976	997
Northern Norway	916	829	1 439
Total	**6 482**	**6 660**	**7 620**

Source: Statistics Norway 1969, 1983, 1992

6.2.3 Sink/source categories

Changes in C stocks are reported for the five main pools under the UNFCCC: living biomass (gains and losses), litter, dead wood, mineral soils, and organic soils. For all land-use classes except for forest land, litter and dead wood are summarized and reported as a part of the dead organic matter pool. The pools are defined as follows:

Living biomass: For all land-use categories except cropland, living biomass is defined as the biomass of living trees with a breast height diameter > 50 mm. Table 6.10 describes in more detail on which land-use categories living biomass is measured in the NFI. The tree biomass is the sum of the biomass estimates of the tree fractions stem wood, stem bark, living branches, dead branches, needles or leaves as well as stump and roots down to a root diameter of 2 mm (see section 6.4.1). On cropland, carbon stock changes in living biomass are calculated on areas with fruit trees.

Table 6.10 Measurements of tree parameters in the NFI given Norwegian land cover and land-use classes. Green cells indicate measurement of trees (a = measurements since 2007, and b = measurements since 2010). Grey cells indicate that trees are not measured on that land-use class. Not all land use and land cover combinations exist (see Table 6.7).

Land cover	Land use								
	Forestry (no other use or restrictions)	City urban area Settlements of different kinds	Cabin area	Recreation area	Military training field	Protected Area, Nature Reserve	Roads/Railroad Airport	Power line	Other
Productive forest land (1)								b	
Non-productive forest land (2)								b	
Other wooded land, Crown cower 5-10% (3)								b	
Wooded mire, Crown cover 5-10%								b	
Coastal calluna heath								b	
Bare rocks, shallow soil								b	
Mire without tree cover									
Lakes and rivers (not sea)									
Grazing land, not regularly cultivated	a	a	a	a	a	a	a	a	a
Arable land, regularly cultivated									
Other areas, gravel pits, mines, gardens, halting places, skiing slopes, forest roads etc.									

Litter: For forest land remaining forest land, the changes in the dead organic matter pool are the changes resulting from the input and decomposition of all dead organic material (woody and non-woody, aboveground and belowground; C input) regardless of size and stage of decomposition. Only the most recalcitrant material (humus) originating from root decomposition is allocated to the soil pool. The changes in the litter and the dead wood pools, respectively, are allocated according to the origin of the model C input (aboveground or belowground elements), the chemical quality and the size of the C input elements – see details in chapter 6.4.1.1. For land converted to or from forest land, the litter pool entails dead organic material in various stages of decay found above the mineral forest soil and developed primarily from leaves/needles, twigs, and woody material (L, F, and H horizons in the Canadian soil classification). Due to the field sampling and laboratory methodology, this includes living fine roots and excludes particles > 2 mm after sample preparation.

Dead wood: For forest land remaining forest land the estimates for CSC in the dead wood pool are modeled (see above for *litter*). For land converted to or from forest land, the dead wood pool entails dead organic material (standing and lying dead wood in various stages of decay) aboveground (dimension > 10 cm) and belowground (dimension > 5 mm). Estimates were found through expert judgement and dimensional limits are approximate.

Mineral and organic soils: The separation of organic and mineral soils differs somewhat between forest land, cropland, and grassland. On forest land organic soils are defined as having an organic layer deeper than 0.4 m. On cropland and grassland, organic soils are defined as soils with more than 10 % C in the topsoil (plow layer). Furthermore, the distinction is made between mixed-mineral organic soils that have between 10 % C and 20 % C and highly organic soils with > 20 % C.

6.3 Land area representation and the National Forest Inventory

The area representation applied in the LULUCF reporting is based on the Norwegian National Forest Inventory (NFI; see section 6.3.1 below). Land accounting is based on an Approach 2 according to IPCC 2006 guidelines. Under the convention reporting we apply a 20-year transition period. Hence, land stays in a conversion class for 20 years (transition period) before it is transferred to a remaining class.

6.3.1 Current NFI design

The NFI can be characterized as a single-phase, permanent, systematic, and stratified survey. An interpenetrating panel design is used, where 1/5th of the sample plots that are evenly distributed across the country (the so-called “panel”) using a Latin square design are measured each year. The Norwegian Institute of Bioeconomy Research is responsible for operating the NFI. Inventory work was started in 1919 with regular inventory cycles. The 11th inventory cycle started in 2015 and will be completed in 2019.

The NFI divides Norway into four strata: lowlands (typically below 800 m above sea level; ASL) except Finnmark county, mountain areas (typically above 800 m ASL) except Finnmark, lowlands in Finnmark, and mountain areas in Finnmark. The lowland strata contain the most productive forests, while the forests in the other strata consist mainly of low productive birch forests. The arctic island groups Svalbard and Jan Mayen are not covered by trees or bushes, and are therefore not considered in the NFI.

NFI sample plots are placed on the intersections of grid lines to ensure a systematic distribution of the plots (Figure 6.6). The distance between neighboring plots is different in the strata. A 3x3 km (Easting x Northing) grid is used in the lowlands including Finnmark county, a 3x9 km grid is used in the mountains not located in Finnmark and a 9x9 km grid is used in the mountainous area of Finnmark county (Figure 6.6).

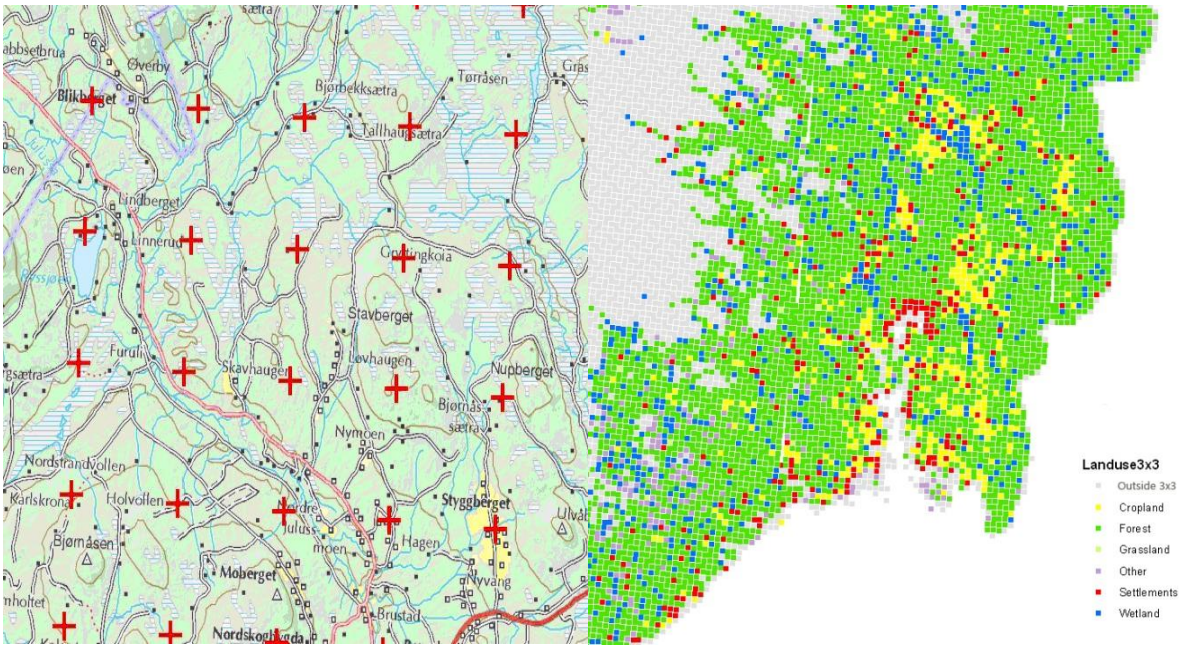


Figure 6.6 The sample plots are covering all land-use categories. In the example map to the left, plots are placed in the systematic 3x3 km grid. On the right-hand side, we see the distribution of land use-categories in the south eastern part of Norway below the coniferous tree line (only 3x3 grid).

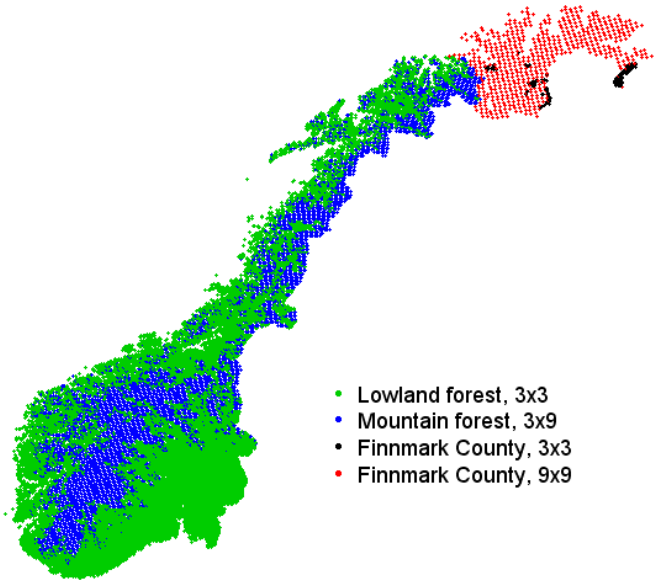


Figure 6.7 Spatial distribution (approximate locations) of the NFI sample plots in the four strata. The sample plots in Finnmark county located on the 3x3 km grid are covering lowlands, while the sample plots on the 9x9 km grid cover mountainous areas.

As can be seen from the estimate of all land-use categories for the year 2010, more than 94 % of the living biomass stock is allocated in the lowland forests outside Finnmark (Table 6.11). The mountain forest outside Finnmark, the mountain forest in Finnmark county, and the lowlands in Finnmark account for 3.7 %, 1.6 %, and 0.4 % of the carbon in living biomass, respectively.

Table 6.11 Area and estimates of carbon stocks in living biomass in 2010 (the reference year is based on observations from 2008-2012) by stratum and associated uncertainties (SE = standard error).

Stratum	**Area (kha)**	**C stock (kt)**	**2 SE (%) C stock**	**Percent (%) of total C stock**
Lowlands outside Finnmark	14 989	423 533	2.9	94.3
Mountain forest outside Finnmark	12 528	16 738	12.3	3.7
Lowlands in Finnmark	135	1 773	21.4	0.4
Mountain forest in Finnmark	4 727	7 164	24.9	1.6
All	**32 378**	**449 208**	**2.9**	**100.0**

A plot that has measured trees in the current inventory is always revisited in the next inventory. Plots that were not visited in the field in the most recent inventory are monitored using aerial images, which are acquired approximately every five years for the entire country. From the aerial images, the plot is assessed for land-use changes and the occurrence of trees. If it is not possible to determine the land-use category with certainty or if there is an indication that the sample plot may be tree covered, the sample plot is visited in the field. Exceptions are cropland and settlements, which are not visited in the field in order to measure tree parameters.

Among other attributes, the positions, diameter at breast height (DBH, diameter measured at 1.3 m above ground) and tree species of all trees with DBH >50 mm are recorded on circular sample plots with a radius of 8.92 m (250 m^2). On plots with 10 trees or less, all tree heights are measured using hypsometers. On plots with more than 10 trees, heights are measured on a relascope-selected subsample with a target sample size of 10 trees per plot (NFLI 2008). The heights of the unmeasured trees are estimated using tariffs (models) calibrated at the plot-level with data from measured trees (Breidenbach et al. 2013).

The area of a stratum A_h was estimated by multiplying the proportion of points on the 3x3 km grid that belong to the stratum h with Norway's land area. The representation factor, also known as the design weight or the inverse of the sampling probability, determines how much area of Norway one sample plot represents. The representation factor of a sample plot is given by A_h/n_h, where n_h is the number of sample plots on the grid that is specific to the stratum.

If a sample plot covers two land use classes, the sample plot, and consequently also the representation factor, is divided between the plot parts according to the proportion of the land-use classes covering the plots. A land-use class must cover at least 20 % of the sample plot in order to be considered. Land-use class cover is recorded in 10 % steps on divided sample plots.

6.3.2 Classification of mineral and organic soil areas

In order to identify the soil type (mineral or organic) for all land-use classes, additional sources to the NFI data are necessary for all sample plots without tree cover. Since the 2015 NIR submission, we have used a baseline 1990 map, classifying all areas as organic or mineral soil for all land uses, and overlaid it with the NFI plots. This enabled geo-referencing of the areas of organic soils for each land-use class and tracking of land-use changes on mineral or organic soils.

Two maps were first combined to obtain spatial soil type information for cropland, grassland, and settlements. The Norwegian agricultural soil classification database contains detailed soil profiles of 59 % of croplands and 6% of grasslands. Information of soil type on the rest of the land area was derived from the national land resource map AR5[27]. The soil type information on forest land, wetlands, and other land were derived from NFI registrations.

Figure 6.8 displays all organic soils and includes non-drained organic soils on forest land and wetlands. On cropland, grassland, and settlements all organic soils were considered drained.

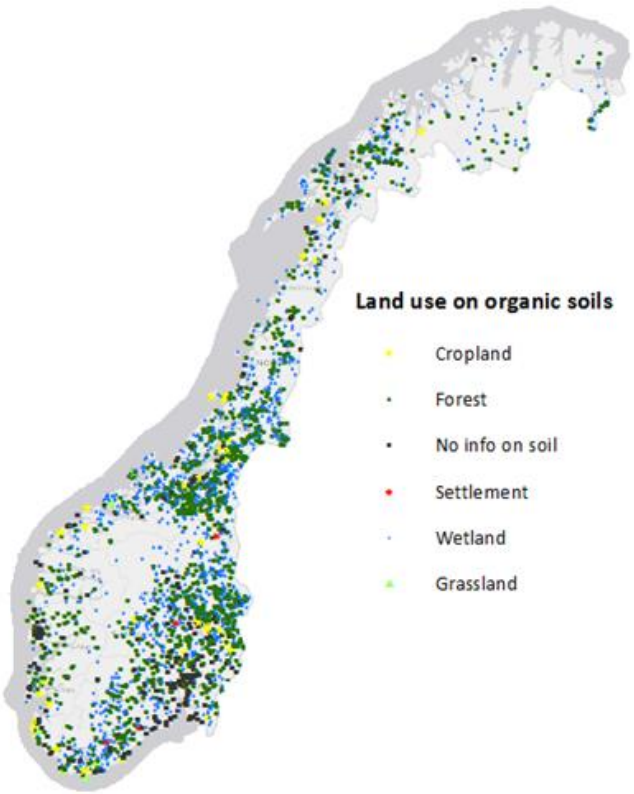


Figure 6.8 Map of NFI plots on organic soil per land-use class for the 1990 baseline.

[27] http://kilden.skogoglandskap.no/?topic=arealinformasjon&layers=ar5_bonitet&X=7260874.41&Y=125323.37&zoom=0&lang=nb&bgLayer=graatone_cache&layers_opacity=0.75

6.3.3 Changes in the NFI design

The NFI consisted of temporary sample plots before 1986. Between 1986 and 1993, all lowland sample plots outside Finnmark were permanently marked. All sample plots located within one to three neighboring counties ("fylke") were measured within one year. Annual estimates representative for the whole country were therefore complicated in those years. The current system with interpenetrating panels was made fully operational in the cycle covering the years 1994 through 1998.

Today, all sample plots are circular with a size of 250 m^2. However, in the inventory period between 1986 and 1993, concentric sample plots were used in some counties. All trees with a DBH >= 50 mm were measured on a circular sample plot with an area of 100 m^2. Trees with a DBH larger than 19.9 cm were measured on a larger sample plot. The area of the large sample plots was 200 m^2 in Østfold, Akershus, Oslo, and Nord-Trøndelag counties, whereas the area was 250 m^2 in all other counties. The sample weights of the trees on these plots were modified to bridge the methodological change in the subsequent inventory period where all sample plots had a size of 250 m^2.

The sample plots in the mountain stratum outside Finnmark were established between 2005 and 2009. The first re-measurements of these plots were consequently started in 2010. The sample plots in the two Finnmark strata were established between 2005 and 2011 with first re-measurements starting in 2012. This made special methods for estimating changes on the plot-level necessary, as described in section 6.2.2.1. Almost 95 % of the carbon stock in living biomass is, however, found in the lowland stratum outside Finnmark. The land use classes observed on the plots in Finnmark and the mountain plots established between 2005-2009 (2005-2011 for Finnmark) were back-casted to 1990. Plots were assigned to one of the two Finnmark strata in the inventory cycle by assessing their location on the 3x3 km grid. In a number of western and northern Norwegian municipalities outside Finnmark, a height threshold separating lowland and mountain areas was set by local forest authorities. In the other parts of Norway, the stratum decision was made using auxiliary information and in the field. The strata classification can therefore be described as a two-phase procedure.

Prior to 2005, the tree heights of three trees per species were measured on each sample plot. Since 2005, 10 trees per plot are measured as described above.

Until 1994 no differentiation between grasslands and croplands was made; both were considered agricultural land. Since 1994, this difference is made and the areas of croplands and grasslands were back-casted.

In the first years of establishing the mountain plots, there were no aerial photos available. Maps (N50) were used to determine which plots could be forested. Those were visited in the field, while the rest of the plots were given a land use class derived from an overlay of the maps (plot center). A plot with a center in a land use class was assumed to be that land use class on its full area (circle of 250 m^2). If the plot center was in water, the sample plot was not visited, even if it was close to forest. Between 2011 and 2015, all plots were checked against aerial images. Land use changes occurred to and from all land use classes. Most commonly, however, parts of the plots in water were then considered other lands or wetland (mire), but in some cases forest or other land use classes. The changed land use class and possible measurements of trees were back-casted to 1990 in those cases.

Until 2005, trees were not measured on land use classes other than forest. Sample plots were only split if one of the parts was forest. In other cases the plots were categorized as fully covering the land use class of the center coordinate. Since 2005, trees are also measured on other land use classes than forest. First “other wooded land” (part of the land use category other lands) was included, further land use classes in 2007 (“grassland” and the rest of “other land” and “cabin areas”) and since 2010 also trees below “power lines” (part of the settlements category) are measured. This resulted in splitting a number of sample plots between other land use classes than forest, which resulted in area changes of those land use classes. The changed land use class and possible measurements of trees were back-casted to 1990 in those cases.

In 2005, the forest definition was changed to be in accordance with the FAO definition, which includes the consideration of crown cover. Until 2005, the forest definition was based on the (potential) productivity of the land, which had to be larger or equal to 0.1 $m^3 ha^{-1} year^{-1}$ to be considered as forest. (In addition, a threshold of 1 $m^3 ha^{-1} year^{-1}$ is used to separate unproductive and productive forest. This is nonetheless not relevant for LULUCF reporting.) Since 2005, the crown cover on a 0.1 ha area around the plot center has to be more than 10 % for a land to be forest. After harvests, areas may be temporarily unstocked but will remain forest in the NFI classification system unless the land use changes later. For young productive forest, also the stem number is considered. All plots with forest according to the new definition that were visited for the first time in the NFI period 2005-2009 (2005-2011 for Finnmark) were back-casted. All plots (not only new plots) in forest according to the new definition were considered forest also in 1990. Exceptions were plots with a human induced afforestation. Exceptions were also made in productive forest if the plot had been assessed as “non forest” in a previous cycle and the age of the trees clearly allowed determining a year of change from some land use class to forest.

6.3.4 Inter- and extrapolation for area and living biomass estimates

The NFI consists of five panels each of which consists of approximately 1/5th of all 22 008 sample plots. Panel #1 was installed[28] in 1994 and the other panels in the following years, such that panel #5 was installed in 1998 (Figure 6.9). After the panels were installed, all plots were re-measured every 5 years. However, all sample plots were visited for the first time and permanently marked between 1986 and 1993. In this period before the panels were installed, the measurement intervals for the sample plots within a panel varied. For example, for panel #1 in 1994, the sample plots were previously measured between one and eight years before.

All estimates are based on linear interpolation of areas and carbon stocks between panel-wise estimates. The first estimate for each panel is for 1989, based on sample plots measured between 1986 and 1993 in the respective panel. Towards the end of the reporting period, estimates were extrapolated based on the last two estimates per panel. This way, the rate of land-use changes is projected based on observations of the last 10 years (Figure 6.9). The extrapolation results in

[28] Installation in this context means that all sample plots within the panel were visited in one year. All sample plots (in the lowlands outside Finnmark) were visited and marked for the first time between 1986 and 1993.

recalculations of the estimates of the last four years in the forthcoming reports as new data become available, and interpolation can be used instead of extrapolation.

An example to illustrate the method: while no extrapolation was necessary for panel #4 in the 2014 reporting (2012 as the final year), four years of extrapolation were necessary for panel #5 (Figure 6.9). Measurements on panel #5 for the year 2013 became available in the 2015 reporting (2013 as the final year), which resulted in a recalculation of the years 2009-2012 for panel #5.

The annual estimate reported is the sum of one estimate in the panel that was measured in the reporting year and the interpolated or extrapolated estimates of the other panels in the reporting year.

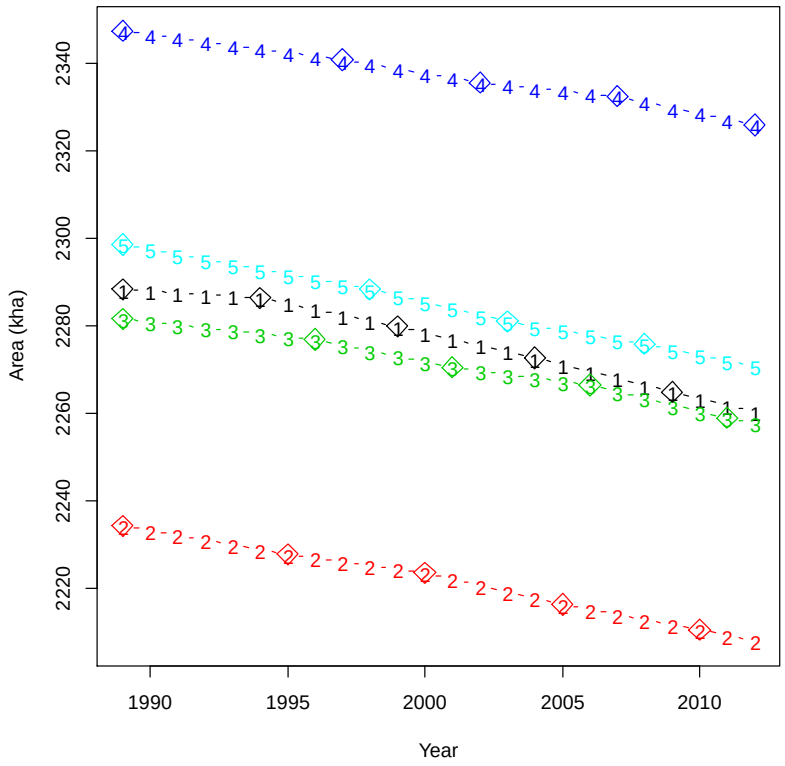


Figure 6.9 Estimated forest land remaining forest land area covering mineral soils within the five NFI panels illustrated with data from 1989 until 2012. Diamonds indicate the measurement year of the sample plots in the respective panel (1-5). The estimated area was interpolated between two measurement years and extrapolated in the years after the last measurement year in each panel. Areas of lands converted to forest land that will change their category to forest land remaining forest land after 2009 are not considered in the graphic.

More formally, the area of a land-use class (A_{LUC}) in a given measurement year (diamonds in Figure 6.9) is the sum over all i=1,…, n_P sample plots within a panel

$$A_{LUC} = \sum_i p_{LUC,i} \cdot rf_i$$

where $p_{luc,i}$ is the proportion (0,…,1) of a land-use class covering a sample plot and rf is the representation factor (the area of Norway which the sample plot represents).

Linear interpolation of stocks means constant changes (gains and losses) between two measurements. Biomass losses (fellings) are mainly due to harvests and are observed over five years

in each panel. In order to reflect the annual variability in harvests, the constantly interpolated or extrapolated biomass losses have been adjusted according to harvest statistics provided by Statistics Norway (Figure 6.10). This results in annual variability of the net carbon changes. The adjustment according to the harvest statistics was carried out for the land-use categories land converted to forest land and forest land remaining forest land.

The change of biomass stocks (gains or losses) within a land-use class in a given measurement year (diamonds in Figure 6.10) is the sum of changes over all sample plots within a panel

$$c_{LUC} = \sum_i p_{LUC,i} rf_i \, c_{LUC,i}$$

where $c_{LUC,i}$ is the mean annual change of the biomass stock per hectare on a sample plot per land-use class. The change $c_{LUC,i}$ can either be a gain (positive change) or a loss (negative change) of biomass. Biomass gains or losses were multiplied with the default factor of 0.5 in order to obtain estimates of carbon gains or losses.

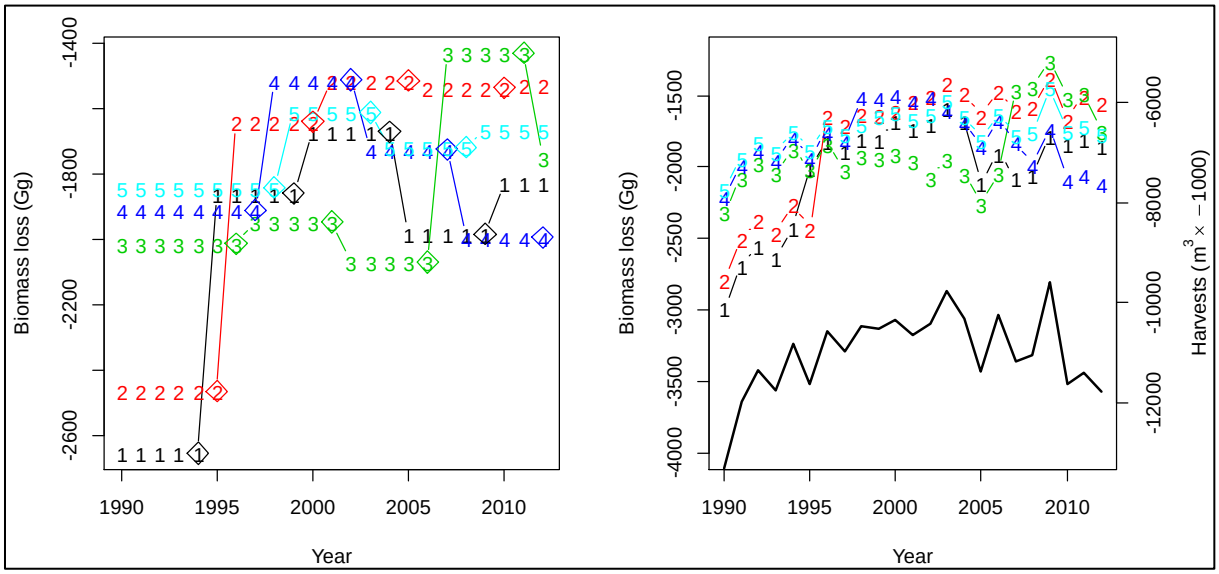


Figure 6.10 Biomass losses in forest land remaining forest land observed on the five panels illustrated with data from 1989 until 2012. Left-hand side: Diamonds indicate the measurement year of the sample plots in the respective panel. The estimated biomass loss was interpolated between two measurement years and extrapolated in the years after the last measurement year in each panel. Interpolation and extrapolation are based on a constant function. Right-hand side: The constant interpolation or extrapolation is adjusted according to harvest statistics (thick black line).

The harvest statistics are based on Statistics Norway's table 03895[29] describing the timber use by assortment and municipality. This table was supplemented by the estimated use of domestic fire wood obtained from Statistics Norway (personal communication). The harvest statistics for the last reporting year are preliminary.

[29] Statistics Norway. (2016). 03895: Commercial removals of industrial roundwood, by assortment [Avvirkning for salg, etter sortiment] (m^3) (K).

6.3.5 Uncertainties in areas and living biomass

Standard errors of area and biomass change estimates used in the key category analysis were estimated based on a 5-year moving average estimate for the mid-year of the last NFI cycle. For example, in NIR 2018, the last NFI cycle includes measurements from the years 2012-2016, which means that the mid year was 2014. Model-related uncertainties resulting from interpolation and extrapolation are ignored. Also model-related uncertainties resulting from the use of biomass models to estimate single tree biomass from diameter and height measurements were ignored since they can be assumed to be small for CSC compared to the sampling error (Breidenbach et al. 2013). Furthermore, the uncertainty resulting from using an estimated instead of measured tree height for some trees on the sample plots was ignored. Also this source of variation can be assumed to be negligible compared to that of sampling. For the most important gain category, living biomass in forest land remaining forest land, 5 % points were added to the standard error (2 SE) by expert judgment to consider the ignored uncertainties.

For the estimation of sampling errors, the estimates of land-use class areas are stratified estimates of land-use class proportions multiplied with Norway's land area (including lakes). Random sampling is assumed in all estimates. The variances can therefore be assumed to be conservative estimates.

The estimated proportion of a land-use class within a stratum is given by

$$p_h = 1/n_h \sum_i y_{hi}$$

where h = (1, …, 4) is the stratum identifier, n is the number of sample plots, y is an indicator variable for a land-use class, which is 1 if the sample plot belongs to the class, and 0 otherwise, and i = 1,…, n_h.

The estimated variance of the proportion is given by

$$var(p_h) = \frac{p_h(1-p_h)}{n_h - 1}.$$

The area estimate of a land-use class *(A_{LUC})* over all strata is then given by the stratified estimator

$$A_{LUC} = A\frac{1}{N}\sum_h N_h p_h$$

where A is Norway's land area, N is the land area divided by the NFI plot size, N_h is the stratum area divided by the plot size, and p_h is the proportion of the respective land-use class. The estimated variance of the area estimate is given by

$$var(A_{LUC}) = A\sum_h \left(\frac{N_h}{N}\right)^2 var(p_h).$$

Similar to the area estimates, estimates of sampling errors of carbon gains or losses are based on the full set of NFI sample plots. The estimate of the total biomass gain or loss within a stratum is given by the ratio estimator

$$T_h = \frac{N_h}{n_h}\sum_{i=1}^{n_h} y_{hi}$$

where n_h is the number of sample plots within a stratum and y is the average annual gain or loss that occurred during the last five years on a sample plot. An estimate of the variance is given by

$$var(T_h) = N_h^2 \frac{s_h^2}{n_h}$$

with $s_h^2 = \frac{1}{n_h - 1} \sum_i (y_{hi} - \bar{y}_{hi})^2$. The total biomass gain or loss estimate (T) over all strata and its variance (var(T)) is the sum over T_h and var(T_h), respectively.

Post-stratification did not improve the precision of biomass gain and loss estimates. We tested climatic zones, counties, and forest districts as possible post-strata.

The estimation of biomass or carbon stocks is not required in the CRF. In this report, stocks were calculated in analogy to the biomass change estimates.

The uncertainties of carbon estimates are given by

$$U(C) = \sqrt{U(T)^2 + U(CF)^2}$$

where U(T) is the uncertainty of the total biomass gain or loss estimate in percent of the estimate $U(T) = \frac{2\sqrt{var(T)}}{T} 100$ and U(CF)=2 % is the relative uncertainty in the carbon fraction.

6.3.6 QA/QC for the NFI data

Fieldwork is conducted by NFI field staff. Qualification requirements are forestry or natural management education at the college level or higher. Before a new employee can work independently, a training period of at least three weeks is conducted. All field staff undergo a week long course prior to each field season. There are currently about 25 employees who perform fieldwork in the period from May to October. It has been a stable situation with few changes in the field personnel, and on average the field workers have more than 10 years experience.

All data collection is done on handheld computers with software developed particularly for the purpose. The field computer program has a number of features built in for quality assurance:

- The program ensures that everything that must be recorded is recorded.
- A series of tests on the logical values of measurements.
- Categorical variables are recorded with the help of menus.

For plots that have been previously registered, the field computer contains data from the previous record. Depending on the character of the variable, quality checks are handled in three different ways:

- The old value is displayed and can be confirmed or amended.
- The old value is hidden, but a warning is given if the new value is not logical compared to the old value.
- The old value is displayed as information before a new registration is done.

Data is sent by e-mail to the data reception center at the main office once a week. The data reception center keeps track of which sample plots have been registered and which plots remain, thereby ensuring that no plots are omitted. The data is then read into a database and further quality checks are made. Incorrect data or questions are returned to the field worker for clarification.

Each field worker is usually visited by a supervisor for one day in the field. Control registrations are carried out by an experienced field worker who makes a second registration for approximately 5 % of all sample plots. The control data is then analyzed to document the quality of field recordings, partly to clarify misunderstandings, and to correct for any systematic errors. Results of control entries are published in a separate report.

During the winter months, there is a systematic review of the data with additional error testing and inspection of all codes and logic. This happens before the data is read into the final table structure.

The database is a relational database that is designed to ensure data quality. Primary keys and foreign keys prevent double accounting and ensure coherence in the data.

6.4 Forest land – 4A

6.4.1 Forest land remaining forest land, 4A1

Forest land remaining forest land covers slightly more than 12 million hectars (ha). Forest ownership in Norway is dominated by private ownership, with many small properties. There were 127 544 forest holdings with more than 2.5 ha of productive forest land in Norway in 2016 (SSB 2015). Due to the ownership structure and specific terrain conditions, Norwegian forestry is diversified and characterized by small-scale activity. The average size of clear-cuttings was estimated to be 1.9 ha in 2003 (Statistics Norway 2004). Approximately 90 % of the harvesting is fully mechanized.

Forest land is the most important land-use category with respect to biomass sequestration in Norway. According to the Approach 2 key category analysis (Section 6.1.4), forest land is a key category for sequestration in living biomass, dead wood, litter, and mineral soils, and emissions from organic soils, because of the uncertainty in both the level and trend.

6.4.1.1 Methodological issues

Living biomass (key category)

The stock change method is used. The method implemented corresponds to Tier 3, which uses a combination of NFI data and models to estimate changes in biomass.

The reported CSC refer to the biomass of all living trees observed on an NFI sample plot with a stem diameter larger than 50 mm at breast height (DBH). Thus, shrubs and non-woody vegetation are not included in the estimates. Since tree coordinates are measured on NFI plots, each tree can be attributed to a land use category. Single tree allometric regression models developed by Smith et al. (2016; 2014), Marklund (1988), and Petersson and Ståhl (2006) are applied to DBH and height measurements from the NFI for estimating the tree biomass. For consistency with estimates reported under the Kyoto Protocol, the tree biomass is defined as the sum of aboveground and belowground biomass. The aboveground biomass of a tree is the sum of the estimates of the fractions of stem, stump, bark, living branches, and dead branches. The belowground biomass is the estimate of the fraction of stump and roots minus the estimate of the fraction of stump. Table 6.12 lists the models used to estimate the biomass of the different tree fractions. The biomass models are defined for Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), and birch (*Betula pendula* and *Betula pubescens*). These species constitute approximately 92 % of the standing forest volume (Larsson & Hylen 2007). Other broad-leaved species constitute most of the remaining eight percent. The birch biomass models are applied to all broad-leaved species. The living biomass is estimated consistently based on the same biomass models from the base year 1990 onwards.

Table 6.12 Biomass models for estimating living biomass. In Marklund's (1988) models, the notation "G (model number)" indicates Norway spruce and "T (model number)" Scots pine.

Component	Reference and specific model
Dead branches	Marklund (1988), G20, T22. Smith et al. (2014) birch/deciduous.
Living branches	Marklund (1988), G12, T14, Smith et al. (2014) birch/deciduous. Includes needles.
Foliage	Smith et al. (2014) birch/deciduous.
Bark	Marklund (1988), G8, T10. Smith et al. (2014) birch/deciduous.
Stem	Marklund (1988), G5, T6. Smith et al. (2014) birch/deciduous.
Stump	Marklund (1988), G26, T28.
Stump and roots (>2 mm)	Petersson and Ståhl (2006), B *i* (for Norway spruce, and Scots pine). Smith et al. (2016) birch/deciduous.

Dead organic matter (key category)

The model used to estimate C stock changes in soils provides a change estimate for total soil organic carbon (SOC), which includes the dead wood, litter, and soil pools. This methodology is used for the forest area on mineral soil only. The estimate of total SOC entails all stages of decomposition and all C input elements regardless of size and origin (input aboveground or belowground). The total SOC change estimate was allocated to the dead wood, litter, and soil pools, respectively. This was done by allocating specific chemical model pools to the reporting pools and by using the information about the dimension of the C input elements as well as its origin as either aboveground or belowground C input (Figure 6.11). Only the changes in the H pool (humus; Figure 6.12) (1.9 %) originating from the belowground C input elements of all sizes were allocated to the changes in the UNFCCC soil sink/source category. The remaining change in the total soil organic C stock was attributed to dead wood (16.5 %) and to litter (81.6 %). The same allocation percentages were used for all years since 1990. See below for a description of the Yasso07-model used for the simulations on mineral soils.

<table>
<tr><th>Origin</th><th colspan="5">Aboveground</th><th colspan="5">Belowground</th></tr>
<tr><td>Chemical component</td><td>A</td><td>W</td><td>E</td><td>N</td><td>H</td><td>A</td><td>W</td><td>E</td><td>N</td><td>H</td></tr>
<tr><td>Non woody</td><td colspan="9" rowspan="2">LITTER</td><td rowspan="3">SOIL</td></tr>
<tr><td>Fine woody</td></tr>
<tr><td>Coarse woody</td><td colspan="9">DEAD WOOD</td></tr>
</table>

Figure 6.11 Conceptual definitions of soil pools based on the chemical composition of Yasso07 output for total soil C stock change. AWENH is defined as: Acid soluble, Water soluble, Ethanol soluble, Non-soluble, and Humus.

Mineral soils (key category)

Choice of method

A Tier 3 method was applied. The emissions and removals of total soil organic C (dead wood, litter, and soil pools) from forest land on mineral soil are estimated using the decomposition model Yasso07 (Tuomi et al. 2008; Tuomi et al. 2009; Tuomi et al. 2011a; Tuomi et al. 2011b). The Norwegian application is described in Dalsgaard et al. (2016). Yasso07 represents processes for mineral soils down to a depth of 1 m and operates using five chemical soil C pools (Figure 6.12).

Decomposition (CO_2 release) and fluxes among the chemical C pools are regulated by climatic input data and parameters governing decomposition, transformation, and fractionation of C inputs. The model is applied to the time series for each individual NFI plot. It is run on an annual time step, but only estimates for the NFI registration years are used. The term "entry" below refers to any combination of an NFI plot and registration year.

For each NFI plot in the category forest land remaining forest land, C changes per hectare since the last measurement of trees on the plot were calculated using Yasso07, as described below. The calculated change was then up-scaled to country-wide estimates using the same method as for living biomass, which is described in section 6.3.4.

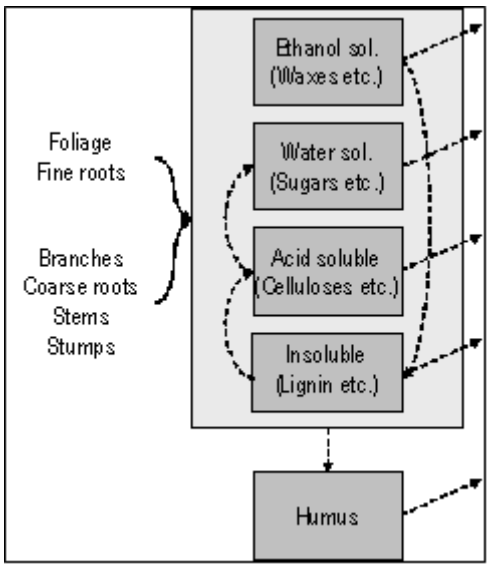


Figure 6.12 Flow diagram for Yasso07. Fluxes significantly different from 0 are indicated by the arrows (Liski et al. 2009).

For each entry (ca. 11 400 NFI plots) annual living tree C input to the model is estimated from tree registrations. On plots where the time series was not complete, back-casting was applied (see section 6.2.2.1). Tree biomass models were used to estimate biomass components (Table 6.12) and annual turnover rates for roots and branches were applied to estimate the annual C input (Table 6.13 and Table 6.14).

Tree C input generated annually from natural mortality and residues from diffuse harvest (i.e. harvest not including commercial thinning or final harvest) was estimated on all entries as a percentage of the standing biomass. Data from the 8th NFI (2000-2004) and the 9th NFI (2005-2009) were used to establish look-up tables for this purpose (Anton-Fernandez & Astrup 2012). Registrations of mortality and harvest on NFI plots started in 1994. The look-up tables are grouped by tree species (broadleaved or conifer), site-index (up to six classes), and age (up to nine classes). Harvest residues from commercial thinning and final harvest were estimated from plot specific registrations (since 1994) of harvested volume. This C input was relevant on a total of 1 688 entries.

The look-up tables mentioned above also contain factors (percentages) describing the biomass development between two inventories. These were used to establish a time series of living biomass and harvest residues (commercial thinning and final harvest) back to 1960 (back-cast). Field

registrations of the 6th inventory (1986-1993) on prior land use and forest management activities were used to establish eight rules covering all relevant NFI plots. For young stands where harvest must have taken place during the back-cast period, harvested biomass and biomass of the old stand back in time was estimated using old NFI inventories, where standing volume was generally lower than found in current inventories. Estimation of C input from the back-cast time-series (including from mortality and diffuse harvest) followed the same procedures as for the NFI time-series but using average distribution (from NFI) to biomass components as individual tree information is not available in the back-casted part of the time series. The 1960-1990 time-series is used to reduce the effect of the equilibrium assumption on the reported values of soil C change in the inventory period (see below).

Table 6.13 Biomass models used in Yasso07 simulations. When models from Marklund (1988) are used, the notation "G" is used for Norway spruce and "T" for Scots pine.

Component	Reference and specific model
Dead branches	Marklund (1988), G20, T22, Smith et al. (2014) birch/deciduous
Living branches	Marklund (1988), G12 and G16, T14 and T18, Smith et al. (2014) birch/deciduous
Foliage	Marklund (1988), G16, T18, Smith et al. (2014) birch/deciduous
Bark	Marklund (1988), G8, T10, Smith et al. (2014) birch/deciduous
Stem	Marklund (1988), G5, T6, Smith et al. (2014) birch/deciduous
Stump	Marklund (1988), G26, T28 (for Scots pine), Smith et al. (2016) birch/deciduous[a]
Roots (> 5 cm)	Marklund (1988), G28, T31, Smith et al. (2016) birch/deciduous[a]
Roots (2 mm–5 cm)	Petersson and Ståhl (2006), B*i* (for Norway spruce, Scots pine) Marklund 1988, G28, G26, T31, T28, Smith et al. (2016) birch/deciduous[a]
Roots (< 2 mm)	0.3 × foliage biomass; (Kjønaas et al. Manuscript)

[a] *No distinct diameter limit is inferred between the two classes of deciduous coarse roots.*

Table 6.14 Annual turnover rates applied for tree C input estimation. Compiled in Peltoniemi et al. (2004) and de Wit et al. (2006).

Component	Norway spruce	Scots pine	Broadleaved	Reference
Foliage	0.143	0.33	1	Tierney and Fahey (2002)
Live and dead branches, roots > 2 mm	0.0125	0.027	0.025	Muukkonen and Lethonen (2004) DeAngelis et al. (1981) Lethonen et al. (2004)
Roots < 2 mm	0.6	0.6	0.6	Matamala et al. (2003)

The C input generated from the ground vegetation is estimated using models based on plot tree species and age (Muukkonen & Mäkipää 2006; Muukkonen et al. 2006). Distinction is made among Norway spruce, Scots pine, and deciduous (birch spp.), with an age span of 0-200 years (Norway spruce and Scots pine) or 0-100 years (deciduous). Output of aboveground biomass is generated for four layers of ground vegetation: i) moss, ii) lichens, iii) herbs and grasses, and iv) shrubs. For shrubs and herbs and grasses, it is assumed that belowground biomass is twice the aboveground biomass. A compilation of studies documenting the above-to belowground-ratio for biomass and the annual turnover rates for ground vegetation litter Table 6.15 can be found in Peltoniemi et al. (2004).

Table 6.15 Annual turnover rates for litter from ground vegetation.

Component	Moss	Lichens	Herbs and grasses	Dwarf shrubs
Aboveground	0.33	0.1	1	0.25
Belowground	-	-	0.33	0.33

The chemical composition of tree C input was based on data used in the development of the Yasso07 model. For ground vegetation litter, the values in Peltoniemi et al. (2004) were used (Table 6.16).

Table 6.16 The fraction of C input made up of acid soluble (A), water soluble (W), ethanol soluble (E), and insoluble (N). See also Figure 6.12. If more than one value was available these were averaged by species and by chemical fraction and normalized to a sum of 1 across all four fractions.

Component[a]	A	W	E	N
Stem				
Norway spruce	0.63, 0.7	0.03, 0.005	0, 0.005	0.33, 0.28
Scots pine	0.66, 0.68	0.03, 0.015	0, 0.015	0.29, 0.28
Deciduous	0.65, 0.78	0.03, 0	0	0.32, 0.22
Roots (<2mm)				
Norway spruce	0.5508	0.1331	0.0665	0.2496
Scots pine	0.5791	0.1286	0.0643	0.228
Deciduous	as foliage	as foliage	as foliage	as foliage
Foliage				
Norway spruce	0.4826	0.1317	0.0658	0.3199
Scots pine	0.5180	0.1773	0.0887	0.2160
Deciduous	0.4079, 0.46	0.198, 0.1929	0.099, 0.0964	0.2951, 0.2507
Living and dead branches				
Norway spruce	as stem	as stem	as stem	as stem
Scots pine[b]	0.3997-0.5307	0.0105-0.0295	0.0382-0.1309	0.411-0.4608
Deciduous	as stem	as stem	as stem	as stem
Roots > 2 mm	as branches	as branches	as branches	as branches
Stumps	as stem	as stem	as stem	as stem
Bark	as foliage	as foliage	as foliage	as foliage
Ground vegetation[c]				
Moss	0.74	0.0867	0.0433	0.13
Lichens	0.836	0.0747	0.0373	0.052
Herbs and grasses	0.27	0.4667	0.2333	0.03
Shrubs	0.56	0.2067	0.1033	0.13

[a] The majority of values are from the Yasso07 user manual (Liski et al. 2009). [b] 25 observations were available. The range is given. [c] From Peltoniemi et al. (2004): W is 2/3 of "extractable"; E is 1/3 of "extractable".

C input was either non-woody (foliage, fine roots, all ground vegetation input), fine-woody (living and dead branches, coarse roots and bark), or coarse-woody (stems and stumps). The dimensions entering Yasso07 for each of the three size-groups are 0, 2, and 10 cm, respectively. Mean C input for all entries are found in Table 6.17.

Table 6.17 Mean values for C input and predicted soil C (AWENH denotes the chemical pools in Yasso07 to which C is distributed).

C input and model estimated soil C stocks (mean values)	Non-woody	Fine-woody	Coarse wood mortality	Coarse wood harvest	Total
C input (kg C m^{-2} yr^{-1})*	0.169	0.055	0.008	0.005	0.237
Equilibrium stock (kg C m^{-2})	3.8	1.0	0.4	0.1	5.3
Equilibrium stock (kg C m^{-2}), A pool	0.37	0.10	0.07	0.01	0.54
Equilibrium stock (kg C m^{-2}), W pool	0.05	0.01	0.01	<0.01	0.07
Equilibrium stock (kg C m^{-2}), E pool	0.05	0.01	<0.01	<0.01	0.06
Equilibrium stock (kg C m^{-2}), N pool	1.70	0.48	0.28	0.04	2.50
Equilibrium stock (kg C m^{-2}), H pool	1.67	0.41	0.07	0.01	2.16
Predicted stock* (kg C m^{-2})	3.8	1.1	0.4	0.1	5.4

**Across all entries in the time-series, excluding back-cast entries.*

For each NFI plot, start values for the five chemical C pools (Figure 6.12) were found by a pre-simulation or spin-up. This was done in two steps: 1) running the model in 5000 annual time steps to equilibrium in all chemical pools[30] and 2) running the model for a C input time series 1960-1990 specifically constructed for this purpose (see above). C input for the equilibrium spin-up was the mean C input estimated for the time of the first field inventory (NFI 6), grouped by tree species and site-index (i.e. at c. 1990). For the back-cast period as well as for the inventory period, total SOC was estimated for each entry, i.e. each time where a registration was available. Plot specific total SOC was found as follows: individual plot estimated annual C input for each entry in the time-series was used as input. Stock from the previous entry was used as the start value. A loop was applied to drive the model in as many years as is found between the entries (mostly five years but this deviates in some cases in the early inventory years). For the first entry, a loop of five years was applied following the spin-up stock.

C input as well as the simulated soil organic C stocks are kept in units of kg C m^{-2}. The Graphical User Interface parameter set for Yasso07 was applied (Tuomi et al. 2011b). To arrive at the reported timeseries, interpolation was done in the same way as for the living biomass estimates.

For spin-up as well as for the time-series, the applied weather data for Norway (Engen-Skaugen et al. 2008) was specifically produced for the NFI grid. Weather data for the equilibrium spin-up was the plot-specific climatic normal for the time period 1961-1990. For the time series simulations, plot specific weather data using the mean for 1991-2008[31] was applied.

The estimate of total SOC changes between entries in the time-series have been distributed to the dead wood, litter, and soil sink/source categories described above under the section on dead organic matter (see also Figure 6.11.).

Activity data

A variety of input data were used for mineral soils. This includes area representation for plots (as described for the NFI), basic NFI registrations (as described for the living biomass) as well as site-

[30] Increasing the spin-up time to 15000 annual time steps resulted in C stock changes of 0.03% lower and C stocks of 0.09% higher than with the chosen standard of 5000 steps (mean values across all plots).

[31] For technical reasons climate data is currently not available for 2009-2016.

index and stand age, complementary models and parameters including biomass models, turnover rates, chemical C input composition, and C input dimensions. Climate data were available from the Norwegian Meteorological Institute. The usage and values of input data are described under *Choice of method* above.

The input data from the NFI database used for the Yasso07 simulations did not account for the fact that certain plots of land were converted to forest land before the current NFI design was completed (see section 6.3) and are to be included as forest land remaining forest land in 2010. These small areas were found by interpolation (see section 6.4.1.1) and were assigned an emission/sequestration rate equal to the mean in the relevant years for the area covered by the methodology described above.

Assumptions/justification

The NFI definition of mineral soil is based on the depth of the organic layer (< 0.4 m). We assume that the decomposition processes on these areas are represented by the model structure and the parameters of the Yasso07 model found from data on mineral soils throughout the world. A more detailed delineation between mineral and organic soils (based on soil taxonomical classification) is currently not possible.

The allocation to the dead wood, litter, and soil pools assumes that there was no transport of humus (H) from the aboveground pools to the mineral soil since 1990. Thus, changes in soil organic C originating from aboveground litter in all stages of decomposition are assumed to be found in the organic layer above the mineral soil. While this is not strictly to be expected in reality, all soil organic C is accounted for and assumptions related to the distribution to the dead wood, litter, and soil pools do not affect the total emissions/removals. The assumptions result in a very small part of the total change to be allocated to the soil pool. According to field studies, changes in the mineral soil are very slow and are often not significantly different from zero (Emmett et al. 2007; Peltoniemi et al. 2004).

Drained organic soils (key category)

CO_2 emissions from drained organic soils on forest land is a key category. Due to the lack of national emissions factors, a Tier 1 method was chosen.

Activity data

To estimate the area of drained organic soils on forest land, statistics on subsidies for draining forest soils to enhance productivity was used. There was an increase in the area drained annually in the 1950's, with a peak of approximately 13 kha yr^{-1} in the early 1960's. Since then, drainage to promote forest production became much less practiced and the establishment of drainage ditches on mires with the aim of forest production was prohibited by law in 2007. Up until 2007, a total accumulated area of 241 kha was reported as drained.

Areas of drained soils for forest production were provided by Statistic Norway and are based on registration of subsidies provided for the implementation of drainage or ditches in connection with planting activities. The areas may be categorized as either forest or peatlands. The drained areas for both categories were summarized and accumulated for the years 1950 to 1989. The total accumulated area from 1990 and onwards is used for the reporting under forest land remaining forest land. However, from 1990 and onwards, only forest areas were included in the statistics.

Peatlands drained after 1990 are included in land converted to forest land, but the total area in the conversion category is derived from the NFI.

The activity data is further stratified into vegetation zones as suggested in the IPCC 2013 Wetlands supplement. All Norwegian forest land is considered boreal. The vegetation registration in the NFI database was studied in order to determine the distribution of drained organic soils to nutrient rich and nutrient poor. A ditch registration was performed on all NFI plots when the permanent sample plots were established (between 1986 and 1993). The plots were classified as ombrotrophic if one of the three conditions were met: 1) peat soils isolated from natural rivers, streams or springs with spruce and birch forest; 2) hummocks dominated with *Calluna vulgaris* and sphagnum mosses on the bottom, or 3) if hummocks were missing, the vegetation was dominated by *Trichophorum cespitosum, Eriophorum vaginatum,* and *Carex pauciflora*. The remaining plots with a ditch registration were classified as minerotrophic peatlands. According to the IPCC 2013 Wetlands supplement, minerotrophic peat soils can be classified as nutrient rich and ombrotrophic as nutrient poor. The results showed that 79 % of all drained plots are nutrient rich and 21 % are nutrient poor. This distribution was applied for estimation of CO_2, N_2O, and CH_4 on forest land remaining forest land.

During the recording of ditches between 1986 and 1993, only ditches less than 25 years of age were recorded. Thus, the NFI contains ditch registration only for ditches etstablished after approximately 1965. A large proportion of the area was drained before this, and that is why the area of drained organic forest soils is not based on the NFI registration but instead on subsidy statistics.

Emission factors

There are no national data on the CO_2 losses due to drainage of organic soils in forest land. We hence used the default emission factors from the IPCC 2013 Wetlands supplement as these represent the most up to date information. The mean national EF derived using the nutrient class distribution described above is 0.79 t C-CO_2 ha^{-1}.

Undrained organic soils

Organic soils on forest land not subject to drainage were assumed to be in equilibrium. No methods are available for the estimation of the C emissions or removals on these areas. Based on NFI registrations since 1990, final harvest or thinning was registered on about 8 % of the forest area (NFI definition of forest, i.e. including areas in conversion in UNFCCC terminology) on organic soil not subject to drainage and on 22 % of the forest area on mineral soils. Thus, the forestry activity on areas with undrained organic forest soils is relatively low. A study was carried out to survey existing empirical evidence on C emissions/removals from undrained organic forest soils. A total number of 30+ publications reporting on open and tree-covered bogs and fens in countries including Finland, Sweden, Canada, and Russia were included in the survey. The overall conclusion was that these areas have been long term C sinks (for millennia; based on peat column studies) and contemporary rates (short term studies 1-10 years) indicate that they on average and in most years act as sinks, but that they in some (dry) years may act as a source. Where comparisons have been made between open and tree-covered areas, there were no indications that open areas had higher accumulation rates than tree-covered areas. Comprehensive studies include Tolonen and Turunen (1996), Turunen et al. (2002), Roulet et al. (2007), and Nilsson et al. (2008).

6.4.1.2 Uncertainties and time-series consistency

Living biomass

The estimation of uncertainties for C stock changes in living biomass on forest land is described in section 6.3.5 and estimated uncertainties are presented in Table 6.3.

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. More details are described in section 6.3.4.

Dead organic matter and mineral soils

The uncertainties for dead organic matter and soil organic matter used in the key category analyses are based on Monte Carlo simulations of the national level of total soil organic C change (i.e. soil + litter + dead wood). One thousand simulation loops were run using the same calculation procedures as described above for forest land remaining forest land – mineral soils, but with variability introduced to a number of parameters (Table 6.18).

Table 6.18 Characteristics of the parameters used in the Monte Carlo simulations.

Parameter	Distribution	Mean	Standard deviation (% of mean)	References
Coarse woody litter dimension (cm)	Normal	10	20 %	Expert judgment
Branch and coarse root turnover (yr^{-1})	Normal	0.0125; 0.027; 0.025[a]	20 %; 25 %[b]	Peltoniemi et al. (2006); expert judgment
Fine root turnover (yr^{-1})	Lognormal	0.6[c]		(Brunner et al. 2013) (Hansson K et al. 2013); expert judgment
Foliage turnover (yr^{-1})	normal; uniform[b]	0.143; 0.33; 0.9-1.0[a]	15 %	Peltoniemi et al. (2006); expert judgment
Ground vegetation turnover (yr^{-1})	Normal	0.33; 0.1; 1.0; 0.25 (aboveground)[d] 0.33; 0.33 (belowground)[e]	40 %	Peltoniemi et al. (2006)
Biomass ratio for ground vegetation, below-to-above	Normal	2	20 %	Peltoniemi et al. (2006)

[a] Spruce, pine and deciduous respectively. [b] Conifers and deciduous respectively. [c] In lognormal: mean -0.51 and standard deviation 0.3. [d] Moss, lichens, herbs/grasses and shrubs respectively. [e] Herbs, grasses and shrubs.

Uncertainty around the Yasso07 model parameters was described in a number of parameter sets (Tuomi et al. 2011b) where covariance among model parameters are taken into consideration. For the C input parameters, a number of parameters were selected because they were assumed to have particularly large uncertainties. The C input parameters were assumed to be independent of each other, but in cases where differences among species or specific components could not be

documented, parameter values were drawn from the same distribution. Most of the parameters were assumed to be normally distributed and negative values were avoided by truncated distributions (negative values replaced by 0). The simulations were run with the Yasso07 model, with spin-up loops coded in Fortran, and the litter estimation run with the R software (R Core Team 2015). The result was an uncertainty estimate of the Yasso07 simulated C stock changes reported in 2014 of 15.5 %, which applied to both the DOM and mineral soil pools. The uncertainty is not likely to diverge with the values reported in the current year's NIR. The simulations are illustrated in Figure 6.13.

Uncertainties in the biomass models (Table 6.12) and the diffuse harvest and mortality frequencies underlying the C input estimates to Yasso07 are currently ignored; mainly for technical reasons. However, we believe that most of the uncertainty associated with the current methodology is captured.

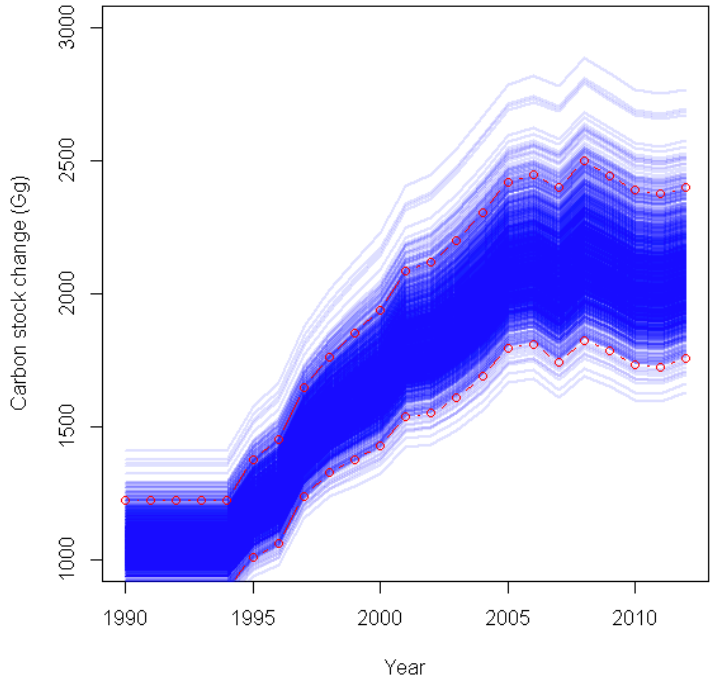


Figure 6.13 Results of the 1000 Monte Carlo simulation runs (blue lines) and 95 % confidence intervals (red lines and circles).

Drained organic soils

Default uncertainties of the emissions factors from the IPCC 2013 Wetlands Supplements were applied, and uncertainties of the areas were estimated by sample error. See Table 6.4.

6.4.1.3 QA/QC and verification

The Tier 1 QC procedures were followed for all source categories. Since the method to estimate C stock changes in living biomass was not generally changed, external QA was not necessary. The area estimates were carried out by two independent experts using two different statistical software systems based on the same database. Similarly, the carbon change estimates were compared on a sample basis.

The NFI database has QA/QC procedures as explained in section 6.1.6. For estimation of C changes in mineral soils on forest land, all input was kept strictly to one unit (kg C m^{-2}). An area based unit makes it easier to compare estimates with those from other studies and regions. Specific attention was given to unit conversions particularly when data were moved from one platform to another. The input data was screened for inconsistencies, i.e. occurrence of null-data/missing data, length of input objects etc. Plot specific C input, scaled in the expected manner with total plot standing biomass and plot specific soil organic C changes, had the expected dynamics (i.e. on average C change on the plot level was negative or low in young stands vs. medium age stands). Average litter input and total SOC output time series were compared with the time series used in the previous year's NIR. The estimated C stocks were low compared to field measurements (de Wit & Kvindesland 1999). Studies with an earlier version of Yasso (de Wit et al. 2006), showed that the model estimated about 40 % of the measured forest soil C stock in southeast Norway. This was suggested to be due, in part, to an overestimation of decomposition rates for recalcitrant organic matter. Comparison of the current model methodology and measured soil C stocks confirmed that Yasso07 underestimates measured stocks and that it may be related to specific soil types and moisture conditions (Dalsgaard, L et al. 2016). The area-based estimates of C change from the current application of Yasso07 were in the range observed in Liski et al. (2005) and Häkkinen et al. (2011). Conclusions from a validation project on soil C changes are found in Dalsgaard et al. (2017). The data from NFI dead wood registrations were supplemented by assumptions generally based on statistics and published quantitative factors (see footnote under 6.4.2.1) and were used to make an alternative calculation (validation) for a reference stock for C in dead wood in forests.

The programming methodology (programming software “R”) was characterized by: 1) a step-by-step development of functions, 2) checking the reproducibility of new functions (new code), and 3) close cooperation among programmers/developers. Code development and code control was done by different people.

6.4.1.4 Recalculations

Living biomass

In the 2018 submission, differences in the annual carbon change estimates were caused by calculating gains and losses on the plot level (instead of net-changes), new biomass models for birch corrections made in the NFI database, and recalculations in the extrapolation period due to the availability of new data throughout the time series.

Dead organic matter and soils

In the 2018 submission, differences in the annual carbon change estimates were caused by calculating gains and losses on the plot level (instead of net-changes), new biomass models for birch corrections made in the NFI database, and recalculations in the extrapolation period due to the availability of new data throughout the time series.

6.4.1.5 Planned improvements

Dead organic matter and soils

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.4.2 Land converted to forest land, 4A2

Land converted to forest land occurs from all land-uses, but with the largest areas from other land, settlements, and grassland. In the case of settlements, there are many types of settlements that have been converted to forest land in Norway. These can roughly be divided into four groups: power lines, roads, extraction (i.e. gravel, sand, and mining), and other. Estimates of C stock changes are provided for living biomass, dead organic matter (DOM), mineral soils, and organic soils for all relevant conversions. Conversion from other land to forest is almost exclusively due to natural succession.

6.4.2.1 Methodological issues

Living biomass

When a stand of trees reaches the predetermined minimum width, size, and crown cover in the forest definition, the stand is measured by the NFI. Estimates of the carbon stock change in this category are carried out as for the category forest land remaining forest land (see section 6.4.1.1).

Dead organic matter (key category)

Grassland, settlement, and cropland to forest are identified as key category for Level assessment 1990, Level assessment 2016 and/or Trend assessment 1990-2016 (see Table 6.6).

Choice of method

A Tier 2 method is used for estimating C changes in dead organic matter (DOM) for land converted to forest land. The method is based on a C stock change rate multiplied by the area under each land-use conversion.

Carbon stock change factors

Carbon stock change factors were estimated specifically for cropland, grassland, wetlands, settlements, and other land converted to forest land. The C change rates were calculated as the sum of the rates for the dead wood and litter pools and based on a C stock estimate that was assumed to be reached within 20 years, according to the default value stock change dependency. A reference stock for forest litter (61 t C ha^{-1}) was estimated as the average C density (t C ha^{-1}) in the L (litter), F (fermentation), and H (humus) layer of 893 forest soil profiles classified as mineral soil types or dry organic soils (Folisols) (de Wit & Kvindesland 1999; Esser & Nyborg 1992; Strand et al. 2016). Profiles were classified according to the Canadian soil classification system and the soil types were Podsols (443), Brunisols (158), Gleysols (76), Regosols (95), Hemic Folisols (35), and Nonsoils (20). Due to the field registration methodology, an LFH layer was not distinguished for Folisols, rather the whole C profile was assigned to the litter pool. Bulk density was found from Norwegian forest soils (Strand et al. 2016). An average reference stock for C in dead wood in forest (5 t C ha^{-1}, Stokland pers. comm) was based on expert judgment[32].

For all land-use conversions, except from other land, we assumed that the full litter stock of 61 t C ha^{-1} would develop over 20 years, resulting in a change rate of 3.05 t C ha^{-1} yr^{-1} and 10 % of the reference dead wood stock resulting in a change rate of 0.025 t C ha^{-1} yr^{-1}. The major part of the conversions from other land to forest land is on wooded land of low productivity. For this conversion, the annual stock change rate was limited to a 5 % relative build up compared to the stock on the previous land use, which resulted in a change rate for litter of 0.15 t C ha^{-1} yr^{-1} and for dead wood of 0.013 t C ha^{-1} yr^{-1} (Table 6.19).

Table 6.19 Annual stock change rates (t C ha^{-1} yr^{-1}) for land converted to forest land.

	Soil	DOM	Litter	Dead Wood	Total
			(t C ha^{-1} yr^{-1})		
Cropland	-1.30	3.08	3.05	0.03	1.78
Grassland	-2.05	3.08	3.05	0.03	1.03
Wetlands	-1.50	3.08	3.05	0.03	1.58
Settlements	0.57	3.08	3.05	0.03	3.65
Other land	0.14	0.17	0.15	0.013	0.31

[32] Based on a series of assumptions: a mean dead wood volume of 8.3 m^3 ha^{-1} (NFI registration), a weighted volume to biomass factor of 0.44 distributed to decay classes 1-5 from NFI registrations, dry biomass densities from Næsset 1999 (for individual decay classes), 50% C, expansion factors to estimate stump and belowground deadwood from NFI data. Further, a constant annual harvest since ca. 1900 of 10 mill m^3 stem wood was assumed (based on Statistics Norway, see Figure 6.4) from which belowground deadwood from harvested trees was estimated. It was also assumed that decomposition rates were identical for all dimensions, climatic regions, and belowground decomposition equaling aboveground decomposition. Dimensions of < 10 cm and dead wood older than 101 years were ignored. The result was 4.5-5.5 t C ha^{-1} depending on the decomposition rate (Næsset 1999, Melin et al. 2009). To complement these calculations, Yasso07 simulations showed an overall mean of 4 t C ha^{-1} in forest originating from coarse woody litter.

Activity data

The total areas of land converted to forest land were estimated by NFI data, which also corresponded to mineral soil areas.

Mineral soils (key category)

Grassland converted to forest land is identified as a key category for, Level assessment 2016 and Trend assessment 1990-2016 (see Table 6.6).

Choice of method, C stock change factors, and activity data

We used a Tier 2 method based on soil organic carbon (SOC) stock change rates multiplied by the area pertaining to each land-use change. The SOC stock change rates were derived by subtracting the mean national soil C stock for the previous land use from the stock of the current land use and dividing this difference by 20 years according to the IPCC methodology. The mean SOC stocks for forest land and cropland were based on measurements. For wetlands, the IPCC default SOC reference stock value was used. For grasslands, the IPCC default stock was modified using national data (see section on Land converted to grassland). No data were available for other land and it was assumed that conversion from other land resulted in a small positive stock change as described above for DOM.

The national forest mean SOC stock estimate was 57 t C ha^{-1} based on the same forest soil database (n=893) as described above for the DOM pool. Upscaling to a depth of 30 cm was made on the basis of field registrations and bulk density was estimated from the function of Baritz et al. (2010). Only mineral soil horizons were included. For non-soils where no differentiation between LFH and mineral horizons were made, all C in the profile was assumed to belong to the IPCC soil pool. The mean SOC stock estimate for cropland was 83 t C ha^{-1}, for grassland 98 t C ha^{-1}, and for wetlands 87 t C ha^{-1}. The resulting SOC change rates are shown in Table 6.19. Due to the lack of data, we assumed that the mean SOC stock for settlements was equal to 80 % of the relevant land use and thus a 20 % SOC loss over 20 years. The areas of land converted to forest land on mineral soils were obtained from the NFI.

Drained organic soils

For conversions to forest land on organic soils, we used a Tier 1 methodology applying the default emission factor for boreal and nutrient rich vegetation zone provided in the IPCC 2013 Wetlands supplement of 0.93 t C ha^{-1}. We assumed that organic soils previously used for grassland, cropland, wetlands, and settlements are drained. The activity data (areas) for organic soils converted to forest land was derived from the NFI.

6.4.2.2 Uncertainties and time-series consistency

Generally, the uncertainties related to emission estimates for all sinks/sources were rather large, partly due to the uncertainty of the area estimate. Uncertainties are shown in Table 6.3 for living biomass and DOM and in Table 6.4 for mineral and drained organic soils.

The time-series were consistently estimated.

6.4.2.3 QA/QC and verification

The internal QA/QC plan was completed as relevant for all source categories under land converted to forest.

6.4.2.4 Recalculations

The recalculations described in section 6.4.1.4 apply. Areas and living biomass were updated with the availability of new data from the NFI as part of the extrapolation method. Recalculations of the emissions from organic soils were also due to an update in the area statistics from Statistics Norway.

6.4.2.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.4.3 Completeness

The reporting of emissions and removals from forest land is complete.

6.5 Cropland – 4B

Agricultural cropland in Norway includes annual crops, temporary grass leys, and horticulture. Most of the area for agriculture is used for annual crops, primarily consisting of grass leys (55 %) used as forage or green manure, cereals (37 %) and a smaller area with root crops (2 %) where potatoes and rutabagas are the most important crops. Consequently, carbon is not stored for long time intervals in aboveground biomass. An exception is horticultural crops, where fruit trees can store large amounts of C. However, the area of perennial woody crops is a small fraction of the cropland area (approximately 0.2 %).

Substantial amounts of C reside in the soil, which is affected by agricultural management practices such as tillage, crop residues input and organic manure application (Paustian et al. 2000). Dead organic matter is not an important source category for cropland in Norway, since agroforestry systems are uncommon. This is with the exception of forest land converted to cropland, where emissions are reported. Over the time-series the total area of cropland has decreased on a national scale, despite that conversion to cropland also occurs, primarily from forest land but also from wetlands on organic soils. CO_2 emissions from living biomass, DOM, mineral and organic soils on croplands are reported in CRF Table 4.B as described below, and CH_4 emissions from organic soils on croplands are reported in CRF Tabel 4(II) as described in section 6.12.2.

6.5.1 Cropland remaining cropland, 4B1

The following emission sources were reported under cropland remaining cropland: C stock changes in living biomass of perennial horticultural crops (fruit trees), C emission from mineral soils due to agricultural management (crop rotations, C inputs, and tillage) and C emission caused by cultivation of organic soils (histosols). By far, the vast majority of emissions are caused by the cultivation of organic soils, which is a key category because of the uncertainty in the level and trend (see section 6.1.4). Net C gains are reported for living biomass and mineral soils.

6.5.1.1 Methodological issues

Annual changes in C stocks on cropland remaining cropland can be estimated as the sum of changes in living biomass and soils by $\Delta C_{CC} = \Delta C_{LB} + \Delta C_{SO}$. Norway applies the Tier 1 steady state assumptions for dead organic matter because agroforestry is generally not practiced. Thus, the agricultural systems have small amounts of dead organic matter. Living biomass is reported for fruit trees and emissions from soils are reported for mineral soils and organic soils (histosols).

Living biomass

Changes in C in living biomass are only considered for perennial woody crops, i.e. fruit trees. Perennial berry bushes are not considered due to the small area of approximately 300 ha (Borgen & Hylen 2013). Orchards may be felled but are considered to remain cropland. It is likely that orchards are converted to annual crops, leys or vegetables, or are replanted with fruit trees. Annual changes in the area of fruit trees fluctuate, leading to both net emissions and removals during the inventory period. However, C stock changes are relatively small.

Choice of method, emission factors, and activity data

Due to a lack of national data on biomass and carbon content in Norwegian fruit trees, we apply the Tier 1 gain-loss method. In the default method the change in C stock in living biomass (ΔC_{LB}) is equal to the C gain (ΔC_G) minus the C loss (C_L) by $\Delta C_{LB} = \Delta C_G + \Delta C_L$.

Statistics Norway collects data on the areas of fruit trees (apples, plums, cherries, sweet cherries and pears). The data were collected as a questionnaire survey with the objective of providing information about yields and production area. We use the data collected for the whole time-series 1990-2015. The area of fruit trees has generally decreased since 1990.

The IPCC default value for biomass accumulation in the temperate climate is 2.1 t C ha^{-1} yr^{-1}, and the corresponding value for C loss when plantations are terminated is 63 t C ha^{-1} yr^{-1}. The default age for fruit trees to reach maturity and cease accumulating C is 30 years.

Assumptions/justification

Given the default method, we assume that: 1) all orchard trees are less than 30 years old, and that growth accumulates at the default growth rate; and 2) all felled orchards are plantations with mature trees around 30 years of age. These assumptions may not be representative for Norway, as Norwegian fruit trees may mature in 20-25 years. However, the activity data does not provide information on the age of the plantations when felled.

Dead organic matter

The Tier 1 method was used assuming no carbon stock change in the dead organic matter pool on cropland remaining cropland and the notation key NO is reported in the CRF tables.

Mineral soils

The majority (roughly 94 %) of agricultural production occurs on mineral soils. Management practices have changed relatively little since 1990. Carbon inputs from animal manure have slightly increased in some parts of the country resulting in C uptake, i.e. positive carbon stock changes.

Choice of method

The Tier 2 method estimates annual changes in soil organic C (SOC) according to Equation 2.25 (IPCC, 2006a), where the annual change in SOC is given by $\Delta SOC = (SOC_0 - SOC_{0\text{-}T})/D$, where D is the time dependency of the stock change factors. SOC_0 is the stock the last year of the inventory period and $SOC_{0\text{-}T}$ is the C stock at the beginning of the inventory period. The default value for D was adjusted to 30 years, given the slower decomposition rates under the cool temperate climate in Norway (Borgen et al. 2012). The SOC stock is calculated as the product of the soil C reference stock (SOC_{REF}), the stock change factor for a given management and climate regime (F), and the associated area (A) given by $SOC = SOC_{REF} \times F \times A$. We used the reference stock and stock change factors estimated by the Introductory Carbon Balance Model (ICBM) in a study where CO_2 emissions were estimated for Norwegian cropland for 1999-2009 (Borgen et al. 2012). The ICBM is an ecosystem model from Sweden developed by Andrén et al. (2004). Soil C reference stocks were estimated for 31 different climatic zones (agrozones) assuming that continuous grass ley cropping was the reference condition. Stock change factors were calculated for eight rotations with and without manure application for each of the 31 agrozones, resulting in a total of 496 stock change factors. The rotations were 1:2 ley-grain, 1:1 ley-grain, 2:1 ley-grain, continuous grain (with and without straw removal), continuous ley,

1:2 roots-grain, and 1:2 roots-ley, where 1:2 means 1 year of root crops and 2 years of ley and so on. Further details of the model application and the stratification are given in Borgen et al. (2012). We calculated annual SOC changes per agrozone and summarized the CSC for the whole country.

Stock change factors and soil C reference stocks

The stock change factors represent the annual response of SOC to a change in management from a reference condition and can be calculated as $F = SOC_{REF}/SOC$. The soil C reference stocks were estimated by solving the ICBM model for steady state conditions using C input equal to continuous ley cropland for each Norwegian agrozone. Average national stock change factors for the 16 crop rotations and average soil C reference stocks per agrozone are listed in Borgen et al. (2012).

Activity data

Area statistics per crop type collected by the Norwegian Agricultural Authority (NAA) were compiled to create crop rotations, manure application, and C input level (Borgen et al. 2012). In brief, Norway was divided into 31 agrozones based on a combination of counties (*fylke*) and climate-based production zones (defined by NAA for subsidy application). Within each agrozone, the relation between the major crops of small grains (cereal and oilseeds), root crops (potato and rutabaga), and grass ley were used to allocate the areas under each of the eight crop rotations. In addition, activity data of the quantity of manure applied to fields of both grain and grass leys (temporary and partly permanent) for each county were received from Statistics Norway. These data correspond to the data used for estimating non-CO_2 emissions related to animal manure for the Agricultural sector. Estimated manure availability was translated into areas receiving animal manure per crop rotation and agrozone. The areas of cropland remaining cropland on mineral soils were estimated by the NFI for the whole time series.

Assumptions

The IPCC Tier 1 and 2 methods assume that the SOC change resulting from a change in management is linear between two steady states. Soil C changes are likely to be more dynamic, and it has been argued that the lower tier methods overestimate net C sequestration, particularly where the soil was not in a steady state at the beginning of the inventory (Sanderman & Baldock 2010). However, at the present time, this method provides an acceptable approximation.

Organic soils (key category)

Organic soils make the largest contribution of CO_2 emissions within the source categories for cropland. It is a key category with a relatively large uncertainty. The Norwegian definition of histosols (organic soils) for cropland is soils with >10 % C in the topsoil layer (0-30 cm).

Choice of method and emission factor

A Tier 1 method is used for estimation of CO_2 emissions from organic soils on cropland. The IPCC Tier 1 method necessitates the use of the default emission factor (EF) to be multiplied by the area (A) of organic cultivated soil according to Equation 2.26 $C_{LOSS} = A \times EF$ (IPCC 2006). Since the 2015 submission, Norway has used the default EFs from the IPCC 2013 Wetlands supplement (IPCC 2014b) for boreal/temperate cropland of 7.9 t CO_2-C ha^{-1} yr^{-1}. For Norway we considered the default value from IPCC to provide a more robust and suitable estimate than the EF based on expert judgment which was used until NIR 2014.

Activity data

The area of agricultural histosols (organic soil) was estimated as described in section 6.3.2.

6.5.1.2 Uncertainties and time-series consistency

Estimation of uncertainty is related to the tier level of the methodology used for each sink/source category and land-use category. For cropland remaining cropland, Tier 1 and 2 methods were applied. The IPCC guidelines include uncertainty estimates for default emission/removal factors.

For cropland remaining cropland, the total uncertainty is equal to the propagation of the uncertainty related to the living biomass (U_{CC_LB}), mineral soils (U_{CC_MS}), and organic soils (U_{CC_OS}) and is given by

$$U_{CC} = \sqrt{{U_{CC\_LB}}^2 + {U_{CC\_MS}}^2 + {U_{CC\_OS}}^2}.$$

For each source category, the uncertainty is a combination of the uncertainties related to the emission factors U_{EF} and the activity data U_A, which is the uncertainty used in the KCA, and can be calculated by

$$U = \sqrt{{U_A}^2 + {U_{EF}}^2}.$$

The uncertainty of the activity data may include errors in census returns as well as differences in the definition between agencies, sampling design, and interpretation of samples. The activity data used under cropland, i.e. areas per crop types and manure production were collected through the subsidy application scheme administrated by NAA and compiled by SSB. The data is based on a total national census. The NAA performs quality control on 5 % of farms to determine if areas are provided correctly. These sample checks show very few errors. The area reported is based on a factor value multiplied by the last year's area, thus errors in previous years may accumulate. However, according to expert judgment given by SSB, the uncertainty of the activity data is estimated to be approximately 0 %.

Living biomass

Sources of uncertainty for the Tier 1 method for living biomass includes the degree of accuracy in the C accumulation and loss rates and the land-use activity data. The IPCC default uncertainty error ranges for aboveground woody biomass accumulation in the temperate climate is ±75 % based on expert judgment. Uncertainty of the activity data was estimated by SSB as approximately 0 %. The areas of orchards are used directly from the NAA/SSB data and are not related to the NFI database. The uncertainty of the C biomass accumulation per unit area is therefore equal to the total uncertainty of the C changes in living biomass on cropland remaining cropland.

Mineral and organic soils

Uncertainty related to emission estimates from soils on cropland can currently only be precisely quantified for the area estimates, which is based on the NFI data. For the area of mineral soils on cropland remaining cropland, the uncertainty estimate was 7 % (Table 6.4). For the mineral soil estimates, the areas per crop type that are used to determine the areas under individual crop rotations were collected and compiled by the Norwegian Agriculture Authority (NAA) and Statistics

Norway (SSB). Since the data are based on a census, it was assumed not to increase the area uncertainty. The uncertainties related to the stock change factors estimated by ICBM were estimated at ± 50 % based on expert judgment, making the total uncertainty 51 %. For organic soils the area uncertainty was 25 % and default uncertainties were used from the guidelines. Total uncertainty for CO_2 emissions from drained organic soils on cropland was 32 % (Table 6.4).

6.5.1.3 QA/QC and verification

The standard Tier 1 QC procedures described in section 6.1.6 were performed for both living biomass and soil estimates. No external QA was performed on the Tier 1 method for estimating C changes in living biomass stocks in orchard trees. Before the 2013 submission, when the Tier 2 for mineral soils on cropland remaining cropland was implemented, quality assurance was done through the standardized peer-review process.

6.5.1.4 Recalculations

Recalculations for CSC in living biomass were made for the year 2015 only due to an update in the activity data from Statistics Norway. The area times-series of both mineral and organic soils were also slightly recalculated due to the annual NFI updates and extrapolation of area data.

6.5.1.5 Planned improvements

There are no planned activites this year that will improve the data quality or the documentation for this source category.

6.5.2 Land converted to cropland, 4B2

Emissions and removals on land converted to cropland are reported from the C stock changes in living biomass, dead organic matter, mineral soils, and organic soils. Carbon stock changes in dead organic matter on other land-use conversions than those to and from forest land can be considered insignificant and are reported with the notation key NO in the CRF-reporter.

Land conversion to cropland primarily occurs from forest land and less so from grassland, wetlands, and settlements. There were no conversions from other land to cropland during the inventory period, and NO is reported in the CRF Table 4.B. Conversion of land to cropland usually results in a net loss of carbon from living biomass and soils to the atmosphere (IPCC 2003). However, the reference soil C stock on settlements and forests is relatively small compared to cropland, and thus net C sequestration is reported, while losses are estimated in the DOM pools for forest land converted to cropland.

6.5.2.1 Methodological issues

Living biomass

For forest land and wetlands converted to cropland, we used the Tier 3 method described for forest land to estimate C stock changes in living biomass. For settlements converted to cropland a Tier 1 method that assumes the immediate gain of the default C stock on settlements of 4.7 t C ha^{-1} changed area (IPCC 2006, p. 8.18) was applied. The category grassland converted to cropland is very small. Nonetheless, as of 2007, changes in the woody biomass are monitored also on grassland. No change in the living biomass was observed for those sample plots converted from grassland to cropland. Therefore, no change was also assumed for one sample plot that was converted to cropland before 2007, and NO is reported for the whole time series. Formally, this is a Tier 2 method.

Dead organic matter (key category)

Carbon stock changes in the dead organic matter (DOM) pool on forest land converted to cropland is a key category for Level assessment 2016 and/or Trend assessment 1990-2016 (see Table 6.6).

Choice of method, C stock change factors, and activity data

A Tier 2 method was used to estimate C stock changes in DOM from forest land converted to cropland. No changes have been made in the method since the 2015 submission. The method is based on a C stock change rate multiplied by the area of forest land converted to cropland as described under land converted to forest land – dead organic matter. The mean C change rate was -3.3 t C ha^{-1} yr^{-1} based on the assumption that all litter and dead wood in an average Norwegian forest would be lost over 20 years. Areas of land converted to cropland were estimated using the NFI data.

For grassland, wetlands, and settlements converted to cropland, we used the Tier 1 method that assumes no carbon stock change in the DOM pool. Emissions are reported as NO.

Mineral soils (key category)

The sink/source category mineral soil on forest land converted to cropland was identified as a key category for Level assessment 1990 and Trend assessment 1990-2016 (see Table 6.6).

Choice of method and C stock change factors

We used a Tier 2 method for estimating C stock changes in mineral soil on land converted to cropland. The same method was used for all land-use conversions and described under forest land in section 6.4.2.1. It is based on annual stock change rates multiplied by the area. The stock change rates were derived from the difference between the mean stock of the previous land use and the cropland stock divided by 20 years according to IPCC default methodology. For settlements we assumed the stock was equal to 80 % of the cropland stock, i.e. a 20 % relative increase in SOC over 20 years. For forest land converted to cropland, the stock change rate for the mineral soil was positive, indicating an uptake of SOC. However, the loss rates in the DOM pool were larger and the net result for the two pools combined was a net C loss (Table 6.20).

Table 6.20 Annual stock change rates (t C ha^{-1}) for land converted to cropland.

	Soil	DOM	Litter	Dead Wood	Total
			(t C ha^{-1} yr^{-1})		
Forest land	1.3	-3.30	-3.05	-0.25	-2.00
Grassland	-0.75	0			-0.75
Settlements	0.83	0			0.83

The mean national SOC stock for cropland was estimated based on 1 418 soil profiles made throughout the country from 1980 to 2012. The data are a compilation of several different sampling projects where soil profiles were examined using an auger, and soil type and thickness were recorded at different horizons. The organic carbon concentration was measured by dry combustion analysis. To estimate the national mean C stock, the C density was calculated per soil horizon and summarized down to 30 cm depth based on the bulk density function for Norwegian cropland from Riley (1996) and assumed zero weight percentage of gravel. The mean national C stock for Norwegian cropland was 83 t C ha^{-1}. The forest stock equal to 57 t C ha^{-1} was also based on measurements (see section 6.4.2.1), whereas the grassland (98 t C ha^{-1}) and the wetlands (87 t C ha^{-1}) stocks were derived from IPCC default reference values (see their respective section for details).

Activity data

Areas of land converted to cropland on mineral soils were estimated using the NFI data and the 1990 baseline map of soil types.

Organic soils (key category)

Forest land and wetlands converted to cropland on organic soils were determined to be key categories for Level assessment 2016 (see Table 6.6).

Choice of method and emission factor

We used a Tier 1 method to estimate emissions from organic soils on land converted to croplands. The default emission factor of 7.9 t C ha^{-1} yr^{-1} was applied, assuming similar emissions as for cropland remaining cropland, and regardless of the previous land use.

Activity data

All areas were derived as described in section 6.3.2.

6.5.2.2 Uncertainties and times-series consistency

Uncertainties were estimated as described in section 6.1.3 and are shown in Table 6.3 for living biomass and DOM, and in Table 6.4 for mineral and organic soils.

6.5.2.3 QA/QC and verification

The Tier 1 QC procedures were performed during the estimation of C stock changes for land converted to cropland. No additional QA was performed.

6.5.2.4 Recalculations

Carbon stock changes of all pools were recalculated because of the revised area data. For conversions from forest to cropland, the recalculations described in section 6.4.1.4 apply.

6.5.2.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.5.3 Completeness

The reporting of emissions from cropland is complete.

6.6 Grassland – 4C

Grasslands cover a very small (approximately 0.7 %) part of Norway. According to the IPCC guidelines, grasslands are defined as grass areas that have insufficient woody biomass to be classified as forest land and that are not considered cropland (IPCC 2006). However, if grazing as a land use is considered more important than forestry, the NFI (National Forest Inventory) classifies a plot as grassland even if the forest definition is met. Grasslands also include range lands and pastures where some mechanical surface harvesting for fodder may take place. The Norwegian interpretation of the IPCC land-use category grassland, which is based on available data, is that grasslands are generally mechanically harvested or grazed, but cannot be plowed. They may be cultivated more or less intensively by the use of fertilization, mechanical harvesting, and utilization of improved species.

In the national agricultural statistics collected through the subsidy application scheme, two types of grassland areas can be identified. These are surface-cultivated grass pastures (*overflatedyrka eng*) and unimproved grazing land (*innmarksbeite*). Surface-cultivated pastures tend to have shallow topsoil layers, often with surface rocks. They can be mechanically harvested but cannot be plowed. Unimproved grazing lands cannot be mechanically harvested (or plowed) and are considered semi-natural landscapes. Furthermore, unimproved grazing land is defined as areas covered by a minimum of 50 % grasses or grazable herbs and enclosed by a fence or a natural barrier. An additional requirement for both grassland types is that the area must be grazed or harvested at least once a year to be eligible for subsidy support.

6.6.1 Grassland remaining grassland, 4C1

For grassland remaining grassland, C stock changes are reported for living biomass and mineral and organic soils. Grassland remaining grassland is a relatively small key category with respect to living biomass according to the level assessment of 1990 and 2016.

6.6.1.1 Methodological issues

Emissions due to changes in dead organic matter are assumed negligible for this category, because little dead wood and litter are generated in grassland systems. Assuming that C stock change in DOM is in a steady state condition is in accordance with the IPCC 2006 guidelines, and the notation key NO is used in the CRF tables.

Living biomass

A Tier 2 method was used. Living biomass on grassland has been measured in the NFI since 2007. The average C stock change (gains and losses) per hectare and year was calculated based on the sample plots measured since 2007. The C gain and loss averages were then multiplied with the area of grassland remaining grassland to obtain the total gain and loss estimates, respectively.

Mineral soils

Choice of method

The default Tier 1 approach was used for estimating CO_2 emissions from grassland remaining grassland on mineral soils. The default IPCC methodology estimates soil C changes based on default stock change factors specific to management and climate regimes and soil C reference stocks specific

to climate and soil type. The annual changes in SOC can be calculated as the difference between the SOC stock at the beginning (SOC_0) and at the end (SOC_{0-T}) of the inventory period (T) divided by the time dependency of the stock change factors (D) and is given by

$$\Delta SOC = (SOC_0 - SOC_{0-T})/D \qquad \text{Equation 2.25 (IPCC 2006).}$$

The time dependency of the stock change factors is by default 20 years. If T is larger than D, then T replaces D and T is equal to the length of the inventory period. This is relevant for the emissions estimated from 2011 and onwards. SOC stocks for any year of the inventory can be calculated as the product of the soil C reference stock (SOC_{REF}), the stock change factors (F), and the area under a given management practice (A) according to

$$SOC = SOC_{REF} \times F \times A \qquad \text{Equation 2.25 (IPCC 2006).}$$

The C reference stock is the soil C stock under the reference condition, which in the default method is native uncultivated soil. The reference stock is specific to climate zone and soil. Exposed bedrock should be assigned a reference stock of zero, however, this is not specifically accounted for.

Activity data

Areas of the two grassland management types were collected by Statistics Norway. These data were collected from farmers' applications for subsidies. Areas of unimproved and improved grassland are given per farm unit. The total area of grassland remaining grassland on mineral soils came from the NFI database. The percentages under each management type were taken from data by Statistics Norway (SSB) and applied to the area of mineral soil. Due to different methodological approaches, the area estimated by NFI is larger than the area reported by SSB (Table 6.21). The difference is larger in the beginning of the inventory period than later, which is partly because the area of unimproved grassland in the SSB data only accounted for fertilized pasture from 1990 to 1997, whereas all unimproved pastures were included in the later years. In general, the area of extensively-managed grassland (unimproved) has increased, while intensively managed (improved) grazing lands have decreased.

Table 6.21 Areas (ha) of unimproved, improved, and total grasslands in Norway from 1990 to 2016.

	Area (ha) from Statistics Norway (SSB)			Area (ha) from the NFI database
Year	**Unimproved grassland**	**Improved grassland**	**Total grassland**	**Grassland remaining grassland (mineral soil)**
1990	81 357	27 180	108 537	225 576
1991	85 453	26 973	112 426	224 892
1992	89 735	27 153	116 888	224 207
1993	94 215	25 975	120 190	223 523
1994	98 422	26 050	124 471	222 838
1995	100 719	26 447	127 166	221 973
1996	103 008	26 672	129 681	221 259
1997	107 900	25 478	133 378	220 457
1998	111 474	29 179	140 653	219 339
1999	121 606	29 517	151 123	217 933
2000	129 133	28 997	158 129	216 888
2001	132 293	28 244	160 536	215 752
2002	135 408	28 067	163 474	214 833
2003	137 061	27 382	164 443	214 274
2004	139 083	26 951	166 033	213 932
2005	142 407	26 770	169 177	213 048
2006	145 588	26 110	171 698	211 895
2007	149 207	25 375	174 582	210 381
2008	150 810	24 327	175 137	208 831
2009	152 352	22 455	174 806	207 010
2010	155 136	20 704	175 839	205 550
2011	156 452	20 119	176 571	204 445
2012	156 407	20 128	176 535	203 520
2013	156 436	19 953	176 389	202 613
2014	155 782	19 851	175 633	201 841
2015	156 106	19 767	175 873	200 889
2016	155 986	19 517	175 503	199 838

The grassland areas per management type were stratified into eight regions (Figure 6.14). The area data from SSB are available on a municipality level facilitating the stratification. Soil maps were collected to stratify the areas according to soil type and to assign specific C reference stocks based on the distribution of soil type within each region.

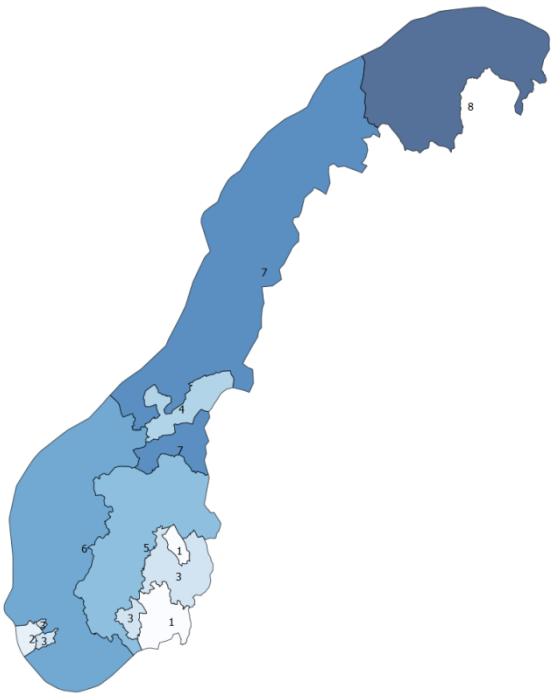


Figure 6.14 Eight regions of Norway used to stratify grassland activity data for the Tier 1 application.

Stock change factors and soil C reference stocks

The default stock change factors developed by Ogle et al. (2004) were used; see Table 6.2 (IPCC 2006). The land-use factor for grassland is one (F_{LU} = 1). There are four management factors (F_{MG}): unimproved/nominal (non-degraded), moderately degraded, severely degraded, and improved grasslands. There are two input factors (F_I): nominal and high input level. For the two types of grassland management identified (unimproved and improved) we assigned the following management factors: F_{MG} = 1 for nominally managed (non-degraded) grassland for permanent unimproved grass (i.e. *innmarksbeite*), and F_{MG} = 1.14 for improved grassland with surface cultivated grassland (i.e. *overflatedryka eng*). The latter factor is assigned to grassland that is sustainably managed with moderate grazing pressure and that receives one improvement of fertilization, species improvement, or irrigation. The input factor is not modified due to a lack of detailed activity data for manure management on the two grass types. Under Norwegian conditions, it is a reasonable assumption that most grassland receives only one improvement in the form of fertilizers annually, as grazing areas are seldom reseeded (except in cases of severe frost damage) and also irrigation is generally not practiced.

To assign the soil C reference stock, an analysis was made of the national soil classification (World Reference Base, WRB, soil taxonomy) database developed by the Norwegian Institute of Bioeconomy Research. The percentage of the total grassland area that has been sampled until now varies between the eight strata defined. The results of the analysis were that high-activity clay (HAC) soils predominate in all climate zones, but spodic soils make up almost one third of the area in region 2 (Figure 6.15).

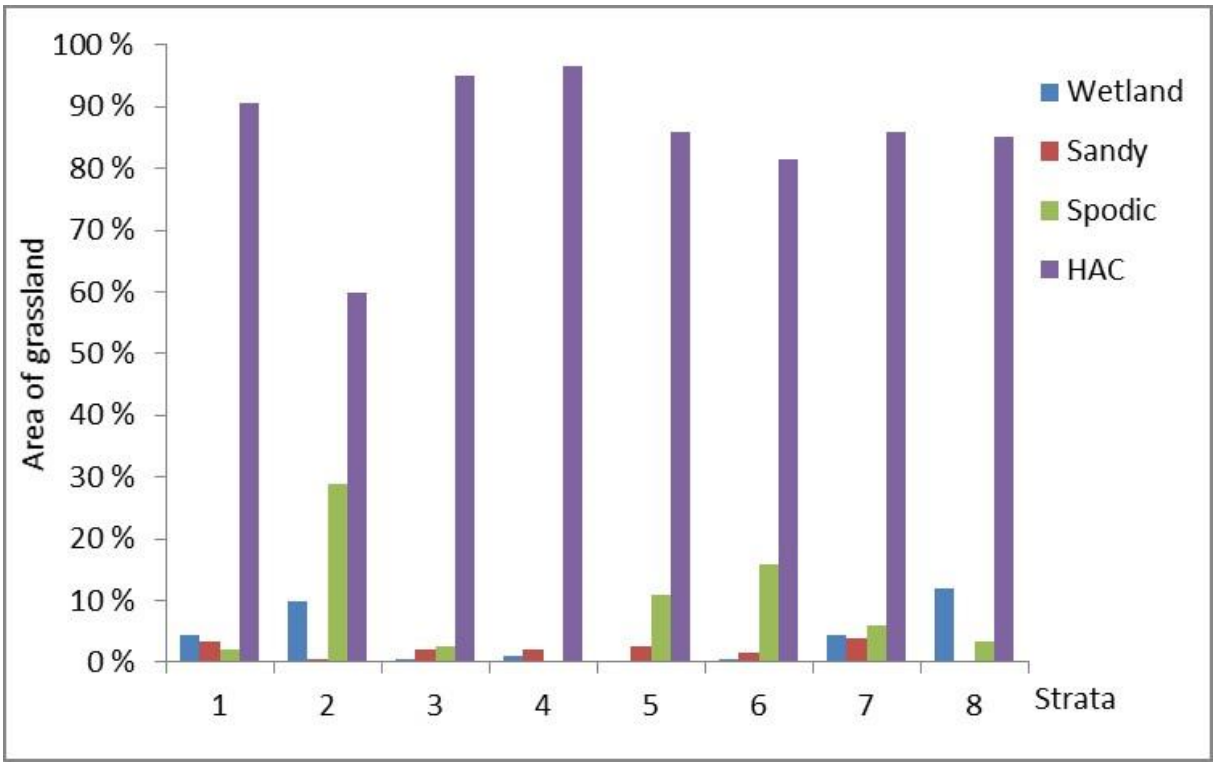


Figure 6.15 Distribution of soil types on grassland areas for the eight strata. The IPCC soil types are high-activity clay soils (HAC): leptosols, fluvisol, phaeosem, albeluvisol, luvisol, umbrisol, cambisol, regosol; wetland soils: gleysols; sandy soils: arenosols; and spodic soils: podzol.

The soil C reference stock (SOC_{REF}) for the cold temperate moist climate zone in 0-30 cm depth are 95 t C ha^{-1}, 71 t C ha^{-1}, 115 t C ha^{-1}, and 87 t C ha^{-1} for HAC, sandy, spodic, and wetland soils, respectively; see Table 2.3 (IPCC 2006). Soil C stock changes were first calculated per stratum and soil type. The final stock changes were given by multiplying the C stocks per stratum and soil type with the fractions for each soil type.

Organic soils

Organic soils on grassland remaining grassland are responsible for minor CO_2 emissions similar to those from mineral soils.

Choice of method

We used the Tier 1 method described for organic soils in cropland remaining cropland (section 6.5.1).

Activity data

The area of organic soil on grassland remaining grassland was derived in the procedure described in section 6.3.2.

Emission factor

The default EF for shallow-drained, nutrient-rich grassland of 3.6 t C ha^{-1} yr^{-1} was applied (IPCC 2014b). The emission factor was changed after studying the orthophotos of the NFI plots of grassland on organic soils. The majority of the plots were either with too many trees to allow proper cultivation and thus overgrown drains, or on fairly thin soil layers (visible bedrock in some places) such as surface cultivated grasslands. We found the shallow drainage factor to be more appropriate.

6.6.1.2 Uncertainties and time-series consistency

The uncertainties were estimated for all sink/source categories under grassland remaining grassland and included in the key category analysis.

For living biomass, the uncertainty estimate of the C stock change and the area were based on the sample variance and estimated as described in section 6.1.3 and is shown in Table 6.3.

For the mineral soil pool, a Tier 1 uncertainty assessment was made considering the uncertainty related to the C stock estimate (the stock change factors) using default values and the activity data using the sample variance. Firstly, we estimated the uncertainty of the SOC stock estimate (U_C) by propagating the uncertainty of the stock change factors and SOC reference stock. The errors of the stock change factors are provided in Table 6.2 (IPCC 2006). For the improved grassland management stock change factor, the uncertainty is ± 11 %. The stock change factor for nominally managed grassland has no associated uncertainty as it is the reference condition. The default C reference stock has an uncertainty of ± 90 %, according to Table 2.3 (IPCC 2006). Secondly, the uncertainty of the activity data was combined with that of the C stock change per hectare. The uncertainty in the activity data (U_A) covers both uncertainty in the estimates of the grassland management type (SSB data) and uncertainty in the areas of grassland remaining grassland determined in the NFI. The first source of uncertainty, which is related to the estimation of the grassland management system, was estimated to be close to zero by SSB. According to the sample validations routinely performed by the collection agency (NAA), farmers are unlikely to make errors (or false reporting) and very few of these errors exist. The second source of uncertainty in the activity data, i.e. of the area estimate of grassland remaining grassland, was determined by the sample error and equal to 14 % (Table 6.4). Although the area included organic soils, we assume that the uncertainty for the mineral soil area is similar. Uncertainties of the area estimates are quantified as described in section 6.1.3. The total uncertainty for the mineral soil estimate was propagated using equation 5.2.1 of the Good Practice Guidance (IPCC 2003) and equal to 91%.

The uncertainty for organic soils is based on default values for the emission factor and on the sample error for the area estimate. Uncertainty estimates for both mineral and organic soils are shown in Table 6.4.

6.6.1.3 QA/QC and verification

The Tier 1 QC procedures were performed both for living biomass, mineral soil, and organic soil emission estimates. The Tier 1 method used for mineral soils was elicited for external QA before the 2013 submission. All necessary documentation was supplied to an international expert for an evaluation of the method application and description. The expert emphasized the need to keep the area of grassland remaining grassland constant at the beginning and end of each inventory period when recalculating the entire time-series. Furthermore, quality checks were implemented to ensure that the total land area per stratum remains constant over the time-series.

6.6.1.4 Recalculations

The recalculations described in section 6.4.1.4 apply. The whole time-series was recalculated for all sources due to the updates in the NFI data.

6.6.1.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.6.2 Land converted to grassland, 4C2

Emissions from land converted to grassland were primarily caused by net C losses in the DOM pool on forest land converted to grassland. There were land-use conversions from forest land, wetlands and settlements to grassland. For forest land converted to grassland, C emissions were estimated from changes in living biomass, DOM, and soils (mineral and organic). All the area of wetlands converted to grassland was on organic soils. Emissions were therefore estimated for stock changes in living biomass and organic soils for this land use conversion. All the area of settlements converted to grassland was on mineral soils.

Forest land converted to grassland is identified as a key category with respect to living biomass, DOM, and mineral soils, in the Level assessment 2016 and Trend assessment 1990-2016 (see Table 6.6).

6.6.2.1 Methodological issues

Living biomass (key category)

The choice of method, activity data, and assumptions related to the estimation of C stock changes in living biomass on land converted to grassland are identical to those described under forest land.

Dead organic matter (key category)

Carbon stock changes in DOM were reported with a Tier 2 method for forest land converted to grassland. For wetlands converted to grassland and settlements converted to grassland we apply the Tier 1 method that assume no net change in the C pool of dead organic matter, thus the notation key NO is used in the CRF-tables.

Method choice, C stock change factors, and activity data

A Tier 2 or Tier 1 method was used (see above). The areas of land converted to grassland were estimated using the NFI data. The C stock change rate estimate of the DOM pool on forest land converted to grassland was -3.30 t C ha^{-1} based on change rates of -3.05 t C ha^{-1} and -0.25 t C ha^{-1} for the litter and dead wood pools, respectively. The change rates were estimated assuming that a C stock of 61 t C ha^{-1} reduces to zero in 20 years (default value). The estimation of the litter and dead wood stocks are described under forest land.

Mineral soils (key category)

A Tier 2 method is used to estimate C stock changes on land converted to grassland (as well as all other land-use conversion).

Choice of method, C stock change factors, and activity data

The Tier 2 method is based on the multiplication of a C stock change rate with the pertaining area. Carbon stock change rates were estimated as the difference between the soil C stocks per land-use class before and after land-use change, divided by 20 years. The C change rate for forest land

converted to grassland was 2.05 t C ha^{-1} yr^{-1}. The estimate of the SOC stock for forest land was 57 t C ha^{-1} based on the measurements as described in section 6.4.2.1. The stock for grassland was based on IPCC default reference stocks per soil type and national area distribution of the soil types. Both stocks were estimated for 30 cm soil depth.

The mean national SOC stock estimate for grassland was 98 t C ha^{-1} and was derived by multiplying the IPCC default stock change factors with the SOC reference stock for average Norwegian grassland. This estimate is based on the national ratio of improved and unimproved grassland management practices and the national distribution of IPCC defined soil types for the grassland area. More specifically, a mean stock change factor was calculated as F = 0.82 × 1 + 0.18 × 1.14 = 1.03, based on the long-term mean distribution of unimproved and improved grassland (82 % and 18 %, respectively) and the default stock change factors of 1 and 1.14 for unimproved and improved grasslands. A mean SOC reference stock was estimated assuming the following distribution: 85 % high-activity clay soil, 2 % sandy soils, 9 % spodic soil, and 4 % wetland soils (i.e. gleysols), resulting in an estimate of SOC_{REF} = (0.85 × 95 + 0.02 × 71 + 0.09 × 115 + 0.04 × 87) t SOC ha^{-1}= 96 t SOC ha^{-1} (see section 6.6.1) for details. The mean national C stock for grassland was 1.03 × 96 t C ha^{-1} = 98 t C ha^{-1}.

The C change rate for settlements converted to grassland was 0.98 t C ha^{-1} yr^{-1}. It is based on the assumption that settlements reference mineral soil C stocks are 80% of those of grassland (same assumption as for settlements converted to forest).

The areas of land converted to grassland were estimated using the NFI data. To get the area of mineral soil on forest land converted to grassland, the area of organic soils was subtracted from the total area.

Organic soils

Emissions from organic soils on land converted to grassland were estimated using the Tier 1 method. Only wetlands on organic soils have been converted to grassland and these areas were assumed drained to enable grassland production.

Method choice, emissions factors, and activity data

The Tier 1 method was used applying a default emissions factor of 3.6 t C ha^{-1} yr^{-1} for shallow-drained grasslands in the temperate zone from the IPCC 2013 Wetlands supplement. The NFI database was used to estimate the areas of wetlands converted to grassland on organic soils.

6.6.2.2 Uncertainties and time-series consistency

The total uncertainties for living biomass, DOM, mineral, and organic soils are shown in Table 6.3 and Table 6.4. All methods were applied consistently for the entire time-series.

6.6.2.3 QA/QC and verification

The standard Tier 1 QC procedures were performed during the estimation of C stock changes for land converted to grassland. No additional QA was performed.

6.6.2.4 Recalculations

The recalculations described in section 6.4.1.4 apply. All emissions of land converted to grassland were recalculated in the current year's submission due to the updates in the NFI data for living biomass and areas.

6.6.2.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.6.3 Completeness

The reporting for grassland is complete.

6.7 Wetlands – 4D

Wetlands in Norway cover almost 12 % of the total land area. Most of the wetlands in Norway are unmanaged mires, bogs and fens, as well as lakes and rivers. Carbon stock changes in living biomass are reported for wooded mires. Managed wetlands include peat extraction areas and reservoirs (dams). For peat extraction sites, both on-site and off-site emissions are reported. On lands converted to wetlands, emissions and removals are reported for living biomass, DOM, and soils. There is no default method for estimating carbon stock changes for flooded land remaining flooded land, we have therefore no estimates for this source.

6.7.1 Wetlands remaining wetlands, 4D1

The NFI contains data on C stock changes in living biomass (trees) on wooded mires, for which the associated emissions and removals have been reported. Carbon stock changes in other sources (DOM and soils) in unmanaged wetlands have not been estimated. Emissions caused by soil C changes during peat extraction have been accounted for according to the 2006 IPCC guidelines (IPCC 2006) and IPCC 2013 Wetlands supplement (IPCC 2014b). On-site and off-site CO_2 emissions from peat extraction (reported as organic soils in CRF table 4.D) is a key category with respect to the 1990 level assessment (Table 6.6).

6.7.1.1 Methodological issues

Living biomass – wooded mires

Wooded wetlands are classified as forest if the definition of forest land is met. If this is not the case, such areas are considered under wetlands remaining wetlands as the subgroup wooded mire. Wooded mires are not considered managed lands, and hence we only report CSC in the living biomass. CSC in DOM, mineral and organic soil are reported as NO.

To estimate CSC in living biomass, we applied the Tier 3 method, which was used for all reported biomass estimates, except for cropland remaining cropland, and land converted to settlements. The method is described in detail in section 6.4.1. The areas of wetlands remaining wetlands and C stocks on wooded mires, are based on the NFI.

Peat extraction (key category)

For wetlands subject to peat extraction we use a Tier 1 approach for on-site emissions and a Tier 2 approach for off-site emissions. Under the default method, the activity data do not distinguish between peatlands under peat extraction, and those being converted for peat extraction (IPCC 2006; IPCC 2014b). The area of land converted to peat extraction is therefore reported as NE. The emissions from removals of trees during clearing are included under living biomass on wooded mires, and reported as IE. Other changes in C stocks in living biomass on managed peat lands are assumed to be zero (IPCC 2006).

The area utilized for peat extraction is estimated to be 2.00 kha for the whole time series 1990 - 2016. On-site emissions caused by peat extraction are thus constant over the inventory period. Soil C stock changes are estimated to be -5.6 kt C yr^{-1}, which is equal to emissions of 20.5 kt CO_2 yr^{-1}. On-site emissions of N_2O and CH_4 are estimated to 0.0009 kt N_2O yr^{-1} and 0.0658 kt CH_4 yr^{-1}, respectively.

Off-site emissions vary with years, and were 40.3 kt CO_2 in 2016, and an average of 40.3 kt CO_2 yr^{-1} over the time-series (1990-2016). Total emissions from peat extraction, including on-site emissions, represents 62.7 kt CO_2-equivalents in 2016, and an average of 62.7 kt CO_2-equivalents yr^{-1} over the inventory period.

Choice of method, activity data, and emission factor

For wetlands subject to peat extraction, on-site emissions are estimated with default emission factors from the IPCC 2013 Wetlands Supplement (boreal / temperate zone), and is hence considered a Tier 1 method. Off-site CO_2 emissions are estimated using a national emission factor of 0.05 t C / m^3 based on expert judgment, and it is therefore a Tier 2 method. We assume a peat dry matter density of 0.1 t m^{-3}, and C content of 50 %.

Table 6.22 Emission factors used for estimation of on- and off-site emissions from peat extraction and their estimated uncertainties.

Gas	Emission factor (EF)	EF uncertainty (% 2 SE)	Activity data uncertainty %	Total uncertainty %
On-site				
CO_2	2.8 t CO_2-C ha^{-1} yr^{-1}	50	100	110
$CH_{4\ LAND}$	6.1 kg CH_4 $ha^{-1}yr^{-1}$	80	100	128
$CH_{4\ DITCH}$	542 kg CH_4 ha^{-1} yr^{-1}	81	100	129
$Frac_{ditch}$	0.05			
N_2O	0.30 kg N_2O-N $ha^{-1}yr^{-1}$	113	100	151
Off-site				
CO_2	0.05 t C m^{-3} air-dry peat	50	50	71

The reported peat extraction area is based on a 2015 study. Norwegian peat producers were surveyed to provide information on current and previous peat extraction production areas. In addition, a supplemental digital orthophoto sampling of identified ditched marsh areas where peat extraction was likely to have occurred was sampled. Off-site emissions from extracted peat volume were based partly on data from the Norwegian Food Safety Authority (1990 – 2007) and partly on information from a peat producer survey conducted in 2015 (covering the years 2008 – 2015). The two data series are not complete for all years, and extrapolation has been done to ensure a consistent time-series. The peat extraction activity data is described in detail in Søgaard and Økseter (2017).

6.7.1.2 Uncertainties and time-series consistency

The estimation of the uncertainty of the area and the C stock of wooded mire is described in section 6.3.5.

For the key category analyses (KCA), on- and off-site CO_2 emission uncertainties were combined by the weighted sum of the variances (square of Total uncertainty % in Table 6.22) assuming no (0) correlation between on- and off-site emissions. The assumption of no correlation is based on the fact that on-site emissions will occur for many years even if no peat extraction would be conducted and off-site emissions would be 0. The weights (w) were given by squared proportions of the total emissions ($w = (40/53)^2 = 0.57$ for off-site emissions and $w = (13/53)^2 = 0.06$ for on-site emissions). Also the uncertainties for CH_4 on land between and in ditches were combined for the KCA. It was the weighted average of the variance of the emission factors for land between and ditch and their

covariance assuming a direct correlation of 1. The correlation of 1 was chosen because of the increase in one area due to an increase in the other, and vice versa. The weight was given by the squared ditch proportion. In sum the uncertainty is assumed to be 110 % for CO_2, 128 % for CH_4, and 151 % for N_2O emissions. Uncertainties for CO_2 emissions estimated from drained organic soils on wetlands used for peat extraction are shown in Table 6.4, and for CH_4 and N_2O in Table 6.5.

6.7.1.3 QA/QC and verification

The QA/QC performed on the NFI area estimates was made for the wooded mire areas. The general QC procedures were performed on all sources under wetlands remaining wetlands. In addition, extensive QA by a national expert was performed for the off-site CO_2 emission factor.

6.7.1.4 Recalculations

The recalculations described in section 6.4.1.4 apply. The estimates of C stock changes in living biomass on wooded mires were recalculated due to the extrapolation method for the area estimate and C stock change in living biomass estimates. For 4.D.1.1 Peat Extraction Remaining Peat Extraction carbon stock change in organic soils, no peat volume data was available for the year 2016. Therefore, the average peat volume from 1990-2015 was used.

6.7.1.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.7.2 Land converted to wetlands, 4D2

Conversion of land to wetlands is most likely a slow process, unless in the form of flooding of land, which enables rapid inundation. Flooding can be human-induced (e.g. created by dams for hydropower production), or non human-induced (e.g. beaver dams). Only a few small-scale hydropower dams have been created in streams in the last 20-30 years and the total area is less than 4 kha. We consider emissions from this conversion category as negligible and report it using the notation key NO. We report C stock changes in living biomass, DOM, and soils for forest land converted to other wetlands. The area of land converted to peat extraction and soil related emissions are reported as NE because it is considered negligible.

6.7.2.1 Methodological issues

Emissions from land converted to wetlands were estimated for living biomass, DOM, mineral and organic soils.

Living biomass

Carbon stock changes in the living biomass pool were estimated using the Tier 3 approach (section 6.4.1.1), where gains and losses are recorded in the NFI. No changes occurred on non-forested land-use categories converted to wetlands.

Dead organic matter

A Tier 2 method was used to estimate C stock changes in DOM on forest land converted to wetlands. The stock change rate was estimated at -3.30 t C ha^{-1} yr^{-1}, based on the assumption that all litter and dead wood in an average Norwegian forest are decomposed over 20 years after conversion. The derivation of the C stock estimates for dead wood and litter are described in section 6.4.2.1.

Table 6.23 Annual stock change rates (t C ha^{-1} yr^{-1}) for forest land converted to wetlands. Other land converted to wetlands was assumed to have all C pools in a steady state condition.

	Mineral Soil	DOM	Litter	Dead Wood	Total
	(t C ha^{-1} yr^{-1})				
Forest land converted to wetlands	1.5	-3.30	-3.05	-0.25	-1.80

Soils

Changes in SOC in mineral soil were estimated using a Tier 2 method. The C stock change rate for forest land converted to wetlands was estimated based on a measured national mean SOC stock of the mineral soil layer at a depth of 30 cm for forest as 57 t C ha^{-1} yr^{-1} and the IPCC default soil C reference stock for wetland soils in a temperate climate of 87 t C ha^{-1} yr^{-1}; Table 2.3 (IPCC 2006). For organic soils we used the default emission factor for nutrient poor, boreal climate on forest land, which is 0.25 t C ha^{-1} yr^{-1}. The conversion of other land to wetlands is not likely to result in any change in SOC, and the notation key NO is reported in the CRF.

6.7.2.2 Recalculations

The recalculations described in section 6.4.1.4 apply. Recalculations due to changes in NFI related data on areas and biomass were performed.

6.7.2.3 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.7.3 Completeness

The reporting for emissions and removals occurring on wetlands is complete.

6.8 Settlements – 4E

Settlements is a diverse land-use class consisting of for example residential areas, roads, recreation areas, powerlines within forests, gravel pits, mines, and industrial areas. The land-use class is especially important for the sub-group of land converted to settlements because of the increase in the size of the area of this land-use class since 1990.

6.8.1 Settlements remaining settlements, 4E1

On settelements remaining settlements we report carbon stock changes in living biomass, DOM, mineral and organic soils using Tier 1 methods. Organic soils on settlements remaining settlements is a key category with respect to the 1990 and 2016 level assesssments.

6.8.1.1 Methodological issues

Living biomass

To estimate CSC in the living biomass pool a Tier 1 method is used, assuming no stock change and NO is reported. This is because trees are traditionally not measured on settlements in the NFI, due to the relatively small amounts of living biomass on settlements (Løken 2012).

In a specific study, trees were measured in land-use classes where trees are usually not measured in the NFI, including those within settlements (Løken 2012). A panel of NFI plots visited in 2009 containing almost 900 plots within settlements was used in the study. Settlements cover slightly more than 2 % of the Norwegian land area, but have a relatively low biomass density and contain only approximately 0.4 % of the total biomass stock (Løken 2012).

DOM and mineral soils

Carbon stock changes in DOM and mineral soil pools are also estimated using a Tier 1 method. This implies an assumption that no CSC occurs, and hence the notation key NO is used.

Organic soils (key category)

According to the IPCC 2006 guidelines, emissions from settlements on drained organic soils can be assumed to be similar to those on croplands (IPCC 2006). Emissions from organic soils in settlements are thus reported with Tier 1 using the default emission factor for croplands, which is 7.9 t C ha^{-1} yr^{-1}.

6.8.1.2 Uncertainties and time-series consistency

Uncertainties are shown in Table 6.3 and estimated as described in section 6.1.3.

6.8.1.3 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure.

6.8.1.4 Recalculations

Emissions from organic soils were recalucated due to the updates in the NFI area.

6.8.1.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.8.2 Land converted to settlements, 4E2

The conversion of land to settlements is a significant source of emissions, primarily due to forest land conversion, which causes large losses in all C pools.

Forest land converted to settlements is identified as a key category with respect to living biomass, DOM, mineral soil, and for organic soil for Level assessment 1990, Level assessment 2016, and/or Trend assessment 1990-2016 (see Table 6.6).

6.8.2.1 Methodological issues

Living biomass (key category)

For lands converted to settlements, except for croplands, tree measurements are usually available before the conversion if the area was tree covered. While trees are not measured on settlements, the NFI records which of the trees are remaining on the converted sample plot the first time the sample plot is visited after the conversion. Diameter and height measurements are, however, not carried out. Based on the information of which trees were removed, the carbon stock change on the converted sample plots is calculated using the last biomass measurement before conversion assuming no increment. The carbon stock of the last measurement minus the carbon stock of the removed trees is then used as the carbon stock of the plot assuming no changes in the future. For forest land, wetlands, and other land converted to settlements, this constitutes a Tier 3 method. The recording of which trees are remaining on a converted sample plot started in 2005. In the time-series before 2005, we assume that all trees were removed in the year when the land-use change was observed. An example of a situation where land is converted to settlements with remaining trees, is a forested sample plot of which the biggest part is converted to a house, while some of the trees are still alive inside what is now a garden.

For grassland, tree measurements are available since 2007 and a Tier 2 method is applied. Sample plots converted from grassland to settlements since 2007 did not have living tree biomass. Therefore, no change was assumed for the sample plots converted from grassland to settlements before 2007. For cropland converted to settlements, no tree measurements are available in the NFI and the carbon stock changes are reported according to a Tier 1 method, assuming immediate loss of the default C stock of 4.7 t ha^{-1} on cropland (IPCC 2006, p. 8.18).

Dead organic matter (key category)

We used a Tier 2 method to estimate C stock changes in DOM on forest land converted to settlements for mineral soil areas. The method is based on C stock change rates multiplied by the area. The change rate for DOM was -3.30 t C ha^{-1} yr^{-1} based on the change rates for litter and dead wood (Table 6.24). We assumed that the C stocks in litter and dead wood of an average Norwegian forest were completely lost over a 20 year period; see section 6.4.2.1 for the estimation of the stocks.

Table 6.24 Annual stock change rates (t C ha^{-1} yr^{-1}) for Land converted to settlements.

Land converted to settlements	Soil	DOM	Litter	Dead Wood	Total
	(t C ha^{-1} yr^{-1})				
Forest land	-0.57	-3.30	-3.05	-0.25	-3.87
Cropland	-0.83	0			-0.83
Grassland	-0.98	0			-0.98
Wetlands	-0.87	0			-0.87

Mineral soil (key category)

Changes in SOC were estimated using a Tier 2 method. The method is based on C stock change rates multiplied by the area as described under forest land. The C stock change rates were based on mean soil C stocks per land-use class. The assumption was made that upon conversion to settlements a 20 % C loss relative to the previous land use occurs over 20 years (IPCC 2006). The mean soil C stock for forest land and cropland were based on measurements as described in the respective chapters and on the IPCC default value for grassland and wetlands. The mean national SOC stock estimates were 57 t C ha^{-1} for forest land, 83 t C ha^{-1} for cropland, 98 t C ha^{-1} for grassland, and 87 t C ha^{-1} for wetlands. We assumed no SOC change when other land was converted to settlements.

Organic soil (key category)

CO_2 emission from drained organic soils on forest land converted to settlements was identified as a key category. Emissions were calculated using the Tier 1 method. According to IPCC (2006), we assume the emission factor for land converted to settlements corresponds to the cropland emission factor of 7.9 t C ha^{-1}.

6.8.2.2 Uncertainties and time-series consistency

Uncertainties are shown in Table 6.3 for living biomass and DOM and in Table 6.4 for organic and mineral soils. The time-series was consistently calculated.

6.8.2.3 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure.

6.8.2.4 Recalculations

The recalculations described in section 6.4.1.4 apply for changes from forests and tree-stocked land use categories. The time-series were recalculated due to updates in the NFI database and the extrapolation method.

6.8.2.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.8.3 Completeness

The reporting for emissions and removals occurring on settlements is complete.

6.9 Other land – 4F

The land use category other land covers approximately 45 % of the total land area in Norway, and reflects the large amount of mountainous and rocky terrain. Land-use changes to other land only occurred from grassland and settlements throughout the inventory period. It is only mandatory to report CSC for land converted to other land.

6.9.1 Other land remaining other land, 4F1

Reporting of emissions from other land remaining other land is not mandatory. Given the size of the area of other land, we analyzed the NFI data to determine the area usage and location of the land-use class. The vast majority of the other land is located above the alpine forest limit and only 21 % is located below (Table 6.25). Area of lands which have soil cover and are located below the alpine tree limit could potentially become forest land. Approximately 7 % of other land fulfills these criteria.

Table 6.25 Distribution of other land related to the alpine location and vegetation.

Location & area usage	**Percentage (%)**
Area above the alpine forest limit	
Other wooded land	4
Bare land	75
Area below the alpine forest limit	
Other wooded land	6
Coastal calluna heath land	1
Bare land	14
Total area of other land	**100**

6.9.2 Land converted to other land, 4F2

Only a small area of grassland and settlements on mineral soils was converted to other land during the inventory period. Carbon stock changes are reported for all sources. There were no areas of forest land, croplands, and wetlands converted to other land and these have been reported as NO.

6.9.2.1 Methodological issues

The area estimates are based on the NFI data. The Tier 3 method described under forest land was used for estimating C stock changes in living biomass. No CSC changes in the living biomass are recorded and NO is reported for the whole times series. For DOM, we use the Tier 1 method that assumes no CSC and report NO.

To estimate SOC changes in mineral soils on grassland converted to other land we used a Tier 2 method with a soil C stock change rate of -0.25 t C ha^{-1} yr^{-1}, equal to a 5 % loss relative to the SOC stock of grassland over the 20 year period. The change rate was multiplied with the area estimate determined by the NFI.

6.9.2.2 Uncertainties and time-series consistency

Uncertainties are estimated as described in section 6.1.3 and are shown in Table 6.3 for living biomass and DOM and in Table 6.4 for mineral and organic soils.

6.9.2.3 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure.

6.9.2.4 Recalculations

The time-series for C stock changes for living biomass, mineral, and organic soils were recalculated due to updates in the NFI database.

6.9.2.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.9.3 Completeness

The reporting for emissions and removals occurring on other land is complete.

6.10 Harvested wood products – 4G

Harvested wood products (HWP) prolong the period carbon is bound in timber after it is removed from the forest. Included in the HWP accounting is the carbon pool inflow in sawnwood, wood-based panels, and paper and paperboard. That is, HWP do not include all wood material that leaves the harvest site, only those parts of the harvest used for the three above mentioned default HWP categories. In the base year 1990, the total HWP pool was 1000 kt CO_2 according to the current calculation approach.

Net annual emissions from HWP in use in 2016 were 19 kt CO_2 for HWP produced and consumed domestically and 66 kt CO_2 for HWP produced and exported. In 2016, the total emissions from the HWP pool were 85 kt CO_2.

Since 2009, there has been a clear trend toward less storage (see Figure 6.16) in the HWP pool. A similar trend can be found for other European countries, including the peak in the period around 2008-2010.

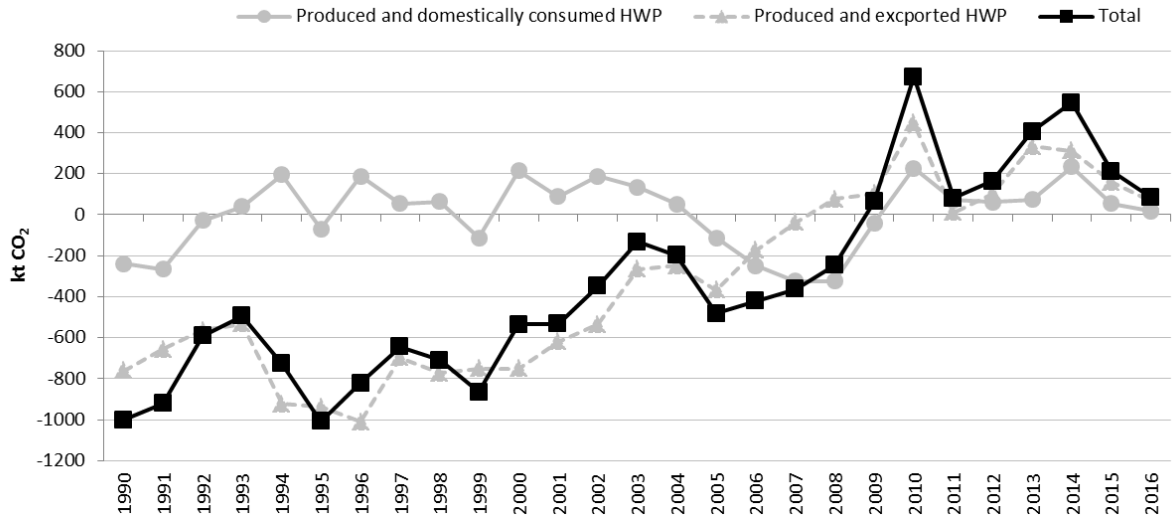


Figure 6.16 CO_2 emissions and removals in HWP (kt CO_2). Source: Norwegian Institute of Bioeconomy Research.

6.10.1 Methodological issues

Choice of method

Emissions and removals reported for HWP are estimated using a Tier 2 method. For consistency reasons the calculations are based on chapter 2.8 in the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014a). The 2013 IPCC KP supplement approach fulfills the requirements in footnote 12 in Table 4.Gs.1. The Tier 2 default options are applied, including the three default HWP categories sawnwood, wood-based panels, and paper and paperboard and their associated half-lives and conversion factors (IPCC 2014a).

To improve the transparency and in order to be in accordance with Table 4.Gs.1, the Norwegian estimates differentiate between domestically produced and consumed HWP and wood products that are produced and exported.

All harvested wood in Norway originates from existing forest lands. The activity data used starts in 1961 and is based on FAO statistics. Calculations have been performed using data from 1961 to 2016. We calculated the historic pool from 1950-1960 according to IPCC (2014a). Only emissions from 1990 and onwards are reported.

The estimation of carbon stocks (C) and annual carbon stock changes (ΔC) for each HWP category was estimated using Eq. 2.8.5 (IPCC 2014a)

$$C\ (i+1) = e^{-k}\ \times C(i) + \left[\frac{(1-e^{-k})}{k}\right] \times Inflow(i)$$

$$\Delta C\ (i) = C\ (i+1) - C\ (i)$$

Where, *i* = year; C (*i*) = the carbon stock (kt C) in the particular HWP category at the beginning of year *i,* with *i* = (1961,…,2015), but only emission estimates for *i* = (1990,…,2015) are reported; *k* is the decay constant for the first-order decay for HWP category (i.e. sawnwood, wood-based panels or paper and paperboards) given in units year^{-1} as *k* = ln(2)/HL, where HL is the half-life of the HWP pool, which is constant and given in the unit years. *Inflow*(*i*) = the inflow to the particular HWP category during year *i;* ΔC (*i*) = carbon stock change of the HWP category during year *i*, kt C year^{-1}.

The approximation of the carbon stocks in HWP pools at initial time C (*i* = t_0 = 1961) was calculated according to Eq. 2.8.6

$$C_{(t0)} = \frac{Inflow_{average}}{k}$$

where

$$Inflow_{average} = \frac{\left(\sum_{i=to}^{t4} Inflow\ (i)\right)}{5}$$

The C stock changes for each of the three HWP categories (sawnwood, wood-based panels, paper and paperboard) were estimated and summed to provide the total for Norway.

Activity data

All the activity data are from the FAO forestry statistics (http://www.fao.org/faostat/en/#data/FO). The initial unit is m^3, except for the pulp and paper where the unit is metric ton. Conversion to carbon was performed using the default conversion factors given by the IPCC (IPCC 2014a). Exported and domestically consumed HWP is calculated and reported separately. The inflow data of domestically produced and consumed are based on consumption (Production – Export). Imported HWP is not included in the calculations (Production approach).

An error was found in the FAO data for export values of paper and paperboard for the year 2011, which has not been corrected on the website. Based on information from Statistics Norway the correct value is 1 320 000 metric tons, compared to 592 311 on the FAO website.

Assumptions

It is assumed that the Tier 2 method reflects the carbon flow in the HWP pool. The assumption of first-order decay (i.e. exponential decay) implies that loss from the stock of products is estimated as a constant fraction of the amount of stock (IPCC 2006).

It is assumed that the default half-lives are representative values for Norway.

6.10.2 Uncertainties and time-series consistency

The reported uncertainty estimates for half-lives are ± 50 % according to IPCC 2006. According to the 2013 IPCC KP Supplement (2014) an overall estimate of the HWP activity data (i.e. sawnwood, wood-based panels, and paper and paperboard) from e.g. FAO, result in an estimated uncertainty of the reported values between -25 % to +5 %.

6.10.3 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure.

6.10.4 Recalculations

Each year, when the new activity data are added from the FAO database, the activity data for the previous five years are checked and updated if needed. The following activity data, which is used as data for inflow for 2011-2015, were updated:

- Paper- and paperboard 2015: export, domestically consumed. These updates in the activity data did not result in recalculation of the total emissions from HWP for the year 2015.

6.10.5 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.10.6 Completeness

The reporting for emissions and removals from harvested wood products is complete.

6.11 Direct N_2O emissions from managed soils – 4(I)

Direct N_2O emissions from managed soils are estimated from N inputs of inorganic and organic origin. N inputs from inorganic N fertilizer applied to forest land are reported. Inorganic fertilizer is not applied to managed wetlands and is hence reported as NO. Any inorganic fertilizer applied in the land use category settlements is included in the agriculture sector and reported as IE in the LULUCF CRF tables. Emissions from the use of organic fertilizers on forest land and settlements are reported. Livestock are generally not grazing managed wetlands (peat extraction areas and flooded lands), and is hence reported as NO. N inputs from organic and inorganic N fertilizer on cropland and grassland are reported as IE and included in the agriculture sector.

6.11.1 Inorganic fertilizer on forest land

N_2O is produced in soils as a by-product of nitrification and denitrification. Fertilizer input is particularly important for this process. However, fertilization of forest land is limited in Norway. The area fertilized was 24 km^2 in 1990 and the area as well as the net amount of N applied have decreased during the inventory period. In 2016 however, there was a large increase in area to approximately 84 km^2 and a corresponding increase in net amount of N applied (Table 6.26). Reported emissions are presented in Table 6.26.

Table 6.26 Estimated emissions from fertilization of forest land 1990-2016.

Year	Fertilizer input (t N)		Net amount N applied (t N)	N_2O emissions (t N_2O)
	Mineral soil	Organic soil		
1990	177	59	236	2.4
1991	326	67	392	3.9
1992	253	102	356	3.6
1993	181	67	248	2.5
1994	169	67	236	2.4
1995	160	60	220	2.2
1996	199	37	235	2.4
1997	232	19	252	2.5
1998	243	23	265	2.7
1999	218	44	261	2.6
2000	135	22	156	1.6
2001	154	19	173	1.7
2002	178	8	187	1.9
2003	85	1	87	0.9
2004	76	2	78	0.8
2005	53	31	84	0.8
2006	34	4	38	0.4
2007	81	1	82	0.8
2008	106	1	107	1.1
2009	113	1	114	1.1
2010	73	0.2	73	0.7
2011	85	0	85	0.8
2012	112	0.1	112	1.1
2013	170	0.2	170	1.7
2014	59	0	59	0.6
2015	91	0	91	0.9
2016	1236	0	1236	12.4

6.11.1.1 Methodological issues

Choice of method

The estimate is based on a Tier 1 method with a default emission factor. Emissions are calculated according to

$$N_2O\ direct\text{-}N_{fertlizer} = (F_{SN} + F_{ON}) \times EF \times 44/28,$$

where F_{SN} is the annual amount of synthetic fertilizer nitrogen applied (kt N) to forest soil. F_{ON} is the annual amount of organic fertilizer applied (kt N) to forest soil, and EF is the emission factor for N_2O emissions from N inputs, kg N_2O-N/kg N input.

Activity data

Statistics Norway supplied unpublished data on the application of synthetic fertilizer. The statistics include the area applied with fertilizer, the amounts and types of fertilizer applied for the period 1995-2015, but only the area and amount of fertilizer applied is available for 2016 due to a change in the data acquisition procedures. For the period 1990–1994, only data for the total fertilized area is available. Data from the period 1995–2004 were used to estimate the amount of N-fertilizer applied for the period 1990–1994.

The amount of fertilizer applied is given as total weight. The nitrogen content depends on the type of fertilizer. Yara supplied sales numbers for forest fertilization. From 1993 to 1994 and onwards, calcium ammonium nitrate based fertilizer has dominated the market for fertilization of forest on mineral soils (Pers. comm. Ole Stampe, Yara Norge AS, 2013). The N-content of calcium ammonium nitrate is 27 % (weight percent). According to Statistics Norway, this fertilizer is applied to approximately 97 % of the fertilized forest land in Norway; it is currently uncertain what fertilizer is applied to the remaining small area percent.

Emission factor

The default emission factor is 1 % of applied N (Table 11.1 IPPC 2006). The emission factor is highly uncertain, with uncertainty range from 0.003 to 0.03 (IPCC 2006).

6.11.2 Organic fertilizer on forest land

In Norway livestock grazes the outer fields during the summer months. The outer fields encompass land classified as other land and forest land. We report emissions from the organic N fertilizer applied by animal manure when livestock graze in the forest. From 1990 to 2016, N_2O emissions from this source have decreased slightly from 0.074 to 0.072 kt N_2O-N yr^{-1} (equivalent to 22.1 to 21.5 kt CO_2 yr^{-1}). It is not possible to provide an estimate for the amount of organic N fertilizer that is applied to land converted to forest land that is separate from the total applied to all forest land. Thus, we use the notation key IE for land converted to forest land in CRF table 4(I).

6.11.2.1 Methodological issues

Choice of method

We use a Tier 1 method to estimate N_2O emissions from organic N inputs on forest land applying the default emission factor of 0.01 kg N_2O-N kg^{-1} N (IPCC 2006). The organic N input was derived from the number of animals grazing in the forest multiplied by an N factor (the amount of N excreted by the animal per year) and the fraction of days of the whole year the animals are assumed to graze in the forest. Sheep, goats, suckle cows, heifers, and horses are typically grazing the outer fields, and the N factor is specific to animal type considering the ratio of sheep/lamb and goat/kid (Table 6.27). Approximately 80 % of the sheep grazing in outfield is organized through local coalition groups. Statistics based on the organized grazing showed a distribution of 38 % sheep and 62 % lamb in 2014, which was assumed a plausible ratio for goat and kid as well. Thus, the N factor used for both sheep and goat was estimated as a weighted average. We assume 100 grazing days in the year.

Table 6.27 N factors applied per animal to estimate organic N input to forest land.

N factors	Horse	Goat	Sheep	Heifer	Suckle cows
(kg N yr^{-1})	14	1	3	17	23

To determine the share of the total animals that graze in the forest and not in the open mountain lands (other land) we overlaid the AR5 land source map with a map of organized grazing lands. Using the most recent data (2014), the results showed that 44 % of the area used for grazing is classified as forest land.

Activity data

The number of animals grazing outer fields for a minimum of 5 weeks was derived using subsidy statistics from Norwegian Statistics (SSB). Subsidy statistics are collected each year. We multiplied the total number of animals per species with 44 % to arrive at the number of animals that graze on forest land.

6.11.3 Organic fertilizer on settlements

Direct N_2O emissions from application of organic N fertilizer in settlements have been reported in the LULUCF sector since NIR 2015. Previously, emissions from the application of sewage sludge on urban lawns, road-side grass-strips, and parks were reported in the waste sector. Emissions have increased slightly from 0.009 kt N_2O-N yr^{-1} in 1990 to 0.021 kt N_2O-N yr^{-1} in 2016 (equivalent to 2.68 to 6.26 kt CO_2 yr^{-1}).

6.11.3.1 Methodological issues

Choice of method

A Tier 1 method was used applying the default emission factor (IPCC 2006). To derive N inputs from organic fertilizer, the total dry matter amount of all types of sewage sludge applied was multiplied by an N content of 2.82 % (Statistics Norway 2001).

Activity data

Data of total amount (dry matter) of sewage sludge are derived from Statistics Norway (SSB) and cover the following distribution types: parks and green areas, soil fertilizer production, cover on landfills, other use and unknown use. The data is collected every year by SSB, and a consistent time series from 1990 was available.

6.11.4 Uncertainties

The uncertainty related to the default emissions factor for N_2O from N additions from mineral and organic fertilizer is provided by the IPCC as the range of 0.003 - 0.03 equal to ±200 %. In addition, we assume that the activity data have ±20 % uncertainty associated with the estimation of inorganic N applied to forest land and organic N applied to settlements. The activity data and the method used to estimate the organic N input to forest land are more uncertain and an error of ±50 % was assumed. The total uncertainties (of the emission factor and the activity data and method) were used in the KCA for each of the three sources.

6.11.5 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure. The method for estimating organic N inputs from animal manure on forest land was evaluated by an external expert. Weaknesses of the current method were pointed out, but it was agreed that no better method is available to provide the estimate required.

6.11.6 Recalculations

There were recalculations for 2015 for organic N fertilizer applications on settlements remaining settlements. Organic fertilizer was reduced from 1 443 191 kg N/yr (NIR 2017) to 1 137 447 kg N/yr (NIR 2018) due to changes in Statistics Norway data.

6.11.7 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.11.8 Completeness

The reporting for Direct N_2O emissions from managed soils is complete.

6.12 Emissions and removals from drainage, rewetting and other management of soils – 4(II)

Rewetting of organic and mineral soils is not practiced in large scale in Norway, and drainage and rewetting (WDR) is not an elected KP activity. Thus, in CRF Table 4(II) we report only emissions from drained organic soils (including peat extraction) as these are mandatory to report. CO_2 emissions from drained organic soils are reported as IE in CRF table 4(II) because they are included in CRF tables 4.A-4.D as C stock changes in the organic soils pool. In CRF table 4(II) we report CH_4 and N_2O emissions from forest land and from wetlands used for peat extraction, and CH_4 emissions from cropland and grassland. NE is reported for rewetting of mineral and organic soils on forest land, cropland, grassland, and wetlands. According to the IPCC guidelines, N_2O emissions from drained organic agricultural soils (cropland and grassland) are reported in the agriculture sector. Both CH_4 and N_2O emissions are key categories for forest land, in the 1990 and 2016 level assessments for CH_4 and in both level and trend assessment for N_2O emissions. CH_4 emissions from cropland is also a key category, in the 2016 level assessment.

Please note that CRF tables *Table4* and *Summary2* are inconsistent due to some emissions of CH_4 and N_2O that cannot be reported in the CRF by detailed area types, according to footnote 4 in Table 4(II) and Table 4(IV). These emissions are entered into the tables only at more aggregated levels. The level of reporting is due to properties of the CRF system, follows decision 24/CP.19, and is not caused by lack of data in the Norwegian emission inventory. The UNFCCC Secretariat did confirm the inconsistency in the sums of the subtotals in 2015.

6.12.1 N_2O emissions from drainage of organic soils (key category)

6.12.1.1 Methodological issues

For the estimation of N_2O emission from drained organic soils on all land uses we use a Tier 1 method based on the 2006 IPCC guidelines (IPCC 2006). The area is multiplied with an emission factor. To make use of the most recent scientific knowledge we apply the emission factors from the IPCC 2013 Wetlands supplement (IPCC 2014b).

Activity data

The area of drained forest soil was provided by Statistic Norway and stratified into boreal nutrient rich and boreal nutrient poor vegetation zones, as described in section 6.4.1.1. For the reporting under 4(II), all forest land, including land converted to forest land, is included in the estimate.

The area of land under peat extraction was estimated as described under section 6.7.1.1.

Emissions factors

The default emission factors from the IPCC 2013 Wetlands supplement were used. All Norwegian forest land is considered boreal and we used the same distribution of nutrient rich and nutrient poor, as described under forest land; organic soils (79 % nutrient rich and 21 % nutrient poor) which gives an average national EF of 2.57 kg N_2O-N yr^{-1}. For the area in the conversion classes, we used the nutrient rich EF (3.2 kg N_2O-N yr^{-1}). N_2O emissions from wetlands used for peat extraction were estimated with the emission factor of 0.3 kg N_2O-N yr^{-1} (IPCC 2014b); see Table 6.22.

6.12.2 CH_4 emissions from drainage of organic soils (key category)

6.12.2.1 Methodological issues

To estimate CH_4 emissions, we used the Tier 1 method applying the EFs of the IPCC 2013 Wetlands supplement (IPCC 2014b). The method accounts for methane fluxes both in the drainage ditches and on the land using the following equation

$$CH_4 = A \times ((1- Frac_{ditch}) \times EF_{CH4\_land} + Frac_{ditch} \times EF_{CH4\_ditch})$$

where, A is the area of drained organic soil; $Frac_{ditch}$ is the fraction of the area occupied with ditches; and EF_{CH4_land} EF_{CH4_ditch} are the emissions factor for the land and the ditch, respectively.

There is no information available in Norway to provide an accurate estimate for the fraction of the area occupied with ditches ($Frac_{ditch}$), we therefore used the default values of 2.5 % for forest land, and 5 % for cropland, grassland, and peat extraction (IPCC 2014b).

Activity data

Activity data of the area of drained forest soil was provided by Statistic Norway and stratified into boreal nutrient rich and boreal nutrient poor vegetation zones, as described in section 6.4.1.1. For the reporting under 4(II), all forest land, including land converted to forest land, was reported. The area of land under peat extraction was estimated as described under section 6.7.1.1. For cropland and grasslands, the estimation of the areas of drained organic soils were as described in section 6.5.1.1 and section 6.6.1.1, and the areas of land converted to cropland and grassland, respectively, are also included in these estimates.

Emission factor

The default EFs for CH_4 from land (EF_{CH4_land}) from the IPCC 2013 Wetlands supplement, given the same distribution of nutrient rich and nutrient poor forest land as for the N_2O and CO_2 estimation, resulted in a mean national EF of 2.97 kg CH_4 yr^{-1}. For cropland the EF is 0 and for grassland we used the factor for shallow-drained, nutrient rich grassland of 39 kg CH_4 yr^{-1}. For peat extraction on wetlands the emission factor is 6.1 kg CH_4 yr^{-1} for the boreal zone (Table 6.22).

The emission factors for CH_4 from the ditches or drains (EF_{CH4_ditch}) were 217 kg CH_4 yr^{-1} for forest land, 1165 kg CH_4 yr^{-1} for cropland and 572 kg CH_4 yr^{-1} for grassland, and 542 kg CH_4 yr^{-1} for peat extraction land.

6.12.3 Uncertainties

The uncertainties associated with the emission factors of the IPCC 2013 Wetlands supplement are summarized in Table 6.5.

To derive the total uncertainty of the emission estimate we aggregated the uncertainty for the emission factor and the area estimate, respectively. For land converted to forest land and the cropland or grassland categories, the area uncertainties were calculated as the sample error in the

NFI. We assumed a 50 % uncertainty for the area of drained forest soils from Statistics Norway and 100 % for the area with peat extraction.

6.12.4 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure.

6.12.5 Recalculations

All times series were recalculated due to the updates in the NFI area data except for peat extraction. An error was made in the calculation of the kt N_2O estimate from peat extraction lands on drained organic soils in the submission years 2015, 2016, and 2017. Different areas were used 400 ha (2015) and 1264 ha (2016), but the same area of 2000 ha was used in the 2017 and 2018 submissions.

6.12.6 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.12.7 Completeness

The reporting for emissions and removals from drainage and rewetting of organic and mineral soils is complete.

6.13 Direct N_2O emissions from N mineralization and immobilization – 4(III)

In the 2006 IPCC Guidelines direct N_2O emissions are estimated from N mineralization-immobilization turnover associated with loss of soil organic matter resulting from change of land use or management of mineral soils on all types of land use. Previously, only land-use changes to cropland were considered to result in N mineralization-immobilization. We estimate N_2O losses from all land uses that have negative C stock changes in the mineral soil pool, and the areas reported in CRF table 4(III) correspond to the areas with negative C stocks changes and not the total area for all land-use conversions. N_2O emissions from N mineralization-immobilization is a small key category in the 2016 level assessment and the 1990-2016 trend assessment.

6.13.1 Methodological issues

6.13.1.1 Choice of method

To estimate N_2O emissions from N mineralization we first calculate the net annual amount of N mineralized in mineral soils resulting from SOC loss (F_{SOM}) from

$$F_{SOM} = \Delta C \times 1/\ CN \qquad \text{Eq. 11.8; (IPCC 2006)}$$

where *ΔC* is the average annual C loss from mineralization of soil for each land-use type (in kt C yr^{-1}) and CN is the C/N ratio of cropland soils. To estimate the N_2O emissions from N mineralization we multiply F_{SOM} with the default emission factor (EF = 0.01 kg N_2O-N yr^{-1}). We consider the method a Tier 1 because we used the default C/N ratio (CN = 15), although most SOC losses were derived using a Tier 2 method.

Certain land-uses (e.g. forest land remaining forest land and cropland remaining cropland) and land-use changes (e.g. settlements converted to cropland or forest land) result in positive SOC stock changes in the mineral soil pool, thus no N_2O emissions are reported from these sub-categories.

6.13.1.2 Activity data

Activity data used for this source is the annual average C losses, which are those reported in the CSC tables 4.A-4.F for each land-use class. The CSC change is estimated as described under the mineral soil pool for each land–use class.

6.13.2 Recalculations

The area changes caused by the NFI updates caused only minor recalculations for this source, except for grasslands converted to forest land. In 2015, 2016, and 2017 reporting years the grasslands converted to croplands areas were mistakenly reported instead of grasslands converted to forest land areas. The areas steadily increased over the time series, but were 3.6 ha higher on average. The increase in areas led to an average increase in emissions from 2011-2015 of 0.001 N_2O kt and unchanged emissions for the remaining years in the time series.

6.13.3 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.13.4 Completeness

Reporting from the source 4(III) Direct N_2O emissions from N mineralization and immobilization is complete.

6.14 Indirect N_2O emissions from managed soils – 4(IV)

Indirect N_2O emissions occur through two pathways: 1) the volatilization of N as NH_3 and NO_X and subsequent deposition of N compounds (atmospheric deposition), and 2) the leaching and runoff of N from land that has been subjected to excess N application from organic or inorganic fertilizers, as well as N mineralized due to soil C loss. CRF table 4(IV) has the two sub-categories 1) atmospheric deposition and 2) nitrogen leaching and runoff. The 2006 IPCC methodology for estimation of indirect emissions includes N inputs from several sources (Eq. 11.9 and 11.10), however, the sources are split between the reporting in the LULUCF and the agriculture sector. The indirect emissions reported in the LULUCF sector under atmospheric deposition are derived from the N inputs coming from synthetic N fertilizer on forest land (F_{SN}) and organic N fertilizer on forest land and settlements (F_{ON}). For the sub-category N leaching and runoff, N inputs arrive as synthetic and organic N fertilizers as for atmospheric deposition, but also from N mineralization immobilization in mineral soils associated with loss of soil C (F_{SOM}). Indirect emissions caused by N inputs from crop residues, urine and dung application from livestock, and N fertilizers on agricultural lands (cropland and grassland) are reported in the agriculture sector.

Please note that CRF tables *Table4* and *Summary2* are inconsistent due to some emissions of CH_4 and N_2O that cannot be reported in the CRF by detailed area types, according to footnote 4 in Table 4(II) and Table 4(IV). These emissions are entered into the tables only at more aggregated levels. The level of reporting is due to properties of the CRF system and follows decision 24/CP.19, and is not caused by lack of data in the Norwegian emission inventory. The UNFCCC Secretariat has confirmed the inconsistency in the sums of the subtotals.

6.14.1 Atmospheric deposition

Indirect emissions reported under atmospheric deposition are estimated from synthetic N fertilizer input on forest land (F_{SN}) and organic fertilizer N inputs on settlements (F_{ON}). Emissions are rather small; 0.0022 kt N_2O in 2016 (0.66 kt CO_2-equvialents).

6.14.1.1 Methodological issues

Method choice

We used the Tier 1 method of the 2006 IPCC guidelines dictating that a fraction ($Frac_{GASM}$ or $Frac_{GASF}$) of the organic and inorganic N inputs (F_{ON} and F_{SN}), respectively, is considered volatilized and multiplied by the emission factor for atmospheric deposition (EF) according to

$$N_2O\text{-}N = (Frac_{GASF} \times F_{SN} + F_{ON} \times Frac_{GASM}) \times EF_{vol} \quad \text{Eq.11.9; (IPCC 2006).}$$

All parameters are default values: $Frac_{GASM}$ = 0.2, $Frac_{GASF}$ = 0.1, and EF = 0.01 kg N_2O-N (kg N)$^{-1}$.

Activity data

The N inputs from synthetic and organic N fertilizer were derived as described in section 6.11.

6.14.2 Nitrogen leaching and run-off

Indirect emissions from leaching and runoff were estimated from the N inputs of synthetic and organic fertilizer on forest land and settlements and from N mineralized due to soil organic matter decomposition.

6.14.2.1 Methodological issues

Method choice

The Tier 1 method was applied where the fraction of all N added to the soils ($Frac_{LEACH}$) is multiplied with the default emission factor EF_{leach} = 0.0075 kg N_2O-N (kg N leaching/runoff)$^{-1}$ by

$$N_2O_{(L)}\text{-}N = (F_{SN} + F_{ON} + F_{SOM}) \times Frac_{LEACH} \times EF_{leach}$$

where F_{SN} is the N input from synthetic fertilizer, F_{ON} is the N input from organic fertilizer, and F_{SOM} is the input from N mineralized decomposition of mineral soils. We applied the default value for $Frac_{LEACH}$ of 0.3.

Activity data

The activity data were derived as described in section 6.11 for organic and inorganic fertilizer and in section 6.13 for N mineralized during soil C loss.

6.14.3 Uncertainties

The uncertainty associated with the default emission factor for N_2O emissions from volatilization and deposition is ± 400 % (IPCC 2006) and has a major influence on the emissions from atmospheric deposition. The EF for leaching has ± 233 % uncertainty (IPCC 2006). In addition, the default values for the fraction of N that is volatilized from synthetic and organic fertilizer and the fraction that is lost by leaching, have high uncertainties. According to the 2006 IPCC guidelines, the uncertainties are ± 200 %, ± 150 %, and ± 167 % for $Frac_{GASF}$, $Frac_{GASM}$, and $Frac_{LEAC}$, respectively. Furthermore, the estimated N inputs (F_{SN}, F_{ON}, and F_{SOM}) also have uncertainties either due to the activity data or methods as mentioned in the previous sections. Aggregating the individual uncertainties, we derive a total uncertainty of ± 447 % for emissions due to atmospheric deposition and ± 300 % from leaching and run-off (Table 6.5).

6.14.4 QA/QC and verification

The QA/QC plan was performed according to the Tier 1 procedure.

6.14.5 Recalculations

Recalculations for atmospheric deposition resulted in reduced N_2O emissions in 2015 from 0.0019 (NIR 2017) to 0.0018 (NIR 2018) due to a reduction in the amount of organic N applied to settlements from 1 443 191 kg N/yr (NIR 2017) to 1 137 447 kg N/yr (NIR2018).

6.14.6 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.14.7 Completeness

Reporting from source 4(IV) Indirect N_2O emissions from managed soils is complete.

6.15 Biomass Burning – 4(V)

Emissions of CO_2, CH_4, and N_2O due to biomass burning are reported for all land-use classes. For cropland and grassland, burning should be reported for woody biomass which is not common on these land-use classes in Norway. Agroforestry is not normally practiced and woody biomass is found mostly in fruit tree orchards and these are generally not burned. Burning of woody biomass in wetlands, settlements, and on other land does not occur either. We therefore report NO for all gasses in all land-use classes, except for forest land. Controlled fires on forest land is reported as NE as very few fire drills are performed and we expect the emissions to be negligible. Wildfires on grasslands are also reported as NE due to the lack of data but also because emissions are considered negligible as wildfires rarely occur on Norwegian grasslands.

6.15.1 Fires on forest land

Prescribed burning of forest takes place in Norway only connected to firefighting rehearsals, comprising a very small area (approximately 15 ha yr^{-1}). Thus, these emissions are reported as NE and assumed negligible. The area subject to wildfires varies considerably from year to year due to natural factors (e.g. variations in precipitation). According to the IPCC 2006 guidelines, emissions of CO_2 from biomass burning in forest land remaining forest land need to be accounted for, however, CO_2 emissions caused by biomass burning are included in the estimate of C stock change in living biomass derived from the stock-change method. Hence, estimates of CO_2 emissions from wildfires are reported as IE.

6.15.1.1 Methodological issues

Emissions of N_2O and CH_4 from forest wildfires are relatively small, and the emissions of CO_2 contribute to the major part of the total emissions (Table 6.28).

Choice of method

There are no national data on emission factors for non-CO_2 gases from forest fires. N_2O and CH_4 emissions from forest wildfires are estimated based on a Tier 1 method from the 2006 IPCC guidelines. The following equation 2.27 is used:

$$L_{fire} = A * M_B * C_f * G_{ef} * 10^{-3}$$

Where: L_{fire} = amount of greenhouse gas (CO_2, CH_4, and N_20) from fire (tonnes), A = area burnt (ha), M_B = mass of fuel available for combustion (tonnes ha^{-1}), C_f = combustion factor (dimensionless), and G_{ef} = emission factor (g kg^{-1} dry matter burnt). Activity data (area burnt) is based on country level estimates. Values used for M_B and C_f are derived by taking into account estimates of the mass and the amount consumed of unproductive forest, productive forest, dead wood, and humus. The quantification of national estimates for biomass burned and carbon released is based on expert judgment.

Table 6.28 Estimates of CO_2, CH_4, and N_2O emissions (kt) from forest fire from 1990 to 2016, and sum of emissions in kt CO_2-equivalents.

Year	CO_2 (kt)	CH_4 (kt)	N_2O (kt)	SUM CO_2-eqv. (kt)
1990	9.74983	0.73015	0.48146	10.96144
1991	16.39590	1.22786	0.80966	18.43342
1992	15.04645	1.12681	0.74302	16.91627
1993	2.78617	0.20865	0.13759	3.13240
1994	3.16571	0.23708	0.15633	3.55911
1995	1.25425	0.09393	0.06194	1.41011
1996	8.77266	0.65697	0.43321	9.86284
1997	9.41687	0.70521	0.46502	10.58710
1998	3.45390	0.25866	0.17056	3.88311
1999	0.71337	0.05342	0.03523	0.80202
2000	1.49074	0.11164	0.07362	1.67599
2001	0.60668	0.04543	0.02996	0.68207
2002	2.89344	0.21669	0.14288	3.25301
2003	6.08545	0.45573	0.30051	6.84170
2004	1.22235	0.09154	0.06036	1.37425
2005	3.57510	0.26773	0.17654	4.01938
2006	32.43060	2.42868	0.60148	34.46076
2007	2.53236	0.18964	0.12505	2.84706
2008	51.50211	3.85691	2.54327	57.90229
2009	8.89877	0.66642	0.43944	10.00462
2010	14.61807	1.09473	0.72187	16.43467
2011	1.94002	0.14529	0.09580	2.18111
2012	0.76764	0.05749	0.03791	0.86304
2013	0.53202	0.03984	0.02627	0.59814
2014	5.94011	0.44485	0.29333	6.67829
2015	0.86648	0.06489	0.04279	0.97416
2016	14.26019	1.06792	0.70419	16.03231

Activity data

Data of burned areas due to wild forest fires are available from the Directorate for Civil Protection and Emergency Planning for 1993–2016. Data are available for the number of fires and the area of productive and unproductive forests that burned. There were only data available for the number of fires between 1990 and 1992, 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. The number of fires was higher in 1990-1992 than later and it has assumed that the area burned was proportionally higher (Rypdal et al. 2005).

Standing volume for unproductive and productive forest were based on average numbers and accounted for 23 and 109 $m^3\,ha^{-1}$, respectively (Granhus et al. 2012). In biomass this is equal to 12 and 55 t ha^{-1}, respectively. The IPCC (2003) estimate that 50 % of the carbon is released during fires is appropriate, because this is assumed to be the C content of woody biomass.

In addition to the lack of data on the tree biomass, there are no exact data on the amount of biomass burned per area. Normally, only the needles/leaves, parts of the humus, and smaller branches would

burn. The mass of trees burned constitute 25 % of the biomass, which is consistent with IPCC (2003). It is also likely that about 1 m^3 dead wood per ha will be affected by the fire due to its dryness. It is difficult to assess how much of the humus is burned, and this is much dependent on forest type. There is about 7 500 kg humus per ha and we assume that 10 % of this is burned. This percentage, however, is very dependent on the vegetation type. The CO_2 estimates provided in (Table 6.28) are for comparison only and to enable estimation of N_2O and CH_4 emissions, and thus, not used in the reported CO_2 emissions.

Table 6.29 Information on forest fires in Norway for 1990–2016 and estimated CO_2 emissions.

Year	Number of fires	Unproductive forest (ha)	Productive forest (ha)	Area burned (ha)
1990	578	679.6	256.4*	936.0*
1991	972	1 142.8	431.2*	1 574.0*
1992	892	1 048.8	395.7*	1 444.5*
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	275.0
1999	148	73.4	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	252.4	93.2	345.6
2006	205	3 222.2	606.7	3 828.9
2007	65	22.2	106.1	128.3
2008	171	1 210.2	1 963.6	3 173.8
2009	109	1 257.9	70.8	1 328.7
2010	62	165.9	602.8	768.7
2011	49	47.8	73.4	121.2
2012	24	35.1	24.9	60.0
2013	40	30.8	15.6	46.4
2014	133	681.7	87.7	769.4
2015	40	141.6	2.0	143.6
2016	341	1 685.9	197.9	1 883.8

*Source: Norwegian Directorate for Civil Protection (DSB) *Area estimated in Rypdal et al. (2005).*

Emission factors

The IPCC (2006) emission ratios of 4.70 g/kg and 0.26 g/kg dry matter burnt are used for methane and nitrous oxide, respectively.

6.15.1.2 Uncertainties

The total uncertainty for wildfires was estimated at 75 % based on the default uncertainty for the non-CO_2 emission factor of 70 % IPCC (2003) and expert judgment on the activity data.

6.15.1.3 Recalculations

Recalculations for this source led to decreased CH_4 emissions of 0.48 kt CO_2-equivalents (0.019 kt CH_4) and increased N_2O emissions of 0.3 kt CO_2-equivalents (0.001 kt N_2O) on average in the time series 1990-2015, in part, due to an update in methodology from 2003 Guidelines to 2006 Guidelines in the 2018 submission. Recalculations for the year 2016 were also a result of an increase in unproductive forest area burned from 141.6 ha in 2015 to 1 685.9 ha in 2016 and productive forest area burned from 2 ha in 2015 to 197.9 ha in 2016 in the 2018 submission.

6.15.1.4 Planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

6.15.2 Completeness

Reporting of emissions from source 4(V) Biomass burning is complete.

6.16 Recalculations for LULUCF

All emissions related to the Norwegian National Forest Inventory (NFI) estimated areas are recalculated every year as well as for the 2018 submission. This is due to the interpolation and extrapolation method used to estimate the areas. Since NIR 2014, areas have been estimated using linear interpolation between the 1/5th of the NFI sample plots that are surveyed every year. One fifth of the area estimates are therefore based on measured sample plots, and four fifths of the estimate is based on interpolation or extrapolation in the final years. Extrapolation affects the four final reporting years and requires a recalculation of these years in the subsequent submissions. There will therefore always be recalculation in the last few years of the time series. The area-related emissions are affected by this and comprise all carbon stock changes estimated for living biomass, litter, dead wood, DOM, mineral and organic soils (CRF Tables 4.A-4.F). In addition, the following non-CO_2 emission sources are also indirectly affected by the area estimates: 4(II) Emissions and removals from drainage and rewetting of organic soils, and source 4(III) Direct N_2O emissions from N mineralization/immobilization. In addition to the interpolation and extrapolation method affecting area estimates, NFI sample plots are surveyed either in the field (if forested) or using aerial images. Corrections of previously attributed land-use categories that are not due to actual land-use changes therefore occur if new information becomes available. This can result in revised area estimates among all categories for the full time series. Another factor affecting recalculations is the calculation for changes in soil C, litter, and deadwood in afforestation and reforestation and deforestation for the inventory year 2015 for which a correction was made.

For the NIR 2018, the following methodological changes have affected all land-use categories and are therefore not listed explicitly below:

- The absolute values of gains and losses are larger this year because we changed the method from NFI plot-level net changes to plot-level gains and losses. This means, a plot can have both gains and losses. Until last year, this was not possible. The total net change was also affected by this change.
- New above- and belowground birch biomass functions Smith (2016); Smith (2014) are now used instead of Marklund (1988).

For the NIR 2018 the whole time-series was recalculated for all C emission sources and sinks due to revised activity data (areas) and a few methodological changes. The largest recalculations occurred for the last four years (2011-2015). Total changes in emissions (including non-CO_2 emissions) caused by recalculations for the LULUCF sector are shown in Figure 6.17.

Quantitatively, the largest changes in estimated C stock changes occurred for forest land and grasslands. The estimated CO_2 uptake on forest land for 2015 was 679 kt smaller in the 2018 submission compared to the 2017 submission. The estimated CO_2 emissions in grasslands for 2015 were 93.9 kt smaller (Table 6.30). The difference between the estimates of total GHG emissions from the LULUCF sector based on the 2017 and 2018 NIR submission was 551 kt CO_2-equivalents for the recalculated year 2015 (Table 6.30).

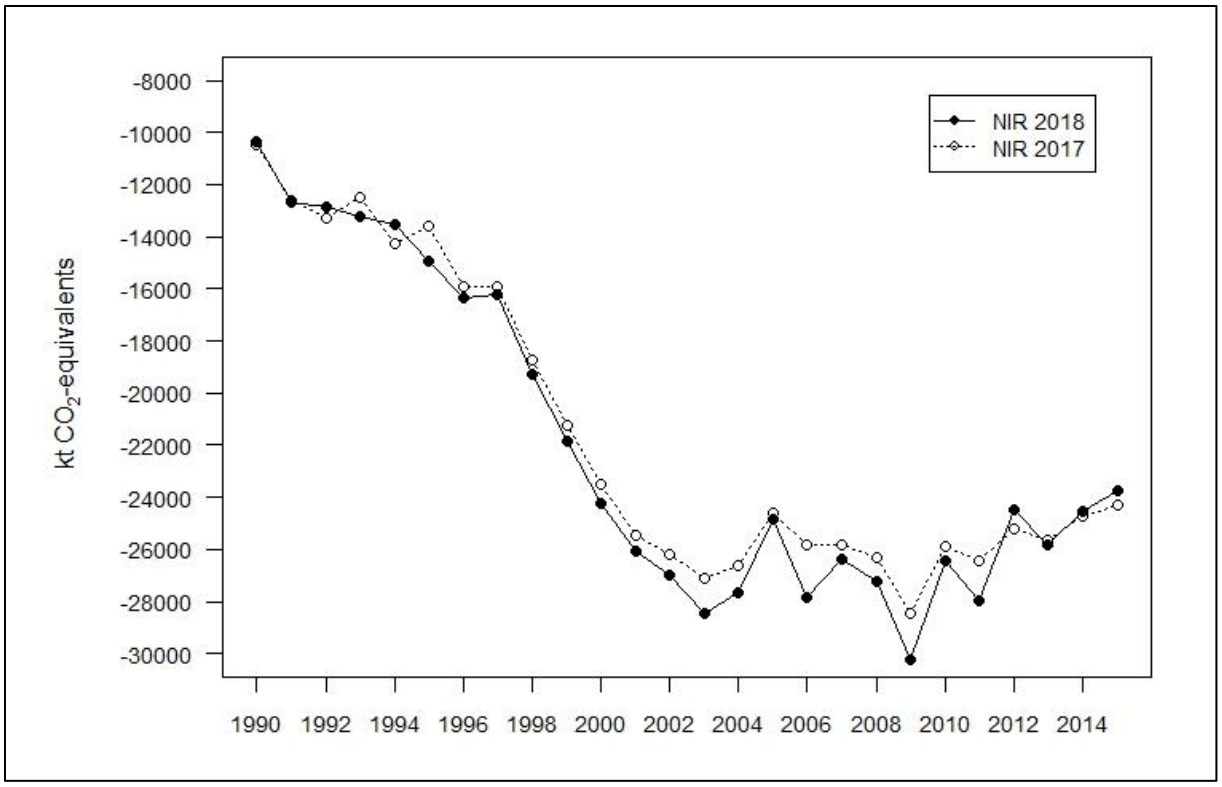


Figure 6.17 Recalculations illustrated for total emissions (kt CO_2-equivalents per year) estimated for the LULUCF sector in the 2018 submission compared to the 2017 submission.

Table 6.30 Recalculated GHG emissions (kt CO_2-equivalents yr^{-1}) for 2015 per land-use category in the LULUCF sector.

	Emissions for 2015 (kt CO_2-equivalents yr^{-1})		
Land-use category	**NIR 2018**	**NIR 2017**	**Absolute difference**
4.A Forest land	-28 296.7	-28 975.4	678.7
4.B Cropland	2 000.5	2 012.5	-12.0
4.C Grassland	180.4	274.3	-93.9
4.D Wetlands	29.7	34.3	-4.6
4.E Settlements	2 089.9	2 107.1	-17.2
4.F Other land	0.95	0.95	0
4.G HWP	212.0	212.0	0
4(IV)Total sum	14.3	14.7	-0.38
Total sum	-23 768.9	-24 319.5	550.6

The reasons for the recalculations within each land-use category and sink/source category and the effects for the last recalculated year of the inventory (2015) are described below.

6.16.1 Forest Land

6.16.1.1 Forest land remaining forest land

- Total CSC for forest land remaining forest land in 2015 was 190 kt C larger in the NIR 2017 submission compared with the NIR 2018 submission.
- Net change in living biomass decreased by 642 kt C from a C uptake of 6 258 kt C in NIR 2017 to 5 617 kt C in NIR 2018. Carbon uptake in dead wood, litter, and mineral soils increased by 74 kt C (from 296 to 370 kt C), 369 kt C (from 1 466 to 1 835 kt C), and 8 kt C (34 to 42 kt C), respectively. Recalculations were caused by the updates in the area estimates in addition to the general methodological changes described above. Application of the new biomass functions also has an effect for soil carbon and DOM as model litter input depends on standing biomass. Emissions from organic soils were also recalculated due to updates in activity data, however, this recalculation was not noticeable.

6.16.1.2 Land converted to forest land

- Compared to last year's reporting, the total C uptake for 2015 on land converted to forest land was 5 kt C larger in the NIR 2018 submission (from 145 to 150 kt C). This was mainly due to the larger C uptake in living biomass, which increased by 6 kt C from 48 kt C (NIR 2017) to 54 kt C (NIR 2018), which occurred primarily on wetlands converted to forest land (3 kt C) and other land converted to forest land (3 kt C). Recalculations in the organic soils and litter pools resulted in slightly smaller C change of 0.01 kt and 1 kt C respectively. The mineral soil pool increased by 2 kt C from -23 kt C to -25 kt C. All recalculations were caused by the updated NFI areas.

6.16.2 Cropland

6.16.2.1 Cropland remaining cropland

- Total C stock loss for 2015 on cropland remaining cropland reduced by 3 kt C from 421 kt C in the 2017 submission to 418 kt C in the 2018 submission, which was primarily caused by the change in the estimation for organic soils.
- C stock changes increased by 0.5 kt C from 20.4 kt C (NIR 2017) to 20.8 kt (NIR 2018) for the mineral soil pool. This was due to area updates by the NFI extrapolation.
- Recalculations in organic soils were caused by the area updates by the NFI extrapolation method. Emissions decreased by 2 kt C from 445 kt C (NIR 2017) to 443 kt C (NIR 2018).

6.16.2.2 Land converted to cropland

- For land converted to cropland the recalculations of the 2015 estimate resulted in smaller C losses (0.4 kt C) from 102.9 kt C to 102.5 kt C.
- Net C stock losses on living biomass decreased by 0.5 kt C and DOM increased by 1.4 kt C, due to the extrapolation method used on the NFI living biomass and area data. C stock losses increased from 20 kt C to 22 kt C for living biomass and from 49 kt C to 50 kt C for DOM.

6.16.3 Grassland

6.16.3.1 Grassland remaining grassland

- Total C stock changes on grassland remaining grassland were recalculated and resulted in emissions changing to removals in 2015 by 16.8 kt C, from -8 kt C to 9 kt C. This was mostly caused by increased removals in living biomass.
- Emissions from organic soils were reduced by 3 kt C from 10 kt C (NIR 2017) to 7 kt C (NIR 2018) due to a slight reduction in the area of organic soils.
- Recalculations in the gains and losses in living biomass were also substantial and the net change in living biomass increased by 14 kt C. Carbon stock gains increased by 24 kt C and losses increased by 10 kt C.

6.16.3.2 Land converted to grassland

- Total C stock loss estimates for 2015 for land converted to grasslands was 9 kt C smaller in the 2018 submission, primarily due to updates in the NFI affecting forest land converted to grassland.
- C stock losses in living biomass and DOM on forest land converted to grassland were decreased by 7.3 kt C and 1 kt C, respectively, from 30 kt C to 23 kt C for living biomass and from 89 kt C to 88 kt C for DOM. The changes were caused by the extrapolation method of the NFI data used for biomass and area estimates.
- Emissions from organic soils were also recalculated. The area of organic soils is very small and occurs only on wetlands converted to grassland. The recalculation reduced emissions by 0.8 kt C from 2.7 kt C (NIR 2017) to 2 kt C (NIR 2018). This was primarily due to reduced organic soil areas from NFI updates.
- Emissions from mineral soils were also recalculated due to the NFI area updates, and resulted in a minor decrease in the C uptake of 0.7 kt C from 56.5 kt C (NIR 2017) to 55.8 kt C (NIR 2018).

6.16.4 Wetlands

6.16.4.1 Wetlands remaining wetlands

- Carbon stock uptake in living biomass on wooded mires was recalculated due to the NFI extrapolation method. The recalculation resulted in a slight increase of 1.2 kt C, from 19 kt C (NIR 2017) to 20 kt C (NIR 2018).

6.16.4.2 Land converted to wetlands

- A minor recalculation for forest land converted to wetlands in the living biomass pool resulted in a reduction of 0.1 kt C.

6.16.5 Settlements

6.16.5.1 Settlements remaining settlements – organic soils

- A small recalculation of 1 kt C was observed as emissions increased from 53 kt C in NIR 2017 to 54 kt C in NIR 2018. The area of organic soils for 2015 was only slightly larger (6.9 kha) in NIR 2018 compared to the 2017 submission (6.7 kha) due to the NFI extrapolation method.

6.16.5.2 Land converted to settlements

- Total C stock losses from the category for 2015 were reduced by 5 kt C in NIR 2018 (509 kt C) compared to NIR 2017 (514 kt C). This was a result of the combined effect of larger living biomass losses and smaller losses from organic soils.
- Living biomass losses on forest land converted to settlements were increased by 7 kt C from 134 kt C (NIR 2017) to 141 kt C (NIR 2018).
- Emissions from organic soils decreased by 4 kt C from 59 kt C (NIR 2017) to 56 kt C (NIR 2018), due to a smaller organic soils area from the NFI. This occurred mostly on forest land converted to settlements.

6.16.6 Other Land

6.16.6.1 Land converted to other land

- There were no recalculations for this source for neither land converted to other land nor grassland converted to other land.

6.16.7 Harvested wood products

- The FAO activity paper and paperboard export data for 2015 had changed from 913 393 to 943 493 metric tonnes. However, this did not change the total emissions from 2015.

6.16.8 Direct N_2O emission from managed soils 4(I)

- There were recalculations for 2015 for organic N fertilizer applications on settlements remaining settlements. Organic fertilizer were reduced from 1 443 191 kg N/yr (NIR 2017) to 1 137 447 kg N/yr (NIR 2018) due to changes in Statistics Norway data. This led to reduced N_2O emissions 0.0227 kt N_2O (NIR 2017) to 0.0179 kt N_2O (NIR 2018). There were no recalculations for forest land inorganic N fertilizer applications.

6.16.9 Emissions and removal from drainage of organic soils 4(II)

- Recalculations for 2015 in this source were minor and caused mainly by the updated area estimates resulting from the NFI extrapolation method, except for peat extraction. An error was made in the calculation of the kt N_2O estimate from peat extraction lands on drained organic soils in the submission years 2015, 2016, and 2017. Different areas were used 400 ha (2015) and 1264 ha (2016), but the same area of 2000 ha was used in the 2017 and 2018 submissions. The error led to 0.0003 kt N_2O (0.089 kt CO_2 equivalents) higher N_2O emissions,

0.0009 kt N_2O (0.268 kt CO_2 equivalents) in 2018 compared to 0.0006 kt N_2O (0.179 kt CO_2 equivalents) in 2017 for the year 2015.

6.16.10 Direct N_2O emissions from N mineralization and immobiliation 4(III)

- The area changes caused by NFI updates caused only minor recalculations for this source except for grasslands converted to forest land. In 2015, 2016, and 2017 reporting years the grasslands converted to croplands areas were mistakenly reported instead of grasslands converted to forest land areas. In the year 2015, the area increased from 6.04 kha (NIR 2017) to 13.28 kha (NIR 2018), which led to an increase in N_2O emissions from 0.02713 kt N_2O (NIR 2017) to 0.02851 kt N_2O.

6.16.11 Indirect N_2O emissions from managed soils 4(IV)

- Recalculations for atmospheric deposition resulted in reduced N_2O emissions from 0.0019 (NIR 2017) to 0.0018 (NIR 2018) due to a reduction in the amount of organic N applied to settlements from 1 443 191 kg N/yr (NIR 2017) to 1 137 447 kg N/yr (NIR2018).

6.16.12 Biomass burning 4(V)

- Recalculations for this source in the year 2015 led to reduced CH_4 emissions from 0.0049 kt CH_4 (NIR 2017) to 0.0026 kt CH_4 (NIR 2018) and increased N_2O emissions from 0.00003 kt N_2O (NIR 2017) to 0.0001 kt N_2O (NIR 2018) due to an update in methodology from 2003 Guidelines to 2006 Guidelines.

7 Waste (CRF sector 5)

7.1 Overview

This sector includes emissions from landfills (CRF 5A), Biological treatment of solid waste (CRF 5B), Incineration and open burning of waste (CRF 5C), and Wastewater treatment and discharge (CRF 5D). Waste incineration from plants with energy utilization is accounted for under Energy industries (CRF 1A1). Waste incineration included in CRF 5C are emissions of greenhouse gases other than CO_2 from methane flared at landfills, and emissions from combustion of hospital waste in hospital incinerators.

The emissions of greenhouse gases from the waste sector decreased by 44.2 per cent (1.0 million tonnes CO_2 equivalents) from 1990 to 2016. The reductions were mainly due to decreased CH_4 emissions from landfills. Indeed, they decreased by 49.5 per cent from 1990 to 2016, corresponding to 1.0 million tonnes CO_2 equivalents. Emissions from Industrial wastewater decreased by 0.05 million tonnes CO_2 equivalents during the same period. Emissions from domestic wastewater handling and composting increased their emissions by 0.02 and 0.06 million tonnes CO_2 equivalents, respectively.

Solid waste disposal on land (i.e. in landfills) is the main emission category within the waste sector, accounting for, in 2016, 83.2 per cent of the sector's total emissions. Wastewater handling in domestic and industrial sectors account for 11.5 and 5.4 per cent of the sectors emission. Composting accounts for 5 per cent of emissions from the waste sector. Emission from waste incineration, without energy recovery, are only minor emissions.

The waste sector accounted for 2.3 per cent of the total GHG emissions in Norway in 2016. Table 7.1 presents the key categories included in the Waste sector.

Table 7.1 Key categories in level or trend in the Waste sector

IPCC	Source category	Gas	Key category according to tier	Method
5A1	Managed Waste Disposal on Land	CH_4	2	2
5D	Wastewater treatment and discharge	CH_4	2	2
5B	Biological treatment of Solid Waste	CH_4, N_2O	2	2

Source: Statistics Norway/Norwegian Environment Agency

7.2 Managed Waste Disposal on Land – 5A1

7.2.1 Anaerobic managed waste disposal sites, 5A1a (Key category for CH_4)

7.2.1.1 Description

CH_4 and non-fossil CO_2 are emitted during biological decomposition of waste. This transformation of organic matter takes place in several steps. During the first weeks or months, decomposition is aerobic, and the main decomposition product is CO_2. When there is no more oxygen left, the decomposition becomes anaerobic, and methane emissions start to increase. After a year or so, CH_4 emissions reach a peak, after that the emissions will decrease over some decades (SFT 1999a), (NCASI 2004).

The emissions of methane from landfills have decreased since 1990 and specifically after 1998 due to reduction of the amount of degradable waste disposed at disposal sites. This emissions reduction is the result of several policies and measures introduced in the waste sector, particularly in the 1990s. With 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 1999 to 2014, a tax was introduced on waste delivered to final disposal sites. In 2014, this tax was 294 NOK per tonne waste. From July 1st 2009, it was prohibited to deposit biodegradable waste to landfills. This results in further reduction of methane emissions.

In addition to the above described policies and measures, landfills receiving biodegradable waste (waste containing degradable organic carbon (DOC)) are required to collect and treat landfill gas. In 2016, 71 landfills, which had installed a landfill gas extraction system, reported extraction of gas. 7 960 tonnes of methane were recovered representing a 7 per cent decrease compared to 2015. Methane extraction increased until 1998, and then underwent fluctuations between 1999 and 2008. The fluctuations were due to instability in the pipeline systems. Due to needs for maintenance of the pipeline system, methane extraction was reduced.

Since 2008, extraction has had a decreasing trend. This can be explained by the increased amounts of waste recycled. The total amount of waste generated has increased by almost 60 per cent from 1995 to 2016, but due to the increase in material recycling and energy utilization, the amount disposed at landfills has dropped substantially since 2008. As a consequence of the prohibition against depositing of biodegradable waste of July 1st 2009, there has been a strong decrease in waste depositing.

Since building the necessary treatment capacity would take time, temporary exemptions were granted in certain cases during a transitional period. Many permits for disposal of biodegradable waste had been given for one year extra, some extended out 2010, and a few within 2011. The transitional period ended on December 31st 2012.

In 2016, methane emissions from managed waste disposal sites were 1.0 million tonnes CO_2-equivalents.

Emissions of CH_4 from solid waste disposal are key category in level assessment for both 1990 and 2016 and in trend assessment due to uncertainty in AD and EF. It should be noted that the IEF for CH_4 varies due to variation of the amount of extracted CH_4 from the landfills.

There are no known semi anaerobic disposal sites in Norway, according to expert judgment (Skullerud, Pers. Comm)[33], only managed anaerobe disposal sites.

Figure 7.1 shows the relative change (Index 1995=100%) in methane emissions from landfills, extraction of methane, solid waste disposed at landfills and total amount of waste generated in Norway.

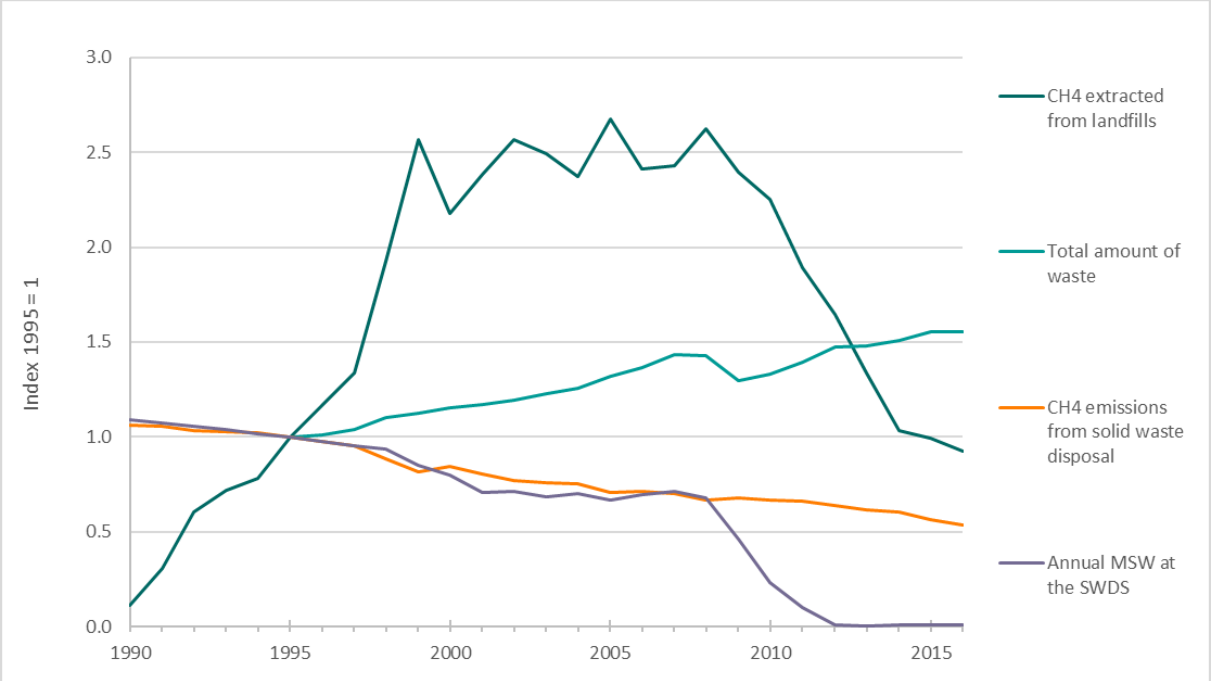


Figure 7.1 Relative change in methane emissions from solid waste disposal, annual MSW at the SWDS, methane extracted from landfills and total amount of waste generated in Norway. 1990-2016 Index 1995 = 1.
Source: Statistics Norway/Norwegian Environment Agency

7.2.1.2 Methodological issues

The model proposed in the IPCC 2006 Guidelines has been used.

This model starts with the calculation of the amount of decomposing $DDOC_m$ (mass of decomposable organic carbon = the part of DOC (degradable organic carbon) that will decompose (degrade) under anaerobic conditions) contained in the material being landfilled.

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 each years, all years can be considered individually in the calculations. This simplifies the model.

[33] Håkon Skullerud 2014: Personal communication by telephone. Statistics Norway

With the start of the reaction set to be January 1st the year following the landfilling, the "motor" of the new calculating model has been made out of these two very simple equations:

$$(7.1) \quad DDOC_{mdiss} = \left(DDOC_{ma(ly)} + DDOC_{md}\right) \times \left(1 - e^{-k}\right)$$

$$(7.2) \quad DDOC_{ma} = \left(DDOC_{ma(ly)} + DDOC_{md}\right) \times e^{-k}$$

Equation (7.1) calculates DDOCmass decomposing ($DDOC_{mdiss}$) as the sum of the not decomposed DDOC mass accumulated from the previous years ($DDOC_{ma(ly)}$), and the DDOC mass landfilled during the previous year ($DDOC_{md}$).

Equation (7.2) calculates the DDOC mass accumulated as not decomposed ($DDOC_{ma}$), which is then used as ($DDOC_{ma(ly)}$) for the following year's calculations using equation (7.1).

The mass of decomposable organic carbon landfilled ($DDOC_{md}$) is estimated using equation (7.3).

$$(7.3) \quad DDOC_{md} = W \times MCF \times DOC \times DOC_f$$

The amount of decomposed $DDOC_m$ being estimated, CH_4 produced, and CH_4 emitted are estimated using the equations stated below ((7.4)-(7.9)).

If the reaction of decomposition is set to start during the year of landfilling and not on January 1st of the following year, equations (7.1) and (7.2) need to be adjusted.

Equation (7.1) must be replaced by equations (7.4) and (7.5).

$$(7.4) \quad DDOC_{mdi} = DDOC_{md} \times \left(1 - e^{-k \times \left(\frac{13-M}{12}\right)}\right)$$

$$(7.5) \quad DDOC_{mdiss} = DDOC_{ma(ly)} \times \left(1 - e^{-k}\right) + DDOC_{mdi}$$

Equation (7.2) must be replaced by equations (7.6) and (7.7).

$$(7.6) \quad DDOC_{ml} = DDOC_{md} \times e^{-k \times \left(\frac{13-M}{12}\right)}$$

$$(7.7) \quad DDOC_{ma} = DDOC_{ma(ly)} \times e^{-k} + DDOC_{ml}$$

The amount of methane produced from decomposition of DDOC is estimated using equation (7.8).

$$(7.8) \quad CH_{4\,prod} = DDOC_{mdiss} \times F \times {}^{16}/_{12}$$

Methane emissions are estimated from the amount of methane produced and the amount of methane recovered. Equation (7.9) details the calculations.

$$(7.9) \quad CH_{4\,emitted\ in\ year\ T} = \left(\sum CH_{4\,prod}(T) - R(T)\right) \times (1 - OX)$$

Where, in equations (7.1)-(7.9):

W : amount landfilled

MCF : Methane Correction Factor

M : Month number for reaction start. (January 1, year after landfilling, M=13)

DOC : Degradable Organic Carbon

DOC_f : Fraction of DOC decomposing, anaerobic conditions

$DDOC_m$: Mass of Decomposable Organic Carbon, anaerobic conditions

$DDOC_{md}$: DDOC mass landfilled

$DDOC_{ml}$: DDOC mass left not decomposed from DDOCm landfilled, year of landfilling

$DDOC_{ma}$: DDOC mass left not decomposed at end of year

$DDOC_{ma(ly)}$: DDOC mass accumulated from last year

$DDOC_{mdi}$: DDOC mass decomposed from DDOCm landfilled, year of landfilling

$DDOC_{mdiss}$: DDOC mass decomposed in calculation year

$CH_{4\ prod}$: CH_4 produced

F : Fraction of CH_4 by volume in generated landfill gas

$16/12$: Conversion factor from C to CH_4

$R(T)$: Recovered CH_4 in year of calculation

OX : Oxidation factor (fraction).

7.2.1.3 Activity data

The methane is formed by decomposition of biological waste in landfills. The decomposition time varies from material to material. Easily 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. The waste accounts consist of data from several sources, such as special surveys, register data and statistics, indirect data sources such as production statistics, foreign trade statistics and different factors combined with activity data. Data from all these sources are combined in the waste accounts, which give an overview of waste quantities in Norway, divided into type of product, material, industry and method of treatment. Waste incineration in the waste accounts includes export, and is thus not comparable with the emission inventory as a substantial amount is exported to Sweden for incineration.

From 2012 onwards, data for the categories food waste, plastics, wood and paper are taken directly from the waste accounts. The amount of sludge deposited are taken from statistics on discharges and treatment of municipal waste water. In addition, there is a category “other” in the waste accounts, of which content is not known. Due to the prohibition to deposit biodegradable waste to landfills it is assumed that no methane is formed from these materials.

Historic data up until 2011 have been recalculated from the former waste category basis, to a waste material basis. The amount of each material type deposited is estimated based on surveys and sorting

analyses. The model is based on types of waste materials for instance food waste (incl. garden waste), paper, wood and textiles. All sources of waste, MSW, industrial, commercial, construction and demolition waste are accounted for in these annual surveys.

Municipal landfills

Historical data for years before 1973 on municipal solid waste deposited are based upon:

1. New statistics on municipal waste, divided into household waste and industrial waste (1974 to 1997),
2. Estimates based on population,
3. Assumption that less people were connected to public waste management during the forties and fifties.

Since 1974, the amount of municipal waste is based upon questionnaires and linear interpolations. 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 1995-2011 the amounts of waste is taken from the waste accounts, with three adaptions:

- Wood content in sludge deposited at industrial sites is added to the amount of deposited wood from the waste accounts,
- Textiles are supposed to consist of 50 per cent plastic (SFT 2005b). The plastic fraction of deposited textiles is therefore subtracted from the amount of deposited textiles and added to deposited plastic,
- The material category “Other materials” is assumed to contain degradable organic matter with an average half-life. This degradable share is added to the amount of paper. The amount is estimated by 0.2 * landfilled ‘other materials’ from manufacturing + 0.5 * 'other combustible' in landfilled mixed waste from all sectors.

Contaminated soils are assumed not to develop methane in landfills. The same applies to waste used as cover material, due to excess oxygen availability.

No bio-degradable hazardous waste is landfilled in Norway.

No organic waste is imported for landfilling, as it is prohibited.

Due to lack of data, linear interpolation of the amount of waste deposited has been applied to the period 1985-1995.

Table 7.2 Amounts deposited in municipal SWDS, 1945-2016. 1 000 tonnes.

Year	Food	Paper	Wood	Textile	Sewage sludge	Plastics
1945	75	148	120	3	7	11
1950	116	228	171	4	10	17
1955	131	256	207	5	11	19
1960	171	335	258	6	14	25
1965	258	422	270	8	18	50
1970	279	463	307	9	20	54
1975	305	513	318	10	22	59
1980	343	584	300	11	23	66
1985	357	635	280	11	24	68
1990	342	461	280	22	21	144
1995	327	286	279	33	17	219
2000	253	249	194	29	13	189
2005	218	195	169	26	4	164
2006	223	217	165	26	6	171
2007	223	227	166	28	2	186
2008	205	216	160	27	2	180
2009	138	143	106	18	3	126
2010	71	69	54	9	2	65
2011	29	33	23	3	2	28
2012	0	1	8	0	1	3
2013	0	1	0	0	2	2
2014	1	1	0	0	5	2
2015	3	2	2	0	3	3
2016	3	2	2	0	1	3

**Figures for the last inventory year are set equal to the previous year because the waste accounts are not updated in time for the emission inventory calculations. Source: Statistics Norway/Norwegian Environment Agency*

Industrial disposal sites

Historical data for industrial waste for years before 1970 are estimated 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 Environment Agency assembles these data in their own

database. Further, these data are imported into the national model for calculating methane from landfills.

Table 7.3 Waste amounts deposited in industrial SWDS, 1945- onwards . 1 000 tonnes.

Year	Food	Paper	Wood	Textile	Plastics
1945	476	339	74 160	756	180
1950	735	524	101 108	1 167	277
1955	825	588	128 056	1 310	311
1960	1 077	767	155 004	1 710	406
1965	1 776	888	181 952	1 869	888
1970	2 000	1 000	208 900	2 000	1 000
1975	2 000	1 000	208 900	2 000	1 000
1980	2 000	1 000	173 872	2 000	1 000
1985	2 000	1 000	138 844	2 000	1 000
1990	2 000	1 000	103 817	2 000	1 000
1995	1936	899	88 800	1 957	759
2000	0	200	677	0	0
2001	0	38	0	0	0
2005- onwards	0	0	0	0	0

Source: Statistics Norway/Norwegian Environment Agency

7.2.1.4 Emission factors

All parameters used in the Norwegian model are IPCC defaults values for Northern Europe. Table 7.4 shows some of the variables used in the calculations of methane emissions from solid waste disposals both municipal and industrial.

Table 7.4 Variables used in the calculations of methane from landfills.

	Type of waste				
Variables	**Food waste**	**Paper**	**Wood**	**Textiles**	**Sewage sludge**
$t_{1/2}$ (half life time) (years)	3.7	11.6	23.1	11.6	3.7
DOC (Mg/Mg)	0.150	0.400	0.430	0.24	0.05
DOC_f (Part of DOC decomposing)	0.5	0.5	0.5	0.5	0.5
Ox. Methane oxidized in top layer	0.1	0.1	0.1	0.1	0.1
F. Part of methane in generated landfill gas	0.5	0.5	0.5	0.5	0.5

Source: IPCC (2006)

In Norway, all SWDS are considered well managed and covering including oxidising material shall apply according to the regulation on SWDS.

7.2.1.5 Uncertainties and time-series consistency

The amount of different waste materials is considered to be known within ±20 per cent. The emission factors used are considered to have the uncertainty range ±30 per cent. More information about the uncertainty estimates for this source is given in Annex II.

The importance of the uncertainties in calculations of methane from landfills will decrease with decreased source contribution and improved IPCC default parameter values, but most likely it will still remain among the main uncertainties in the Norwegian GHG inventory.

The methodology Statistics Norway/the Norwegian Environment Agency use to calculate methane emissions from landfills is consistent 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.

In 2014, a major revision of the methodologies of the waste accounts took place. The time series for waste amounts has not been recalculated to take this new information into account. There are several reasons for this, among others that many sources for the statistics do not have numbers for earlier years. Since 2012, publication divides wastes into new categories, different from the previous categories. The category “mixed waste” is no longer separated into its different material types. See Statistics Norway’s documentation of the waste accounts for more details about the revisions (Statistics Norway Annually-b). This change in the waste accounts introduces a certain degree of inconsistency in the time series of the activity data used for the calculation of methane emissions from municipal landfills. However, due to the measures described in 7.2.1.1, the amount of biological waste deposited at SWDS is currently very low, and the effect of the alterations in the waste accounts are thus considered to be negligible.

7.2.1.6 Source specific QA/QC and verification

Internal checks of time series for all emission sources are conducted every year along with the new inventory production.

Internal checks are carried out for time series of waste data, methane recovered at landfill sites and calculated methane emissions from the model. Corrections are made if necessary.

The Norwegian Environment Agency contacts landfill sites to discuss outliers and major changes in the trend of methane recovery. Corrections are made if necessary.

7.2.1.7 Recalculations

Activity data has been updated. Updated figures of sludge deposited at MSWDS for 2014 has replaced earlier used figures from 2013. This revision does not influence on the emissions estimated for 2014.

7.2.1.8 Planned improvements

There are no improvements planned for this sector.

7.3 Unmanaged Waste Disposal Sites – 5A2

In Norway, landfilling of solid waste has been regulated and controlled for some decades, and unmanaged landfills date from before 1970. Furthermore, the methane emissions for all years have been calculated from the total amounts of landfilled materials. Therefore, unmanaged waste disposal sites are not occurring and hence Norway does not separately report emissions from unauthorized/unmanaged SWDSs.

7.4 Biological treatment of Solid Waste – 5B (Key category for CH_4)

7.4.1 Composting and Anaerobic digestion of organic waste – 5B1 and 5B2

7.4.1.1 Description

This section covers the biological treatment of solid waste.

Composting is an aerobic process. A large fraction of the degradable organic carbon (DOC) in the waste material is oxidized into carbon dioxide (CO_2). CH_4 is also formed during the process, in anaerobic sections of the compost, but is largely oxidized in the aerobic sections of the compost. Composting can also produce emissions of N_2O.

Anaerobic digestion of organic waste expedites the natural decomposition of organic material without oxygen, i.e. biogas production.

In the Norwegian inventory, emissions from compost production and biogas production without energy recovery are included in this category. CH_4, N_2O and CO_2 are emitted during this process. CO_2 emissions from compost production are biogenic.

According to the Tier 2 key category analysis emissions of CH_4 and N_2O from Biological treatment of solid waste (CRF 5B) are key categories in trend assessment (1990-2016).

7.4.1.2 Methodological issues

Emissions from composting of municipal waste have been calculated according to the Tier 1 default methodological guidance available in the guidelines (IPCC 2006).

CH_4 emissions from biological treatment

$$(7.10)\quad CH_4\ Emissions = \sum_i (M_i * EF_i) * 10^{-3}$$

Where:

CH_4 Emissions	: total CH_4 emissions in inventory year, Gg
M_i	: mass of organic waste treated by biological treatment type *i*, Gg
EF	: emission factor for treatment *i*, g CH_4/kg waste
i	: composting or anaerobic digestion

In Norway, composting of solid biological waste includes composting of:

- organic waste from households and other sources,
- garden and park waste (GPW),
- sludge,
- home composting of garden and vegetable food waste.

CH_4 emissions from anaerobic digestion at biogas facilities are estimated based on the amount of waste treated at biogas facilities multiplied by the IPCC default emission factor. Norway is currently improving the data quality for both the amount of waste treated in biogas facilities, and the amount

of energy produced. When the data is available, Norway will consider to use them in the calculation of the emissions.

Composting is performed with simple technology in Norway; this implies that temperature, moisture and aeration are not consistently controlled or regulated. During composting, a large fraction of the degradable organic carbon (DOC) in the waste material is converted into CO_2. Anaerobic sections are inevitable and cause emissions of CH_4. In the same manner, aerobic biological digestion of N leads to emission of N_2O (IPCC 2006).

N_2O emissions from composting

$$(7.11)\quad N_2O\ Emissions = \sum_i (M_i * EF_i) * 10^{-3}$$

Where:

N_2O Emissions	: total N_2O emissions in inventory year, Gg
M_i	: mass of organic waste treated by biological treatment type i, Gg
EF	: emission factor for treatment i, g N_2O/kg waste

Emissions from compost production are considered to be complete; calculations include composting at all nationally registered sites and best available estimated data for home composting.

7.4.1.3 Activity data

All Norwegian waste treatment plants are obligated to statutory registration and reporting of all waste entering and leaving the plants. All waste streams are weighed, categorized according to a waste type and type of treatment. Data is available for all years since 1995.

Activity data for the years since 1995 are collected from Statistics Norway's, waste statistics. Data for 1991 is also available from the waste statistics. For the year 1990, activity data for 1991 have been used, while AD for 1995 is used for 1992 to 1994.

Table 7.5 Amount of waste biologically treated at composting and biogas facilities, 1990-2016. Tonnes of waste on wet basis.

Year	Composting	Anaerobic digestion
1990	21 000	0
1995	57 000	0
2000	234 000	0
2005	319 232	4 768
2006	317 076	29 924
2007	408 706	31 294
2008	393 000	62 000
2009	354 877	83 123
2010	359 384	86 616
2011	296 000	105 000
2012	407 000	57 000
2013	441 000	77 000
2014	328 000	80 000
2015	309 000	289 000
2016*	309 000	289 000

**Figures for the last inventory year have been set equal to the previous year because the waste accounts have not been updated in time for the emission inventory calculations.*
Source: Statistics Norway

Home composting

The last waste category involved in composting is home composting of garden waste and vegetable waste. The activity data for this category is available for the years 2009 to 2012 from Statistics Norway. The amount of organic waste from households composted for the period 1990-2008 is estimated assuming that 3 per cent of all households composts their garden and vegetable food waste (Lystad 2005). The average value of the period 2009-2012, 2.6 per cent, has been used for the following period.

Table 7.6 Number of households with home composting and amount of organic waste composed, 1990-2016. Tonnes.

Year	Number of households with home composting	Amount of organic waste composted
1990	53 114	8 200
1995	55 980	10 234
2000	58 846	12 607
2005	61 107	15 764
2010	57 307	14 310
2011	57 479	13 703
2012	54 786	12 852
2013	58 848	14 135
2014	59 569	14 200
2015	60 356	14 390
2016	61 193	14 326

Source: Statistics Norway

7.4.1.4 Emission factors

Emissions from composting, and anaerobic digestion in biogas facilities, will depend on the composition of waste composted, the amount and type of supporting material used (such as wood chips and peat), the temperature, the moisture content and the aeration during the process.

Table 7.7 gives the default factors for CH_4 and N_2O emissions from biological treatment for the Tier 1 method used in the Norwegian inventory (IPCC 2006). The CO_2 produced and emitted during composting is short-cycled C and is therefore regarded as CO_2 neutral (Boldrin et al. 2009).

Table 7.7 Composting emission factors. kg/tonnes.

	Composting	Anaerobic digestion at biogas facilities	Home composting
CH_4	4	0.8*	4
N_2O	0.3	NO	0.3

*Amount of waste on a wet basis

Source: IPCC (2006)

7.4.1.5 Uncertainties and time-series consistency

The amount of waste biological treated at composting and biogas facilities is considered to be known within ±20 per cent. The amount of waste composted at home is considered to be known within ±100 per cent. The emission factors used are considered to have the uncertainty range ±100 per cent. More information about the uncertainty estimates for this source is given in Appendix D.

The methodology Statistics Norway/the Norwegian Environment Agency use to calculate emissions from biological treatment of solid waste is consistent for the whole time series.

7.4.1.6 Source specific QA/QC and verification

Internal checks of time series for all emission sources are conducted every year along with the new inventory production.

Internal checks are carried out for time series of waste data and calculated methane emissions. Corrections are made if necessary.

7.4.1.7 Recalculations

Composting facilities
In the previous submissions, the amount of composted waste for the years 1993 and 1994 had been set equal to the 1995 value. In this submission, figures for 1993 and 1994 have been estimated by interpolating values for the period 1992-1995. Emissions of CH4 and N2O have been reduced by 0.04 and 0.06 per cent in 1993, and 0.02 and 0.03 per cent in 1994, respectively. Activity data have also been updated for the years 2013 and 2014.

Home composting
The number of households which composts wastes has been updated for the year 2014.

Biogas facilities
The amount of waste treated at biogas facilities have been revised for 2013 and 2014.

The emission factor used for estimation of CH_4 emissions from anaerobic digestion at biogas facilities has been corrected from 1 to 0.8 kg CH_4/tonnes. Emissions have increased by 20 per cent for all years.

7.4.1.8 Planned improvements

Norway is currently improving the data quality for both the amount of waste treated in biogas facilities, and the amount of energy produced. When the data become available, Norway will consider using them in the calculation of the emissions.

7.5 Waste incineration – 5C

7.5.1 Description

Emissions from waste incineration in district heating plants are reported under energy industries (CRF 1A1a), **as the energy** is utilized, and therefore described in Chapter 3. In 2016, there were 18 waste incineration plants where household waste was 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 (CRF 1A1a). Waste, other than household waste, is also used as energy source in some manufacturing industries. These emissions are reported and described in the relevant subsectors under energy in manufacturing industries (CRF 1A2). Flaring off-shore and in refineries are included under fugitive emissions (CRF 1B2c). Flaring in chemical industry is included under chemical process emissions (CRF 2B8a). In this chapter, the focus will be on waste reported in IPCC sector 5C. This includes emissions from flaring of landfill gas at waste treatment plants, flaring of biogas in industry and hospital waste.

In Norway, the open burning of private yard waste is under different restrictions according to the respective municipality. These restrictions include what can be burned, but also the quantity, how, when and where it can be burned. In some municipalities, a complete ban is imposed. There is no registration of private waste burning and the activity data on this subject are difficult to estimate. Citizens are generally encouraged to compost their yard waste or to dispose of it through one of the many waste disposal/recycling sites. Emissions from open burning of waste are not estimated.

7.5.2 Methodological issues

Emissions from flaring of landfill gas by landfills are estimated. However, CO_2 emissions from flaring of landfills are not included in the inventory, as these are considered as being of biogenic origin. Emissions have been estimated by multiplying the amount of gas flared with the emission factors shown in Table 7.10.

Emissions from combustion of hospital waste have been calculated based on an emission factor and the amount hospital waste incinerated. Since 2006, hospital wastes have been incinerated in municipal waste incineration plants and emissions are then reported under energy industries (CRF 1A1a).

7.5.3 Activity data

Landfill gas

The total amount of landfill gas extracted each year is reported by landfill owners to the Norwegian Environment Agency. The data are based on measurements of both amount of gas and CH_4 content. Most landfill owners are required to measure continuously, and as a minimum to report: Hours of operation, amount of gas extracted, volume percentage of CH_4, and amount of CH_4 used for flaring, heat, and electricity. The landfill operator reports the percentage of methane, along with the total amount of landfill gas (volume) to the Norwegian Environment Agency. The amount of recovered methane is then calculated.

Statistics Norway subtracts the amount utilized for district heating and thermal power, which is given by the energy statistics in Statistics Norway. Information on the amount flared is given by the Norwegian Environment Agency.

Emissions from the amount of landfill gas flared is included under 5C1a, municipal solid waste. Emissions from landfill gas used for district heating and used in other sectors are reported in the relevant subsectors under Energy (CRF 1A1 and 1A4).

Table 7.8 Amount of landfill gas flared and used for energy purposes. Tonnes.

Year	5C. Flared	1A1a Public electricity and heat production	1A4a, Other sectors, commercial/institutional
1990	879	0	67
1995	5 951	208	2 472
2000	12 459	3 654	2 698
2005	8 995	187	13 925
2006	8 093	177	12 528
2007	9 542	1 767	9 668
2008	10 769	3 061	8 826
2009	9 870	4 752	6 041
2010	8 273	4 077	7 066
2011	6 965	3 428	6 002
2012	4 969	4 483	4 650
2013	3 210	5 474	2 848
2014	4 587	251	4 070
2015	4 808	251	4 265
2016[1)]	4 808	593	4 265

1. Figures for the last inventory year have been set equal to the previous year for 5C1a and 1A4a. These figures will be updated in next year submission.
Source: Statistics Norway/ Norwegian Environment Agency

Natural gas

The amount of natural gas flared by the production of methanol is, as recommended by the ERT, reported under 2B8.

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, as there has been no collection of hospital waste data, and due to the lack of better information, the waste amount of 1999 has been used to calculate the emissions for the subsequent years.

Hospital incinerators have gradually been closed down, mainly due to new emission limit values. Since 2006, no hospital incinerator has been running and hospital waste has been incinerated in incinerators for municipal waste. Therefore, emissions are included under energy (CRF 1A1a).

Table 7.9 Estimated amount of hospital waste incinerated in hospital incinerators. 1 000 tonnes.

Year	Hospital waste incinerated
1990	0.63
1995	0.48
2000	0.24
2001	0.24
2002	0.14
2003	0.14
2004	0.14
2005	0.14
2006 onwards	0

Source: Statistics Norway

7.5.4 Emission factors

Table 7.10 presents the emission factors used for calculating emissions from flaring, cremation and hospital waste.

Table 7.10 Emission factors for flare, cremation and hospital waste incineration.

Component	Flare Landfill gas[1] and biogas	Hospital waste
	kg/tonnes	Tonnes/tonnes
CO_2	0	0.3
CH_4	0.37	0.00023
N_2O	0.0015	0.000035

Source: [1]SFT (1996)

7.5.5 Uncertainties and time-series consistency

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 incinerated the subsequent years may vary from the data reported in 1999 currently used in the inventory for the period 2000-2005. Uncertainty has been estimated to ±30 per cent.

Emission factors

Uncertainty estimates for greenhouse gases are presented and discussed in Annex II.

If the composition of the hospital waste is different from the one, which the emission factors are based on, the calculated emissions will be incorrect. Combustion engineering and processes also influence the emissions. See Annex II.

7.5.6 Source specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. See Section 1.2 for a description of the general QA/QC procedures of the Norwegian emission inventory.

7.5.7 Recalculations

Estimated emissions of CH_4 and N_2O from cremation have been removed for all years. There are no emission factors available in the IPCC 2006 Guidelines.

Activity data from flaring of biogas from two plants have been corrected for the years 1991-2006. It increases CH_4 and N_2O emissions.

7.5.8 Planned improvements

Include emissions from flaring of biogas in industry. By a mistake, emissions from flaring of biogas in industry are omitted for all years in this year submission. This will be included next year. There are no other planned activities this year that will improve the data quality or the documentation for this source category.

7.6 Wastewater treatment and discharge – 5D (Key category for CH_4)

7.6.1 Overview

In 2016, wastewater handling accounted for 11.5 per cent of the emissions in the waste sector. CH_4 and N_2O emissions from Wastewater handling have been reduced by 18.4 per cent between 1990 and 2016, emissions been relatively stable since 1998.

Wastewater can be a source of methane (CH_4) when treated or disposed anaerobically. It can also be a source of nitrous oxide (N_2O). Carbon dioxide (CO_2) from wastewater is not considered in the IPCC Guidelines because of its biogenic origin and should not be included in national total emissions.

Sludge is produced in all wastewater handling. It consists of solids that are removed from the wastewater. This sludge must be treated further before it can be safely disposed of. In Norway, some of the wastewater sludge is treated aerobically, emissions are then included in composting (CRF 5B). Some facilities treat sludge anaerobically, producing biogas. During this process, CH_4 is produced. Emissions from the use of the produced CH_4 are included in the energy and industry sectors. Emissions of CH_4 from such facilities, due to unintentional leakages during process disturbances or other unexpected events, are included in this source category – 5D.

N_2O emissions from sewage sludge applied on fields are not treated in this chapter and are included in the LULUCF sector according to the guidelines (IPCC 2006).

According to the Tier 2 key category analysis, CH_4 emissions from wastewater handling are key category in level assessment in 1990 and trend assessment (1990-2016).

The Norwegian wastewater treatment system is characterized by a few big and advanced aerobic wastewater treatment plants (WWTP) and many smaller WWTP. In 2016, 65 per cent of Norway's population was connected to high-grade treatment plants with biological and/or chemical treatment. Furthermore, 18 per cent of the population was connected to mechanical or other types of treatment, 15 per cent of the population was connected to small wastewater facilities (less than 50 pe) and the remaining 2 per cent had direct discharges.

There is almost 2 700 wastewater facilities with a capacity of more than 50 population equivalents (pe) in Norway which treated wastewater from 85 per cent of the population in 2016.

The source category 5D includes estimation of CH_4 and N_2O emission from wastewater handling; i.e. wastewater collection and treatment. CH_4 is produced during anaerobic conditions and treatment processes, while N_2O may be emitted as a bi-product from nitrification and denitrification processes under anaerobic as well as aerobic conditions.

It is not possible to fully distinguish between emissions from industrial and domestic wastewater, as Norwegian industries, to a great extent, are coupled to the municipal sewer system. Wastewater streams from households and industries are therefore mixed in the sewer system prior to further treatment at centralised WWTP.

Industrial wastewater may be treated on-site or released into domestic sewer systems. If it is released into the domestic sewer system, the emissions are included in the domestic wastewater emissions (CRF 5D1). Norway estimates CH_4 emissions from on-site industrial wastewater treatment

not connected to domestic sewer systems. Only industrial wastewater with significant carbon loading that is treated under intended or unintended anaerobic conditions will produce CH_4. Industries which have been considered are:

- Pulp and paper industry,
- Chemical industry,
- Food processing industries.

As a response to previous reviews, Norway has initiated collection of activity data from Norwegian industry to enhance completeness of emissions from wastewater handling. Norway has conducted investigations on industries with separate wastewater facilities in the chemical industry, and has concluded that no company in this industry has anaerobic treatment of wastewater. In the food processing industry, all identified plants have aerobic treatment except from one. In this plant, the methane generated is flared.

Two companies in the pulp and paper industry have been identified as running anaerobic wastewater treatment facilities. The methane emissions generated from this treatment are either flared or used for energy purposes. Emissions from energy recovery have been included in energy combustion for Manufacturing Industries and construction (sector 1A2d) pulp, paper and print, for the years 1991-2016 as recovery began only in 1991.

Emissions from flaring have been included in the waste incineration sector (CRF 5C).

7.6.2 Methodological issues

7.6.2.1 Domestic wastewater

CH_4

CH_4 from domestic waste water treatment plants

Methane emissions from domestic wastewater have been calculated according to the IPCC default methodology (2006):

$$(7.12)\quad CH_4 Emissions = \left[\sum_j \left(U_i \times T_{i,j} \times EF_j\right)\right](TOW - S) - R$$

Where:

U_i: fraction of the population I income group i

$T_{i,j}$ Degree of utilisation of treatment/discharge j, for each income group i

EF_j Emission factor for treatment/discharge j, kg CH_4 / kg BOD

TOW: Maximum methane-producing capacity (kg CH_4/kg BOD)

S Organic component removed as sludge (kg BOD / yr)

R Amount of CH_4 recovered in the inventory yr.

In Norway, all domestic wastewater treatment plants are aerobic and are considered well managed. Therfore, only direct discharge has been considered in the calculation of CH_4 emissions. Also, both

amount of organic component removed as sludge and amount recovered CH_4 have not been considered in the calculation.

Equation (7.12) can then be simplified by equation (7.13):

$$(7.13)\quad CH_4 Emissions = EF \times TOW$$

With:

$$(7.14)\quad EF = B_0 \times MCF \qquad \textit{and} \qquad (7.15)\quad TOW = N \times BOD$$

Where:

B_0 Maximum CH_4 producing capacity, kg CH_4/kg BOD

MCF: Weighted average methane correction factor by population

N: Population total in Norway, 1000 persons

BOD: Organic load in biochemical oxygen demand, kg BOD/1000 persons/year

Unintentional leakage of CH_4 from biogas facilities

According to IPCC (2006), emissions of CH_4 from biogas facilities may occur unintentionally due to leakages during process disturbances or other unexpected events. Emissions have been estimated as a fraction of the produced biogas using equation (7.16).

$$(7.16)\quad CH_4 = CH_{4\,generated} \times 0.005$$

N_2O

Emissions of nitrous oxide from domestic and commercial wastewater treatment have been estimated for both the part of the population connected to large wastewater treatment plants (WWTP) (>50 pe) and the part of the population not connected to large WWTP. The former includes the part of industries connected to the large WWTP while the latter includes N_2O emissions from human sewage, which are not treated in sewage treatment.

N_2O emissions from large WWTP

N_2O emissions from the part of the population and industries connected to large treatment plants (>50 pe) have been estimated based on nitrogen content in wastewater effluent and N_2O emissions occurring as a by-product in biological nitrogen-removal plants. This method is assumed to be more precise than the IPCC Tier 1 method based on annual per capita protein intake.

N_2O emissions from domestic wastewater nitrogen effluent have been calculated by multiplying the total amount of nitrogen supplied to the resipents by the IPCC default emission factor of 0.005 kg N_2O-N/kg sewage-N produced. Emissions in N needs to be converted into N_2O using the conversion ratio of N into N_2O: 44/28. Emissions have been estimated using equation (7.17).

$$(7.17)\quad N_2O = N_{supplied\ to\ pipelines} \times 0.005 \times \frac{44}{28}$$

N_2O emissions in **biological nitrogen removal-plants** have been estimated using equation (7.18), assuming that 2 per cent of the nitrogen removed from the plants will form N_2O.

$$(7.18)\quad N_2O = N_{removed} \times 0.02 \times \frac{44}{28}$$

The amount of N removed is multiplied by 2 per cent and emissions are then converted using the conversion ratio of N into N_2O: 44/28.

Data on the amount of nitrogen removed in biological steps of the actual wastewater treatment plants is gathered from Statistics Norway's wastewater statistics.

N_2O emissions from other domestic wastewater handling

For the part of the population that is not connected to large treatment plants, the N_2O emissions have been estimated as recommended by the IPCC review team, using a Tier 1 method. This method is based on annual per capita protein intake assuming consumed and non comsumed protein.

Emissions are calculated using the equation (7.19):

$$(7.19)\quad N_2O_{(s)} = Protein \times Fncp \times Frac_{NPR} \times NR_{PEOPLE} \times EF_6 \times \frac{44}{28}$$

Where:

$N_2O_{(s)}$:	N_2O emissions from human sewage (kg N_2O –N/ yr)
Protein:	Annual per capita protein intake (kg/person/yr)
NR_{PEOPLE}:	Number of people not connected to treatment plants
EF_6:	Emissions factor (default 0.005 (0.002-0.12) kg N_2O –N/kg sewage- N produced)
$Frac_{NPR}$:	Fraction of nitrogen in protein (default = 0.16 kg N/kg protein).
Fncp	Factor for non-consumed protein added to wastewater

7.6.2.2 Industrial wastewater

Organic material in industrial wastewater is often expressed in terms of COD (chemical oxygen demand). CH_4 emissions from on-site industrial wastewater treatment are estimated based on the amount COD released into recipient. Emissions of methane from industrial wastewater are calculated according to the IPCC default methodology described in equation (7.20):

$$(7.20)\quad CH_4 = COD \times B_0 \times MCF$$

Where:

COD:	chemical oxygen demand (industrial degradable organic component in wastewater)
B_0:	Maximum methane-producing capacity (kg CH_4/kg COD)
MCF:	Methane correction factor

Emissions from the following industries are included in the Norwegian inventory:

- Pulp and paper industry
- Chemical industry
- Food processing industries

CH_4 and N_2O emissions from industries connected to large treatment plants (>50 pe) are included in domestic waste water handling sector (CRF 5D1).

7.6.3 Activity data

7.6.3.1 Domestic wastewater

CH_4 emissions from domestic WWTP

Norwegian population data are extracted from Statistics Norway's population statistics. A country-specific value of 21.9 kg BOD/person/year has been used for the degradable organic component value in the waste (D), for all years (Berge & Mellem 2013).

Unintentional leakage of CH_4 from biogas facilities

Productions of biogas from biogas facilities ($CH_{4\ generated}$) are reported to the Norwegian Environment Agency.

N_2O emissions from large and small WWTP

Data for the amount of nitogen released into recipients are extracted from Statistics Norway's waste water statistics.

Data for the number of people in Norway connected to waste water treatment plants are extracted from the waste water statistics at Statistics Norway (2014a).

In 1990, 75 per cent of the Norwegian population was connected to WWTP. The population connected to large WWTP (>50 pe) is available for the whole period 1990-2016, while the population connected to small WWTP (<50 pe) is only available after 2002. Knowing the total Norwegian population connected for 1990, population connected to small WWTP has been estimated by interpolation for the period 1990-2002.

N_2O emissions from other domestic wastewater handling

Protein is annual per capita protein intake (kg/person/year). The Directorate for Health and Social Affairs has estimated the amount of daily per capita protein intake for Norway for 1997 (Johansson L. Solvoll 1999). In 1997, the daily per capita protein intake for Norway amounted to 86 gram, corresponding to 31.39 kilos per person per year.

No similar survey has been performed since then. Nevertheless, for the years 1990, 1995, 1999, 2000 and the period 2003-2016, the Norwegian Directorate for Health has estimated the potential protein intake for the population (Directorate for Health and Social Affairs 2013). Potential protein intake has been estimated using equation (7.21):

$$(7.21)\quad Potential\ protein\ intake\ = production\ + import\ - export$$

This estimation assumes that all the products are eaten and does not take into consideration the food ending up as waste. To avoid overestimations, potential protein intake are not used directly as protein intake in the inventory. Indeed, the trend of potential protein intake has been extrapolated to the protein intake estimated for 1997 (1.39 kilos per person) so as to build the time series. These estimations rely on recommendations from the Directorate for Health and Social Affairs (Johansson,

pers. Comm.[34]). Table 7.11 presents the potential protein intake in both g/person/day and kg/person/year and the estimated annual protein intake per capita.

Table 7.11 Potential protein intake, and estimated protein intake, in g/person/day, kg/person/year, for the years 1990-2016.

Year	Potential protein intake g/person/day	kg/person/year	Index 1997 =100	Estimated protein intake kg/person/year
1990	**94**	34.3	100.5	31.6
1995	**93**	33.9	99.5	31.2
2000	**95**	34.7	101.6	31.9
2005	**100**	36.5	107.0	33.6
2006	**98**	35.8	104.9	32.9
2007	**105**	38.3	112.3	35.3
2008	**104**	38.0	111.2	35.0
2009	**102**	37.2	109.1	34.2
2010	**100**	36,5	107.0	33.6
2011	**100**	36.5	107.0	33.6
2012	**100**	36.5	107.0	33.6
2013	**101**	36.9	108.0	33.9
2014	**99**	36.1	105.9	33.2
2015	**99**	36.1	105.9	33.2
2016*	99	36.1	105.9	33.2

Numbers in bold come from the Norwegian Directorate for Health and Social Affairs
**Figures for the last inventory year are set equal to the previous year because data from the Norwegian Directorate for Health and Social Affairs are not updated in time for the emission inventory calculations*.

Non-consumed protein has been taken into account in the estimation of protein added to wastewater. It has been set to 10 per cent of consumed protein. Therefore, Fncp, the factor for non-consumed protein added to wastewater has been set equal to 1.1.

7.6.3.2 Industrial wastewater

CH_4 emissions from industrial WWTP

The amount COD released into recipient is reported by industries to the Norwegian Environment Agency.

[34] Johansson, L. (2005): Personal information by telephone, Directorate for Health and Social Affairs

Table 7.12 Potential protein intake, and estimated protein intake, in g/person/day, kg/person/year, for the years 1990-2016.

Year	COD released into recipient from industrial WWTP (tonn)
1990	143 748
1995	125 087
2000	91 376
2005	86 108
2006	84 139
2007	79 872
2008	77 706
2009	73 643
2010	86 999
2011	80 094
2012	72 384
2013	67 077
2014	58 720
2015	57 868
2016	56 887

Source: Statistics Norway

N_2O emissions from industrial WWTP

N_2O emissions from industries connected to large treatment plants (>50 pe) are included in domestic wastewater handling sector (CRF 5D1) while N_2O emissions from industries with their own WWTP are not estimated and therefore, not included in this inventory.

7.6.4 Emission factors

CH_4 emissions from domestic and industrial WWTP

The default emission factor for B_0 of 0.6 kg CH_4/kg BOD is used (IPCC 2006). The methane correction factor (MCF) is, according to good practice, given by the fraction of BOD that will ultimately degrade anaerobically. A country-specific MCF factor has been estimated by Statistics Norway for the years after 2000, based on the part of the population connected to tanks with anaerobic conditions and a MCF of assumed to be equal to 1 for this type of treatment. Information on the part of the population connected to tanks with anaerobic conditions are taken from Statistics Norway (wastewater statistics). It corresponds to the population connected to the WWTP categorized as "Sealed tank" and a fraction of the population connected to the category "Separate toilet system". These are the treatment methods assumed to be anaerobic and hence to emit CH_4. A country-specific MCF factor of about 0.01 has been estimated for the years after 2000 for the whole Norwegian population.

So as to estimate a country-specific MCF factor for the previous years, it has been assumed that, in 1990, 2 per cent of the population was connected to anaerobic treatment systems and that the share gradually decreased until 2000. The estimated trend is consistent with the estimated factors for the period 2000-2016. Table 7.13 gives an overview of the country-specific MCFs used in the Norwegian emission inventory.

Table 7.13 The methane conversion factor (MCF) for the period 1990-2016.

	1990	1995	2000	2005	2010	2011
MCF	0.02	0.015	0.011	0.009	0.009	0.008
	2012	**2013**	**2014**	**2015**	**2016**	
MCF	0.008	0.009	0.008	0.008	0.008	

Source: Statistics Norway

Unintentional leakage of CH_4 from biogas facilities

Unintentional leakages are generally between 0 and 10 per cent of the amount of CH_4 generated. In the absence of further information, 5 per cent is used as a default value for estimating the CH_4 emissions from unintentional leakage from Norwegian biogas facilities.

N_2O emissions from large WWTP

N_2O emissions in **biological nitrogen removal-plants** have been estimated assuming that 2 per cent of the nitrogen removed from the plants will form N_2O. This country-specific emission factor is given in SFT (1990).This assumption is based on measurements in plants and comparisons to factors used in Sweden. This emission factor is used for all plants except for one.

It has been hypothesized that one plant had a much higher performance, i.e. a lower percentage of processed N emitted as N_2O. In 2011, N_2O emissions were measured at various spots within the treatment plant, as well as the concentrations of N_2O in the liquid phase throughout, including the exit water. The results verified that the performance of this process, with respect to N_2O emission, is much better than the emission factor used for the other treatment plants. On the average, the emission of N_2O -N to air from the entire plant (through the chimney) amounted to 0.2 per cent of the processed N. If the N_2O lost as dissolved N_2O in the exit water is included, the percentage increases to 0.3 (Bakken et al. 2012). For this WWTP, it has then been assumed that 0.3 per cent of the nitrogen removed from plants will form N_2O. This emission factor has been used for that plant for all years since 1996, the year when the nitrification and denitrification reactors were fully operational. For the period 1990-1996, the default emission factor of 2 per cent has been used.

N_2O emissions from other domestic waste water handling

For the part of the population that is not connected to large WWTP, IPCC default emission factors have been used:

- EF_6: 0.005 kg N_2O/kg sewage-N produced has been used.
- $Frac_{NPR}$, the fraction of nitrogen in protein, has been set equal to 0.16 kg N/kg protein.

N_2O emissions from on-site industrial WWTP

N_2O emissions from industries with their own WWTP are not included in this inventory. A quantitative assessment has been conducted with emissions from other European countries and has shown that emissions are far under the estimating threshold. Therfore N_2O emissions from on-site industrial WWTP have not been included in the inventory.

7.6.5 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are presented and discussed in Annex II. A general assessment of time series consistency has not revealed any time series inconsistencies in the emission estimates for this category.

7.6.6 Source specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. See Section 1.2 for the description of the general QA/QC procedure.

7.6.7 Recalculations

The IPCC default emission factor of 0.01 kg N_2O-N per kg sewage-N produced (IPCC, 1997) has been changed to 0.005 kg (IPCC 2006). N_2O emissions have been reduced by 50 per cent for this category. Minor correction has been made in the number of people not connected to waste water treatment and in the number of people connected to different waste water treatment systems for the years 2012-2014.

Data for the amount of nitogen released into recipients have been revised for the years 2002-2014. It led to minor changes in emissions of N_2O. See chapter 10 for more details.

7.6.8 Planned improvements

Emissions from the amount of CH_4 that is flared or recovered for energy use has been reported to the energy sector and should be subtracted from total emissions. Following up 2016 review, Norway has begun to investigate possible double counting between emissions from waste water treatment and emissions from flaring included in sector 1A2 (manufacturing industries and construction). The results of this investigation will be presented in the next submission

7.7 Other emissions sources from the waste sector – 5E

7.7.1 Description

This category is a catchall for the waste sector. Formerly, the Norwegian inventory included N_2O emissions from sludge applied to field. According to guidelines (IPCC 2006), this category has been included in the LULUCF sector. No GHG emissions are currently included in this category.

7.7.2 Recalculations

No recalculation has been made in this category.

7.7.3 Planned improvements

There are currently no planned improvement for this source category.

8 Other (CRF sector 6) (if applicable)

9 Indirect CO_2 and nitrous oxide emissions

9.1 Description of sources of indirect emissions in GHG inventory

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

Indirect emissions of N_2O from NO_X and NH_3 from energy, industrial processes and waste are included as memo items in the inventory. For agriculture, only indirect emissions from burning of crop residues are included as memo items. Indirect emissions from manure management, fertilizers, and etcetera are included in the inventory proper.

In NIR 2015 Norway wrote the following “Indirect CO_2 emissions from CO is not included in the inventory this year. We assume that indirect CO_2 emissions should have been included for silicium carbide, magnesium production and well testing off shore. We estimate the emission to vary between 15-90 000 t CO_2, the lower part of the interval the latest year.” We looked into this issue and concluded in NIR 2016 not to estimate indirect CO_2 emissions from the three sources and the arguments are as followed

- Well testing
  The CO_2 emission factor for well testing of oil in 2013/14 is 3.17 and 3.20 kg CO_2/kg oil and for natural gas 2.34, 2.5 and 3.73 kg CO_2 per Sm^3. This indicate that all carbon in the oil and gas is included in the emission factors and hence additional estimation of indirect CO_2 emissions of CO would imply double counting.

- Production of magnesium, silicon and calcium carbide
  Estimated CO_2 emissions from the three source categories included in the inventory includes all carbon that is put into the processes and carbon in products and dust is deducted. Therefore, indirect CO_2 emissions from CO are not estimated to avoid double counting.

Fossil carbon in the emissions of CH_4 and NMVOC from several non-combustion sources are included in the Norwegian emission inventory. See Table 9.1.

Table 9.1 Source categories in the inventory where indirect CO_2 emissions is calculated for CH_4 and NMVOC.

1.B.1.a: Coal Mining and Handling
1.B.2.a.3: Oil and Natural Gas and Other Emissions from Energy Production; Oil; Transport
1.B.2.a.4: Oil and Natural Gas and Other Emissions from Energy Production; Oil; Refining/Storage
1.B.2.a.5: Oil and Natural Gas and Other Emissions from Energy Production; Oil; Distribution of Oil Products
1.B.2.b.2: Oil and Natural Gas and Other Emissions from Energy Production; Natural Gas; Production
1.B.2.c: Oil and Natural Gas and Other Emissions from Energy Production; Venting and Flaring
2.B.5: Carbide Production
2.B.8.a: Petrochemical and Carbon Black Production; Methanol
2.B.8.b: Petrochemical and Carbon Black Production; Ethylene
2.B.8.c: Petrochemical and Carbon Black Production; Ethylene Dichloride and Vinyl Chloride Monomer
2.C.2: Ferroalloys Production
2.D.3: Solvent use

Indirect CO_2 emissions have been included in the Norwegian emission inventory for many years. Indirect CO_2 emissions are included in the emission estimates for each source category at the most dissaggregated level, and are thus included in the sums named "Total CO_2 equivalent emissions without land use, land-use change and forestry" and "Total CO_2 equivalent emissions with land use, land-use change and forestry" in the summary tables in the CRF Reporter. Thus, in order to achieve correct totals including indirect CO_2, table 6 of the CRF Reporter does not include indirect CO_2 emissions, as this would have led to double counting in the summary table totals "including indirect CO_2". The indirect CO_2 emissions are given in Table 9.2 for transparency.

Table 9.2 Indirect CO_2 emissions from CH_4 and NMVOC, 1990-2014. Kilotonnes.

	Energy	IPPU	Agriculture	LULUCF	Waste	Total
1990	475.66	119.20	NA	NA	NE	594.86
1991	513.17	104.85	NA	NA	NE	618.02
1992	607.16	108.32	NA	NA	NE	715.48
1993	672.82	108.85	NA	NA	NE	781.68
1994	712.76	116.08	NA	NA	NE	828.84
1995	767.22	113.31	NA	NA	NE	880.54
1996	774.68	119.61	NA	NA	NE	894.29
1997	790.42	115.80	NA	NA	NE	906.22
1998	781.17	116.43	NA	NA	NE	897.60
1999	815.89	113.66	NA	NA	NE	929.54
2000	883.57	108.70	NA	NA	NE	992.27
2001	930.26	110.81	NA	NA	NE	1 041.07
2002	788.97	112.54	NA	NA	NE	901.51
2003	670.41	113.42	NA	NA	NE	783.82
2004	580.59	116.03	NA	NA	NE	696.62
2005	442.06	104.94	NA	NA	NE	547.00
2006	364.58	96.98	NA	NA	NE	461.56
2007	364.59	97.26	NA	NA	NE	461.85
2008	276.08	93.67	NA	NA	NE	369.75
2009	253.49	79.22	NA	NA	NE	332.70
2010	233.22	94.54	NA	NA	NE	327.76
2011	210.12	96.43	NA	NA	NE	306.55
2012	204.86	100.04	NA	NA	NE	304.90
2013	219.17	103.48	NA	NA	NE	322.65
2014	269.15	103.67	NA	NA	NE	372.82
2015	252.07	110.02	NA	NA	NE	362.09
2016	236.36	109.96	NA	NA	NE	346.32

9.2 Methodological issues

The indirect CO_2 emissions from oxidised CH_4, CO and NMVOC i calculated from the content of fossil carbon in the compounds. For CH_4, and CO the factors for indirect emissions are simply calculated on basis of mass of molecules. For NMVOC the average carbon fraction is also taken into account. The default value for carbon fraction, 0.6, is used. This leads to the emission factors 2.75 kg CO_2/kg CH_4, 1.57 kg CO_2/kg CO and 2.2 kg CO_2/kg NMVOC. The NMVOC factor is for all other source categories than NMVOC from loading and storage of crude oil off shore. There we use the emission factor 3.0 kg CO_2 per kg NMVOC from CMR Instrumentation (2011) (Måle- og beregningsprogram for bestemmelse av utslipp av NMVOC I forbindelse med bøyelasting 2011, only in Norwegian) (Measuring program for emissions of NMVOC from loading of crude oil).

9.3 Uncertainties and time-series consistency

Uncertainty estimates for greenhouse gases are given in Annex II.

9.4 Category-specific QA/QC and verification

The general QA/QC methodology is given in chapter 1.2.3.

9.5 Category-specific recalculations

The emission factor for indirect CO_2 from NMVOC from distribution of oil products has been altered from the standard factor 2.2 to 3.13 kg CO_2 per kg NMVOC, which is the same as the combustion factor.

9.6 Category-specific planned improvements

There are no planned activities this year that will improve the data quality or the documentation for this source category.

10 Recalculations and improvements

10.1 Explanations and justifications for recalculations, including in response to the review process

The Norwegian greenhouse gas emission inventory has in 2018 been recalculated for the entire time series 1990-2015 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 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 the expert review teams (ERTs) under the UNFCCC. The figures in this inventory are, 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 revised UNFCCC Reporting Guidelines. 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.

10.2 Specific description of the recalculations

10.2.1 Energy

Most of the recalculations have been performed for the inventory year 2015, because the energy figures for 2014 used in the previous inventory were preliminary. There will always be some changes in the energy figures. For petroleum products, corrections in one sector 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 emissions calculated by the plants and reported to the Norwegian Enviroment Agency, whereas *calculated emissions* are emissions calculated by Statistics Norway, based on figures on energy use reported to Statistics Norway.

1A1ai Public electricity and heat production: *Electricity Generation*

- Completeness. Figures on use of bio gas in electricity generation in 2015, which previously were missing, have been included. This causes minor emission increases for CO_2 (biomass), CH_4 and N_2O.

1A1aiii Public electricity and heat production: *Heat plants*

- Completeness. Figures on use of bio gas in heat plants in 2015, which previously were missing, have been included. This causes minor emission increases for CO_2 (biomass), CH_4 and N_2O.

1A3bi-iv Road transport

- Accuracy. Revised emission factors. A revised version of the Handbook of Emission Factors (HBEFA) has been taken into use. The new version contains updated factors for emissions of nitrogen oxides from new diesel cars (Euro 4 and higher). The update has resulted in significantly higher emissions of nitrogen oxides from personal cars (1A3bi), and also minor changes in emission of methane and nitrous oxide. The revision also affects emissions from military vehicles reported in 1A5b.
- Reallocation. The revised version of HBEFA also result in reallocation of CO_2 emissions from category 1A3bi to the categories 1A3bii-iv for the years 2007 to 2015. The relative changes in the emissions are small, below one per cent for 1A3bi-iii, and below three per cent for 1A3biv.

1A4b Residential

- Accuracy. Country specific emission factor for emissions of N_2O from residential wood burning has replaced the general emission factor from IPCC 2006 Guidelines. This has decreased N_2O emissions for all years, ranging from 54 to 59 tonnes annually.
- Consistency. Emission factor for CH_4 from charcoal has been changed from 6 to 5.9, in accordance with the factor used for manufacturing industries. Causes marginal emission reductions.

1A5b Military

- Accuracy. Revised emission factors for road traffic – see description under 1A3b above.

IB2a3 Oil and natural gas: Transport

- Correction of error. NMVOC emissions in 2015 increase by 20 tonnes, due to previously use of an erroneous figure. Corresponding change in indirect CO_2.

IB2a4 Refining/storage

- Revised data. Reported CH_4 figure from one plant in 2015 has been increased by 8 tonnes. Corresponding change in indirect CO_2.

1B2av Distribution of oil products

- Revised data. Marginal reduction in activity data in 2015, causes corresponding reduction in indirect CO_2 from NMVOC emissions.

10.2.2 Industrial processes and product use

2A4d – Other prosess uses of carbonates

- Consistency. Process emissions of CO_2 from the use of dolomite in one plant have been increased for the years 1994-2007. The increase ranges from 80 tonnes in 1994 to 2 700 tonnes in 2007. The reason for the increase is to improve the consistency of the time series.
- Updated activity data (correction of error). Process emissions of CO_2 from the use of dolomite and fly ash in one plant has been revised due to new information from the plant. The plant informed that limestone has been replaced completely by fly ash and provided new information on the use of limestoe and fly ash for parts of the time series. This results in higher emissions in the range of about 1 100 to 18 100 tonnes CO_2 in the years 1997-2008 and lower emissions in the range of of 11 300 to 15 200 tonnes CO_2 in the years 2009-2010 and 2014-2015.

2C2 Ferroalloys production

- Revised data. Changes in reported figures on CO_2, CH_4 and N_2O from one plant in 2011 and N_2O in 2012. CO_2 increased by 56 ktonnes in 2011, other changes are minor.

2D31 Solvent use

- Updated activity data (correction of error). An error was detected in activity data for 2012 and 2015. The indirect CO_2 emissions from NMVOC from solvent use (2D3a) increased by about 2 per cent both years.
- Correction of error. Marginal reduction in indirect CO_2 emissions 2013-2015, due to the removal of erroneously included figures on NMVOC emissions for a plant that was closed down in 2012.

2G2 SF_6 from other product use

- Updated activity data (change in assumption) 2003-2015. According to the industry, the production of sound isolated windows with SF_6 stopped in 2002/2003, thus the amount of gas used for production has been set to zero from 2003 and forward. This results in significantly lower (between 6 and 36 per cent) emissions of SF_6 from this source (2G2) for all years (2003 and onward).
- Updated activity data (change in assumption) 2015. Emissions from decomissioning of sound insulated windows produced in 1985 (first year of production) is now included. This leads to an increase in the emissions of SF_6 from this source (2G2) in 2015 of about 100 percent.

10.2.3 Agriculture

3A1 Enteric fermentation – Mature non-dairy cattle

- Revision of emission factor. The estimation of methane emissions from enteric fermentation in mature non-dairy cattle (beef cows) is completely revised, see Annex IX. This has reduced the estimated emission per animal and year from 110 kg to 82 kg. The population of beef cows have increased consistently from 1990 to 2016. The reduction of CH_4 emissions was 179 tonnes in 1990 and 1695 tonnes in 2015. In 2015, the size of the reduction was about 2 per cent of total CH_4 emissions from enteric fermentation, or about 1 per cent of total greenhouse gas emissions from agriculture.

3Ba3 Manure management system - Swine

- Correction of error. VS factor for sows and boars:
  Since piglets 10-30 kg were introduced as separate animal category, the VS factor for sows are to include piglets 0-10 kg, as opposed piglets 0-30 kg previously. This induces a change in VS factor for sows from 437.3 kg per year to 307.9 kg per year. In the years 1990-2011, it is the same relative change, but at a lower level since the VS factor increases from 1990-2011. The error is that the change in VS factor was implementet this year. The correction reduces the emissions up to about 140 tonnes CH_4, which is between 1 and 2 per cent of all methane emissions from manure management systems.

3B Manure management system – Swine, sheep, goats and horses

- Correction of error. Formula that estimates emission factors for MMS 1990-2012:
  When the methodology of the 2006 IPCC Guidelines was introduced, emission factors for the various MMS categories were changed. To fit the new emission factors to the activity data used through the time series (in essence the manure survey of 2000, (Gundersen & Rognstad 2001)), a formula to recalculate the emission factors was made since the categories in the surveyes used in the estimations were an aggregate of IPCC categories. An error in this forumula for the N_2O calculations has been discovered. The error affected the estimated emissions from swine, sheep, goats and horses, and slightly from pigs. The error does not affect the estimations for other animals, nor the estimations for 2013 and the years after since the manure survey of 2013 is used for 2013 and after. The effect of the correction is shown in Table 10.1

- Correction of error. Manures cellars for sheep, goats and horses redefined from liquid storage to pit storage:
  The part of the manure from sheep, goats and horses that is disposed in manure cellars are normally in a dry state, and hence should be defined to pit storage rather than liquid storage. This redefinition changes the emission factors for this part of the manure (ref. 2006 IPCC Guidelines, chapt. 10, table 10.21). Table 10.1 shows the changes in emission for selected years since 1990. In 2010, when these two corrections had largest influence, the correction represented 0.4 per cent of total greenhouse gases from agriculture.

  The change in definition influences only N_2O estimations because the CH_4 emissions from manure storage for these animals are estimated according to Tier 1 methodology.

Table 10.1 Total emissions from swine, sheep, goats and horses from manure management systems. Tonnes N_2O

	2017 submission	Figures from the 2017 submission after correction of formula that estimates emission factors for MMS	2018 submission, which includes correction of formula and new definition of manure cellars.
1990	161.5	121.0	109.3
1995	176.6	131.9	119.1
2000	182.1	136.2	123.3
2005	192.2	156.0	134.0
2010	198.6	161.8	138.3
2011	197.3	160.9	137.3
2012	195.1	159.0	135.4
2013	165.1	165.1	143.0
2014	164.9	164.9	142.7
2015	166.0	166.0	143.1

3Da6 Cultivation of organic soils

- Updated activity data.The area of grassland has been revised for the years 2012-2015, reducing the estimated area between 7 per cent (2012) and 26 per cent (2015). This has given a reduction in emissions of 6400 CO_2 equivalents in 2015, corresponding to about 0.14 per cent of all greenhouse gas emissions from the agrictultural sector.

3Db1 Indirect N_2O emissions from managed soils - Atmospheric Deposition

- Emissions of NH_3 and NO_X serves as activity data in the estimations of indirect emissions of N_2O from deposition. One improvement and one correction of error have given a change in the activity data for source 3D12 Indirect N2O emissions from managed soils - Atmospheric Deposition.

  1. Improvement: Revised estimations of NH_3 from inorganic fertilisers.
     The emission factors from EEA (2016) have been taken into use in the calculations of NH_3 from inorganic fertilisers, replacing national factors of uncertain origin. This has more

than doubled the emissions of NH_3 from this source. The estimated emissions before and after the change emission factors is shown in Table 10.2. In 2015, these emissions of NH_3 were the cause of about 20 per cent of the N_2O emissions from 3Db1 Atmospheric Deposition.

Table 10.2 Estimated NH_3 emissions from use of inorganic fertilizers. Submission 2017 and 2018. 1000 tonnes NH_3 and per cent change.

	Submission 2018	**Submission 2017**	**Per cent increase**
1990	4 699	1 274	268.8
1995	4 718	1 279	268.9
2000	4 679	1 301	259.6
2005	4 764	1 482	221.5
2010	3 657	1 389	163.3
2011	4 183	1 541	171.4
2012	4 035	1 628	147.9
2013	4 078	1 691	141.2
2014	4 344	1 898	128.9
2015	4 286	2 095	104.6

Source: Estimations by Statistics Norway

2. Correction of error. Revised definition of the $frac_{gasm}$ factor.
   $Frac_{gasm}$ is used as emission factor for estimating emissions of NH_3 from sewage sludge and other organic fertilisers. This factor is revised to only include N lost as NH_3 and NO_X during spreading. NH_3 and NO_X lost in MMS are no longer included. This has reduced the emission factor from about 20-22 kg (NH_3–N + NO_X–N)/kg N applied to about 13-14 kg (NH_3–N + NO_X–N)/kg N applied, and the NH3 emissions from these sources have been reduced correspondingly. In 2015, these emissions of NH_3 were the cause of about 2 per cent of the emissions from 3Db1 Atmospheric Deposition.

10.2.4 Land use, Land–Use Change and Forestry

All emissions related to the Norwegian National Forest Inventory (NFI) estimated areas are recalculated every year as well as for the 2018 submission. This is due to the interpolation and extrapolation method used to estimate the areas. Since NIR 2014, areas have been estimated using linear interpolation between the $1/5^{th}$ of the NFI sample plots that are surveyed every year. One fifth of the area estimates are therefore based on measured sample plots, and four fifths of the estimate is based on interpolation or extrapolation in the final years. Extrapolation affects the four final reporting years and requires a recalculation of these years in the subsequent submissions. There will therefore always be recalculation in the last few years of the time series. The area-related emissions are affected by this and comprise all carbon stock changes estimated for living biomass, litter, dead wood, DOM, mineral and organic soils (CRF Tables 4.A-4.F). In addition, the following non-CO_2 emission sources are also indirectly affected by the area estimates: 4(II) Emissions and removals from

drainage and rewetting of organic soils, and source 4(III) Direct N_2O emissions from N mineralization/immobilization. In addition to the interpolation and extrapolation method affecting area estimates, NFI sample plots are surveyed either in the field (if forested) or using aerial images. Corrections of previously attributed land-use categories that are not due to actual land-use changes therefore occur if new information becomes available. This can result in revised area estimates among all categories for the full time series. Another factor affecting recalculations is the calculation for changes in soil C, litter, and deadwood in afforestation and reforestation and deforestation for the inventory year 2015 for which a correction was made.

For the NIR 2018, the following methodological changes have affected all land-use categories and are therefore not listed explicitly below:

- The absolute values of gains and losses are larger this year because we changed the method from NFI plot-level net changes to plot-level gains and losses. This means, a plot can have both gains and losses. Until last year, this was not possible. The total net change was also affected by this change. New above- and belowground birch biomass functions Smith (2016); Smith (2014) are now used instead of Marklund (1988).

For the NIR 2018 the whole time-series was recalculated for all C emission sources and sinks due to revised activity data (areas) and a few methodological changes. The largest recalculations occurred for the last four years (2011-2015). Total changes in emissions (including non-CO_2 emissions) caused by recalculations for the LULUCF sector are shown in Figure 10.1.

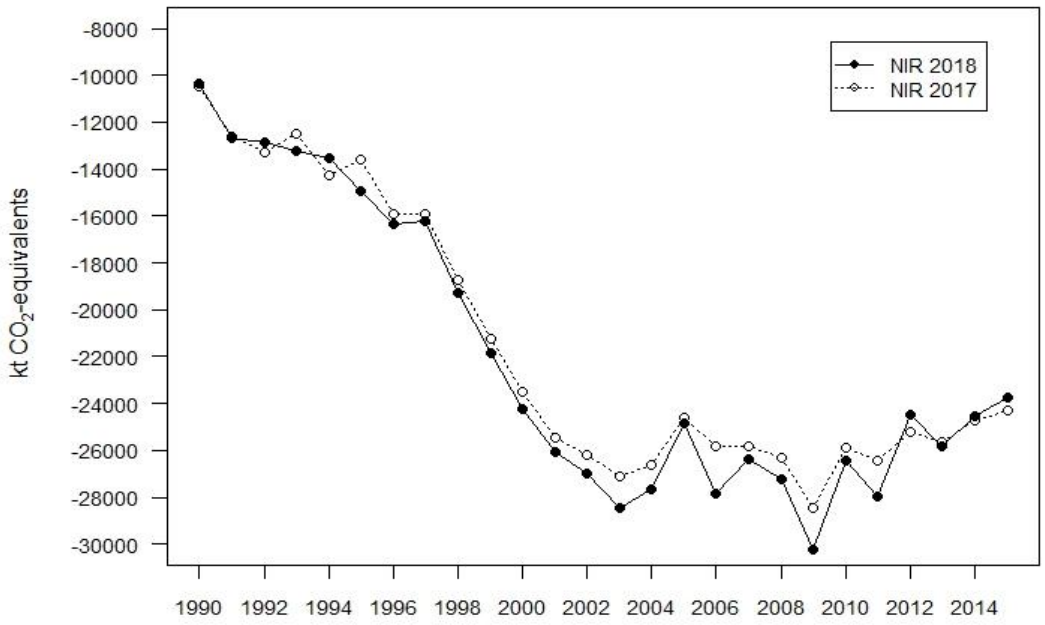


Figure 10.1 Recalculations illustrated for total emissions (kt CO_2-equivalents per year) estimated for the LULUCF sector in the 2018 submission compared to the 2017 submission.

Quantitatively, the largest changes in estimated C stock changes occurred for forest land and grasslands. The estimated CO_2 uptake on forest land for 2015 was 679 kt smaller in the 2018 submission compared to the 2017 submission. The estimated CO_2 emissions in grasslands for 2015

were 93.9 kt smaller (Table 10.3). The difference between the estimates of total GHG emissions from the LULUCF sector based on the 2017 and 2018 NIR submission was 551 kt CO_2-eq for the recalculated year 2015 (Table 10.3).

Table 10.3 Recalculated GHG emissions (kt CO_2-eq yr^{-1}) for 2015 per land-use category in the LULUCF sector.

	Emissions for 2015 (kt CO_2-eq yr^{-1})		
Land-use category	**NIR 2018**	**NIR 2017**	**Absolute difference**
4.A Forest land	-28 296.7	-28 975.4	678.7
4.B Cropland	2 000.5	2 012.5	-12.0
4.C Grassland	180.4	274.3	-93.9
4.D Wetlands	29.7	34.3	-4.6
4.E Settlements	2 089.9	2 107.1	-17.2
4.F Other land	0.95	0.95	0
4.G HWP	212.0	212.0	0
4(IV)Total sum	14.3	14.7	-0.38
Total sum	-23 768.9	-24 319.5	550.6

The reasons for the recalculations within each land-use category and sink/source category and the effects for the last recalculated year of the inventory (2015) are described below.

4A1 Forest land remaining forest land

- Total CSC for forest land remaining forest land in 2015 was 190 kt C larger in the NIR 2017 submission compared with the NIR 2018 submission.
- Net change in living biomass decreased by 642 kt C from a C uptake of 6 258 kt C in NIR 2017 to 5 617 kt C in NIR 2018. Carbon uptake in dead wood, litter, and mineral soils increased by 74 kt C (from 296 to 370 kt C), 369 kt C (from 1 466 to 1 835 kt C), and 8 kt C (34 to 42 kt C), respectively. Recalculations were caused by the updates in the area estimates in addition to the general methodological changes described above. Application of the new biomass functions also has an effect for soil carbon and DOM as model litter input depends on standing biomass. Emissions from organic soils were also recalculated due to updates in activity data, however, this recalculation was not noticeable.

4A2 Land converted to forest land

- Compared to last year's reporting, the total C uptake for 2015 on land converted to forest land was 5 kt C larger in the NIR 2018 submission (from 145 to 150 kt C). This was mainly due to the larger C uptake in living biomass, which increased by 6 kt C from 48 kt C (NIR 2017) to 54 kt C (NIR 2018), which occurred primarily on wetlands converted to forest land (3 kt C) and other land converted to forest land (3 kt C). Recalculations in the organic soils and litter pools resulted in slightly smaller C change of 0.01 kt and 1 kt C respectively. The mineral soil pool increased by 2 kt C from -23 kt C to -25 kt C. All recalculations were caused by the updated NFI areas.

4B1 Cropland remaining cropland

- Total C stock loss for 2015 on cropland remaining cropland reduced by 3 kt C from 421 kt C in the 2017 submission to 418 kt C in the 2018 submission, which was primarily caused by the change in the estimation for organic soils.
- C stock changes increased by 0.5 kt C from 20.4 kt C (NIR 2017) to 20.8 kt (NIR 2018) for the mineral soil pool. This was due to area updates by the NFI extrapolation.
- Recalculations in organic soils were caused by the area updates by the NFI extrapolation method. Emissions decreased by 2 kt C from 445 kt C (NIR 2017) to 443 kt C (NIR 2018).

4B2 Land converted to cropland

- For land converted to cropland the recalculations of the 2015 estimate resulted in smaller C losses (0.4 kt C) from 102.9 kt C to 102.5 kt C.
- Net C stock losses on living biomass decreased by 0.5 kt C and DOM increased by 1.4 kt C, due to the extrapolation method used on the NFI living biomass and area data. C stock losses increased from 20 kt C to 22 kt C for living biomass and from 49 kt C to 50 kt C for DOM.

4C1 Grassland remaining grassland

- Total C stock changes on grassland remaining grassland were recalculated and resulted in emissions changing to removals in 2015 by 16.8 kt C, from -8 kt C to 9 kt C. This was mostly caused by increased removals in living biomass.
- Emissions from organic soils were reduced by 3 kt C from 10 kt C (NIR 2017) to 7 kt C (NIR 2018) due to a slight reduction in the area of organic soils.
- Recalculations in the gains and losses in living biomass were also substantial and the net change in living biomass increased by 14 kt C. Carbons stock gains increased by 24 kt C and losses increased by 10 kt C.

4C2 Land converted to grassland

- Total C stock loss estimates for 2015 for land converted to grasslands was 9 kt C smaller in the 2018 submission, primarily due to updates in the NFI affecting forest land converted to grassland.
- C stock losses in living biomass and DOM on forest land converted to grassland were decreased by 7.3 kt C and 1 kt C, respectively, from 30 kt C to 23 kt C for living biomass and from 89 kt C to 88 kt C for DOM. The changes were caused by the extrapolation method of the NFI data used for biomass and area estimates.
- Emissions from organic soils were also recalculated. The area of organic soils is very small and occurs only on wetlands converted to grassland. The recalculation reduced emissions by 0.8 kt C from 2.7 kt C (NIR 2017) to 2 kt C (NIR 2018). This was primarily due to reduced organic soil areas from NFI updates.
- Emissions from mineral soils were also recalculated due to the NFI area updates, and resulted in a minor decrease in the C uptake of 0.7 kt C from 56.5 kt C (NIR 2017) to 55.8 kt C (NIR 2018).

4D1 Wetlands remaining wetlands

- Carbon stock uptake in living biomass on wooded mires was recalculated due to the NFI extrapolation method. The recalculation resulted in a slight increase of 1.2 kt C, from 19 kt C (NIR 2017) to 20 kt C (NIR 2018).

4D2 Land converted to wetlands

- A minor recalculation for forest land converted to wetlands in the living biomass pool resulted in a reduction of 0.1 kt C.

4E1 Settlements remaining settlements – organic soils

- A small recalculation of 1 kt C was observed as emissions increased from 53 kt C in NIR 2017 to 54 kt C in NIR 2018. The area of organic soils for 2015 was only slightly larger (6.9 kha) in NIR 2018 compared to the 2017 submission (6.7 kha) due to the NFI extrapolation method.

4E2 Land converted to settlements

- Total C stock losses from the category for 2015 were reduced by 5 kt C in NIR 2018 (509 kt C) compared to NIR 2017 (514 kt C). This was a result of the combined effect of larger living biomass losses and smaller losses from organic soils.
- Living biomass losses on forest land converted to settlements were increased by 7 kt C from 134 kt C (NIR 2017) to 141 kt C (NIR 2018).
- Emissions from organic soils decreased by 4 kt C from 59 kt C (NIR 2017) to 56 kt C (NIR 2018), due to a smaller organic soils area from the NFI. This occurred mostly on forest land converted to settlements.

4F2 Land converted to other land

- There were no recalculations for this source for neither land converted to other land nor grassland converted to other land.

4G Harvested wood products

- The FAO activity paper and paperboard export data for 2015 had changed from 913 393 to 943 493 metric tonnes. However, this did not change the total emissions from 2015.

4(I) Direct N_20 emission from managed soils

- There were recalculations for 2015 for organic N fertilizer applications on settlements remaining settlements. Organic fertilizer were reduced from 1 443 191 kg N/yr (NIR 2017) to 1 137 447 kg N/yr (NIR 2018) due to changes in Statistics Norway data. This led to reduced N_2O emissions 0.0227 kt N_2O (NIR 2017) to 0.0179 kt N_2O (NIR 2018).There were no recalculations for forest land inorganic N fertilizer applications.

4(II) Emissions and removal from drainage of organic soils

- Recalculations for 2015 in this source were minor and caused mainly by the updated area estimates resulting from the NFI extrapolation method, except for peat extraction. An error was made in the calculation of the kt N_2O estimate from peat extraction lands on drained organic soils in the submission years 2015, 2016, and 2017. Different areas were used 400 ha

(2015) and 1264 ha (2016), but the same area of 2000 ha was used in the 2017 and 2018 submissions. The error led to 0.0003 kt N_2O (0.089 kt CO_2 e) higher N_2O emissions, 0.0009 kt N_2O (0.268 kt CO_2 e) in 2018 compared to 0.0006 kt N_2O (0.179 kt CO_2 e) in 2017 for the year 2015.

4(III) Direct N_20 emissions from N mineralization and immobilization

- The area changes caused by NFI updates caused only minor recalculations for this source except for grasslands converted to forest land. In 2015, 2016, and 2017 reporting years the grasslands converted to croplands areas were mistakenly reported instead of grasslands converted to forest land areas. In the year 2015, the area increased from 6.04 kha (NIR 2017) to 13.28 kha (NIR 2018), which led to an increase in N_2O emissions from 0.02713 kt N_2O (NIR 2017) to 0.02851 kt N_2O.

4(IV) Indirect N_20 emissions from managed soils

- Recalculations for atmospheric deposition resulted in reduced N_2O emissions from 0.0019 (NIR 2017) to 0.0018 (NIR 2018) due to a reduction in the amount of organic N applied to settlements from 1 443 191 kg N/yr (NIR 2017) to 1 137 447 kg N/yr (NIR2018).

Biomass burning 4(V)

- Recalculations for this source in the year 2015 led to reduced CH_4 emissions from 0.0049 kt CH_4 (NIR 2017) to 0.0026 kt CH_4 (NIR 2018) and increased N_2O emissions from 0.00003 kt N_2O (NIR 2017) to 0.0001 kt N_2O (NIR 2018) due to an update in methodology from 2003 Guidelines to 2006 Guidelines.

10.2.5 Waste

5A Managed Waste Disposal sites

- Revised activity data. For the years after 2012 figures on disposed waste in Statistics Norway's waste statistics have been updated.
- Correction of error. Updated figures for 2015 for extraction of CH_4 from landfills. The removal of a previous double counting for one landfill has led to an emission reduction of 146 tonnes CH_4.
- Emissions of CH_4 increased by almost 30 tonnes in 2013 and 2014, and 717 tonnes in 2015.

5B Biological treatment of Solid Waste

5B1 Composting of Solid Waste

- Revised activity data. For the years after 2012 figures on biological treatment, the amount composted in Statistics Norway's waste account have been updated. Emissions of CH_4 and N_2O have been reduced by 0.3 and 0.5 per cent in 2012, and 0.1 and 0.2 per cent in 2015

5B2 Anaerobic digestion at biogas facilities

- Revised activity data. The amount of waste treated at biogas facilities for 2012-2015 have been revised. Emissions of CH_4 have been reduced by less than 0.01 per cent in 2012-2014, emissions increased by 0.08 per cent in 2015

5D2 Domestic waste water

- Correction of activity data. Minor correction has been made in the number of people not connected to large waste water treatment plants for the years 1991-2015. Small increase in emission of N_2O for all years.
- Completeness. For one waste water treatment plant, reported N_2O emission for 2001 and 2003 was previously erroneously omitted. For 2001 the reportet figure for 2002 has been used, while the average of the figures reported for 2002 and 2004 have been used for 2003. Minor increase in emission of N_2O.

5D2 Industrial waste water

- Correction of error. Revised activity data. COD values have been revised for some industries for the period 1990-2015. It led to minor changes in estimated CH_4 emissions.

10.2.6 KP-LULUCF

Recalculation for the year 2015 for KP-LULUCF for each activity is shown in Table 10.4.

Table 10.4 Recalculated GHG emissions (kt CO_2-eq yr^{-1}) for 2015 per activity of KP-LULUCF.

	Emissions for 2015 (kt CO_2-eq yr^{-1})		
KP activity	**NIR 2018**	**NIR 2017**	**Absolute difference**
Afforestation	-542.97	-589.78	46.81
Deforestation	2 250.70	2 614.14	-363.44
Forest management	-27 797.83	-28 467.39	669.56
Cropland management	1 773.47	1 789.44	-15.97
Grazing land management	1.53	68.47	-66.94
Total	-24 315.10	-24 585.12	270.02

For the NIR 2018, the following methodological changes have affected all land-use categories and are therefore not listed explicitly below:

- The absolute values of gains and losses are larger this year because we changed the method from NFI plot-level net changes to plot-level gains and losses. This means, a plot can have both gains and losses. Until last year, this was not possible. The total net change was also affected by this change.
- New above- and belowground birch biomass functions are now used instead of Marklund.

For afforestation (A) and reforestation (R) and deforestation (D), an error found in the 2015 submission for ARD (pools SOM, litter, and deadwood) on mineral soil was corrected. The correction

ensured that ARD areas after a period of 20 years (with transition from one assumed equilibrium to another) consistently are assigned emissions reflecting their current land use.

Total recalculations for the KP-LULUCF submissions for the year 2015[35] resulted in reduced C uptake of 270 kt CO_2-eq from -24 585 kt CO_2-eq (NIR 2017) to -24 315 kt CO_2-eq (NIR 2018) including non-CO_2 emissions. The majority of the change was due to the reduction in CO_2 uptake for FM (reduced by 670 kt CO_2-eq). The CO_2 uptake for AR decreased by 47 kt CO_2-eq, while emissions reduced by 363 kt CO_2-eq for D, by 16 kt CO_2-eq for CM, and by 67 kt CO_2-eq for GM, including non-CO_2 emissions. Recalculation for CH_4 emissions were minor and reduced total KP-LULUCF CH_4 emissions by 2 kt CO_2-eq, from 159 kt CO_2-eq to 157 kt CO_2-eq. N_2O emissions were also recalculated and decreased by 9 kt CO_2-eq from 346 kt CO_2-eq to 337 kt CO_2-eq. Recalculations of CO_2 emissions were more important and these are described below for each KP activity.

4(KP-I) A.1 Afforestation and reforestation

- Total CO_2 sequestration for AR decreased by 49 kt CO_2 from 615 kt CO_2 to 566 kt CO_2, which was primarily due to the increased C uptake of 23 kt CO_2 in the aboveground living biomass (from 162 CO_2 to 185 kt CO_2) and by 5 kt CO_2 in the belowground biomass (from 50 kt CO_2 to 55 kt CO_2). C uptake in the litter pool decreased by 105 kt CO_2 from 538 kt CO_2 to 433 kt CO_2. CO_2 emissions in the mineral soil pool were reduced by 29 kt CO_2 from 115.6 kt CO_2 to 89.7 kt CO_2. All recalculations were due to the changes in the NFI area and living biomass data. NFI harvest data are used to distribute the known total harvests to the reported activities such as afforestation. Due to the aforementioned change from plot-level net change to plot-level gains and losses, NFI harvest data for 1990-1995 now provided some contribution (in the range of 250-209 t C), which was NO previous to the 2018 NIR. The change did not affect the 2015 data for net CO_2 emissions/removals for AR (0.03 kt CO_2 in both the 2017 and 2018 report).

4(KP-I) A.2 Deforestation

- Total CO_2 emissions for deforestation were reduced by 358 kt CO_2 from 2 582 kt CO_2 to 2 224 kt CO_2. This was caused by the combination of reduced C emissions in litter (289 kt CO_2 from 1 583 kt CO_2 to 1 294 kt CO_2), dead wood (23.7 kt CO_2 from 130 kt CO_2 to 106 kt CO_2), and below ground biomass (9.5 kt CO_2 from 146.7 kt CO_2 to 137.2 kt CO_2). Also increased removals from mineral soils (31 kt CO_2; from 98 kt CO_2 to 129 kt CO_2) and emissions from aboveground biomass (3.7 kt CO_2 from 528 kt CO_2 to 531.7 kt CO_2). As well as decreased emissions from organic soils (10 kt CO_2 from 293 kt CO_2 to 282 kt CO_2). Recalculations for all C pools were due to the updates in the NFI data.

4(KP-I) B.1 Forest management

- Carbon removals in the FM activity reduced by 670 kt CO_2. The majority of the reduction occurred in the living biomass; removals aboveground biomass was reduced by 1 722 kt CO_2

[35] Note that recalculations for KP-LULUCF, as decribed in the following, refer to absolute values of the activities, and not the value that is accounted for under KP2.

from 18 318 kt CO_2 to 16 596 kt CO_2 and belowground by 638 kt CO_2 from 4 583 kt CO_2 to 3 945 kt CO_2. The removals in the litter, dead wood, and mineral soil pools all increased C uptake by 1 351 kt CO_2 (from 5 372 kt CO_2 to 6 723 kt CO_2), 273 kt CO_2 (from 1 084 kt CO_2 to 1 357 kt CO_2), and 31 kt CO_2 (from 123 to 154 kt CO_2), respectively. NFI harvest data are used to distribute the known total harvests to the reported activities such as forest management. Due to the aforementioned change in the 2018 NIR from plot-level net change to plot-level gains and losses, removals from FM 2015 increased with 35.83 kt CO_2 from -30.50 kt CO_2 to -66.33 kt CO_2.

4(KP) B.2 Cropland management

- Total CO_2 emissions for the CM activity were reduced 16 kt CO_2 (from 1 700 kt CO_2 to 1 684 kt CO_2). Removals in aboveground biomass increased by 1.5 kt CO_2 from 3 kt CO_2 to 4.5 kt CO_2 as did belowground biomass which increased 0.7 kt CO_2 from 1.3 kt CO_2 to 2 kt CO_2. The removals in the mineral soil pool increased 2.8 kt CO_2 from 68.7 kt CO_2 to 71.5 kt CO_2. The emissions in the organic soil pool decreased 11 kt CO_2 from 1 773 kt CO_2 to 1 762 kt CO_2

4(KP) B.3 Grazing land management

- Recalculations for the GM activity resulted in reduced emissions by 66 kt CO_2 from 61 kt CO_2 to -5 kt CO_2. This was primarily the result of the combined effect of increased C uptake in above- and belowground living biomass (38 kt CO_2 for aboveground and 15 kt CO_2 for belowground) and reduced emissions from organic soils 12 kt CO_2. Recalculation for living biomass was due to the updates in the NFI database. The change in the NFI database affected the area of organic soils under GM.

10.3 Implications for emissions levels and trends, including time-series consistency

Table 10.5 shows the effects of recalculations on the emission figures for CO_2, CH_4 and N_2O 1990-2015. Table 10.6 shows the effect of recalculations on the emission figures for HFCs, PFCs and SF_6 1990-2015. Table 10.7 shows the effects of recalculations for the trends in emissions 1990-2015.

Table 10.5. Recalculations in 2018 submission to the UNFCCC compared to the 2017 submission. CO_2, CH_4 and N_2O. 1000 tonnes CO_2 equivalents.

	CO_2			**CH_4**			**N_2O**		
	Previous subm.	Latest subm	Diff (%)	Previous subm.	Latest subm	Diff (%)	Previous subm.	Latest subm	Diff (%)
1990	35704.4	35704.4	0.0	5800.2	5788.4	-0.2	4230.8	4210.8	-0.5
1991	34069.3	34069.3	0.0	5767.4	5755.4	-0.2	4071.9	4053.0	-0.5
1992	34831.9	34831.9	0.0	5848.3	5835.8	-0.2	3538.5	3519.2	-0.5
1993	36531.6	36531.6	0.0	5945.9	5932.1	-0.2	3727.5	3706.8	-0.6
1994	38445.9	38446.0	0.0	6007.7	5991.6	-0.3	3800.4	3777.4	-0.6
1995	38476.7	38477.2	0.0	5885.0	5867.3	-0.3	3830.4	3807.6	-0.6
1996	41593.2	41593.8	0.0	5964.2	5944.1	-0.3	3849.7	3826.1	-0.6
1997	41691.5	41698.9	0.0	5959.7	5939.0	-0.3	3835.4	3812.3	-0.6
1998	41948.0	41956.7	0.0	5760.0	5737.2	-0.4	3921.2	3898.9	-0.6
1999	42699.7	42709.5	0.0	5631.8	5608.7	-0.4	4144.5	4121.3	-0.6
2000	42202.1	42215.9	0.0	5703.6	5674.3	-0.5	3940.3	3916.6	-0.6
2001	43539.7	43559.8	0.0	5741.4	5711.5	-0.5	3871.5	3847.2	-0.6
2002	42661.7	42667.0	0.0	5590.0	5560.0	-0.5	4117.7	4089.3	-0.7
2003	43914.7	43921.8	0.0	5697.9	5667.4	-0.5	3975.1	3947.4	-0.7
2004	44327.4	44337.0	0.0	5685.5	5654.9	-0.5	4126.9	4100.0	-0.7
2005	43553.9	43560.7	0.0	5488.8	5455.4	-0.6	4196.2	4169.1	-0.6
2006	43919.3	43923.3	0.0	5362.5	5328.3	-0.6	3862.8	3837.0	-0.7
2007	45848.1	45851.9	0.0	5481.7	5446.8	-0.6	3692.3	3666.3	-0.7
2008	44898.1	44903.0	0.0	5338.9	5307.2	-0.6	3251.6	3225.1	-0.8
2009	43216.7	43205.4	0.0	5378.9	5343.0	-0.7	2706.0	2674.5	-1.2
2010	45838.5	45823.3	0.0	5398.4	5365.1	-0.6	2621.6	2589.1	-1.2
2011	44926.6	44982.6	0.1	5242.7	5208.6	-0.7	2608.6	2580.5	-1.1
2012	44558.5	44560.8	0.0	5219.9	5175.2	-0.9	2633.2	2589.4	-1.7
2013	44302.7	44302.7	0.0	5243.9	5221.3	-0.4	2584.4	2558.9	-1.0
2014	43965.9	43952.7	0.0	5318.3	5281.0	-0.7	2578.0	2560.2	-0.7
2015	44664.0	44650.5	0.0	5192.3	5182.9	-0.2	2617.3	2596.4	-0.8

Table 10.6. Recalculations in 2018 to the UNFCCC submission compared to the 2017 submission. HFCs, PFCs and SF_6. 1000 tonnes CO_2 equivalents.

	HFCs			PFCs			SF_6		
	Previous subm.	Latest subm.	Diff (%)	Previous subm.	Latest subm.	Diff (%)	Previous subm.	Latest subm.	Diff (%)
1990	0.04	0.04	0.00	3894.80	3894.80	0.00	2098.54	2098.54	0.00
1991	9.91	9.91	0.00	3456.70	3456.70	0.00	1983.46	1983.46	0.00
1992	19.95	19.95	0.00	2637.22	2637.22	0.00	672.58	672.58	0.00
1993	31.64	31.64	0.00	2648.27	2648.27	0.00	703.76	703.76	0.00
1994	49.88	49.88	0.00	2342.53	2342.53	0.00	837.57	837.57	0.00
1995	92.00	92.00	0.00	2314.05	2314.05	0.00	579.82	579.82	0.00
1996	129.48	129.48	0.00	2107.62	2107.62	0.00	547.68	547.68	0.00
1997	191.50	191.50	0.00	1882.70	1882.70	0.00	553.17	553.17	0.00
1998	244.07	244.07	0.00	1711.98	1711.98	0.00	693.29	693.29	0.00
1999	316.02	316.02	0.00	1599.97	1599.97	0.00	833.74	833.74	0.00
2000	383.27	383.27	0.00	1518.45	1518.45	0.00	891.41	891.41	0.00
2001	473.31	473.31	0.00	1531.26	1531.26	0.00	754.79	754.79	0.00
2002	578.22	578.22	0.00	1658.79	1658.79	0.00	227.34	227.34	0.00
2003	557.60	557.60	0.00	1051.11	1051.11	0.00	217.37	216.54	-0.38
2004	597.10	597.10	0.00	1016.75	1016.75	0.00	263.34	262.15	-0.45
2005	614.26	614.26	0.00	955.32	955.32	0.00	297.67	296.12	-0.52
2006	678.03	678.03	0.00	859.08	859.08	0.00	202.33	200.41	-0.95
2007	715.30	715.30	0.00	951.19	951.19	0.00	72.73	70.46	-3.13
2008	806.08	806.08	0.00	895.99	895.99	0.00	62.39	59.76	-4.21
2009	856.15	856.15	0.00	438.35	438.35	0.00	58.63	55.65	-5.08
2010	1064.54	1064.54	0.00	238.39	238.39	0.00	71.91	68.59	-4.62
2011	1105.75	1105.75	0.00	262.64	262.64	0.00	57.92	54.26	-6.33
2012	1140.81	1140.81	0.00	200.51	200.51	0.00	57.55	53.54	-6.96
2013	1155.15	1155.15	0.00	181.04	181.04	0.00	60.62	56.28	-7.16
2014	1235.58	1228.41	-0.58	178.92	178.92	0.00	54.74	50.07	-8.54
2015	1232.90	1225.74	-0.58	146.39	146.39	0.00	55.25	69.79	26.32

Table 10.7. Trends in emissions 1990-2015. 2018 submission compared to 2017 submission. GHG. Per cent change 1990-2015.

	Total GHG	**CO2**	**CH4**	**N2O**	**PFCs**	**SF6**	**HFCs**
This submission	**4.21**	**25.06**	**-10.46**	**-38.34**	**-96.24**	**-96.67**	**2 792 071**
Previous submission	**4.21**	**25.09**	**-10.48**	**-38.14**	**-96.24**	**-97.37**	**2 808 441**

10.4 Implemented and planned improvements, including in response to the review process

The Norwegian Environment Agency co-ordinates the development and improvements of the inventory's different sectors. The recommendations from the review process are recorded in a spread sheet together with the needs recognized by the Norwegian inventory experts to form a yearly inventory improvement plan. Needs identified by use of the data for purposes other than reporting is also included. The overall aim of inventory improvement is to improve the accuracy and reduce uncertainties associated with the national inventory estimates. Each issue is assigned to a sector/theme and the overview tracks where the issue has originated from and the organization/person responsible for following up the recommendations. The overview is discussed among the agencies and each issue is given a priority and a deadline. Each organization in the inventory preparation therefore has responsibility for the development of the inventory. The issues are prioritized on the basis of the recommendations from the ERT and available human and financial resources.

The national greenhouse gas inventory has undergone substantial improvements over the recent years, and the inventory is considered to be largely complete and transparent. There was no review of the inventory in 2017, so the latest annual inventory review report is ARR2016[36]. Many of the recommendations in the ARR2016 have already been followed up and are reflected in the 2017 NIR. Implemented improvements since the 2017 NIR and how these are related to the review process are described in Table 10.8.

[36] http://unfccc.int/resource/docs/2017/arr/nor.pdf

Table 10.8 Implemented improvements in response to the review process.

Sector/issue	ERT recommendation/ self-initated	Source	Implementation	Internal Identificati-on code
General				
Energy				
Energy, road transportation (1A3b)	Version 3.3 of the HBEFA emission model was published in 2017	Self-initiated	The new version of the HBEFA emission model was implemented	EK.61
IPPU				
IPPU, SF_6	The time series for SF_6 emissions used to calculate SF_6 emissions needed to be updated.	Self-initiated	Activity data has been updated in the model used to calculate SF6 emisisons, see chapter 4.8.2.7.	IK.67
Agriculture				
Agriculture, Enteric fermentation - beef cow (3A)	Revise the equations used for calculating enteric methane from beef cow.	Self initiated	The estimation of methane emissions from enteric fermentation in beef cows is revised. The new estimations is based on representative data about the Norwegian beef cow population. The methodology is documented in NIR Annex IX	JK.52
LULUCF[37]				
Waste				
Waste, Wastewater treatment and discharge, Industrial wastewater (5D2)	The ERT recommends that Norway provide more information in the NIR on the level of AD available for industrial wastewater treatment plants, especially oil refinery, pulp and paper, pharmaceutical and chemical companies	ARR 13, §91 ARR 2016, W3	AD have been added to the National Inventory report in chapter 7.6 wastewater treatment and discharge.	AK.27
KP-LULUCF[38]				

Improving the inventory and the reporting is a contious process and there are still some issues previously identified that need to be addressed. Table 10.9 gives an overview of the planned improvements.

[37] Self-initiated improvements, not related to ARR findings, are described in the recalculations for LULUCF, chapter 10.2.4.

[38] Self-initiated improvements, not related to ARR findings, are described in the recalculations for KP-LULUCF, chapter 10.2.6.

Table 10.9 Plan for improvements for the Norwegian GHG inventory.

Sector/ issue	ERT recommendation/ self-initated	Source	Plan for improvement	Internal Identifi-cation code
General				
General, QAQC	The ERT found that the NIR (p. 11 and annex V, p. 23) was not clear regarding who is performing QA activities. During the review, Norway provided more information on the QA procedures and how they are performed by people other than those involved in the original calculations of the inventory. Specifically, the Party noted that there are two different QA routines: the inventory team performs QA on data collected by other institutions (i.e. QA on input data); and QA performed by reviewers not involved in preparing the inventory refers to the QA of the inventory itself. The Party further noted that, in 2016, it has a project aimed at improving the QC routines of the inventory (excluding LULUCF) and that annex V of the NIR will be revised as a result of this project. The ERT finds that such procedures are in line with the 2006 IPCC Guidelines and that they should be better documented in the NIR. The ERT encourages Norway to transparently describe in the NIR the results of the project aimed at improving the QC routines	ARR2016, G.17	The project aimed at improving the QC routines continues in 2018. Implemented and planned improvements are described in a text box in Annex V of this NIR.	GK.34
Energy				
Energy, reference approach (1A(b))	The ERT recommends that Norway report on the time frame and progress of the revised energy balance system in the 2017 submission, highlighting the resulting reduction in statistical differences for solid fuels	ARR2014, §26 ARR2016, E.4/E.17	Statistics Norway published a revised energy balance for 2010-2016 in 2017. In 2018, the balance will be extended back to 1990 and the balance data incorporated into the emission inventory. The results will be used for improving the information in CRF and NIR in the 2019	EK.63

Sector/ issue	ERT recommendation/ self-initated	Source	Plan for improvement	Internal Identifi-cation code
			submission. A brief presentation of the project is included in section 3.6.2.	
Energy, reference approach (1A(b))	The ERT recommends that the Party transparently describe the technical solution that aims to improve the link between the energy balance and IEA reporting, including providing any preliminary results in the 2017 submission, and then improve the alignment of the energy balance and IEA reporting for the 2018 submission	ARR2014, §26 ARR2016, E.5/E.18	Statistics Norway published a revised energy balance for 2010-2016 in 2017. In 2018, the balance will be extended back to 1990 and the balance data incorporated into the emission inventory. The results will be used for improving the information in CRF and NIR in the 2019 submission. A brief presentation of the project is included in section 3.6.2. The effect on the link between IEA reporting and the energy balance data in the Reference approach will be reviewed in NIR 2018.	EK.31a
Energy, feedstocks, reductants and non-energy use of fuels (1A(d) etc)	E.7: Improve QC procedures to ensure consistency of the information reported on feedstocks, reductants and NEU in different CRF tables E.8: Review and revise the reporting in CRF table 1.A(d) and improve QC procedures to ensure consistency of the reporting E.20: The ERT recommends that Norway report on the time frame and progress of the revised energy balance system including any improvements in the consistency of the information on feedstocks, reductants and non-energy use of fuels reported in the CRF tables	ARR2014, §29 and previous ARRs ARR2016, E.7/E.20, E.8	Statistics Norway published a revised energy balance for 2010-2016 in 2017. In 2018, the balance will be extended back to 1990 and the balance data incorporated into the emission inventory. The results will be used for improving the information in CRF and NIR in the 2019 submission. A brief presentation of the project is included in section 3.6.2.	EK.8

Sector/ issue	ERT recommendation/ self-initated	Source	Plan for improvement	Internal Identifi-cation code
Energy, road transportation (1A3b)	The ERT found that CH4 from LPG vehicles was reported as NO. In the Saturday Paper, the ERT recommended that, in the absence of country-specific estimates for this category, the Party resubmit with emissions estimates (...) using IPCC 2006 default factors. In the ARR, the ERT recommends that the Party derive updated AD (...) Alternatively, the ERT recommends that the Party demonstrate that the current approach of keeping AD flat does not lead to an underestimate of emissions in 2014	ARR2016, E.26	Activity data will be revised as part of the implementation of new energy balance. Revised emission data were included in CRF table 1.A(a) in the 2017 submission. The emission factors used are described in NIR chapter 3.2.5.3	EK.38
IPPU				
Agriculture				
LULUCF				
Waste				
Waste, Wastewater treatment and discharge, (5D)	The ERT noted that in CRF table 5.D the notation key “NE” is used for total organic product (kt DC/year) for domestic, industrial and other wastewater. Nevertheless in the NIR it is stated that biochemical oxygen demand and COD data are available and used to estimate emissions. The ERT recommends that Norway present total organic product data in the NIR and in CRF table 5.D	ARR 2016, W8	Organic product data will be included in the next submission	AK.44
Waste, Wastewater treatment and discharge, Industrial wastewater (5D2)	Investigate possible overestimation of emissions. In addition, the ERT recomends Norway to applay the IPCC 2006 Guidelines to estimate CH_4 emissions from industrial wastewater (EQUATION 6.4) considering that the amount of CH_4 that is flared or recovered for energy use should be subtracted from total emissions. The ERT also noted that emissions from CH_4 recovery for energy generation should be	ARR 2016, W9	Norway has included this recommendation in its improvement plan	AK.39

Sector/ issue	ERT recommendation/ self-initated	Source	Plan for improvement	Internal Identifi-cation code
	reported in the Energy Sector taking into account the avoidance of double counting emissions from flaring and energy used			
KP-LULUCF				

Part II: Supplementary information required under article 7, paragraph 1

11 KP-LULUCF

11.1 General information

Norway provides supplementary information under Article 7 of the Kyoto Protocol (KP) for the Land Use, Land-Use Change and Forestry sector. The information provided in this chapter is in accordance with relevant CMP decisions such as Decision 16/CMP.1, 2/CMP.7, 2/CMP.8, 6/CMP.9 and the 2006 IPCC Guidelines, the 2013 IPCC KP Supplement (IPCC 2014a), and the IPCC 2013 Wetlands Supplement (IPCC 2014b).

In the first commitment period of the Kyoto Protocol (2008-2012) Norway reported on emissions and removals from the obligatory activities Deforestation (D) and Afforestation/reforestation (AR) under Article 3.3, in accordance with Paragraph 6 of the Annex to Decision 16/CMP.1. In addition, Norway decided to elect the voluntary activity Forest Management (FM) under Article 3.4 for inclusion in its accounting.

For the second commitment period (2013-2020) Norway reports, in accordance with paragraph 7 of decision 2/CMP.7, Annex I, emissions and removals from Article 3.3 activities and from Forest Management under Article 3.4. In addition, Norway has elected the voluntary activities Cropland Management (CM) and Grazing Land Management (GM) in its accounting under Article 3.4 and reports emissions and removals from all sources and sinks under these KP Article 3.4 activities. In the second commitment period Norway has chosen commitment-period accounting.

This chapter covers information on emissions and removals from activities under Article 3.3 and 3.4 of the Kyoto Protocol for the years 2013, 2014, 2015, and 2016, and is in accordance with Annex II of decision 2/CMP.8. Reported emissions and removals from areas under the KP activities includes the following sources and sinks: carbon stock changes in aboveground biomass, belowground biomass, litter, dead wood, mineral soils and organic soils, direct N_2O emissions from N fertilization (for AR, D, and FM), emissions and removals from drained and rewetted organic soils, N_2O mineralization in mineral soils, indirect N_2O emissions from managed soils, and N_2O and CH_4 emissions from biomass burning.

Areas where afforestation and reforestation and deforestation activities have occurred in Norway are small compared to the area of forest management. Estimated C sequestration for the activity FM is substantial, and there is also a C uptake as a result of AR. The activities deforestation and cropland management are sources of net emissions for all reported years, while grazing land management has small net emissions in the years 2013-2016. Table 11.1 shows the emissions and removals for each KP activity for the base year 1990 (where relevant), and for each year of the second commitment period. During the first three years of the second commitment period (from 2013 to 2015) emissions from CM show an increasing trend, for which the main reason is the cultivation of wetlands resulting in emissions from organic soils. Compared to the base year (1990) however, the accumulated emissions to be accounted from CM represent a small removal for the first four years of the committment period. Compared to the base year which had removals, emissions from GM were observed in the first four years of the second committment period. This increase is caused mostly by emissions from the mineral soil pool and primarily reflects the assumptions provided in the Tier 1

method used for the estimation of CSC on grasslands remaining grassland. The majority of the emissions from D occur in the litter pool.

Table 11.1 CO_2, N_2O, and CH_4 emissions (kt CO_2 equivalents yr^{-1}) and CO_2 removals of all pools for Article 3.3 and 3.4 under the Kyoto Protocol for the base year (1990) and for each year of the second commitment period.

	Net emissions/removals (kt CO_2–equivalents yr^{-1})				
Year	**Afforestation/ reforestation**	**Deforestation**	**Forest management**	**Cropland management**	**Grazing land management**
1990			-12 890.88	1 782.49	-77.35
2013	-569.52	2 367.59	-29 934.63	1 759.48	7.20
2014	-557.23	2 249.09	-28 626.29	1 771.05	3.97
2015	-542.97	2 250.70	-27 797.83	1 773.47	1.53
2016	-519.18	2 325.99	-28 396.13	1 769.89	0.37

Source: Norwegian Institute of Bioeconomy Research

11.1.1 Relation between UNFCCC land classes and KP activities

The land classification under the convention can be directly translated into activities under the KP with two exceptions. First, land-use changes reported under the convention includes human-induced and non-human induced land-use change, whereas only human-induced land-use changes are reported under KP. Second, the 20-year transition period for land-use changes is not applied under KP, which means that land cannot leave a land-use change category. However, we do apply appropriate methods to estimate the emissions or removals from land that has been in a conversion category in the reporting to the UNFCCC for more than 20 years.

The correspondence between the national land cover and land-use categories (Table 6.7) and the KP activities is illustrated by a translation matrix (Table 11.2). Briefly, land classified as the activity D is the sum of forest land converted to cropland, grassland, wetlands, settlements, and other land (direct human-induced land-use change). Analogously, land classified for the activity AR is the sum of cropland, grassland, wetlands, settlements, and other land converted to forest land, but only where the conversions are directly human-induced (Table 11.2). Once land is classified as D, it stays in D even if subsequent afforestation takes place. Land classified as the activity FM is forest land that has remained forest land since 1990 and land conversions to or from forest that are not caused by human activity. Cropland management entails the activities on land that has remained cropland since 1990 and non-forest related land conversion to or from cropland since 1990. Land classified as grazing land management is land that has remained grassland since 1990 and land-use conversion to or from grassland, with the exception of those related to forest land or cropland.

Table 11.2 Land-use change matrix with classification of the KP activities and the corresponding land-use classes. The following notations are used for classification of land-use changes. AR: Article 3.3 Afforestation/Reforestation, D: Article 3.3 Deforestation, FM: Article 3.4 Forest management, CM: Article 3.4 Cropland management, GM: Article 3.4 Grazing land management, and O: Other activities. In the case of non-human induced land-use transition, the activity in brackets () is assigned.

		Reporting year					
Base year	Land-use	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land
1990	Forest land	FM	D	D	D (FM)	D	FM
	Cropland	AR	CM	CM	CM	CM	CM
	Grassland	AR	CM	GM	GM	GM	GM
	Wetlands	AR (FM)	CM	GM	O	O	O
	Settlements	AR	CM	GM	O	O	O
	Other land	AR (FM)	CM	GM	O	O	O

Specifically, the annual change in the area of D is not exactly equal to the annual change in the area of FM (Table 11.3), because only human-induced land-use changes are reported under the KP. Also, areas of AR and D do not exactly equal the areas of lands converted to forest land (LF) and forest land converted to lands (FL), respectively, under the Convention reporting. The difference between the sum of AR and FM and the sum of LF and forest land remaining forest land under the Convention is equal to the non-human induced changes from other land to forest land.

Furthermore, since 2011, an additional reason for the lack of correspondence between AR and LF, and between D and FL, is the application of the 20-year transition period in the Convention reporting, where areas are classified in transition (as land in conversion) for 20 years before they enter a remaining land-use category. This means that the area of land converted to forest land in 1990, 1991, and 1992 under the Convention will enter the forest land remaining forest land category in 2011, 2012, and 2013, respectively. However, for KP-LULUCF reporting, the areas reported for the activities AR and D remain AR and D for the whole reporting period and are thus not reported as a FM activity after 20 years. A full time-series of the areas considered for the activities AR, D, FM, CM, and GM from 1989 to 2016 is presented in Table 11.3.

Table 11.3 Time-series of area estimates (kha) for the activities Afforestation/Reforestation (AR), Deforestation (D), Forest management (FM), Cropland management (CM), and Grazing land management (GM) for 1989-2016.

	Area (kha)				
Year	**Afforestation/ Reforestation (AR)**	**Deforestation (D)**	**Forest management (FM)**	**Cropland management (CM)**	**Grazing land management (GM)**
1989	0	0	12202.22	940.09	229.96
1990	1.94	4.1	12198.38	939.81	229.32
1991	3.88	8.19	12194.54	939.53	228.69
1992	5.82	12.29	12190.71	939.25	228.06
1993	7.77	16.39	12186.87	938.97	227.42
1994	9.71	20.49	12183.03	938.69	226.79
1995	11.76	25.45	12178.33	938.59	225.8
1996	13.79	30.6	12173.44	938.37	224.95
1997	15.96	36.56	12167.82	938.15	224.15
1998	18.3	42.75	12161.9	938.07	223.03
1999	20.57	49.17	12155.93	938.05	221.81
2000	23.02	55.46	12149.91	937.68	220.94
2001	25.49	61.9	12144	937.64	219.99
2002	28.01	67.83	12138.5	937.17	219.25
2003	29.87	73.41	12133.35	936.88	219.05
2004	31.89	78.93	12128.08	936.47	218.89
2005	34.32	85.15	12122.12	936.29	218.37
2006	36.84	91.6	12115.84	935.57	217.93
2007	39.33	98.6	12109.75	935.21	217.43
2008	42.68	106.22	12103.26	934.85	216.74
2009	45.98	114.2	12096.7	934.76	215.86
2010	48.32	121.36	12091.59	934.79	215.52
2011	50.29	127.78	12089.7	935.55	215.01
2012	52.32	133.49	12088.66	935.84	214.4
2013	53.92	138.89	12087.82	936.13	213.88
2014	55.54	144.11	12087.02	936.28	213.45
2015	57.64	149.74	12085.49	936.37	212.76
2016	59.93	155.74	12082.35	936.1	212.15

11.1.2 Definitions of elected activities under Article 3.4

Forest management is defined according to forest lands described in chapter 6.2.1. The values used in the National Forest Inventory are in accordance with the range of parameters in the definition from the Global Forest Resources Assessment (FRA) 2005 and IPCC 2003 (Table 11.4). Forest land is land with tree-crown cover of more than 10 %. The trees have to be able to reach a minimum height of 5 m at maturity in situ. Minimum area and width for forest land considered in the Norwegian inventory is 0.1 ha and 4 m, respectively, which is a discrepancy from the definition in FRA 2005 (0.5 ha and 20 m). Furthermore, forest roads are considered as settlements. Young natural stands and all plantations established for forestry purposes, as well as forests that are temporarily unstocked, e.g. as a result of harvest or natural disturbances, are included under forest management.

Table 11.4 Parameters for the definition of forest land in IPCC 2003, the Global Forest Resources Assessment (FRA) 2005, and in the National Forest Inventory (NFI).

Parameters	IPCC 2003	FRA 2005	Values used (NFI)
Minimum land area	0.05 – 1 ha	0.5 ha	0.1 ha
Minimum crown cover	10 – 30%	>10%	>10%
Minimum height	2 – 5 m	5 m	5 m
Minimum width		20 m	4 m

Cropland management is defined as the acitvities that occur on cropland and cropland is defined as described in chapter 6.2.1. Croplands are areas that are annually cropped and regularly cultivated and plowed. Both annual and perennial crops are grown. It also encompasses grass leys that are in rotations with annual crops, which may include temporarily grazed fields that are regularly cultivated. This category also includes arable land that has been annually cropped and regularly plowed, but has since then been abandoned. These areas remain in the cropland management category until they have a regrowth of trees that make them unsuitable for plowing. In addition, to the areas classified as cropland remaining cropland, cropland management also includes all non-forest conversion to or from cropland.

Grazing land management is defined as the activities that occur on grassland, which is described in chapter 6.2.1. Grasslands are areas utilized for grazing on an annual basis. More than 50 % of the area should be covered with grass and it can be partly covered with trees, bushes, stumps, rocks etc. The grass may be mechanically harvested but the soil cannot be plowed. Land with tree cover may be classified as grassland if grazing is considered more important than forestry even if the forest definition is met. In addition to the areas classified as grassland remaining grassland, grazing land management also includes all non-forest and non-cropland conversion to or from grassland.

11.1.3 Description of how the definitions of each activity under Article 3.3 and 3.4 have been applied consistently over time

The Norwegian National Forest Inventory (NFI) provides data on land use, land-use change and forestry for the greenhouse gas reporting related to Article 3.3 and Article 3.4. A detailed description of the NFI can be found in chapter 6, section 6.3.

Estimates of areas subject to Afforestation/Reforestation (AR), Deforestation (D), Forest Management (FM), Cropland Management (CM) and Grazing land Management (GM) are based on the NFI, which has been carried out continuously since 1986. Land use obtained between 1986 and 1993 serves as the baseline for the area and living biomass estimates on 31 December 1989. Because no data from permanent sample plots exists before 1986 and relatively small changes have been detected for forest land as well as the other land-use classes, we have chosen not to take into account changes that may have occurred prior to 1990.

All forests in Norway are considered managed and this includes recreational areas, protected areas, and nature reserves. All forests in Norway are used either for wood harvesting, protecting and protective purposes, recreation, and/or to a greater or smaller extent, for hunting and picking berries, and are therefore subject to the FM activity.

11.1.4 Hierarchy among Article 3.4 activities and how they have been consistently applied in determining how land was classified

As Norway has included FM, CM, and GM under Article 3.4 of the Kyoto Protocol in the accounting for the second commitment period, it is necessary to determine the hierarchy among Article 3.4 activities. Forest management takes precedence over both cropland and grazing land management. Norway has further decided that cropland management takes precedence over grazing land management, because it covers a larger area and it is more important in terms of emissions per area. Thus, the hierarchy is as follows: forest management > cropland management > grazing land management. In practice, this means that grassland converted to cropland will change activity from grazing land to cropland management, but cropland converted to grassland will remain as cropland management activity. Article 3.3 activities (AR and D) always take precedence over Article 3.4 activities.

11.2 Land-related information

11.2.1 Spatial assessment units used for determining the area of the units of land under Article 3.3

The activity data used for determining the area of the units of land under Article 3.3 are the 250 m^2 large NFI sample plots (see detailed description in chapter 6.3). A land conversion will be recorded as soon as 20 per cent or more of the plot area is converted to another land use class. Sample plots are split between two land use classes if one of the land use classes covers at least 20 % of the plot area. Since 1986, all plots are classified according to a national land cover and land-use classification system, which is consistently translated to KP activities.

The NFI database provides activity data for the entire country. However, there is no time-series of field observations in Finnmark County and the mountain forest stratum before 2005. For plots in Finnmark County and the mountain forest stratum, information from maps, registers, and old and new aerial photographs were used to determine the land use of each plot in the base year 1990. The models used to back-cast the living biomass on these sample plots were based on the methods described in the LULUCF chapter (chapter 6). All land-use changes, except for one, were observed in the lowland forest stratum outside Finnmark.

11.2.2 Methodology used to develop the land transition matrix

The land-use transition matrix (Table 11.2) is based upon changes in the land-use category of the sample plots surveyed in a given year. Changes in land use are recorded for the year the land use is observed. A full NFI cycle, i.e. plots observed over a 5-year period, are used for estimating areas of land-use categories. Extrapolation is used in the last 4 years of the reporting period (see section 6.3.4).

11.2.3 Maps and/or database to identify the geographical locations and the system of identification codes for the geographical locations

All the NFI plots are geo-referenced and each plot has a unique identification code. According to the IPCC good practice guidance, the coordinates of these plots are classified information. However, a list of sample plots can be provided to the expert review team upon request. The approximate spatial distribution of the areas subject to the activities under Article 3.3 and to the activity FM under Article 3.4 is given in Figure 11.1. Figure 11.2 displays the approximate location of the activities FM, CM, and GM under Article 3.4.

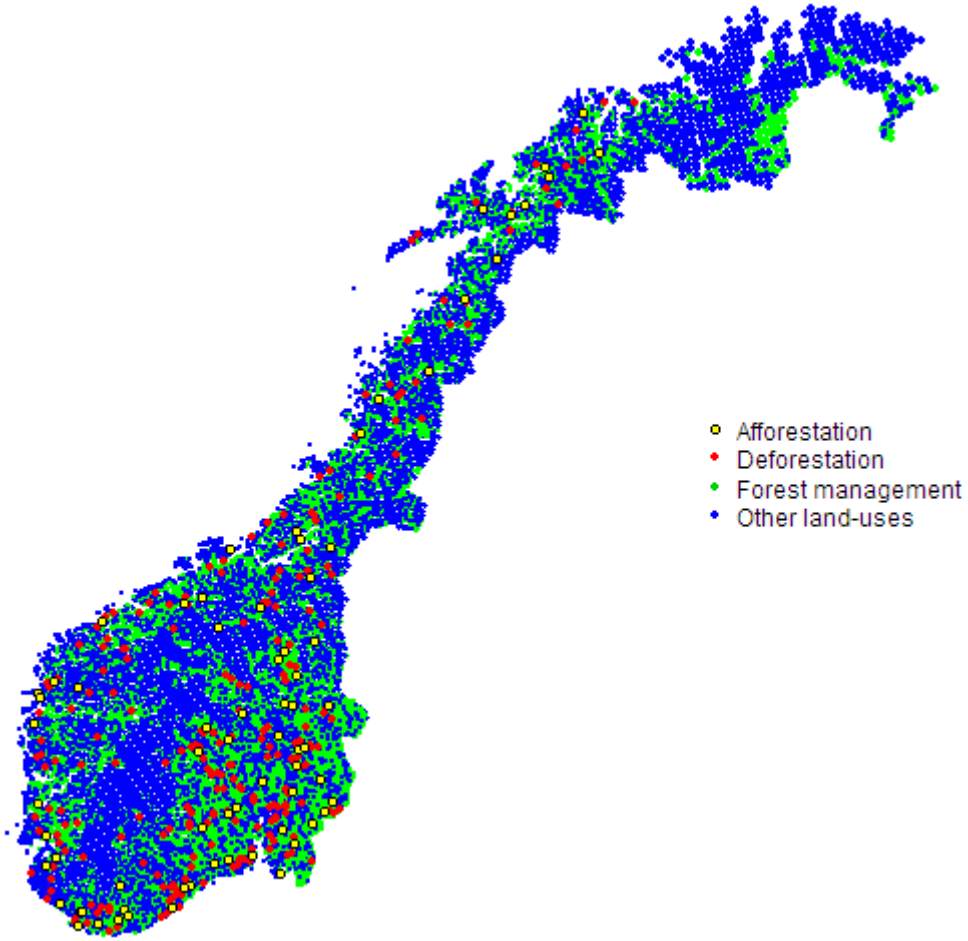


Figure 11.1 Spatial distribution (approximate location of sample plots) of Article 3.3 activities afforestation and deforestation, and the Article 3.4 activity forest management from 1990 to 2016. Symbol sizes for plots with afforestation and deforestation activities are increased to improve the visibility of these activities.

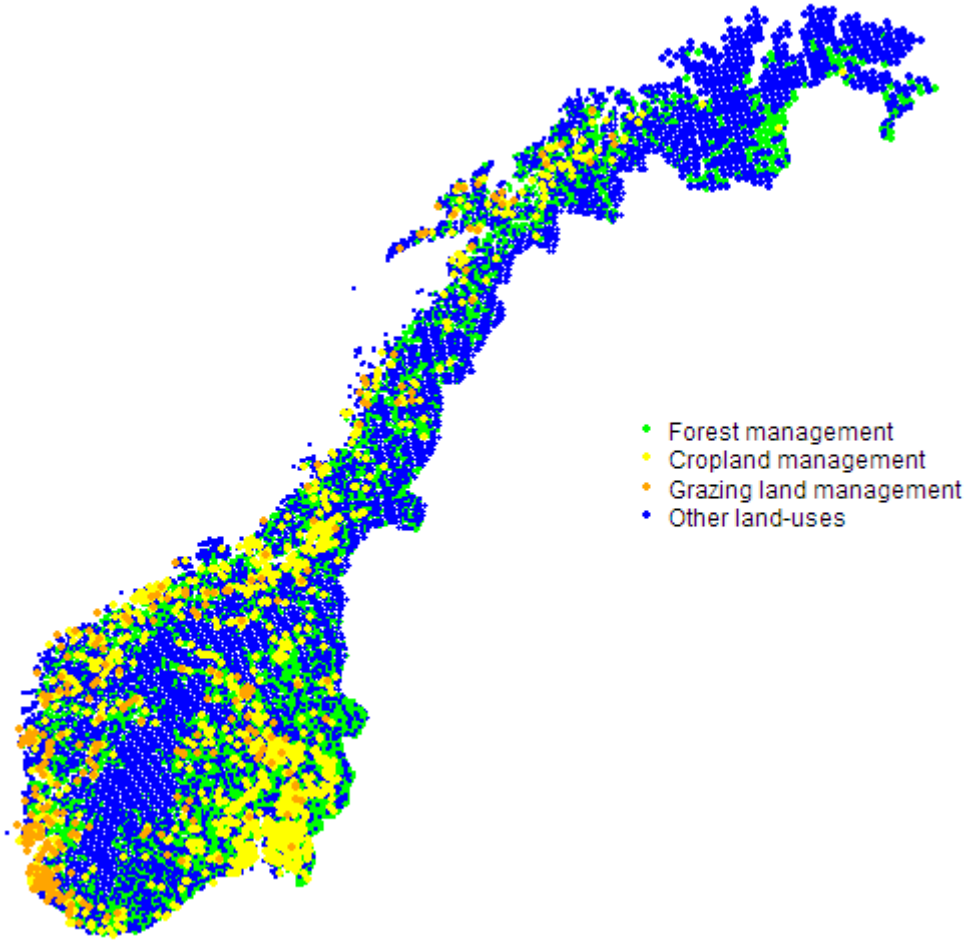


Figure 11.2 Spatial distribution (approximate location of sample plots) of elected Article 3.4 activities for 2016 in Norway. Symbol sizes for plots with cropland or grazing land management activities are increased to improve the visibility of these activities.

11.3 Activity specific information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

Methods and activity data used to calculate the emissions reported under KP-LULUCF are in general identical to those applied in the reporting under the Convention (chapter 6). They are in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) and we refer to chapter 6 for detailed descriptions. In this chapter we provide information about methods specific for reporting under KP. All relevant methods are in accordance with the 2013 IPCC KP supplement (IPCC 2014a) and the IPCC 2013 Wetlands Supplement (IPCC 2014b).

11.3.1.1 Differences in the methodologies used for the KP and the Convention reporting

For AR and D, the methods used to estimate carbon stock changes were identical to those used for the corresponding land-use change. However, there was one difference in the carbon stock change rate for dead wood used for other land converted to forest land. The rate 0.025 t C ha^{-1} yr^{-1} was used in KP to better reflect a human-induced conversion, whilst 0.013 t C ha^{-1} yr^{-1} was used in the Convention reporting. Carbon stock changes (CSC) in living biomass must be divided between above- and belowground for all KP activities. For cropland management, the Tier 1 method for living biomass does not provide this division. We assumed that 30 % of the loss or gains occur belowground and 70 % aboveground. No other methodological differences exist for CSC estimation in any pools between the Convention and the KP reporting. Further, for ARD areas after a period of 20 years (with transition from one assumed equilibrium to another) the CSC in soil, deadwood and litter are assigned emissions reflecting their current land use, while their area is still included in the appropriate ARD categories.

To estimate direct and indirect N_2O emissions under FM and AR, respectively, we used a multiplication factor based on the percentage of the area under AR or FM of the total forested land (AR + FM area). The multiplication factor is calculated annually. The same approach was applied for biomass burning.

Methods used to estimate N_2O from N mineralization-immobilization due to soil C loss and emissions and removal from drained and rewetted organic soils were also identical to those used in the reporting under the Convention.

11.3.2 Uncertainty estimates

Sampling errors for proportions (areas) and totals (carbon stock change) are estimated according to standard sampling methodology based on the 5 most recent years of NFI data (see section 6.3.4). The sample plots in the NFI are systematically distributed. Since we have assumed random sampling, the variances are conservative estimates. Uncertainties in terms of standard errors related to the estimates of area are shown in Table 11.5. Uncertainties in terms of standard errors related to the estimates of net C stock changes are shown in Table 11.6.

Table 11.5 Uncertainty of annual area estimates.

Activity	Area 2SE (%)
Afforestation/Reforestation	24
Deforestation	14
Forest management	2
Cropland management	7
Grazing land management	13

Uncertainties in C stock changes are dependent on area uncertainties and the variability in the C stock changes per unit area. Uncertainties for the C stock change estimates in living biomass are based on standard sampling methodology for the estimates of totals, except for CM where default uncertainties are given and for GM where it is based on expert judgement. Uncertainties for the C stock change estimates per hectare in the dead wood, litter, and soil pools were based on expert judgment, except for FM. Uncertainties in area estimates and per hectare estimates were combined to arrive at the final estimates presented in Table 11.6. For FM, the estimates for dead wood, litter, and the soil pool were estimated using Yasso07-model and a Monte-Carlo method was applied to determine the associated uncertainty (section 6.4.1.2). Assumptions behind the expert judgments used for AR and D are described in chapter 6, see section 6.4.2.1.

Table 11.6 Uncertainties of annual C stock changes.

Activity	AG and BG living biomass 2SE (%)	Dead wood + litter 2SE (%)	Mineral soils 2SE (%)	Organic soils 2SE (%)
Afforestation/Reforestation	47	100 – 200	50 – 100	50
Deforestation	47	100 - 182	50 – 100	19
Forest management	12	15	15	50
Cropland management	75*****	NO	50	19
Grazing land management	115**	NO	91	50

** Uncertainties for living biomass in cropland management (fruit orchards) are based on the default method. ** Expert judgement.*

11.3.3 Changes in data and methods since the previous submission (recalculations)

Recalculation for the year 2015 for KP-LULUCF for each activity is shown in Table 11.7.

Table 11.7 Recalculated GHG emissions (kt CO_2-equivalents yr^{-1}) for 2015 per activity of KP-LULUCF.

	Emissions for 2015 (kt CO_2-equivalents yr^{-1})		
KP activity	**NIR 2018**	**NIR 2017**	**Absolute difference**
Afforestation	-542.97	-589.78	46.81
Deforestation	2 250.70	2 614.14	-363.44
Forest management	-27 797.83	-28 467.39	669.56
Cropland management	1 773.47	1 789.44	-15.97
Grazing land management	1.53	68.47	-66.94
Total	-24 315.10	-24 585.12	270.02

For the NIR 2018, the following methodological changes have affected all land-use categories and are therefore not listed explicitly below:

- The absolute values of gains and losses are larger this year because we changed the method from NFI plot-level net changes to plot-level gains and losses. This means, a plot can have both gains and losses. Until last year, this was not possible. The total net change was also affected by this change.
- New above- and belowground birch biomass functions by Smith et al. (2014) and Smith et al. (2016) are now used instead of Marklund.

For afforestation (A) and reforestation (R) and deforestation (D), an error found in the 2015 submission for ARD (pools SOM, litter, and deadwood) on mineral soil was corrected. The correction ensured that ARD areas after a period of 20 years (with transition from one assumed equilibrium to another) consistently are assigned emissions reflecting their current land use.

Total recalculations for the KP-LULUCF submissions for the year 2015[39] resulted in reduced C uptake of 270 kt CO_2-equivalents from -24 585 kt CO_2-equivalents (NIR 2017) to -24 315 kt CO_2-equivalents (NIR 2018) including non-CO_2 emissions. The majority of the change was due to the reduction in CO_2 uptake for FM (reduced by almost 670 kt CO_2-equivalents). The CO_2 uptake for AR decreased by 47 kt CO_2-equivalents, while emissions reduced by 363 kt CO_2-equivalents for D, by 16 kt CO_2-equivalents for CM, and by 67 kt CO_2-equivalents for GM, including non-CO_2 emissions. Recalculation for CH_4 emissions were minor and reduced total KP-LULUCF CH_4 emissions by 2 kt CO_2-equivalents, from 159 kt CO_2-equivalents to 157 kt CO_2-equivalents. N_2O emissions were also recalculated and decreased by 9 kt CO_2-equivalents from 346 kt CO_2-equivalents to 337 kt CO_2-equivalents. Recalculations of CO_2 emissions were more important and these are described below for each KP activity.

11.3.3.1 Afforestation and reforestation – KP. A.1

- Total CO_2 sequestration for AR decreased by 49 kt CO_2 from 615 kt CO_2 to 566 kt CO_2, which was primarily due to the increased C uptake of 23 kt CO_2 in the aboveground living biomass (from 162 CO_2 to 185 kt CO_2) and by 5 kt CO_2 in the belowground biomass (from 50 kt CO_2 to 55 kt CO_2). C uptake in the litter pool decreased by 105 kt CO_2 from 538 kt CO_2 to 433 kt CO_2.

[39] Note that recalculations for KP-LULUCF, as decribed in the following, refer to absolute values of the activities, and not the value that is accounted for under KP2.

CO_2 emissions in the mineral soil pool were reduced by 26 kt CO_2 from 115.6 kt CO_2 to 89.7 kt CO_2. All recalculations were due to the changes in the NFI area and living biomass data. NFI harvest data are used to distribute the known total harvests to the reported activities such as afforestation. Due to the aforementioned change from plot-level net change to plot-level gains and losses, NFI harvest data for 1990-1995 now provided some contribution (in the range of 250-209 t C), which was NO previous to the 2018 NIR. The change did not affect the 2015 data for net CO_2 emissions/removals for AR (0.03 kt CO_2 in both the 2017 and 2018 report).

11.3.3.2 Deforestation – KP. A.2

- Total CO_2 emissions for deforestation were reduced by 358 kt CO_2 from 2 582 kt CO_2 to 2 224 kt CO_2. This was caused by the combination of reduced C emissions in litter (289 kt CO_2 from 1 583 kt CO_2 to 1 294 kt CO_2), dead wood (23.7 kt CO_2 from 130 kt CO_2 to 106 kt CO_2), and below ground biomass (9.5 kt CO_2 from 146.7 kt CO_2 to 137.2 kt CO_2). Also increased removals from mineral soils (31 kt CO_2; from 98 kt CO_2 to 129 kt CO_2) and emissions from aboveground biomass (3.7 kt CO_2 from 528 kt CO_2 to 531.7 kt CO_2). As well as decreased emissions from organic soils (10 kt CO_2 from 293 kt CO_2 to 282 kt CO_2). Recalculations for all C pools were due to the updates in the NFI data.

11.3.3.3 Forest management – KP.B.1

- Carbon removals in the FM activity reduced by 670 kt CO_2. The majority of the reduction occurred in the living biomass; removals from aboveground biomass was reduced by 1 722 kt CO_2 from 18 318 kt CO_2 to 16 596 kt CO_2 and from belowground by 638 kt CO_2 from 4 583 kt CO_2 to 3 945 kt CO_2. The removals in the litter, dead wood, and mineral soil pools all increased by 1 351 kt CO_2 (from 5 372 kt CO_2 to 6 723 kt CO_2), 273 kt CO_2 (from 1 084 kt CO_2 to 1 357 kt CO_2), and 31 kt CO_2 (from 123 kt CO_2 to 154 kt CO_2), respectively. NFI harvest data are used to distribute the known total harvests to the reported activities such as forest management. Due to the aforementioned change in the 2018 NIR from plot-level net change to plot-level gains and losses, removals from FM 2015 increased with 35.83 kt CO_2 from -30.50 kt CO_2 to -66.33 kt CO_2.

11.3.3.4 Cropland management – KP.B.2

- Total CO_2 emissions for the CM activity were reduced by 16 kt CO_2 (from 1 700 kt CO_2 to 1 684 kt CO_2). Removals in aboveground biomass increased by 1.5 kt CO_2 from 3 kt CO_2 to 4.5 kt CO_2. Removals in belowground biomass increased by 0.7 kt CO_2 from 1.3 kt CO_2 to 2 kt CO_2. The removals in the mineral soil pool increased by 2.8 kt CO_2 from 68.7 kt CO_2 to 71.5 kt CO_2. The emissions in the organic soil pool decreased by 11 kt CO_2 from 1 773 kt CO_2 to 1 762 kt CO_2.

11.3.3.5 Grazing land management – KP. B.3

- Recalculations for the GM activity resulted in reduced emissions by 66 kt CO_2 from 61 kt CO_2 to -5 kt CO_2. This was primarily the result of the combined effect of increased C uptake in above- and belowground living biomass (38 kt CO_2 for aboveground and 15 kt CO_2 for

belowground) and reduced emissions from organic soils 12 kt CO_2. Recalculation for living biomass was due to the updates in the NFI database. The change in the NFI database affected the area of organic soils under GM.

11.3.4 Omissions of carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

No omissions were made of any C pools or GHG emissions.

11.3.5 Provisions for natural disturbances

Norway does not apply the provisions for natural disturbances to its accounting in the second commitment period.

11.3.6 Emissions and removals from the harvested wood product pool

The reporting of emissions and removals from the HWP pool under the KP is done in accordance with Decision 2/CMP.7, Annex § 16 and 27-32, and Decision 2/CMP.8 Annex II, § 2(g)(i-vii). Emissions from HWP in solid waste disposal sites are reported in the waste sector. As the FMRL is not based on a projection (but the 1990 base year), it is not relevant to provide further information in this regard. There is no double accounting from the HWP pool in the second commitment period because emissions/removals were not accounted under the first commitment period according to the Marrakesh Accords (Decision 11/CP.7), thus there is no need to exclude these emissions/removals from the accounting under the second commitment period. For reporting under deforestation, the Tier 1 method is applied and carbon stock changes in the HWP pool are reported as zero (NO).

Norway uses the Tier 2 method to estimate carbon stock change in the harvested wood products pool. The calculations follow (IPCC 2014a) including: the three default HWP categories sawnwood, wood-based panels, and paper and paperboard along with their associated half-lives and conversion factors.

All the activity data are obtained from FAO forestry statistics[40]. The initial unit is m^3, except for the pulp and paper, where the unit is metric ton. Exported and domestically consumed HWP is calculated and reported separately. The inflow data of domestically produced and consumed HWP are based on consumption (Production – Export), since including export could result in double counting.

The following are specifics from IPCC (2014a) and applicable only to the reporting of HWP under KP and do not apply for the Convention reporting:

The annual fraction of feedstock for HWP production originating from domestic harvest is estimated applying Eq. 2.8.1 (IPCC 2014a)

$$f_{IRW}\,(i) = \frac{IRW_p\,(i) - IRW_{EX}\,(i)}{IRW_p\,(i) + IRW_{IM}\,(i) - IRW_{EX}\,(i)}$$

[40] FAO data available from: http://www.fao.org/faostat/en/#data/FO

where f_{IRW} (i) = fraction of industrial roundwood for the domestic production of HWP originating from domestic forests in year *i;* IRW_p (i) = domestic production of industrial roundwood in year i*;* IRW_{IM} (i) = import of industrial roundwood in year *i;* IRW_{EX} (i) = export of industrial roundwood in year *i.*

The annual fraction of feedstock for paper and paperboard production originating from domestically produced wood pulp is estimated applying Eq. 2.8.2 (IPCC 2014a)

$$f_{PULP}\,(i) = \frac{PULP_p\,(i) - PULP_{EX}\,(i)}{PULP_p\,(i) + PULP_{IM}\,(i) - PULP_{EX}\,(i)}$$

where f_{PULP} (i) = fraction of domestically produced pulp for the domestic production of paper and paperboard in year *i;* $PULP_p$ (i) = production of wood pulp in year *i;* $PULP_{IM}$ (i) = import of wood pulp in year *i;* $PULP_{EX}$ (i) = export of wood pulp in year *i.*

The annual fraction of feedstock for HWP originating from forest activities under Article 3.3 and 3.4 (FM or AR or D) in year *i* is calculated from the total harvest (kt C) applying Eq. 2.8.3 (IPCC 2014a)

$$f_j\,(i) = \frac{harvest\,(i)}{harvest_{Total}\,(i)}$$

where f_j (i) = fraction of harvest originating from the particular activity *j* in year *i, j* = activity FM or AR or D in year *i* (aboveground C losses in living biomass as reported in the CRF tables 4(KP-I)A.1, 4(KP-I)A.2, and 4(KP-I)B.1).

The annual HWP resulting from domestic harvests related to activities under Article 3.3 and 3.4 was estimated as the product of the production of the commodity, the annual fraction of the feedstock, and the fraction of the domestic feedstock for each of the HWP categories applying IPCC 2014 Eq. 2.8.4.

The carbon stock change of the HWP pool was estimated for each of the KP activities AR and FM by

$$HWP_j\,(i) = [HWP_p\,(i) \times f_{DP}\,(i) \times f_j\,(i)]$$

where HWP_j (i) = the reported estimates in the CRF tables = HWP resulting from domestic harvest associated with activity *j* in year *i*, in $m^3\ yr^{-1}$ or $Mt\ yr^{-1}$, HWP_p (i) = production of the particular HWP commodities (i.e. sawnwood, wood-based panels, and paper and paperboard) in year *i*, in $m^3\ yr^{-1}$ or $Mt\ yr^{-1}$, f_{DP} (i) is the fraction of domestic feedstock for the production of the particular HWP category originating from domestic forest in year *i*, and f_{DP} (i) = f_{IRW} (i) for HWP categories 'sawnwood' and 'wood-based panels', f_{DP} (i) = (f_{IRW} (i) x f_{PULP} (i)) for HWP category 'paper and paperboard' with: f_{IRW} (i) = 0 if f_{IRW} (i) < 0 and f_{PULP} (i) = 0 if f_{PULP} < 0, where: f_j (i) = fraction of domestic feedstock for the production of the particular HWP category originating from domestic forests in the activity *j* = FM or AR.

For land subjected to deforestation, gains and losses in the HWP pool is reported as NO to resemble instantaneous oxidation.

Harvests (h) in a reporting year were reported as

$$h = l \cdot f$$

where l are the reported losses of the aboveground living biomass in the year of interest and the activity considered, and f = 0.564 is the stem fraction. The stem fraction is the average proportion of stem biomass of the total biomass and is calculated from all registered trees on NFI plots in the season prior to harvest independent of tree species.

11.3.7 Information on whether emissions and removals have been factored out

Emissions and removals have not been factored out.

11.4 Article 3.3

11.4.1 Activities under Article 3.3 began on or after 1 January 1990 and before 31 December of the last year of the commitment period and are directly human-induced

The NFI covers the period of consideration. The permanent plots were established between 1986 and 1993. Since then the plots have been monitored continuously beginning with the first re-inventory in 1994 (see chapter 6.3). By repeatedly assessing the land cover and land use on each plot, the NFI records land-use changes to and from forest land.

In order to be included as AR and D activities under Article 3.3, land-use changes must be directly human-induced. For AR and D, land-use changes are considered directly human-induced in the following two cases: (1) all conversions to forest land from land-use categories which are considered managed (cropland, grassland, and settlements); and (2) conversions from wetlands or other land (non-managed lands) to forest land, when actual evidence of management is present. Such evidence consists of planting and ditching, which can both be documented via the current status of the forest in combination with aerial photos. Land-use changes from wetlands or other land to forest land is considered to be the natural expansion of the forest if no direct evidence of management is present. Land-use changes between forest land, wetlands, or other land can either be reported as FM in cases of non-human induced changes, or reported as AR or D for human-induced changes (see Table 11.2).

11.4.2 How harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

Young natural stands and all plantations established for forestry purposes, as well as forests that are temporarily unstocked as a result of e.g. harvest or natural disturbances, are included under forest management and not treated as deforestation. The NFI teams assess land cover and land use according to national criteria (see Table 6.10) that are defined in the field protocol (NFLI 2008). They are also trained to distinguish between forest management operations and land-use change. As a general rule, land will be considered temporarily unstocked if the stumps and ground vegetation are still present, and there is no construction work done on the area. The area is considered deforested if the ground vegetation is removed (e.g. if the area is leveled), and/or other construction work is done on the area.

11.5 Article 3.4

11.5.1 Activities under Article 3.4 occurred since 1 January 1990 and are human-induced

The NFI covers the period of consideration for all activities elected (FM, CM, and GM). The permanent plots were installed from 1986 until 1993. From 1994 and onwards the plots have been monitored continuously. As described above, certain criteria apply.

11.5.2 Information relating to Cropland Management, Grazing Land Management, Revegetation, and Wetland Drainage and Rewetting, if elected, for the base year

To identify the areas included in the cropland management (CM) and grazing land management (GM) activities in the base year (1990), we define the management practices identically to those on cropland and grassland as defined under the Convention. The management practices on the cropland land-use class are the same as those that take place on land included under the CM activity. This is the same for the grassland land-use class and the GM activity. The only difference is that CM or GM can include land that was cropland or grassland in 1990 and has since been converted to a non-forest category (e.g. settlements). Under the KP reporting, land can only leave an activity if it enters another activity on a higher hierarchical level. Therefore, the following land use and land-use change classes[41] are considered under CM and GM:

CM = **CC** + **GC** + **WC** + **SC** + **CS** + CG + CW + CO,

GM = **GG** + **WG** + **SG** + OG + **GO** + **GS** + GW.

Conversion categories that have occurred in Norway are in bold and underlined. Due to the 20 year conversion rule applied under the Convention, areas of some land-use change classes were not identical to those reported under the Convention. Under the Convention, areas in the categories land converted to cropland and land converted to grassland will be transferred to CC or GG after 20 years. Under the KP, these areas will therefore automatically stay in CM or GM even after 20 years. However, areas of cropland or grassland converted to other land-uses would also be transferred to the remaining category of that land-use under the 20 year rule. We therefore did not apply the 20 year rule for the CS, GS, and GO land-use change classes that are included in CM or GM. This is illustrated in the CRF tables (4(KP-I)B.2 and 4(KP-I)B.3) in the sub-division under Norway for CM and GM.

[41] The land-use change class abbreviations are: C = Cropland, G = Grassland, W = Wetlands, S = Settlements, and O = Other land. The first letter in the abbreviation is the starting class and the second letter is the class in which the land remains or is converted to. For example, the abbreviation CC means “Cropland remaining Cropland” and GC means “Grassland converted to Cropland”.

11.5.3 Emissions and removals from Forest Management, Cropland Management, and Grazing land Management under Article 3.4 are not accounted for under activities under Article 3.3

Neither the NFI used to track land areas, nor the methodologies applied to estimate emissions and removals from activities under Article 3.4 allow any double counting.

11.5.4 Conversion of natural forests to planted forests

This is not applicable for Norway.

11.5.5 Methodological consistency between the reference level and forest management reporting and technical corrections

Norway has chosen 1990 as the base year for the forest management reference level (FMRL). The FMRL presented in the appendix to decision 2/CMP.7 has been recalculated. Hence, a technical correction is required.

The corrected FMRL and the technical correction were obtained in the following way:

- First, all FM-related net C stock changes in 1990 (kt CO_2 equivalents.) were added to obtain the corrected FMRL.
- Second, the technical correction was obtained by subtracting the original FMRL from the corrected FMRL. The technical correction is the same for all years. See Table 11.8 for more details and the current technical correction.

The biggest differences compared to the original FMRL are due to:

- Increased net carbon stock gains in living biomass due to a changed interpolation procedure.
- Reduced net uptake in the dead organic matter and mineral soil pools since Yasso07 is now used on a NFI plot scale.
- The inclusion of HWP.
- Increased emissions from drained organic soils since the default Tier 1 emission factors have increased from the 2003 good practice guidance (IPCC 2003) to the IPCC 2013 Wetlands Supplement (IPCC 2014b).
- The use of new country-specific biomass functions for birch by Smith et al. (2014) and Smith et al. (2016).

Further details on the methodological changes have been described in the relevant sections of chapter 6 LULUCF.

Table 11.8 Components of the original and corrected Forest Management Reference Level (FMRL).

Source/sink	Original FMRL (kt CO_2-eq./year)	Corrected FMRL (kt CO_2-eq./year)
Living biomass [a]	-6 420	-10 188.68
Dead organic matter [b]	-2 040	-2 564.50
Mineral soils [c]	-3 060	-48.99
Biomass burning (Wildfires – N_2O and CH_4) [d]	2	1.21
Fertilization [e]	1	6.35
Drainage of (organic) soils under Forest management [f]	150	986.31
HWP [g]	NE	-1 082.59
N_2O emissions due to land-use conversions and management change in mineral soils [h]	NE	NO
Sum	**-11 370** [i]	**-12 890.88** [j]
Forest Management Reference Level (FMRL)	**-11 400** [k]	
Technical correction		**-1 490.88**
Corrected FMRL		**-12 890.88**

[a] *All Norwegian forests including mountain forest and Finnmark were considered in the original FMRL. Sum of "Above" (cell S11) and "Below-ground biomass Net change" (cell V11) in the CRF table "4(KP-I)B.1 1990" converted to CO_2 equivalents. (C stock change x 44/12).*

[b] *Below the coniferous limit in the original FMRL. All Norwegian forests including mountain forest and Finnmark in the corrected FMRL. Sum of "Litter" (cell W11) and "dead wood" (cell X11) in the CRF table "4(KP-I)B.1 1990" converted to CO_2 equivalents.*

[c] *Below the coniferous limit and denoted "Soil organic matter" in the original FMRL. The value for the corrected FMRL is obtained from cell Y11 of the CRF table "4(KP-I)B.1 1990" converted to CO_2 equivalents.*

[d] *Sum of CH_4 (cell I27) and N_2O (cell J27) converted to CO_2 equivalents. for "Forest management" in the CRF table "4(KP-II)4 1990". GWP were 25 for CH_4 and 298 for N_2O (see http://www.ipcc.ch/publications_and_data/ar4/wg1/en/errataserrata-errata.html#table214).*

[e] *Direct and indirect N_2O emissions from N fertilization (cell D13) in the CRF table "4(KP-II)1 1990" converted to CO_2 equivalents. for "Forest management".*

[f] *Only included CO_2 and N_2O in the original FMRL. Also contains CH_4 in the corrected FMRL. "Organic soils" in the table "4(KP-I)B.1 1990" (cell Z11) and "Drained organic soils" in the CRF table "4(KP-II)2 1990" (cells E17 and F17) converted to CO_2 equivalents.*

[g] *Cell M9 in the CRF table "4(KP-I)C 1990".*

[h] *This source is now included but was 0 for 1990 in the current reporting (cell E17 in the CRFtable "4(KP-II)3 1990").*

[i] *Sum refers to the FMRL as given in Table 3 in the submission to the UNFCCC from March 2011, available: http://unfccc.int/files/meetings/ad_hoc_working_groups/kp/application/pdf/awgkp_norway_2011.pd. The actual value is -11367 but the values were reported in Mt and rounded to the second decimal, ie. 11.4 Mt CO_2-equivalents./year cf. footnote [k].*

[j] *Since the 2016 submission, this value is taken from cell E11 of the current CRF table "4(KP) 1990" directly, rather than adding the values in this table. Therefore, the last digit of the value is not exactly equal to the sum of the sources/sinks above. A possible difference of the last digit is due to rounding.*

[k] *FMRL as inscribed in the appendix to the annex to Decision 2/CMP.7, ie. -11.400 (kt CO_2-equivalents./year).*

11.5.6 Information about emissions or removals resulting from the harvest and conversion of forest plantations to non-forest land

This is not applicable for Norway.

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4.

According to the IPCC guidelines, the key-category analysis for KP can be based on the assessment made for the Convention inventory reporting (see chapter 1.5 for details). Additionally, the key categories are reported in CRF table NIR 3. Both Approach 1 and Approach 2 assessments are made for the whole inventory including the LULUCF sector (Table 1.1; Table 1.2). The key-category analysis is made specific to sink/source categories per individual land-use conversion (e.g. forest land converted to cropland instead of land converted to cropland). The analysis can, therefore, not be directly translated into the KP activities, but by combining the information in Table 6.6 and the relation between Convention land-use categories and KP activities shown in Table 11.2, we can derive the key categories. Any sink/source under the AR, D, CM or GM activities was considered as a key category if at least one of the land-use transitions within the activity was identified as a key category in the analysis.

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) reports for 2017 (for the first and the second commitment period) are reported as annex VII to this document and will be made available at the UNFCCC website. The name of the files are SEF_NO_2017_CP1.xlsx and SEF_NO_2017_CP2.xlsx.

12.2 Summary of information reported in the SEF tables

The tables below show the amount of different units; AAUs, ERUs, CERs, tCERs, lCERs and RMUs, from CP1 and CP2 within the registry, and on which account type these units are present at the end of 2017.

Table 12.1 AAUs from CP1

AAUs	**# CP1 UNITS**
Party holding account	5 984 774
Entity holding account	85 225
Article 3.3/3.4 net source cancellation accounts	1 824 462
Other cancellation accounts	8 433 893
Retirement account	253 134 092
TOTAL amount	**269 462 446**

Table 12.2 ERUs from CP1 and CP2

ERUs	**# CP1 UNITS**	**# CP2 UNITS**
Party holding account	NO	738 305
Entity holding account	NO	84 848
Other cancellation accounts	1 098 212	
Retirement account	2 605 670	NO
TOTAL amount	**3 703 882**	**823 153**
TOTAL CP1 + CP2 ERUs	**4 527 035**	

Table 12.3 CERs from CP1 and CP2

CERs	**# CP1 UNITS**	**# CP2 UNITS**
Party holding account	NO	15 945 955
Entity holding account	NO	619 315
Other cancellation accounts	19 701 689	
Voluntary cancellation accounts		151 128
Retirement account	9 260 279	NO
TOTAL amount	**28 961 968**	**16 716 398**
TOTAL CP1 + CP2 CERs	**45 678 366**	

Table 12.4 tCERs from CP1 and CP2

tCERs	# CP1 UNITS	# CP2 UNITS
Party holding account	NO	NO
Entity holding account	NO	NO
Other cancellation accounts	35 424	
Voluntary cancellation accounts		NO
Retirement account	NO	NO
TOTAL amount	**35 424**	**NO**
TOTAL CP1 + CP2 tCERs	**35 424**	

Table 12.5 RMUs from CP1 and CP2

RMUs	# CP1 UNITS	# CP2 UNITS
Party holding account	NO	NO
Entity holding account	NO	NO
Article 3.3/3.4 net source cancellation accounts	9 947 523	NO
Other cancellation accounts	7 333 333	
Voluntary cancellation accounts		NO
Retirement account	1 824 462	NO
TOTAL amount	**19 105 318**	**NO**
TOTAL CP1 + CP2 RMUs	**19 105 318**	

The registry did not contain any lCERs from CP1 or CP2.

The total amount of the units in the Norwegian registry at the end of 2017 corresponded to 338 808 589 tonnes CO_2 eq.

The following account types did not contain any units:

- lCER Replacement Account for Expiry (CP1 and CP2)
- lCER Replacement Account Non-Submission Report (CP1 and CP2)
- lCER Replacement Account Reversal in Storage (CP1 and CP2)
- Mandatory Cancellation Account CP2
- Net Source Cancellation Account CP2
- Non-compliance Cancellation Account (CP1 and CP2)
- Retirement Account CP2
- tCER Replacement Account for Expiry (CP1 and CP2)

The following account types did not exist in the registry:

- Article 3.1 ter and quarter ambition increase cancellation account
- Article 3.7 ter cancellation account
- Cancellation account for remaining units after carry-over
- lCER cancellation account for expiry
- lCER cancellation account for reversal of storage
- lCER cancellation account for non-submission of certification report
- Previous Period Surplus Reserve account (PPSR)
- tCER cancellation account for expiry

12.3 Discrepancies and notifications

Table 12.6 Discrepancies and notifications

Annual Submission Item	Reporting information
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	No discrepant transaction occurred in 2017.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2017.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2017.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as of 31 December 2017.
15/CMP.1 annex I.E paragraph 17 Actions and changes to address discrepancies	No discrepant transactions occurred in 2017.

We have not submitted the R2- R5 reports since none of these events have occurred in the registry, and these reports would thus be empty.

12.4 Publicly accessible information

Information relating to the Norwegian registry, which is deemed to be public information, can be accessed via the Kyoto Protocol Public Reports page in the national registry. The SEF reports may also be downloaded from the registry web site, http://www.miljodirektoratet.no/no/Tema/klima/CO2_kvoter/Klimakvoteregisteret/public_reports/. In accordance with the requirements of the Annex 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 line with the data protection requirements of Regulation (EC) No 45/2001 and Directive 95/46/EC and in accordance with Article 110 and Annex XIV of Commission Regulation (EU) No 389/2013, the information on account representatives, account holdings, account numbers, legal entity contact information, all transactions made and carbon unit identifiers, held in the EUTL, the Union Registry and any other KP registry (required by paragraph 45 and paragraph 48) is considered 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 2017.

Holding and transaction information of units (Paragraph 47)

General remarks

Holding and transaction information is provided on a holding type level due to more detailed information on transactions being considered confidential according to Article 110 of Commission Regulation (EU) no 389/2013, ref. paragraph 47(a), 47(d), 47(f) and 47(l).

Article 110 of Commission Regulation (EU) no 389/2013 provides that "Information, including the holdings of all accounts, all transactions made, the unique unit identification code of the allowances and the unique numeric value of the unit serial number of the Kyoto units held or affected by a transaction, held in the EUTL, the Union Registry and other KP registry shall be considered confidential except as otherwise required by Union law, or by provisions of national law that pursue a legitimate objective compatible with this Regulation and are proportionate".

Paragraph 47(b)

No AAUs were issued on the basis of the assigned amount pursuant to Article 3, paragraphs 7 and 8 in 2017.

Paragraph 47(c)

Norway does not host JI projects. Therefore no ERUs have been issued on the basis of Article 6 projects.

Paragraph 47(e)

No RMUs were issued in 2017.

Paragraph 47(g)

No ERUs, CERs, AAUs or RMUs were cancelled on the basis of activities under Article 3.3 and 3.4 in 2017.

Paragraph 47(h)

No ERUs, CERs, AAUs and RMUs were cancelled following determination by the Compliance Committee that the Party does not comply with its commitment under Article 3, paragraph 1 in 2017.

Paragraph 47(i)

The total quantity of other ERUs, CERs, AAUs and RMUs cancelled in 2017 were 2 584 394 units.

Paragraph 47(j)

No ERUs, CERs, AAUs nor RMUs were retired in 2017.

Paragraph 47k

Norway carried over 5 459 924 ERUs from the previous commitment period in 2017. Norway did not carry over CERs or AAUs from the previous commitment period in 2017.

Paragraph 47(a) bis

Norway did not have any previous period surplus reserve account (PPSR) at the beginning of 2017, and therefore had no AAUs in such an account.

Paragraph 47(h) bis

No AAUs were cancelled under Article 3, paragraphs 1 ter and 1 quarter in 2017.

Paragraph 47(h) ter

No AAUs were cancelled under Article 3, paragraph 7 ter in 2017.

12.5 Calculation of the commitment period reserve (CPR)

The reporting of the calculation of the commitment period reserve, pursuant to decision 11/CMP.1, 15/CMP1, 1/CMP.8 and 3/CMP.11 is as follows:

The commitment period reserve is the lower of the two values given by 90 percent of the assigned amount and eigth times 100 percent of the total emissions in the most recently reviewed inventory.

The assigned amount for Norway for the Kyoto Protocol's second commitment period has been set to 348 914 303 t CO_2 equivalents through the review of our report to facilitate the calculation of its assigned amount (FCCC/IRR /2016/NOR).

90 per cent of the assigned amount:

The review report (FCCC/IRR/2016/NOR) determined that with the appropriate rounding rules, 90 per cent of the assigned amount equals:

= 314 022 874 ton CO_2 equivalents

100 per cent of eight times its most recently reviewed inventory:

The common approach/guidance is that for this approach of calculating the CPR, the most recent inventory submission should be used because, at the end of the review, this becomes the most recently reviewed inventory. Hence, the emissions without LULUCF in 2016 (53 242 518 ton CO_2 equivalents) are used. With the appropriate rounding rules, 100 per cent of eight times the most recently reviewed inventory equals:

= 425 940 144 ton CO_2 equivalents

For Norway, the lowest number is equivalent to 90 per cent of Norway's assigned amount. Norway's commitment period reserve is therefore:

= 314 022 874 ton CO_2 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. The National Greenhouse Gas Inventory System in Norway consists of three parts; the Norwegian Environment Agency (national entity), Norwegian Institute for Bioeconomy Research and Statistics Norway. Statistics Norway is undergoing a reorganization of staff and work areas between its two offices/locations; Oslo and Kongsvinger. The experts compiling the emission inventory for all sectors except LULUCF, have up to now been located in Oslo. This group of experts will through 2018 be replaced by a new staff located in Kongsvinger. The long term goal of this relocation is to improve data quality by increasing the contact and collaboration between the departments producing the input (activity) data and the inventory compilers.

14 Information on changes in national registry

Table 14.1 shows the changes to the national registry of Norway that have occurred in 2017.

Table 14.1 Changes to the national registry of Norway in 2017.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	None
15/CMP.1 Annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	The version of the EUCR released after 8.0.7 (the production version at the time of the last Chapter 14 submission) introduced minor changes in the structure of the database. These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model is provided in Annex A. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced since version 8.0.7 of the national registry are listed in Annex B. Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of 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 regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced since version 8.0.7 of the national registry are listed in Annex B. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission.
The previous Annual Review recommendations	See below

The latest annual review report for Norway is FCCC/ARR/2016/NOR. In this review report, the recommendation concerning the national registry made in the previous review report was considered as resolved and no additional finding concerning the national registry was made during the review of the 2016 technical review.

The latest Standard Independent Assessment Reports for Norway are SIAR/2076/1/2 for part 1 (completeness) and SIAR/2017/2/2 for part 2 (substance). There was one recommendation concerning the Norwegian national registry in the SIAR reports.

Table 14.2 Follow-up to recommendations for the registry.

Reference	**Recommendation description**	**Response**
P1.2.13	In review of the accounting of the Kyoto Protocol units, the assessor identified that the information regarding the actions and changes taken to address discrepancies was not reported properly in the Party's NIR. The assessor recommends to add a statement in NIR saying that no actions were taken by the Party to address the issue	No actions or changes were made to address discrepancies

15 Information on minimization of adverse impacts in accordance with Art. 3.14

Norway has striven to follow a comprehensive approach to climate change mitigation from policy development started around 1990, addressing all sources as well as sinks, in order to minimise adverse effects of climate policies and measures of climate policies and measures on the economy. In developing environmental, as well as the economic and energy policy, Norway strives to formulate the policy on the polluter pays principle and to have a market-based approach where prices reflect costs including externalities.

As regards emissions of greenhouse gases, costs of externalities are reflected by levies and by participation in the European Emissions Trading Scheme (EU ETS). These instruments place a price on emissions of greenhouse gases. Norway believes that the best way to reduce emissions on a global scale, in line with the two degree target and striving for 1.5 degree limit, would ideally be to establish a global price on emissions. Pursuing a global price on emissions would be the most efficient way to ensure cost-effectiveness of mitigation actions between different countries and regions, and secure equal treatment of all emitters and all countries. This will help minimise adverse impacts of mitigation. For more information about levies on energy commodities and the design of the EU ETS, see Chapter 4. of the seventh National Communication.

Norway is involved in several initiatives that contribute to technology transfer and capacity building to developing countries in shifting the energy mix away from fossil fuels to more renewable energy systems. These initiatives are reported here as relevant activities under Article 3.14 of the Kyoto Protocol.

National strategy for green competitiveness

The government presented a national strategy for green competitiveness in October 2017. The aim of the strategy is to provide more predictable framework conditions for a green transition in Norway, while maintaining economic growth and creating new jobs. In October the government also appointed an expert commission to analyze Norway's exposure to climate risk.

Cooperation on carbon capture and storage

Both the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change have pointed out that CO2 capture and storage (CCS) will be an important mitigation tool. In order for CCS to become a viable mitigation tool, countries and companies need to invest in technology development and demonstration of CO2 capture and storage projects.

Carbon capture and storage (CCS) is one of five priority areas for enhanced national climate action. Norway strives to disseminate information and lessons learned from projects in operation in the petroleum sector, new large scale projects under planning and from research, development and demonstration projects. The information and lessons learned are shared both through international fora, and through bilateral cooperation with developing and developed countries.

Norway has a long experience with CCS. Since 1996, CO2 from natural gas production on the Norwegian shelf has been captured and reinjected into sub-seabed formations. The CCS projects from natural gas on the Sleipner, Gudrun and Snøhvit petroleum fields are the only CCS projects currently in operation in Europe and the only projects in the offshore industry.

The Technology Centre Mongstad (TCM) is the world's largest facility for testing and improving CO2 capture technologies. TCM has been operating since 2012, providing an arena for targeted development, testing and qualification of CO2 capture technologies on an industrial scale

Norway also provides funding for CCS projects abroad in cooperation with other countries and through existing programmes and institutions.

In Norway, funding for CCS research is provided through the CLIMIT programme. The CLIMIT programme is a national programme for research, development and demonstration of technologies for capture, transport and storage of CO2 from fossil-based power production and industry. The programme supports projects in all stages of the development chain, from long-term basic research to build expertise to demonstration projects for CCS technologies. Projects under the CLIMIT programme have yielded important results for the development of CCS in Norway and internationally.

In addition, a Centre for Environment-friendly Energy Research for CCS, NCCS, has been established. The centre is co-financed by the Research Council of Norway, industry and research partners.

The Norwegian Government has an ambition to realize at least one new full-chain CCS demonstration facility. The results from the feasibility studies[14], presented in July 2016, show that it is technically feasible to realize a CCS chain in Norway, but that the costs are relatively high compared to the current quota price in the EU ETS. A flexible transport solution and ample storage capacity can contribute to realising capture from further sources. That way, the initial investment on CO_2 infrastructure can be utilised by several projects. The government has continued the planning of a large scale CCS project in Norway, and concept studies are being conducted in 2017 and early 2018. The Norwegian Parliament will decide whether to continue the project into a Front End Engineering and Design (FEED) phase during the first half of 2018.

In order for CCS to play an effective role in climate change mitigation, international cooperation on developing and commercialising new technology is essential. Norway collaborates with other countries through a number of regional and international forums. Examples of such forums are North Sea Basin Task Force, Clean Energy Ministerial, Mission Innovation and The Carbon Sequestration Leadership Forum. Norway furthermore provides funding for CCS projects abroad in cooperation with other countries and through existing programmes and institutions. For example, Norway is currently supporting a CCS project in South Africa.

Cooperation with developing countries related to fossil fuels – "Oil for Development"

The Norwegian Oil for Development (OfD) programme, which was launched in 2005, 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 sound way. A description of the OfD program can be found at:

https://www.norad.no/en/front/thematic-areas/oil-for-development/. The programme is currently engaged in 12 countries, mainly in Africa.

The operative goal of the program is "economically, environmentally and socially responsible management of petroleum resources which safeguards the needs of future generations."

Petroleum plays an important role in an increasing number of developing countries. Oil and gas hold the promise of becoming vital resources for economic and social development. Unfortunately, in many cases it proves difficult to translate petroleum resources into welfare for the people. 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 can be useful for developing countries with proven petroleum resources, or countries that are in the exploration phase.

OfD takes a holistic approach meaning that management of petroleum resources, revenues, environment and safety are addressed in a coherent manner. Norwegian public institutions enter into long-term agreements with public institutions in partner countries. Assistance is directed towards three main outcomes: 1) policy makers set goals, define and assign responsibilities, 2) the authorities regulating the petroleum sector carry out their assigned responsibilities and 3) policy makers and regulatory authorities are held accountable for their management of the petroleum sector.

OfD assistance is tailor-made to the particular needs of each partner country. It may cover the designing and implementing legal frameworks, mapping of resources, environmental impact assessments, handling of licenses, establishing preparedness to handle accidents and oil spills, health, safety and environmental legislation, petroleum fiscal regimes and petroleum sovereign wealth fund issues as well as initiatives related to transparency, anti-corruption and climate change.

A Steering Committee formulates 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 Climate and Environment, The Ministry of Transport and Communications. The OfD secretariat resides in the Norwegian Agency for Development Cooperation (Norad). The OfD secretariat is responsible for coordination and implementation of the program. Norwegian embassies play a key role in the program, as they are responsible for the overall bilateral relations, have competence on the the local situation and have extensive development cooperation responsibilities. Key implementing institutions are the Norwegian Petroleum Directorate, the Norwegian Environment Agency, the Petroleum Safety Authority, the Norwegian Coastal Administration, the Norwegian Tax Administration and Statistics Norway. A range of research institutions, international organizations and consultancies are also involved. Furthermore, several national and international NGOs are contributing to the OfD initiative. These organizations are in particular involved in building civil society 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 cooperates with Statistics Norway and coordinates its activities with the Office of the Auditor General of Norway.

There have been no major changes to these policies and activities in 2017.

Cooperation with developing countries related to renewable energy – "Clean energy for Development"

Energy has been at the core of Norway's development assistance policy for several years. There has been a steady increase in funds allocated to clean energy activities during recent years, both within multilateral and bilateral development assistance. For various reasons priorities of the ODA changed significantly in 2015. Overall spending to clean energy for development was reduced and amounted to about NOK 500 million in 2017. The budget for 2018 is increasing again to 570 million NOK, and the Government is aiming at further increase for the next years.

Seven core countries receive most of the funding (Haiti, Liberia, Mozambique, Myanmar, Nepal, Tanzania, and Uganda), but the Initiative is also engaged on a smaller scale in some other countries.

Increased focus on energy issues and their importance in the climate agenda, coupled with a significant increase of funds allocated to energy related activities within Norwegian development assistance, required better coordination of Norwegian efforts. The Clean Energy for Development Initiative was launched in 2007 to address these challenges.

The overall objective of Norway's contribution to renewable energy is to contribute to access SDG 7 and the Paris agreement.

The main focus on the investments will be directed towards intervenstions that contribute ta an enabling environment for commercial and private investemenst in the energy sector. Important avtivities are policy dialogue, sector reforms, legislation, insitutional cooperation, planning and regional cooperation. The public power infrastructure, such as the distriution and transmission system is also important for private investments to take place and as such also an area for Norway's development cooperation. Increased access is supported by grant funding for extension of the electricity grid as well as off-grid solutions.

Further, Norway provide support for feasibility studies, training, infrastucture in order to reduce risk as incentives for private investors in power production.

The Norwegian Investment Fund for Developing Countries (Norfund) is providing risk financing as equity and loans to clean energy projects together with private investors. Over time, Norfund is investing half of its capital in clean energy. The current investments in clean energy from Norfund is approx. NOK 8 Billion. The Governemnet has increased fund allocations to Norfund significantly over the past years.

1 Gigaton Coalition

Renewable energy and energy efficiency programs in developing countries are making great strides towards closing the gap in greenhouse gas emissions required to reach the goal of limiting global warming to 2 degrees Celsius. However, most of these efforts have neither been measured nor reported. In order to highlight the importance of their contribution to closing the emissions gap. The 1 Gigaton Coalition aims to measure and report reductions of greenhouse gas emissions resulting from renewable energy and energy efficiency initiatives and programmes that are not accounted for in the Emissions Gap Report, which are estimated to be 1 GtCO2e by 2020.

The 1 Gigaton Coalition will support countries to measure and report reductions of greenhouse gas (GHG) emissions resulting from their activities and initiatives in the energy sector. The Coalition aims to do so by creating a methodology in the annual 1 Gigaton Coalition reports, which will highlight specific countries and programmes by applying this methodology.

The 1 Gigaton Coalition was launched at COP 20 and is initiated and supported by the Government of Norway, and is coordinated by the United Nations Environment Programme (UNEP).

Even if the pledges in the Paris Agreement on Climate Change are implemented, we will still not reduce greenhouse gas emissions enough to meet the goals. The UN Environment Emissions Gap Report 2017 states that for the 2°C goal, this shortfall could be 11 to 13.5 gigatonnes of carbon dioxide equivalent. For the 1.5°C goal, it could be as much as 16 to 19 gigatonnes.The third report of the 1 Gigaton Coalition shows that internationally supported renewable energy and energy efficiency projects implemented in developing countries between 2005 and 2016 are projected to reduce greenhouse gas emissions by 0.6 Gigatons of carbon dioxide (GtCO2) annually in 2020. When scaled up using international climate financing commitments, these efforts could deliver 1.4 GtCO2 in annual reductions by 2020. Emission reductions from internationally supported RE and EE projects could be on the order of 1.4 GtCO2e per year by 2020 if committed public finance for climate mitigation is used to scale up these activities.

The report also shows that data availability and information sharing remain a perennial challenge, one that is preventing countries and supporting organizations from systematically evaluating their work's impact, although renewable energy and energy efficiency projects and policies are growing in developing countries. The 1 Gigaton Coalition has developed a database of about 600 internationally supported projects implemented in developing countries between 2005 and 2016. Furthermore, the report shows that non-state and subnational actors have taken on a leading role in scaling up climate action. The case studies in the report show that low-carbon forms of development – particularly city-based public private partnerships – generate multipleco-benefits. These include improved environmental and human health, economic stimulusand employment creation, enhanced gender equality, and other societal gains that supportthe 2030 Agenda for Sustainable Development.

Consequence assessments

Norway has issued Instructions for Official Studies and Reports (Utredningsinstruksen), laid down by Royal Decree. These Instructions deal with consequence assessments, submissions and review procedures in connection with official studies, regulations, propositions and reports to the Storting. The Instructions are intended for use by ministries and their subordinate agencies. The Instructions form part of the Government's internal provisions and deviation may only be allowed pursuant to a special resolution. The provisions make it mandatory to study and clarify financial, administrative and other significant consequences in advance.

In addition, Norway has a legal framework that deals specifically with environmental impact assessments. The purpose is to promote sustainable development for the benefit of the individual, society and future generations. Transparency, predictability and participation for all interest groups

and authorities involved are key aims, and it is intended that long-term solutions and awareness of effects on society and the environment will be promoted.

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The Norwegian Environment Agency is working for a clean and diverse environment. Our primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

We are a government agency under the Ministry of Climate and Environment and have 700 employees at our two offices in Trondheim and Oslo and at the Norwegian Nature Inspectorate's more than sixty local offices.

We implement and give advice on the development of climate and environmental policy. We are professionally independent. This means that we act independently in the individual cases that we decide and when we communicate knowledge and information or give advice.

Our principal functions include collating and communicating environmental information, exercising regulatory authority, supervising and guiding regional and local government level, giving professional and technical advice, and participating in international environmental activities.