A brief introduction to the Norwegian greenhouse gas emission inventory

This text is an abstract of the first chapters of the Norwegian Inventory Report, submitted to the UNFCCC in April 2018. It also includes an overview of the different source categories in national and international reporting

Content

Preparing the inventory

Institutional, legal and procedural arrangements

The Norwegian greenhouse gas emission inventory has been produced for more than three decades. It started with CO_2, and has gradually been expanded with other emission components. The Norwegian Environment Agency, Statistics Norway and the Norwegian Institute of Bioeconomy Research (NIBIO) are the responsible institutions.

The Norwegian Environment Agency, Statistics Norway, and the Norwegian Institute of Bioeconomy Research work together to fulfill the requirements for the national system. An overview of institutional responsibilities and cooperation is shown in Figure 1.

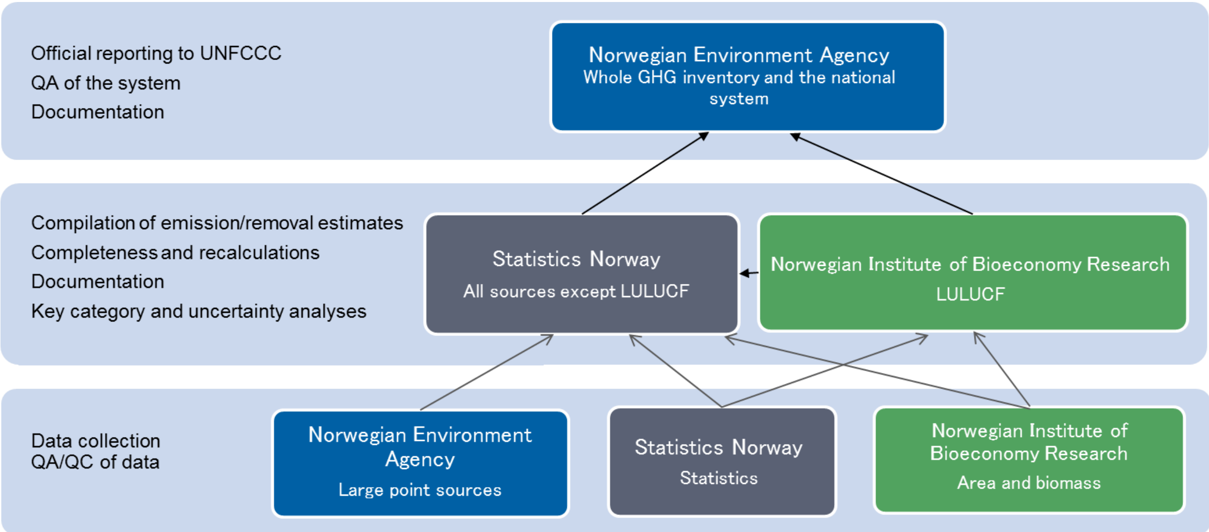

Figure 1 Overview of institutional responsibilities and cooperation

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, Industrial Processes and Product Use (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 emission 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. The Norwegian Institute of Bioeconomy Research is responsible for estimating emissions from the LULUCF sectors, collects almost all data and calculates the emissions.

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.

Brief description of methodologies and data sources used

Details of the methods and framework for the production of the emission inventory are given in the Norwegian Emission Inventory 2018[1] .

The emission estimation methodologies are being improved on a annual basis, to improve both activity data and emission factors. As far as possible, data collection relevant to the emission inventories is integrated into other surveys and statistics.

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 models are used as input to the general model.

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

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

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.

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 be allocated to technical sources, i.e. different technologies used in fuel combustion.

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, technical source, and pollutant.

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:

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

[1] http://www.miljodirektoratet.no/Documents/publikasjoner/M985/M985.pdf

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 (such as emission from agricultural soils, enteric fermentation, industrial processes) 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.

Data sources

The data sources used in the Norwegian inventory are as follows:

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).

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. The 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.

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; 2011). 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.

Quality control and verification

The reporting obligations has extensive guidance on quality control to ensure that the emission estimates is of high quality. The Norwegian emission inventory preparation includes established routines including 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 quality control procedures are performed every year;
- Source category-specific quality control procedures are performed for important emission sources with regard to emission factors, activity data and uncertainty estimates.

Results from the National Inventory Report 2018

This report summarizes the main trends in greenhouse gas emissions in Norway, taken from the report to the UNFCCC in 2018. It also gives a brief description of the national system for calculating and reporting greenhouse gas emissions.

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 (NIR) is prepared in accordance with the revised UNFCCC Reporting Guidelines on Annual Inventories. The methodologies used in the calculation of emissions and removals are consistent with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[2].

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

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

Aggregated emissions and removals of greenhouse gases expressed in CO_2 equivalents are 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. The emission sectors or source categories used for reporting is also stated in the UNFCCC Reporting Guidelines on Annual Inventories. Emissions are reported in a Common Reporting Format (CRF). In Annex 1 there is a table explaining the differences between the source categories in the CRF-reporting format given in this report and the national reporting format from Statistics Norway.

The CRF divides emissions into five main source categories:

- Energy
- Industrial processes and product use (IPPU)
- Agriculture
- Land use and land use change (LULUCF)
- Waste

The energy source category includes all emissions from energy use, both combustion emissions and fugitive emissions. This includes emissions from stationary energy use and transport. The IPPU sector includes non-combustion emissions from the energy sector and emissions from use of products such as solvents and HFCs. The agricultural sector includes emissions from animal husbandry and from agricultural soils, while emissions and removals from e.g. managed forests and land use change is included in the LULUCF sector. The waste sector constitutes emissions from waste management and

[2] https://www.ipcc-nggip.iges.or.jp/public/2006gl/

wastewater handling. This way of organizing emission estimates results in a different split of emissions than a purely economic approach. Emissions from manufacturing industries will for instance be split between the energy and IPPU sectors, and emissions from tractors and other machinery used in agriculture will be allocated to the energy sector.

Indirect CO_2 emissions originating from the fossil part of CH_4 and NMVOC are calculated according to the reporting guidelines to the UNFCCC. 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.

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

Overall emission trends

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[3]. 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 removals from the LULUCF sector was 24.4 million tonnes CO2 equivalents in 2016. The total emissions distribution among the main CRF sectors from 1990 to 2016 is illustrated in Figure 2.

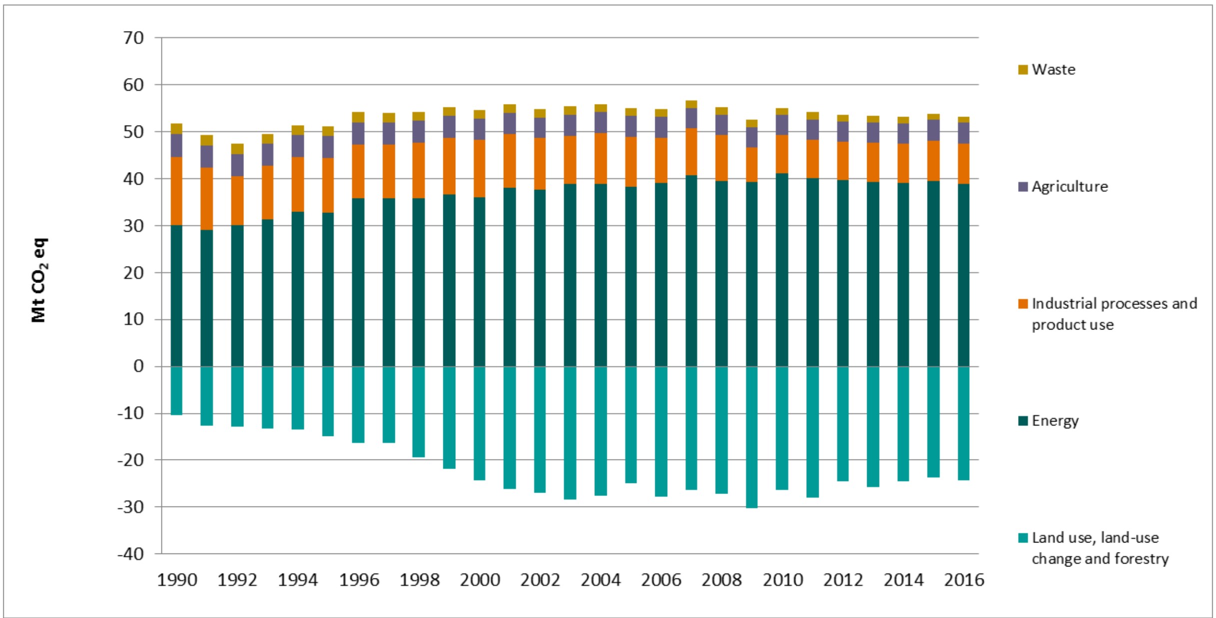

Figure 2. Total emissions of greenhouse gases by sources and removals from LULUCF in Norway, 1990-2016 (Mtonnes CO_2 equivalents). Source: Statistics Norway/Norwegian Environment Agency/Norwegian Institute of Bioeconomy Research

Table 1 and Figure 3 illustrates the annualdevelopment of GHG emissions from the CRF sectors (not

[3] In the reporting, 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).

including LULUCF) in percentage change, relative to 1990.

Table 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

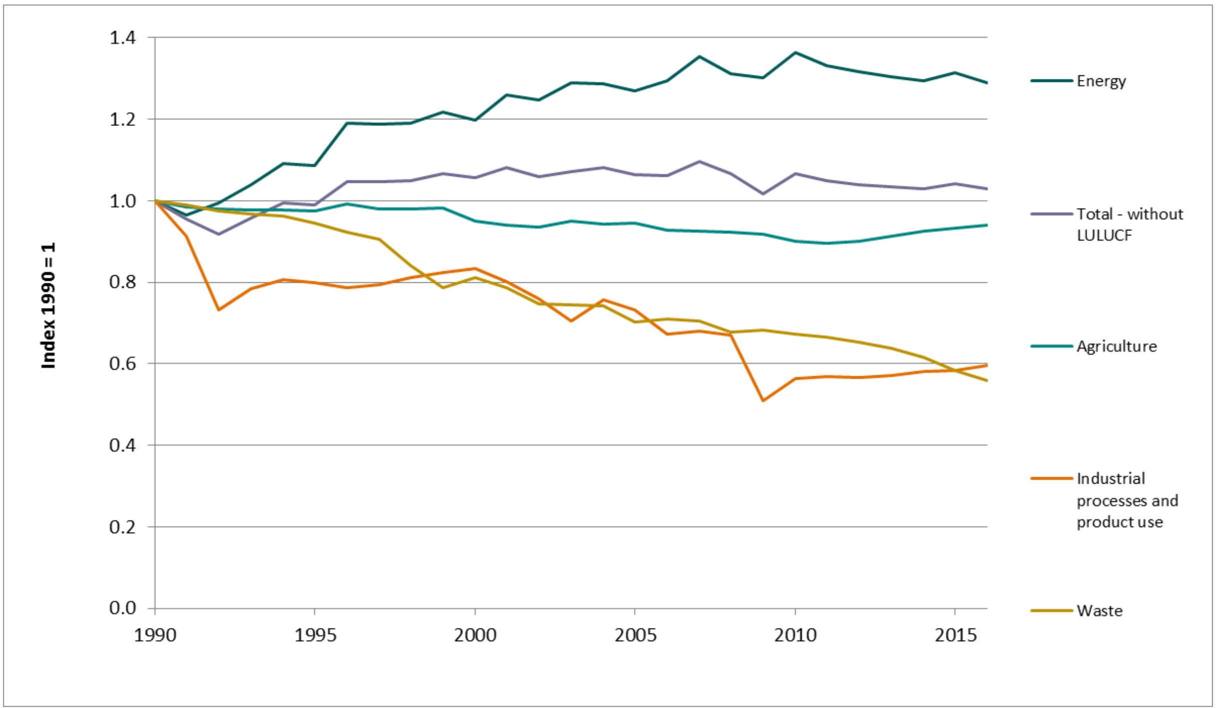

Figure 3. Changes in emissions of greenhouse gases, relative to 1990, illustrated by UNFCCC source categories, 1990-2016. Index 1990 = 1. Source: Statistics Norway/Norwegian Environment Agency

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.

Emission inventory of the different greenhouse gas

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 (Figure 3).

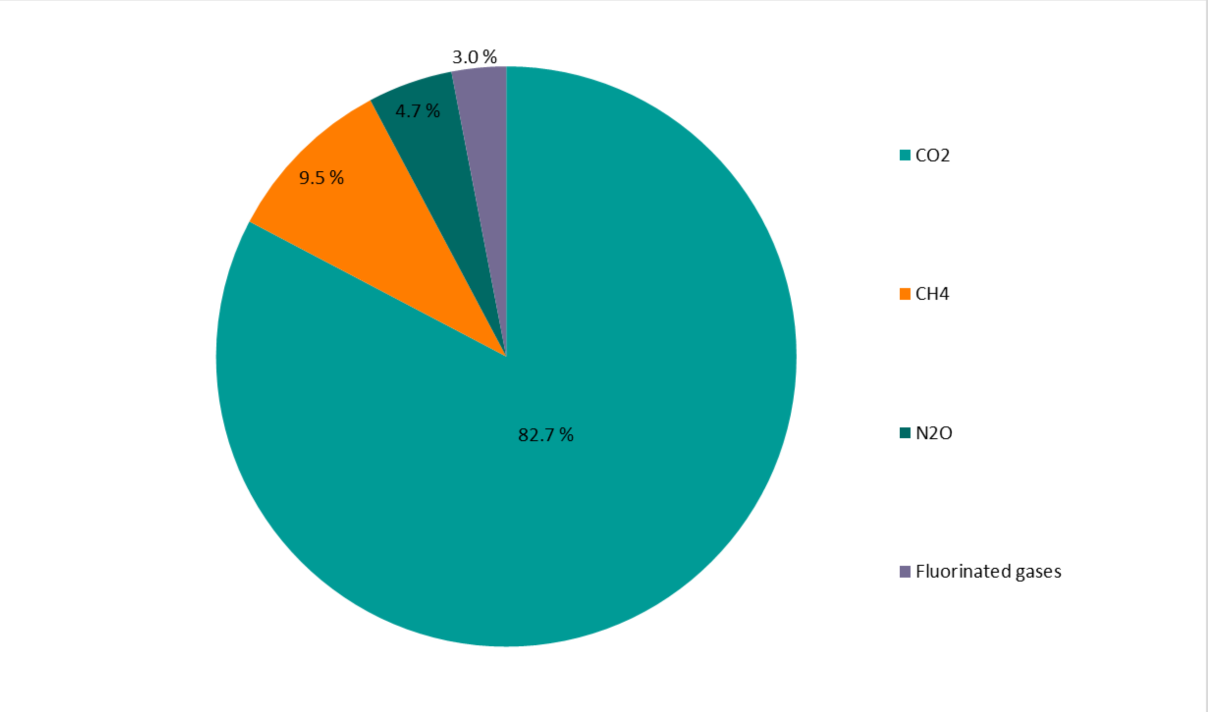

Figure 3. Distribution of emissions of greenhouse gases in Norway by gas, 2016.
Source: Statistics Norway/Norwegian Environment Agency

Figure 4 illustrates the changes in per cent for the different greenhouse gases for the period 1990 to 2016. 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.

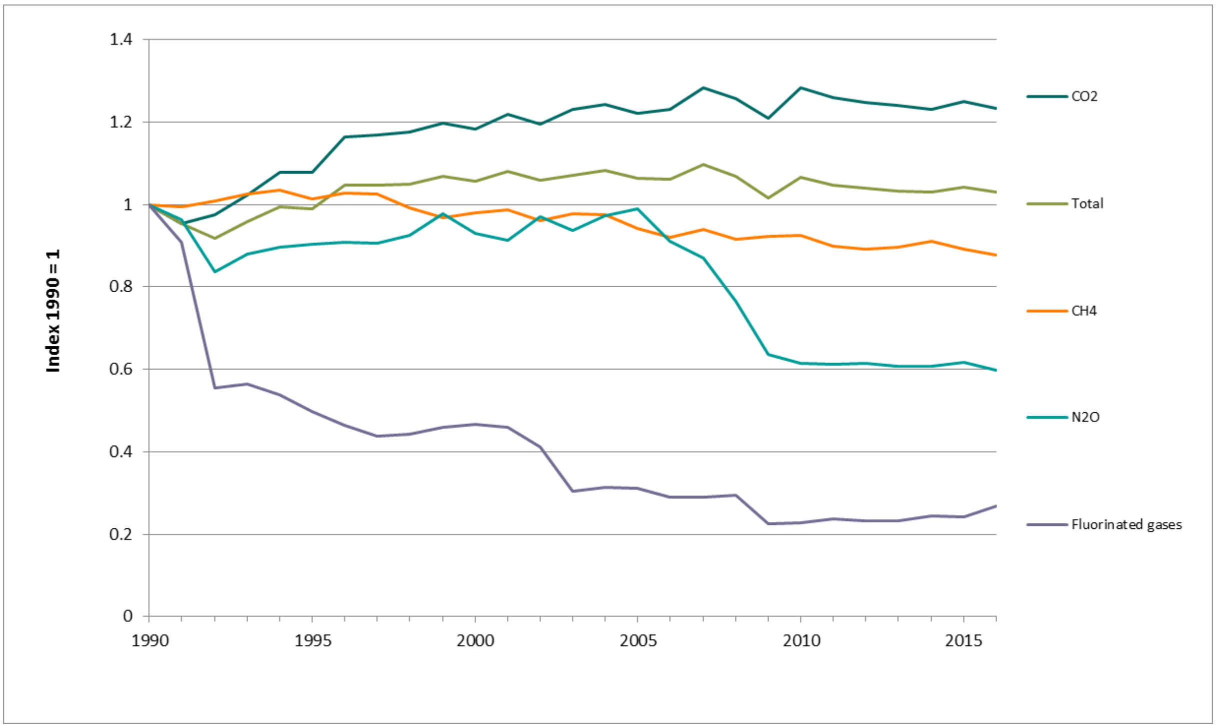

Figure 4. Changes in emissions of greenhouse gases, relative to 1990, by gas, 1990-2016. Index 1990 = 1. Source: Statistics Norway/Norwegian Environment Agency

CO_2 emissions increased significantly from 1990 to 2016 with 8.3 million tonnes CO_2 eqivalents.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.

Emissions of CH_4 and N_2O decreased by 0.7 and 1.7 million tonnes CO_2-equivalents, respectively. During the same period, PFCs and SF_6 emissions decreased with 3.7 and 2.0 million tonnes CO2 equivalents, while HFCs has increased from almost 0 to 1.4 million tonnes CO_2 equivalents.

Emission trends by sector

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

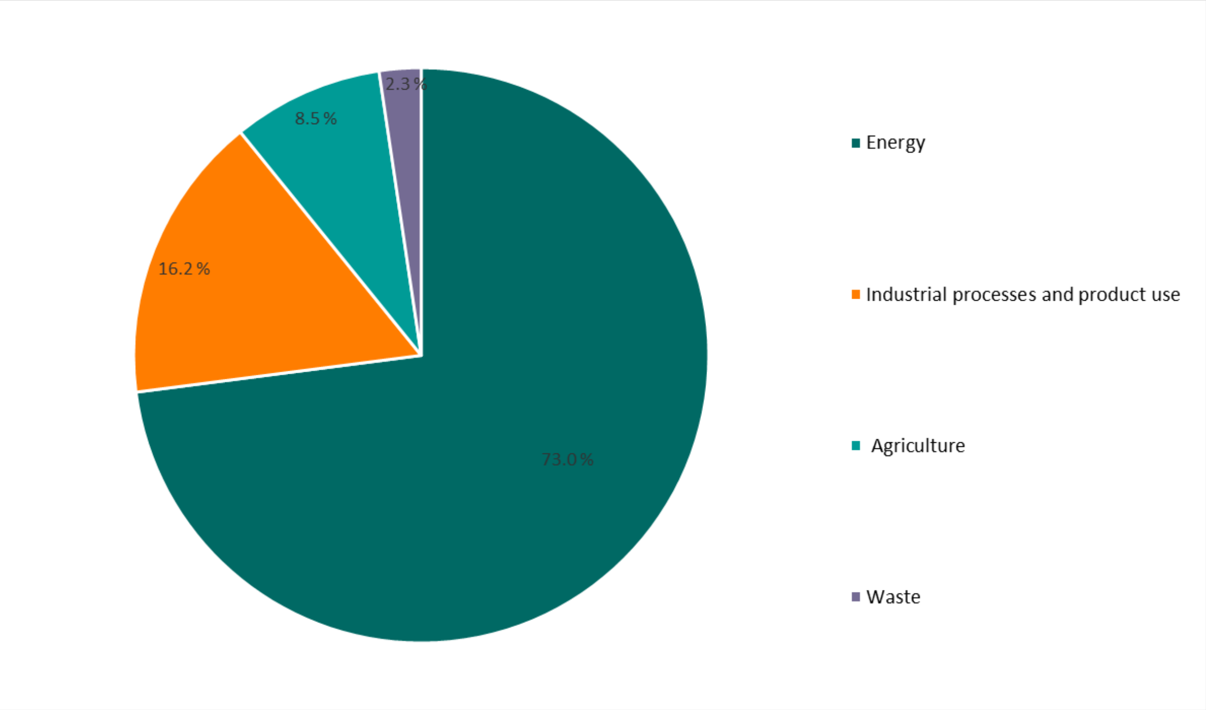

Figure 5. Distribution of GHG emissions in Norway in 2016 by sector, excluding LULUCF.
Source: Statistics Norway/Norwegian Environment Agency

Figure 6 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.

[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).

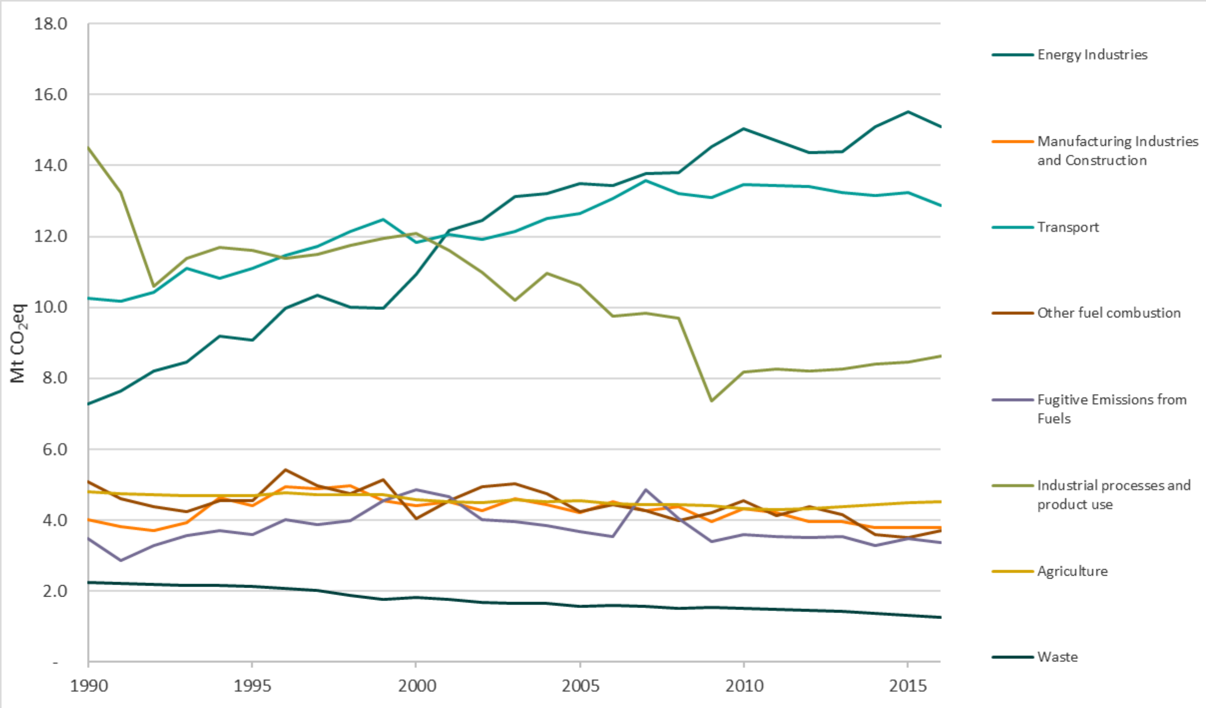

Figure 6. Development of emissions of all GHG (Mtonnes CO_2 eq.) from the different sectors, excluding LULUCF, 1990-2016. Source: Statistics Norway/Norwegian Environment Agency

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

Energy

The energy sector consist of fuel combustion in the following sub-sectors:

- Energy industries (such as the oil and gas industries, electricity production and district heating)
- Transport (such as road transport, sea trasport and aviation)
- Manufacturing industries
- Construction (such as machinery used at construction sites)
- Fugitive emission from fuels (such as evaporative emissions from oil and gas extraction)
- Other combustion (such as agriculture, forestry and fisheries, residential sector and commercial/institutional sectors)

Emission changes from 1990 to 2016, relative to 1990, are presented for various sub-sectors in the energy sector in 7.

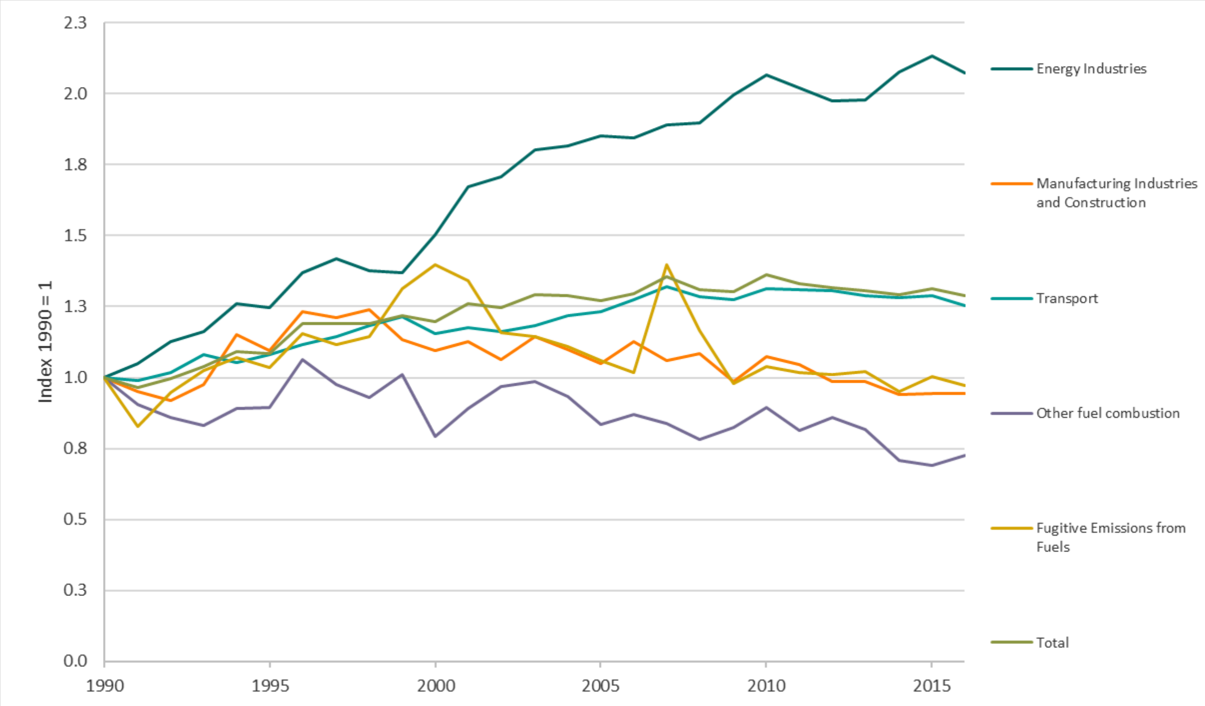

Figure 7. Changes in emissions of greenhouse gases, relative to 1990, for the various sub-sectors within the energy sector, 1990-2016. Index 1990 = 1. Source: Statistics Norway/Norwegian Environment Agency

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 fuel combustion in **Energy Industries** were 107.3 per cent higher in 2016 than in 1990. 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. Emissions from **Manufacturing Industries and Construction** have remained relatively stable since 1990, with a small decrease of 0.2 Mtonnes CO_2 eq. 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. Road transportation accounts for 77.1 per cent of emissions from the

[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.

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 emission trends from the main transport modes are illustrated in Figure 8.

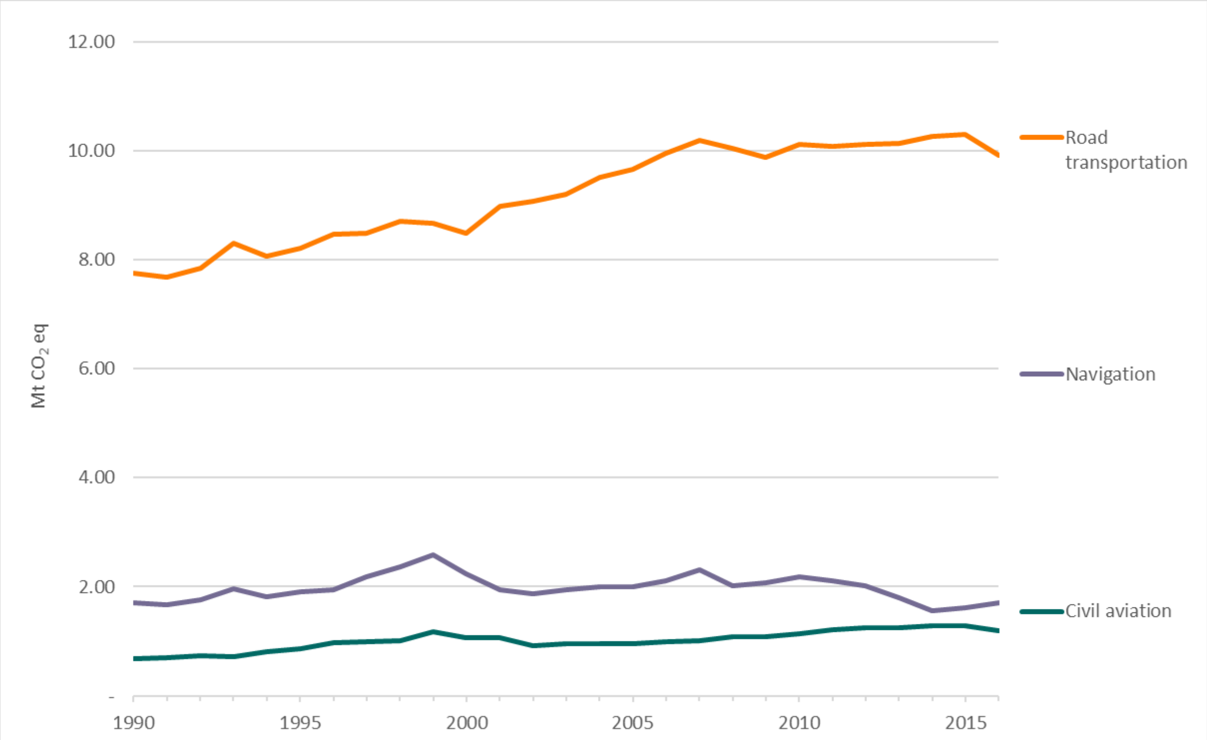

Figure 8. Emissions in million tonnes CO_2 equivalents from the most important modes of transport, 1990-2016. Source: Statistics Norway/Norwegian Environment Agency

GHG emissions from road transportation increased by 27.7 per cent from 1990 to 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.

The sub-sector "**Other fuel combustion**" in Figure includes, in particular, fuel combustion in agriculture, forestry and fisheries, residential sector and commercial/institutional sectors (CRF category 1A4). Since 1990, emissions from stationary combustion in the residential sector (have decreased by 73.0 per cent, mainly due to decrased fossil energy consumption due to electrification of heating infrastructure and energy efficiency.

The sub-sector "**Fugitive emissions from fuels"** in Figure 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 mainly 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.

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 94 shows the variations in the contribution to GHG emissions from 1990 to 2016 of the different IPPU sub-sectors.

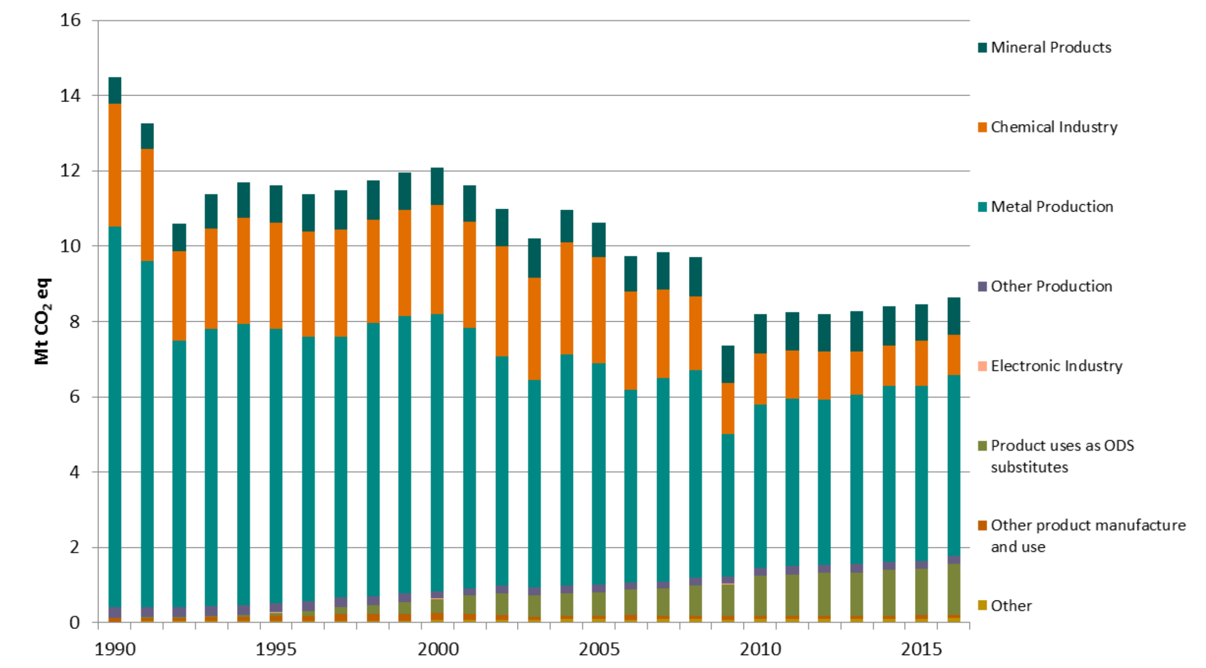

Figure 94. Total greenhouse gas emissions (Mtonnes CO_2-eq.) in the IPPU sub-sector in Norway, 1990-2016[6]. Source: Statistics Norway/Norwegian Environment Agency

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 products have been used as reducing agents or raw materials. Greenhouse gases are then emitted as process related gases.

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 and 9.0 per cent of national GHG emissions. The large decrease in emissions in 2009 reflects low production levels of ferroalloys, due to lower economic activity and economic recession

Emissions of PFCs have decreased by 95.2 per cent since 1990. The reduction from 1990 is due to improvement of technology and process control in aluminium production. 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. Between 2015 and 2016, emissions increased by 27.2 per cent due to increased production and to a low anode effect frequency for one plant in 2015.

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.

In 1990, SF_6 from magnesium foundries accounted for 4.0 per cent of the national total GHG

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

emissions. Emissions decreased until the closure of all plants in 2007. Reductions in SF_6 emissions 9over 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. Reductions of N_2O emissions during the period 1990-2016 from nitric acid production are due to changes in the production processes of nitric acid, 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. There has also been reductions for ammonia and carbide production. Emissions have decreased by 10.4 per cent since 2015, mainly due to the increase of ammonia production.

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.

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 GHG emissions 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 dairy 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.

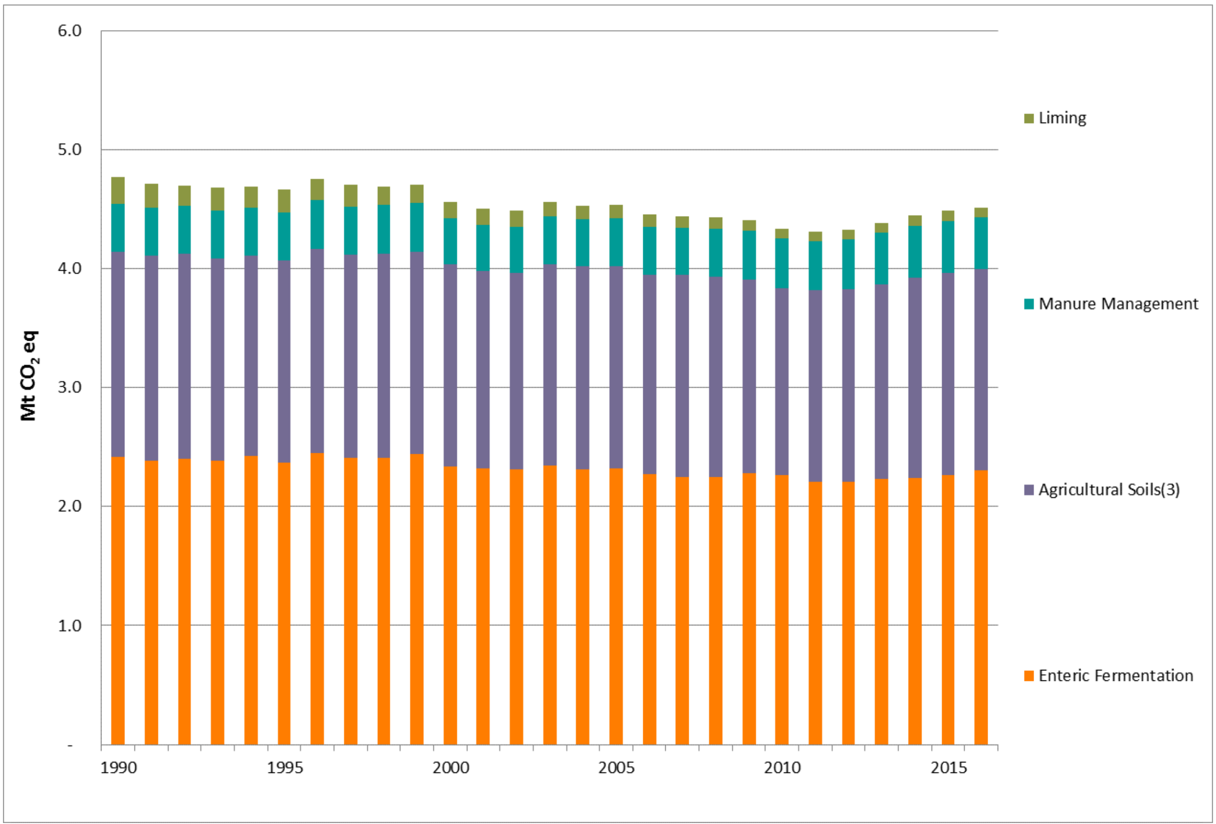

Figure 10 Total greenhouse gas emissions (Mtonnes CO_2-eq.) in the agriculture sub-sectors in Norway, 1990-2016. Source: Statistics Norway/Norwegian Environment Agency

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 11. 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.

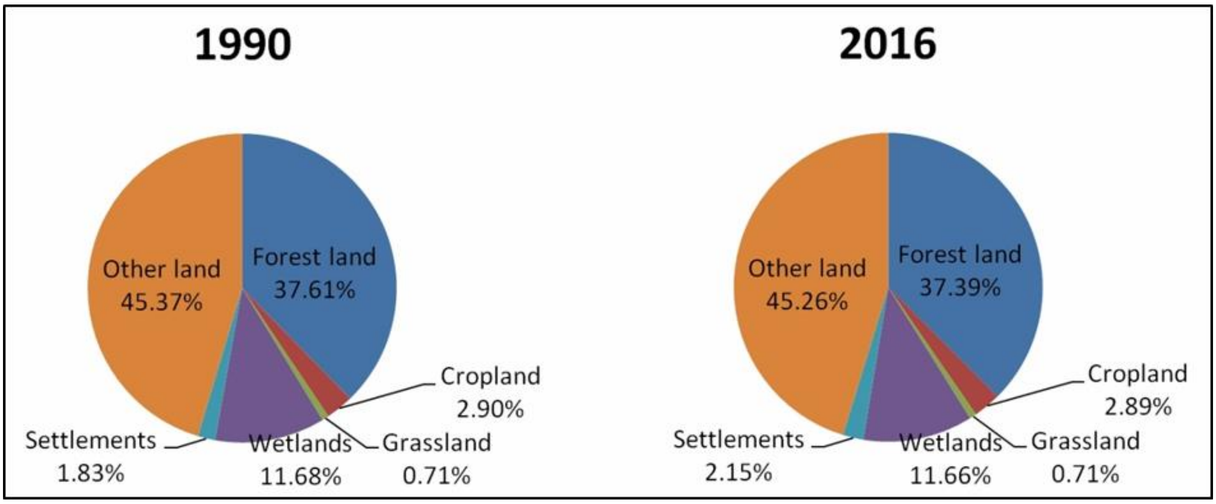

Figure 11 Area (%) distribution between the IPCC land-use categories, 1990 and 2016.
Source: The Norwegian Norwegian Institute of Bioeconomy Research

Figure 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.

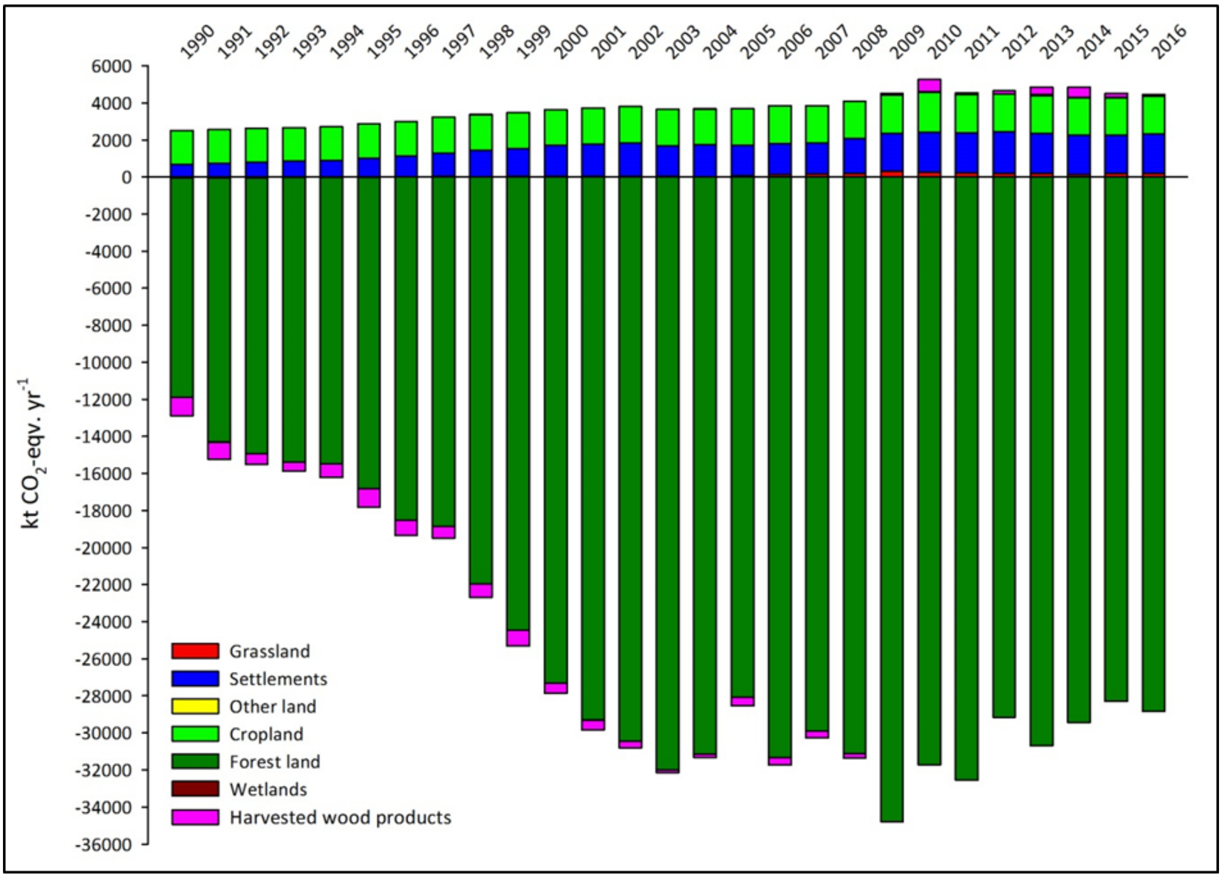

Figure 12 Net CO_2 emissions and removals (kt CO_2-equivalents per year) from the LULUCF sector by land-use category (forest land, cropland, grassland, wetlands, settlements, other land, and harvested wood products) from 1990 to 2016, including emissions of N_2O and and CH_4.
Source: Norwegian Institute of Bioeconomy Research

All emissions and removals are estimated according to the 2013 Kyoto Protocol supplement (IPCC 2014).

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, estimated Carbon sequestration for the activity forest management is substantial, whereas net emissions occur from deforestation, cropland and grazing land management. In addition, Carbon sequestration from afforestation/reforestation is estimated.

Table 2. 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.

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. 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 3.

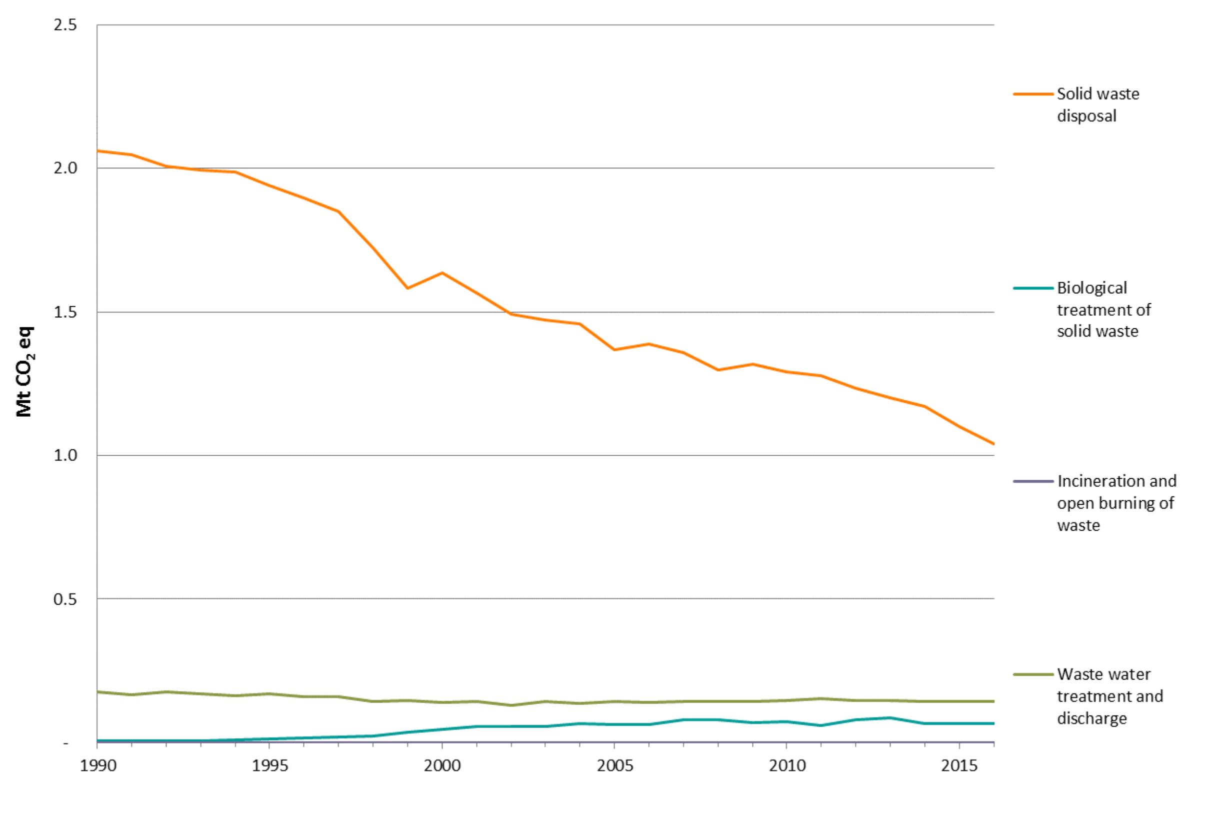

Figure 5. Total emissions of greenhouse gases (Mtonnes CO_2-eq.) in Norway from the waste sub-sectors, 1990-2016. Source: Statistics Norway/Norwegian Environment Agency

There has been a decrease of methane emissions from landfills since 1990, which has led to a decrease in methane emissions altogether. 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. 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.

Source categories in national and international reporting

Statistics Norway annually publishes official statistics on emissions to air, including greenhouse gases. These statistics form the basis for the reported emissions to UNFCCC, but the division between emission sources is somewhat different. While the CRF source category division is used for reporting and monitoring towards international commitments, the Statistics Norway source category division is frequently used nationally, for instance in mitigation analyses and evaluation of national targets regarding greenhouse gases. Table 3 and Table 4 shows the allocation of Statistics Norway source categories in CRF source categories and vice versa in 2016. For the LULUCF sector there is no official national statistics, and the CRF source categories are used most frequently both nationally and internationally.

Table 3 Share of Statistics Norway source categories in different CRF source categories in 2016

CRF source category	Statistics Norway source category	Share of Statistics Norway source categories per CRF source category
1A Fuel combustion activities	1.1 Oil and gas extraction - stationary combustion	36 %
	2.1 Manufacturing industries and mining - stationary combustion	10 %
	3.0 Energy supply	5 %
	4.1 Heating in other industries	2 %
	4.2 Heating in households	1 %
	5.1 Passenger cars	15 %
	5.2 Light duty vehicles	4 %
	5.3 Heavy duty vehicles	8 %
	5.4 Motorcycles and mopeds	0 %
	6.1 Railways	0 %
	6.2 Domestic aviation	4 %
	6.3 Costal navigation	8 %
	6.4 Motorized equipment etc.	6 %
	9.9 Other	0 %
1B Fugitive emissions from fuels	1.1 Oil and gas extraction - stationary combustion	40 %
	1.2 Oil and gas extraction - process emissions	25 %
	2.1 Manufacturing industries and mining - stationary combustion	2 %
	2.2 Manufacturing industries and mining - process emissions	32 %
	9.9 Other	1 %
2A Industrial processes - Mineral industry	2.2 Manufacturing industries and mining - process emissions	99 %
	9.9 Other	1 %

2B Industrial processes- Chemical industry	2.1 Manufacturing industries and mining - stationary combustion	12 %
	2.2 Manufacturing industries and mining - process emissions	88 %
2C Industrial processes - Metal industry	2.2 Manufacturing industries and mining - process emissions	100 %
2D Industrial processes - Non-energy products from fuels and solvent use	4.1 Heating in other industries	5 %
	4.2 Heating in households	17 %
	5.3 Heavy duty vehicles	7 %
	9.3 Products containing fluorinated gases, solvents etc.	51 %
	9.9 Other	20 %
2E Industrial processes - Electronic industry	9.3 Products containing fluorinated gases, solvents etc.	100 %
2F Industrial processes - Product uses as substitutes for ODS	9.3 Products containing fluorinated gases, solvents etc.	100 %
2G Industrial processses - Other product manufacture and use	9.3 Products containing fluorinated gases, solvents etc.	76 %
	9.9 Other	24 %
2H Industrial processes – Other	2.2 Manufacturing industries and mining - process emissions	100 %
3A Enteric fermentation	7.1 Agriculture - enteric fermentation and manure	100 %
3B Manure management	7.1 Agriculture - enteric fermentation and manure	100 %
3D Agricultural soils	7.1 Agriculture - enteric fermentation and manure	29 %
3D Agricultural soils	7.2 Agriculture - fertilizer and other	71 %
3F Field burning of agricultural residues	4.1 Heating in other industries	100 %
3G Liming	7.2 Agriculture - fertilizer and other	87 %
	9.9 Other	13 %
3H Urea application	7.2 Agriculture - fertilizer and other	100 %
5A Solid waste disposal	9.1 Landfill gas	100 %
5B Biological treatment of solid waste	9.9 Other	100 %
5C Incineration and open burning of waste	2.1 Manufacturing industries and mining - stationary combustion	29 %
	4.1 Heating in other industries	71 %
5D Wastewater treatment and discharge	9.9 Other	100 %

Table 4 Share of CRF source categories in different Statistics Norway source categories in 2016

Statistics Norway source category	CRF source category	Share of CRF source categories per Statistics Norway source category
1.1 Oil and gas extraction - stationary combustion	1A Fuel combustion activities	90 %
	1B Fugitive emissions from fuels	10 %
1.2 Oil and gas extraction - process emissions	1B Fugitive emissions from fuels	100 %
2.1 Manufacturing industries and mining - stationary combustion	1A Fuel combustion activities	94 %
	1B Fugitive emissions from fuels	2 %
	2B Industrial processes- Chemical industry	3 %
	5C Incineration and open burning of waste	0 %
2.2 Manufacturing industries and mining - process emissions	1B Fugitive emissions from fuels	14 %
	2A Industrial processes - Mineral industry	12 %
	2B Industrial processes- Chemical industry	12 %
	2C Industrial processes - Metal industry	60 %
2.2 Manufacturing industries and mining - process emissions	2H Industrial processes – Other	1 %
3.0 Energy supply	1A Fuel combustion activities	100 %
4.1 Heating in other industries	1A Fuel combustion activities	98 %
	2D Industrial processes - Non-energy products from fuels and solvent use	1 %
	3F Field burning of agricultural residues	1 %
	5C Incineration and open burning of waste	0 %
4.2 Heating in households	1A Fuel combustion activities	92 %
	2D Industrial processes - Non-energy products from fuels and solvent use	8 %
5.1 Passenger cars	1A Fuel combustion activities	100 %
5.2 Light duty vehicles	1A Fuel combustion activities	100 %
5.3 Heavy duty vehicles	1A Fuel combustion activities	99 %
	2D Industrial processes - Non-energy products from fuels and solvent use	1 %
5.4 Motorcycles and mopeds	1A Fuel combustion activities	100 %
6.1 Railways	1A Fuel combustion activities	100 %
6.2 Domestic aviation	1A Fuel combustion activities	100 %
6.3 Costal navigation	1A Fuel combustion activities	100 %
6.4 Motorized equipment etc.	1A Fuel combustion activities	100 %

7.1 Agriculture - enteric fermentation and manure	3A Enteric fermentation	71 %
	3B Manure management	14 %
	3D Agricultural soils	15 %
7.2 Agriculture - fertilizer and other	3D Agricultural soils	94 %
	3G Liming	6 %
	3H Urea application	0 %
9.1 Landfill gas	5A Solid waste disposal	100 %
9.3 Products containing fluorinated gases, solvents etc.	2D Industrial processes - Non-energy products from fuels and solvent use	7 %
	2E Industrial processes - Electronic industry	0 %
	2F Industrial processes - Product uses as substitutes for ODS	89 %
	2G Industrial processses - Other product manufacture and use	4 %
9.9 Other	1A Fuel combustion activities	1 %
	1B Fugitive emissions from fuels	10 %
	2A Industrial processes - Mineral industry	3 %
	2D Industrial processes - Non-energy products from fuels and solvent use	13 %
	2G Industrial processses - Other product manufacture and use	6 %
	3G Liming	3 %
	5B Biological treatment of solid waste	20 %
	5D Wastewater treatment and discharge	44 %

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