SFT Report 1742/2000

Greenhouse Gas Emissions in Norway 1990-1998

Reporting according to the UNFCC guidelines

Preface

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force in 1994. It requires parties to report emissions and sinks of greenhouse gases annually.

This report has been prepared in accordance with the UNFCCC Reporting Guidelines on Annual Inventories adopted in November 1999 by decision 3/CP.5. The methodology used in the calculation of emissions is set out in the revised IPCC Guidelines for emission inventories approved by the UNFCCC.

The Norwegian Pollution Control Authority is responsible for the report, which has been written by Torgrim Asphjell, Marit Viktoria Pettersen, Eilev Gjerald and Harold Leffertstra. Statistics Norway (SN) has supplied data and valuable comments as part of the SN/SFT co-operation programme on emission inventories.

Janne Sollie

The Norwegian Pollution Control Authority

Oslo, August 2000

Table of contents

SUMMARY 4

1. INTRODUCTION 6

2. EMISSIONS 8

2.2. Methane (CH_4) 12

2.3. Nitrous oxide (N_2O) 14

2.4. Perfluorcarbons (PFCs) 15

2.5. Sulphur hexafluoride (SF_6) 16

2.6. Substitutes for ozone depleting substances (HFCs and PFCs) 17

2.7. Precursors (CO, NO_X and NMVOC) and SO_2 19

3. BIOTIC CO_2 SINKS 20

4. INTERNATIONAL AVIATION AND MARINE BUNKER FUELS 21

5. METHODS OF ESTIMATION 22

5.1. The Norwegian inventory model in general 22

6. UNCERTAINTY 23

7. VERIFICATION 24

7.1 Suitability of method 24

7.2 Results for Norway 26

7.3 Uncertainties/problems during the work 26

7.4 Conclusions 27

REFERENCES 29

APPENDIX 1: COMMENTS TO TABLES IN APPENDIX 2 30

APPENDIX 2: REPORTING TABLES 31

Summary

This report presents an inventory of greenhouse gas (GHG) emissions and sinks in Norway from 1990 to 1998. Emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tetrafluoromethane (CF_4), hexafluoroethane (C_2F_6), sulphur hexafluoride (SF_6) and HFCs (HFC-134a, HFC-143a, HFC-125, HFC-152a, HFC-23 and HFC-32) are described with regard to source categories. Emissions are reported according to UNFCCC Common Reporting Format.

As a general rule, the estimation methods follow the Guidelines for National Greenhouse Gas Inventories published by the Intergovernmental Panel on Climate Change (IPCC). However, other methods have been used where appropriate, as described in chapter 5. According to the Guidelines, national methods may be used when they better reflect national circumstances and are well documented.

Year	CO_2	CH_4	N_2O	CF_4	C_2F_6	SF_6	HFC 134a	HFC 125	HFC 143a	HFC23, 32, 152a and 227	CO_2 - EQU.
	Mtonnes	ktonnes	ktonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	Mtonnes
1990	35,1	315	16,6	441	18	92				0,1	52,1
1991	33,6	320	16,1	369	14	87	0			0,4	49,9
1992	34,3	326	13,9	294	11	29	0,2			0,6	48,1
1993	35,9	332	15,1	290	10	32	1,7			0,8	50,3
1994	37,9	340	15,4	251	9	32	5,4	0,5	0,2	0,8	52,4
1995	38,2	343	15,7	229	8	24	10,1	2,4	1,5	1,0	52,4
1996	41,1	346	15,7	214	5	25	17,2	5,5	3,9	1,5	55,3
1997	41,4	351	15,5	201	8	23	26,2	9,7	6,8	2,71	55,6
1998	41,7	346	16,4	185	7	29	38,2	14,7	10,4	5,34	56,2
1990-98	19%	10%	-1%	-58%	-61%	-68%	-	-	-	-	8%

Table 1: Emissions of greenhouse gases for the years 1990-1998. Overall emissions of the greenhouse gases are also given as CO_2 equivalents, based on Global Warming Potential (GWP) values.

Total emissions of greenhouse gases, measured as CO_2 –equivalents, were about 56,2 million tonnes in 1998 (see table 1). From 1997 to 1998 the emissions have increased by 1%. For the period 1990-1998 the increase in the emissions was 8%. They decreased by 8% from 1990 to 1992, but from 1992 to 1998 the emissions again increased by 17%, mainly as a result of higher CO_2 emissions.

Emissions of CO_2 in 1998 were 41,7 million tonnes. This is approximately 1% higher than in 1997 and 19% above 1990 emissions. The increase from 1990 to 1998 is mainly a result of growth in oil- and gas production in addition to higher emissions from mobile sources.

Emissions of CH_4 have been slowly increasing during the 1990s. From 1997 to 1998 this trend was reversed due to decreased emissions from oil- and gas industry and waste disposal sites.

Anthropogenic **emissions of N_2O** in 1998 were estimated at 16.4 ktonnes. The emissions have increased by 6% from 1997 to 1998. For the period 1990-1998 there has been a decrease of 1% in the emissions. Since last years reporting N_2O-emissions from agricultural sources have been recalculated resulting in a decrease in estimated emissions by 0.3 Mtonnes CO_2-equivalents.

The **emissions of PFCs** (CF_4 and C_2F_6) from Norwegian aluminium plants in 1998 were calculated to be approximately 192 tonnes. From 1997 to 1998 there was a decrease by 9% in the emissions of PFC-gases. From 1990 to 1998 the emissions of PFC-gases were reduced by as much as 58%. This is due to improved technology and process control. The timeseries from 1990 to 1998 has been recalculated for this year’s report, resulting in a 0.5 Mtonnes CO_2-equivalents increase in estimated emissions of PFCs in the baseyear 1990.

Emissions of SF_6 in 1998 are estimated at approximately 29 tonnes. From 1997 to 1998 they increased by 26%. In the period 1990-1998, the emissions have been reduced by 68%. The decrease is a result of reduced production levels for magnesium in addition to improved production routines. The use of SF_6 as a cover gas in magnesium production accounts for 83% of the total SF_6 emissions.

In the IPCC Guidelines there are tiered methods for calculation of emissions of HFCs, PFCs and the SF_6 as substitutes for ozone-depleting substances. These emissions are reported as both potential emissions (Tier 1) and actual emissions (Tier 2). In summary tables etc. actual emissions are reported.

The actual **emissions of HFCs** (“tier 2” methodology) in Norway were about 0,13 million tonnes of CO_2-equivalents in 1998, and they have increased by 50% since 1997. In comparison the emissions in 1990 were insignificant. As the phasing out of CFCs and HCFCs accelerates, a further strong growth in consumption of HFCs is expected in the years to come.

In 1998, CO_2 emissions from ships and aircraft in international traffic bunkered in Norway amounted to 3.7 million tonnes. Emissions of NO_X were 61.9 ktonnes. From 1990 to 1998, CO_2 emissions from ships in international traffic bunkered in Norway increased by 93% and NO_X emissions rose by about 96%. For aviation the increase was 37% for CO_2 and 47% for NO_x over the same period.

The net anthropogenic sink of CO_2 in the Norwegian forests in 1998 is estimated at 17.6 million tonnes. This considerable accumulation is due to a large increment in the standing volume of forests. The amount of CO_2 removed by forest growth is hence much larger than the amount of emitted CO_2 from harvested wood.

1. Introduction

This report presents the national emissions of greenhouse gases and the biotic carbon dioxide (CO_2) sinks in Norway. The following greenhouse gases are included: Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), PFCs (CF_4 and C_2F_6), sulphur hexafluoride (SF_6) and HFCs (HFC-134a, HFC-125, HFC-143, HFC-152a, HFC-23 and HFC-32). Emission data for precursors (NO_X, CO and NMVOC) and SO_2 are also given.

To make it possible to compare the climatic effects of the GHGs, we have presented the emissions of greenhouse gases measured as CO_2 equivalents based on data for Global Warming Potential (GWP), calculated for a time horizon of 100 years according to the IPCC guidelines.

This report has been prepared in accordance with the UNFCCC Reporting Guidelines on Annual Inventories adopted on November 1999 by decision 3/CP.5.
The methodology used in the calculation of emissions is set out in the revised IPCC Guidelines for emission inventories approved by the UNFCCC (IPCC 1996).

When emissions and trends are described in chapter 2 the focus is on ”national” nomenclature and source categories, since this approach is more suitable for characterising the national emissions. This approach better reflects distinctive Norwegian sources like the oil- and gas industry and some other industrial sectors. However, as already mentioned, all the tables are filled in according to the CRF.

As a general rule, the estimation methods follow the Revised 1996 IPCC Guidelines for national Greenhouse Gas Inventories. However, other methods have been used where necessary, as described in chapter 5.

Statistics Norway (SN) and the Norwegian Pollution Control Authority (SFT) co-operate to provide emission inventories for several air pollutants in Norway. SFT contributes with emission factors for all sources and measured emission data for large industrial plants. SN has developed various emission models based on the information from SFT and other industrial and energy statistics. The emission figures for CO_2, CH_4 and N_2O, as well as for $NO_{X,}$ CO, NMVOC and SO_2, have been prepared this way. Emission figures for PFCs, SF_6 and HFCs have been provided by SFT.

The methodology used in the emission inventory is described in the report ”The Norwegian Emission Inventory – Documentation of methodology and data for estimating emissions of greenhouse gases and long-range transboundary air pollutants” (SN/SFT 2000b).

Figures for net biotic CO_2 sinks are calculated on the basis of emissions from fuelwood, wood waste and annual CO_2 accumulation in Norwegian forests. However, in accordance with the IPCC 1996 Revised Guidelines, this sink is not included in the overall Norwegian GHG inventory.

In accordance with The UNFCCC Reporting Guidelines, emissions from international aviation and marine bunker fuels are not included in the overall Norwegian greenhouse gas inventory. However, the inventory includes emissions from fishing wessels, coastal traffic and aircraft bunkering in Norway. In chapter 4 we present separate emission data based upon fuel sold to ships in international traffic bunkered in Norwegian harbours and to foreign aeroplanes in international traffic bunkered at Norwegian airports.

2. Emissions

In 1998 total emissions of greenhouse gases, measured as CO_2-equivalents, were about 56,2 million tonnes. Since 1990 the total emissions of greenhouse gases have increased by 8%.

The increase is mainly due to higher CO_2-emissions from all the most important national sectors. This trend has to some degree been counteracted by decreased emissions of PFCs and SF_6 from aluminium- and magnesium plants. Emissions of CH_4 and N_2O have been relatively stable over the same period, except for minor fluxes related to emissions from oil/gas-industry and fertiliser production respectively.

Norwegian emission patterns are characterised by chemical and metallurgical industry and a large, and increasing, oil- and gas sector. About one fourth of the mobile emissions originates from coastal navigation (traffic) and fishing-wessels. Electricity generation is almost entirely hydroelectric, so emissions from stationary combustion are mainly from industry (including offshore platforms).

From 1990 to 1998 the increase in CO_2-emissions from the oil- and gas industry has been the most pronounced. This is the result of large increases in production volume.

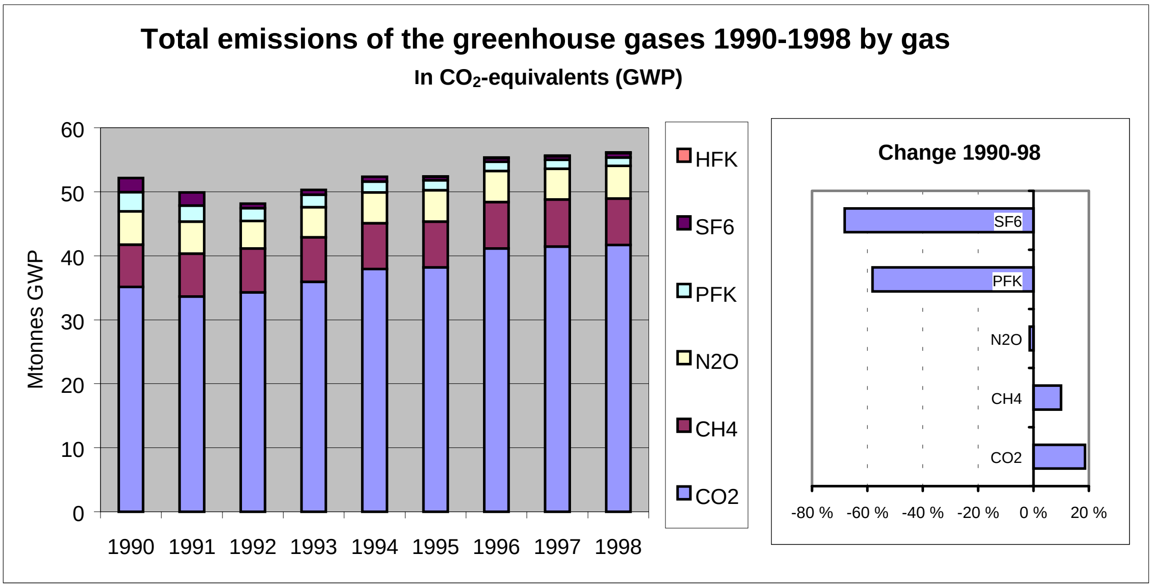


Figure 1: Emissions of greenhouse gases 1990-98 by gas.

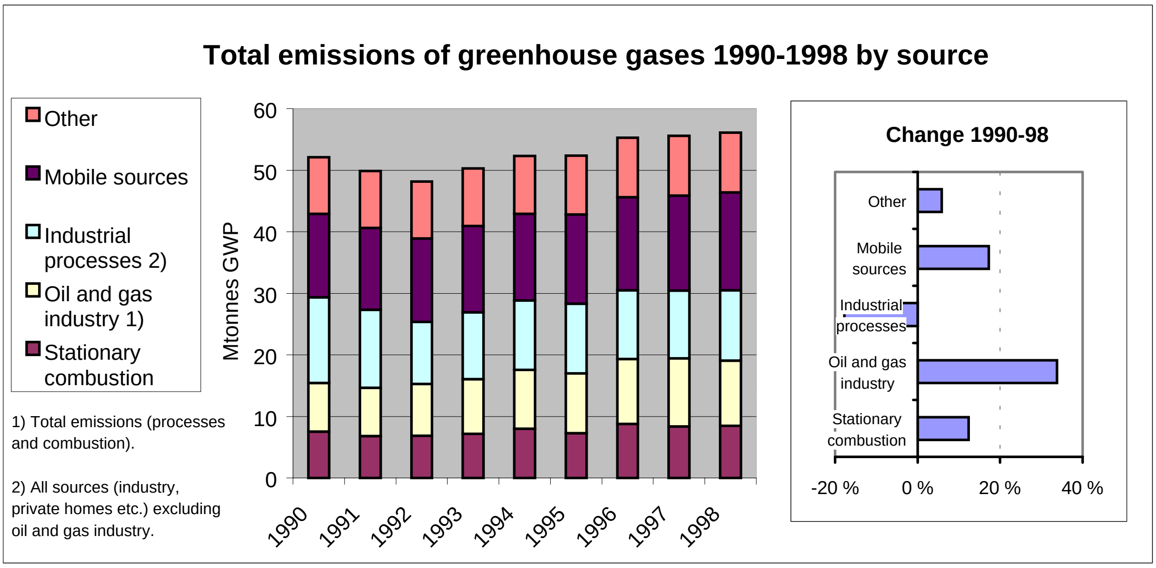


Figure2: Emissions of greenhouse gases 1990-98 by source.

2.1. Carbon dioxide (CO_2)

Norwegian CO_2-emissions are characterised by industrial sources related to oil- and gas extraction and the production of metals, minerals and chemicals. A relatively large share of the transport-related emissions originates from coastal navigation and the fishing fleet. Since generation of electricity is almost exclusively hydroelectric, emissions from stationary combustion are dominated by industrial sources.

From 1990 to 1998 total CO_2-emissions have increased by 19%. Most major sectors have contributed to this increase, but the increases from the oil- and gas industry have been the most pronounced.

In 1998 total Norwegian emissions of CO_2 were 41.7 Mtonnes. This is an increase of 1% from 1997, mainly caused by increased emissions from coastal navigation, light vehicles and metal-production. Emissions from oil and gas industry, however, decreased by 4% from 1997 to 1998.

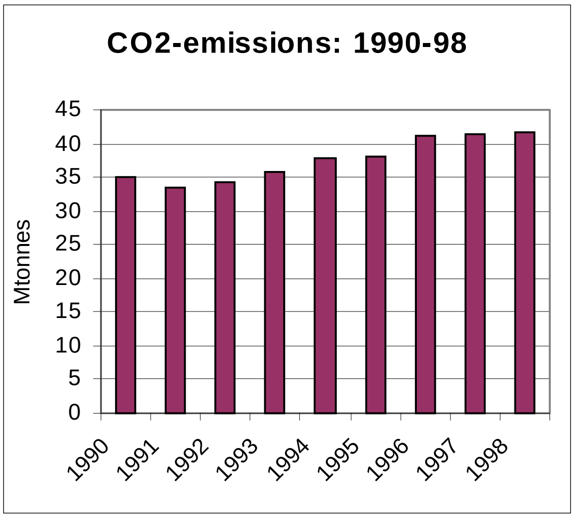


Figure 3: CO_2 emissions 1990-98

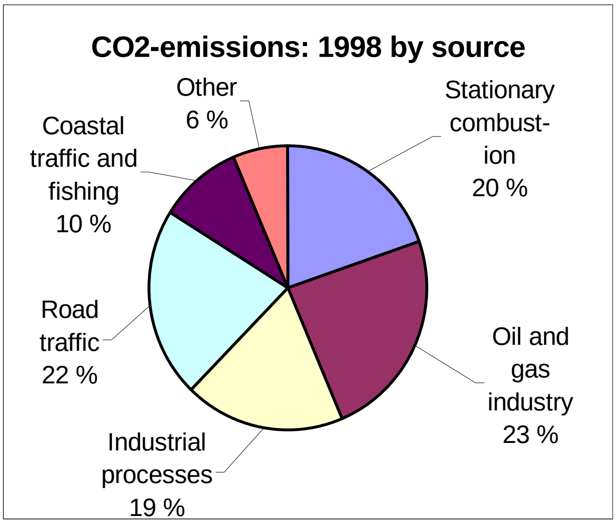


Figure 4: CO_2 emissions by source 1998.

The increased emissions from the oil- and gas industry are a result of large increases in production volume. Because of technical and administrative improvements, induced by a CO_2-taxation regime, the emissions pr. unit produced oil/gas have been decreasing. Due to technical factors related to a shift to older and more marginal oil-and gas fields, this trend has however been reversed in the last few years.

For road traffic the increase in emissions is particularly due to increased traffic by heavy duty vehicles (34%). The increase in emissions from light vehicles (8%) has been somewhat slowed down because of a significant shift from gasoline- to diesel-powered vehicles and the general improve of fuel efficiency in newer vehicles.

Emissions of CO_2 from domestic air traffic increased by 25% from 1990 to 1998, due to a general increase in air-traffic partly because of increased capacity.

Emissions from coastal navigation increased by 32% due to increased transport of freight and a general trend towards faster vessels.

Chemical production (fertiliser, carbides, petrochemical) and domestic heating are the only significant sources with a decreasing emission trend.

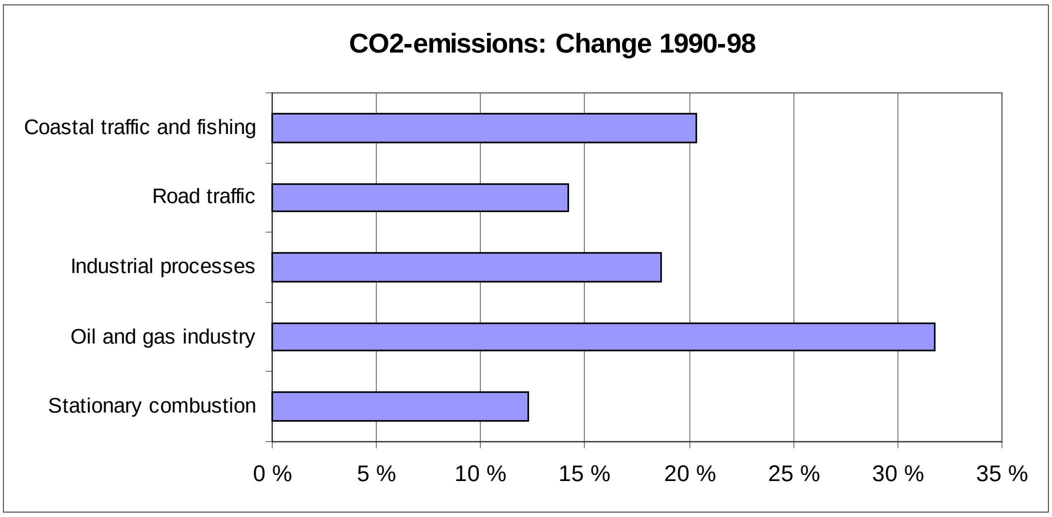
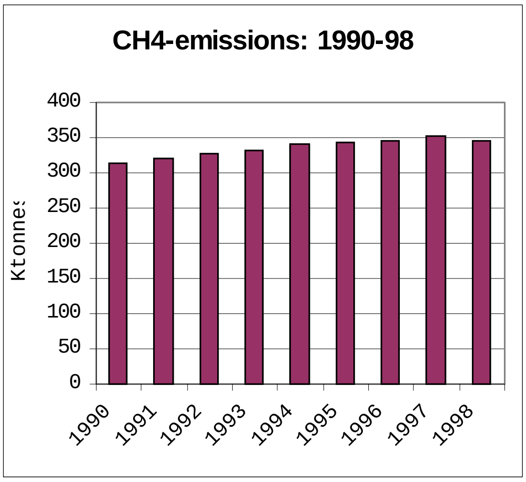


Figure 5: CO_2 -emissions change in emissions from important sources 1990-1998.

2.2. Methane (CH_4)

87% of the emissions of methane originates from waste treatment and agriculture. These sources are relatively stable from year to year, and are little affected by short-term economic cycles. Combustion and evaporation/leakage in the oil- and gas industry account for 8% of the total emissions, while minor sources include emissions from petrol cars, domestic heating and coal mining.

From 1997 to 1998 emissions dropped for the first time during the 1990s. This is due to a 9% decrease in emissions from the oil and gas industry, caused by reduced production volumes, and a 2% reduction of emission from waste treatment, due to increased recycling of waste and increased burning of methane from landfills.



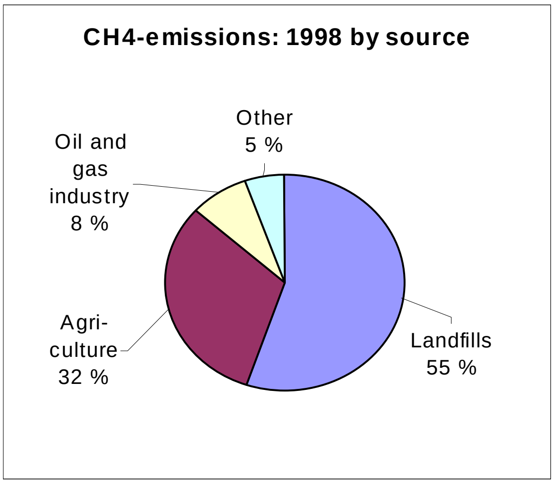


Figure 6: Methane emissions 1990-98

Figure 7: Methane emissions by source in 1998.

From 1990 to 1998 total CH_4-emissions have increased by 10%. This is mainly due to an approximately 10 ktonn increase in each of the three important sectors landfills, agriculture and oil- and gas industry.

The emissions from agriculture are mainly from animal manure. Few technical measures have been carried out on this field. In the waste treatment sector a potentially larger increase has been avoided by flaring/use of methane gas from landfills and increased energy-recycling.

Emissions from oil- and gas industry are largely caused by landing and loading of crude oil. Technical measures that will reduce these emissions are emerging. In general the emissions from the petroleum industry are influenced by a gradual shift of activities from oil to natural gas.

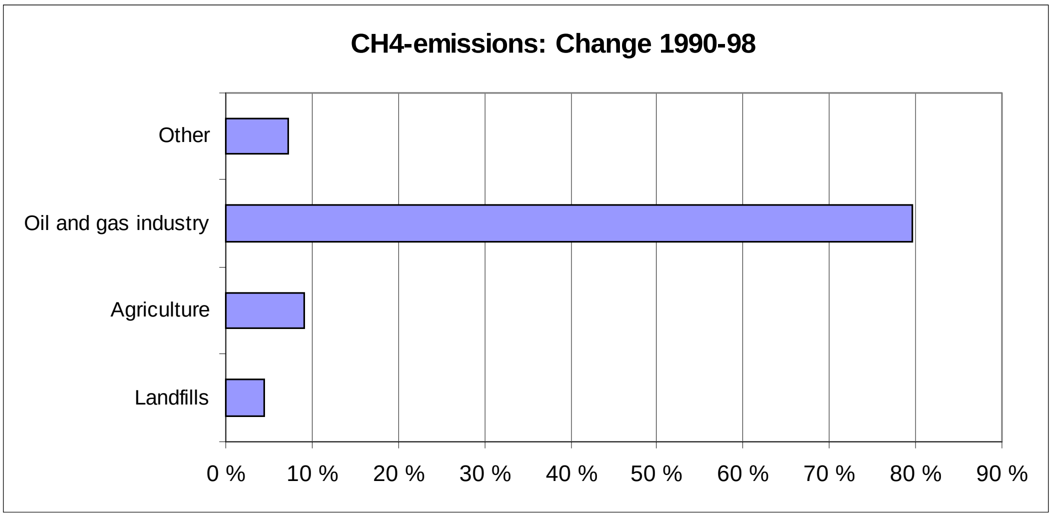


Figure 8: CH_4 emissions; change in emissions from important sources 1990-1998.

2.3. Nitrous oxide (N_2O)

Emissions from agriculture (manure and nitrogenous fertiliser) account for half of the Norwegian emissions of N_2O. These emissions have been rather stable through the 1990s.

Since last years reporting emissions caused by leaching and runoff from agricultural land have been recalculated. In previous submissions to UNFCCC an IPCC default value of 30% was used for leaching and runoff, while in this submission a national factor of 18% is used. For the baseyear 1990 this has resulted in a decrease in estimated emissions by 0.3 Mtonnes CO_2-equivalents.

The other major source is the two plants manufacturing nitrogenous fertiliser. Changes in production processes led to decreased emission in the beginning of the 1990s, while there was a moderate increase in emission in the following years due to increased production volumes. From 1997 to 1998 there was a 14% increase in emissions.

Emissions from mobile sources are increasing considerably because of the introduction of catalytic converters, and accounts now for 10% of total N2O-emissions.

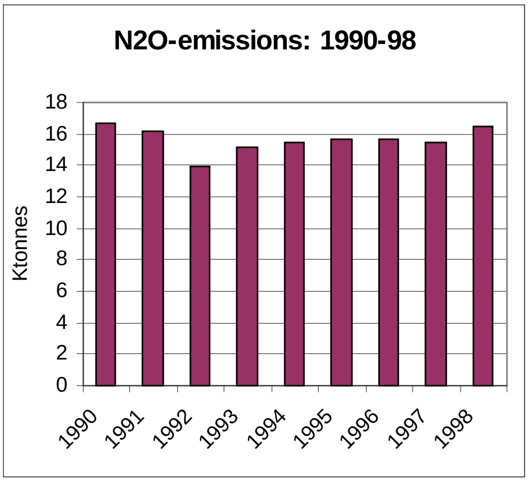


Figure 9: Emissions of nitrous oxide 1990-98.

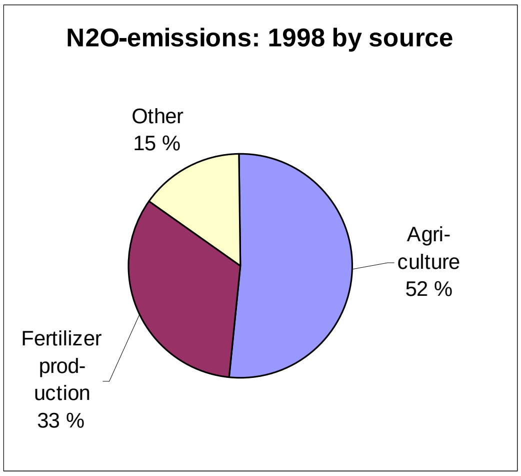


Figure 10: Emissions of nitrous oxide 1998 by source.

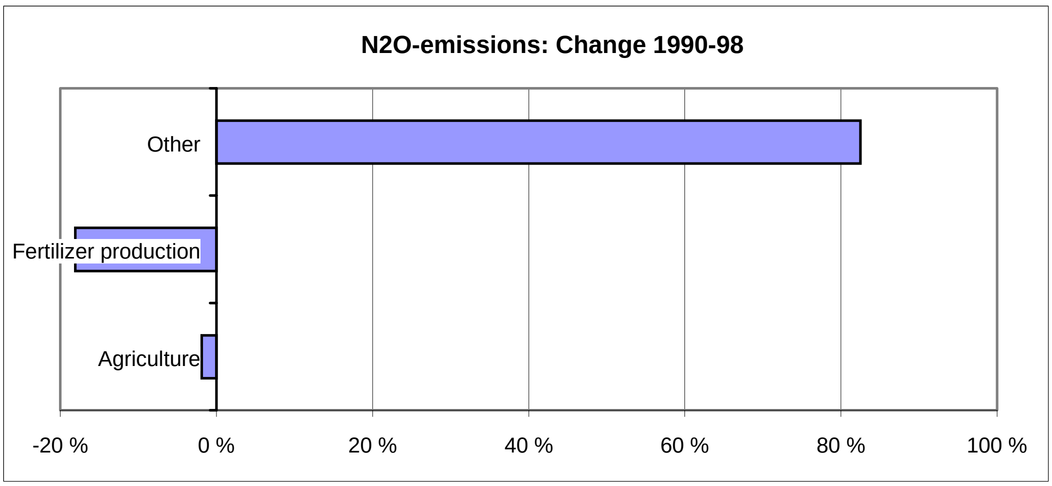


Figure 11: N_2O emissions; change in emissions from important sources 1990-1998 (Change in source "other" is mainly due to large increases in emissions from petrol cars).

2.4. Perfluorcarbons (PFCs)

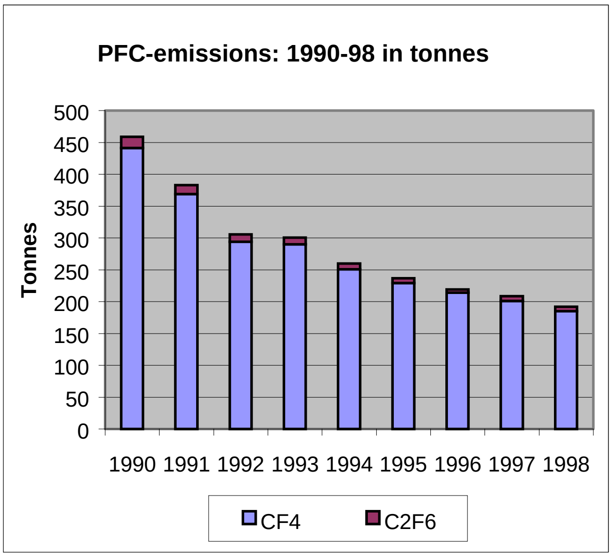
The emissions of perfluorcarbons, e.g. tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) from Norwegian aluminium plants in 1998 are calculated to 185 and 7 tonnes respectively, corresponding to 1.27 million tonnes of CO_2 equivalents.

From 1990 to 1998 the emissions of PFC-gasses were reduced by 58%. This is explained by improved technology and process control, which has caused a reduction of the emissions per tonne aluminium produced from 0.53 to 0.19 kg PFC from 1990 to 1998.

Emission measurements have been carried out at the plants during the last few years. Based on an analysis of this data, the timeseries from 1990 to 1998 has been recalculated for this year's report. This recalculation has resulted in a major change in the 1990 emissions (see Appendix 2, Table 8(a)s2 and table 10s4).

The recalculation, which was induced by new measurements in the aluminium industry, resulted in a 0.5 Mtonnes CO_2-equivalents increase in estimated emissions of PFCs in the baseyear 1990. This revision has, however, had little impact on estimated total emissions of greenhousegases in 1990, because it has been largely offset by recalculation of other sources like N_2O-emissions from agriculture (see ch. 2.3).

PFCs may be used as substitutes for ozone-depleting substances. In Norway, only one compound is used for this purpose, namely C_3F_8 (PFC-218). The actual emissions of C_3F_8 have been calculated to be 60 kg in 1998, corresponding to 420 tonnes of CO_2-equivalents (see also ch. 2.6).



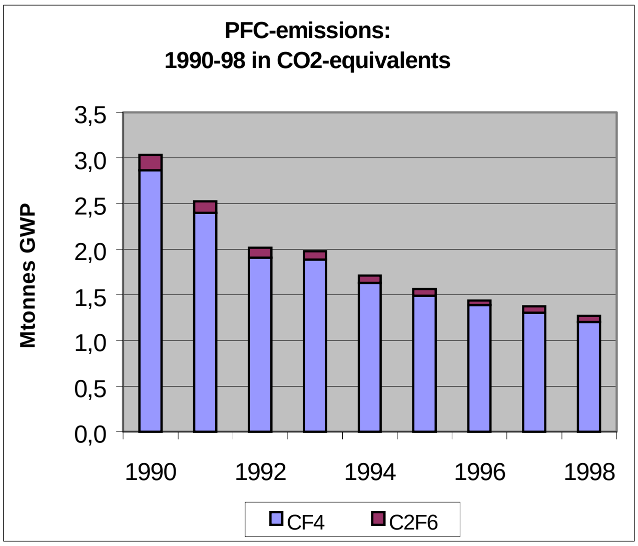


Figure 12 and figure 13: Emissions of PFC gases (CF_4 and C_2F_6) 1990-98 in tonnes and Mtonnes CO_2-equivalents.

2.5. Sulphur hexafluoride (SF_6)

The largest emission source in Norway is magnesium production where SF_6 is used to cover the surface of liquid magnesium to prevent it from oxidising. The covering gas is emitted to air after use. Emissions have been reduced through the 1990s due to improvements in technology and process-management.

Similar applications in the aluminium industry have been phased out because of changes in process (from Soederberg to Pre-baked).

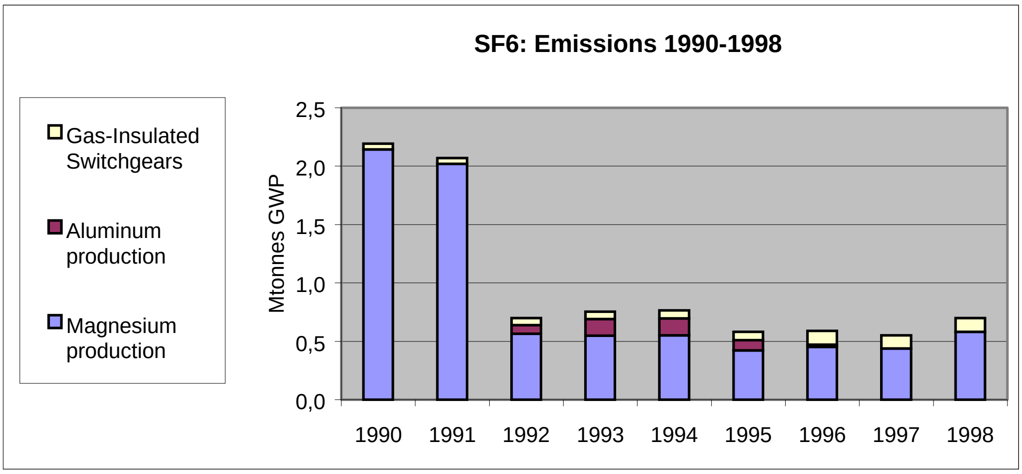


Figure 14: Emissions of Sulphur hexafluoride (SF_6) 1990-98 by source.

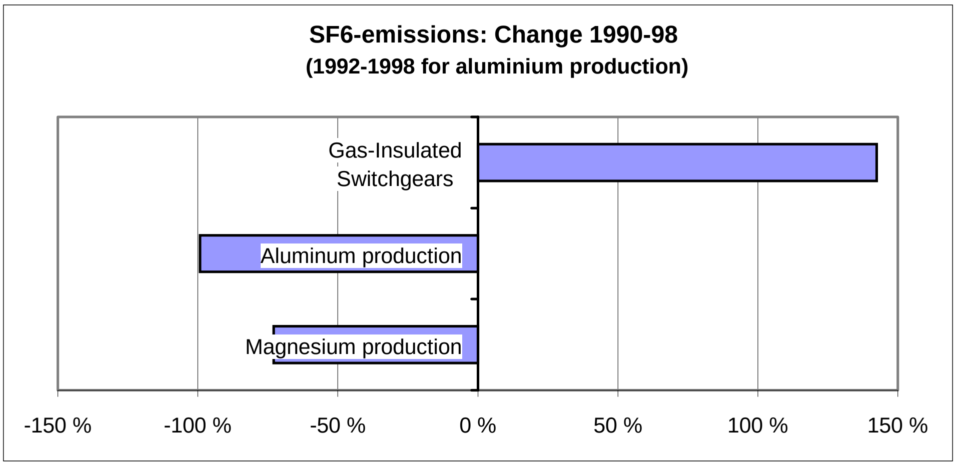


Figure 15: SF_6- emissions; change in emissions from important sources 1990-1998.

2.6. Substitutes for ozone depleting substances (HFCs and PFCs)

In 1998/99, SFT initiated a project to estimate the actual emissions of HFCs and PFCs for applications where ozone-depleting substances have been employed earlier (SFT 1999b) according to the Tier 2 methodology. We calculated emissions employing a bottom-up approach. In Norway there is no production of HFCs or PFCs, and production of equipment containing these chemicals does only occur to a small extent. The project therefore focuses on import of chemicals and import and export of products containing HFC/PFC. The resulting estimates showed that the HFCs and PFCs contributed with about 133 ktonnes of CO_2 equivalents in 1998, or about 0.3 % of the total emissions of GHG in Norway. During the period 1995-1998 the emissions increased by a factor of five.

The application category Refrigeration and air conditioning contributed with the largest part of the HFC and PFC emissions in 1998. About 94 % originated from this category in terms of CO_2 equivalents. The total emissions from this source in 1998 corresponded to about 126 ktonnes of CO_2 equivalents.

Foam and foam blowing were the second most important source of emissions of HFCs in 1998. The emissions from this category were about 5 ktonnes of CO_2 equivalents. They accounted for 4 % of the total emissions of HFCs/PFCs. Emissions from fire extinguishing products reached 2 ktonnes in terms of CO_2 equivalents in 1998, which was about 2 % of the total HFC/PFC emissions. Solvents and aerosol propellants containing HFCs emitted about 240 tonnes of CO_2-equivalents. Their share of the total emissions of HFCs/PFCs was modest and accounted for less than 1 %.

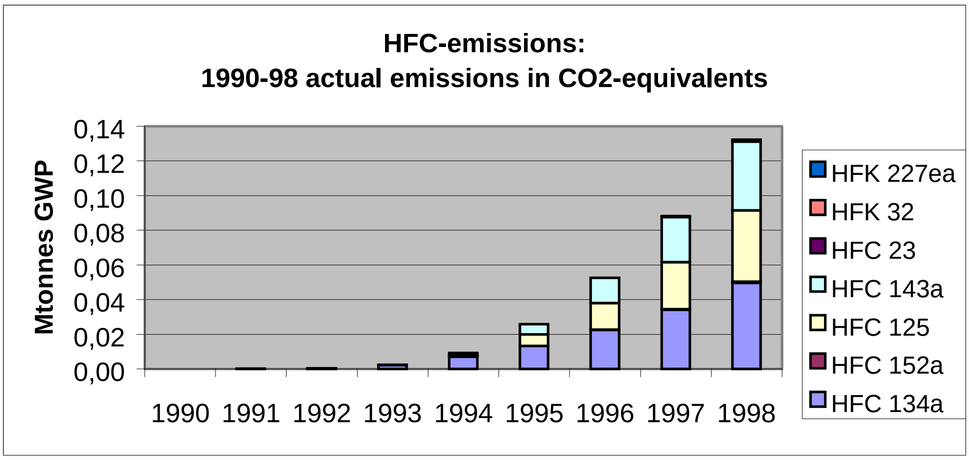


Figure 16: Emissions of HFC-gases 1990-98 by gas. Actual emissions (Tier 2)

1998	CO_2-equv. (ktonnes)
Total	133
Refrigeration and air conditioning	125.8
Foam	5.1
Fire extinguisher	2.0
Solvent	0.04
Aerosol propellant	0.2

Source: SFT and SN

Table 2: Actual emissions of HFCs/PFCs according to Tier 2. 1998

Halocarbons; Emissions in tonnes	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Actual emissions (Tier 2)									
- HFC-134a	0	0.04	0.19	1.74	5.39	10.15	16.83	25.94	38.20
- HFC-143a	0	0	0	0	0.19	1.52	3.86	6.84	10.43
- HFC-152a	0.13	0.41	0.65	0.79	0.82	0.99	1.47	1.56	4.79
- HFC-125	0	0	0	0	0.47	2.38	5.47	9.71	14.73
- HFC-23	0	0	0	0	0	0	0.01	0.04	0.07
- HFC-32	0	0	0	0	0	0.01	0.03	0.15	0.33
- HFC-227ea	0	0	0	0	0	0	0.05	0.11	0.15
- PFC-218	0	0	0	0	0	0	0	0.06	0.06
Potential emissions (Tier 1a)									
- HFC-134a	0	1.0	2.2	31	40	47	61	81	259.59
- HFC-143a	0	0	0	0	4.0	25	25	43	43.59
- HFC-152a	3.0	3.0	3.0	1.0	1.1	4.5	3.4	6.8	49.78
- HFC-125	0	0	0	0	11	31	38	61	62.57
- HFC-23	0	0	0	0	0	0	0.1	0.5	0.1
- HFC-32	0	0	0	0	0.1	0.1	0.3	2.3	1.65
- HFC-227ea	0	0	0	0	0	0	1.6	1.3	0.58
- PFC-218	0	0	0	0	0	0.3	0.3	0	1.0

Table 3: Actual and potential emissions of HFCs and PFCs in Norway. 1990-1998 (tonnes).

We have also calculated the potential emissions employing the Tier 1b methodology. The ratio between potential and actual emissions in 1998 was about five.

2.7. Precursors (CO, NO_X and NMVOC) and SO_2

Precursors are gases, e.g. NO_X, CO and NMVOC, which have an indirect effect on the climate through their influence on other greenhouse gases, especially ozone. SO_2 has a climate effect by increasing the level of aerosols.

Mobile sources make the most important contribution to emissions of CO and NO_X. Oil and gas production, particularly crude oil loading to ships, is the most important source of NMVOCs in Norway. Raw material producing industries, metal production in particular, is the most important SO_2 source.

From 1990 to 1998 the emissions of CO have decreased by 25%, mainly because of new emission standards for motor vehicles.

Emissions of NO_X decreased by 3% from 1990 to 1995, but have since then been climbing to a level in 1998 that is about 2% higher than the 1990 level. Reduced emissions from road traffic due to the introduction of stricter emission regulations have been counteracted by increased emissions from oil/gas production and coastal navigation.

Emissions of NMVOCs increased by 23% from 1990 to 1996 due to a rise in oil production, and in spite of reduced emissions from road traffic. However from 1996 and onwards this trend was reversed, due to introduction of recycling of oil vapour at one of the oil terminals.

Emissions of SO_2 were reduced by 44% from 1990 to 1998. Stationary sources and industrial processes are the most important contributors to these emissions. The reduction is mainly explained by a reduction in the sulphur content of all oil products and lower process emissions from ferro-alloy and aluminium production and refineries.

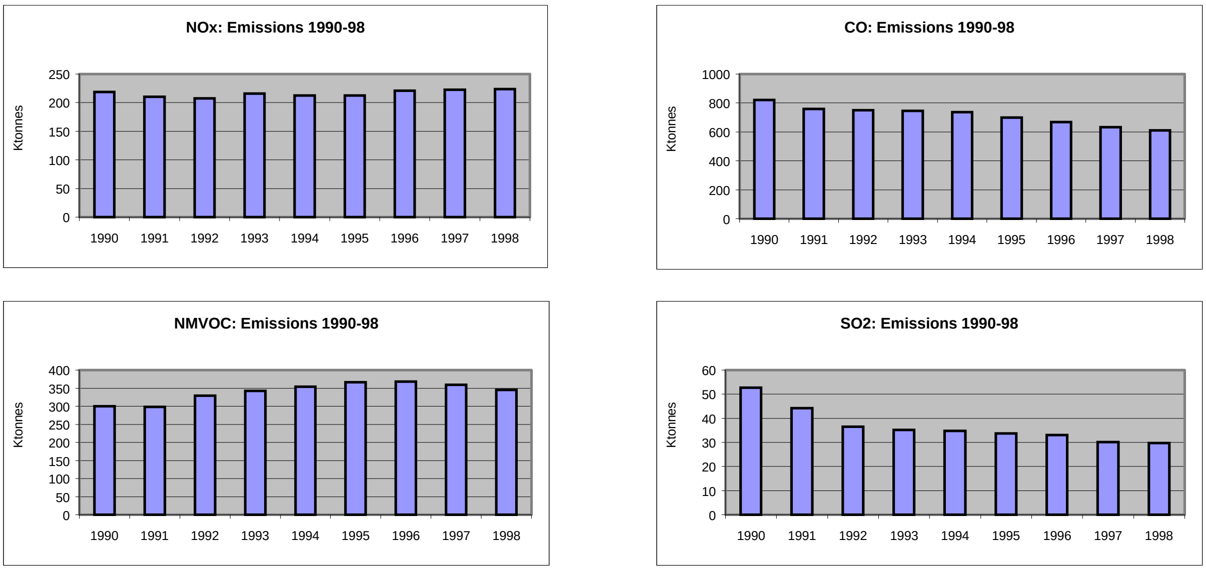


Figure 17: Emissions of NOX, CO, NMVOC and SO2 1990-1998.

3. Biotic CO_2 sinks

Harvesting the forest has a long tradition in Norway. Up to the beginning of this century the harvest was about the same as the regrowth. Since then the standing volume of Norwegian forests has increased, it has almost doubled from 1925 to 1990, while the harvest has been about the same (10 million m^3 per year). The result is a considerable net increment and hence accumulation of carbon in forests. The standing volume yields a carbon reservoir of 250 million tonnes (1995), including bark, stumps, branches and roots.

The gross increment of carbon in Norwegian forests is estimated to being equivalent to 33.5 million tonnes of CO_2 in 1998. A total of 15.9 million tonnes of CO_2 were depleted by e.g. felling, which resulted in a net sink of 17.6 million tonnes of CO_2, see table 4. This is about 1 million more than in 1997. The net sink is equivalent to about 35 % of the total emissions of CO2 in Norway in 1998, with an opposite sign. CO2 emissions and removals from soil have not yet been estimated, but we have initiated a project where the objective is to calculate the carbon stock change in soil.

From Table 4 it can be seen that harvested wood resulted in emissions of 12.7 million tonnes of CO2, while other depletion gave emissions of 3.2 million tonnes. According to the Revised IPCC Guidelines, felled wood is calculated as emissions the year of harvest. The figure for felling consists of emissions from commercial consumption, fuel wood consumption and other private wood consumption. “Other depletion” signifies emissions from logging and sivilcultural waste and natural losses.

Carbon is stored in wood, which is used in a vast number of commodities, e.g. furniture, books, paper, and especially dwellings and other buildings. This storage serves as a reservoir of carbon. The accumulated carbon in wood products is not included in the national inventory reported to UNFCCC. The net accumulation of biotic CO2 in products was calculated to approximately 0.5 million tonnes in 1993 (SFT 1996). Carbon in paper and paper products, leather and natural textiles are then included. This is equivalent to about 3 % of the yearly change in the carbon reservoir of the forest.

	CO_2-removals (mill. tonnes CO_2) 1998
Gross increment	33.5
Felling	
▪ Commercial consumption	-10.6
▪ Fuel wood consumption	-1.8
▪ Other private wood consumption	-0.3
Other depletion	
▪ Logging and sivilcultural waste	-0.8
▪ Natural losses	-2.4
Total gross depletion	-15.9
Net growth	17.6

Table 4: Emissions and removals in Norwegian forests 1998.

4. International aviation and marine bunker fuels

In accordance with the IPCC Guidelines, emissions from international aviation and marine bunker fuels are not included in the overall Norwegian greenhouse gas inventory, but are presented separately, see table 5 and table 6. Emissions from helicopters are included in the totals for aircraft.

In 1998, CO_2 emissions from ships and aircraft in international traffic bunkered in Norway amounted to a total of 3.7 million tonnes, which corresponds to about 8 % of the total Norwegian CO_2 emissions. The emissions decreased by 5 % from 1997 to 1998. Since 1990 the emissions have increased by as much as 76 %.

We see that the emissions of CO_2 from ships in international traffic have almost doubled from 1990 to 1998. The emissions of CO_2 from aircraft increased by 37 % in the same period. The reason for this increase is primarily due to growth in traffic. We know that the aircraft engines are more fuel-efficient now than some years ago, which means that the growth in traffic has been higher than the growth in emissions.

Marine	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO_2	1.5	1.3	1.6	1.7	1.8	2.3	2.5	3.1	2.9
CH_4	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
N_2O	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
NO_X	30.3	25.6	32.1	34.3	37.8	46.2	50.7	63.0	59.4
CO	1.4	1.2	1.5	1.6	1.8	2.2	2.4	3.0	2.8
NMVOC	1.1	0.9	1.2	1.3	1.4	1.7	1.9	2.3	2.2
SO_2	9.9	9.7	12.3	13.5		13.7	15.4	19.9	17.0

Aviation	1990	1991	1992	1993	1994	1995	1996	1997	1998
CO_2	0.6	0.5	0.6	0.6	0.6	0.6	0.7	0.8	0.8
CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO_X	1.7	1.6	1.6	1.8	1.7	1.7	2.1	2.3	2.5
CO	1.7	1.6	1.6	1.8	1.7	0.9	1.0	1.2	1.3
NMVOC	0.5	0.5	0.5	0.5	0.5	0.1	0.2	0.2	0.2
SO_2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table 5 and table 6: Emissions of CO_2, CH_4, N_2O, NO_X , CO, NMVOC and SO_2 from ships and aircraft in international traffic bunkered in Norway. 1990-1998. 1000 tonnes. CO_2 in mill. tonnes

Emissions of NO_X from ships were 59.4 ktonnes or 27 % of the total Norwegian NO_X emissions in 1998. During the period from 1990 to 1998, NO_X emissions almost doubled. NOx-emissions resulting from international aviation increased by 47% from 1990 to 1998.

Emissions of N_2O, CH_4, and NMVOC from international aviation and marine bunker fuels are small compared to total Norwegian emissions of these gases.

5. Methods of estimation

The methods of estimation of all gases are harmonised with current IPCC guidelines for reporting national greenhouse gas emissions. However, national specific estimation methodologies have been used when they illustrate Norwegian conditions better. The methodology, emission factors, activity data and measurements used in the Norwegian inventory model are described in The Norwegian Emission Inventory Methodology is described in (SFT/SSB 2000b) which is enclosed to this report.

5.1. The Norwegian inventory model in general

The emission figures for CO_2, CH_4, N_2O, HFCs and for the precursors CO, NO_X,¸ NMVOC and SO_2 are estimated in collaboration between Statistics Norway (SN) and the Norwegian Pollution Control Authority (SFT). SFT contributes with emission factors from all sources and measured emission data from large industrial plants. SN is responsible for activity data (e.g. on energy use), emission models and calculations.

In the Norwegian emission inventory model all emissions are calculated in a four-dimensional cube model, with the axes components, technical emission sources, emission carriers (e.g. fuels) and economic sectors. This model includes the greenhouse gases CO_2, CH_4 and N_2O and in addition the precursors NO_X, SO_2, NMVOC, and CO. Thus, emissions can be listed by a multitude of combinations of fuels, sources and sectors. The combustion emissions are calculated by combining the fuel consumption distributed on emission sources and economic sectors with fuel-, source-, sector- and pollutant specific emission factors. If measured emission estimates are available, these are used instead of the calculated emissions. Aggregated emission factors are input to the main emission model. Emissions from road traffic, methane from landfills and emissions of HFC are calculated in a special model in a detailed manner. The non-combustion emissions are estimated by combining activity data with emission factors, by more complicated calculations. The emission factors are either estimated from measurements or taken from special investigations. The non-combustion emissions are fitted into the cube model by an appropriate emission carrier, emission source and economic sector.

The Norwegian national inventory model covers all the recognised important sources for the emissions of all the above mentioned components. The industrial emissions are fairly well covered by measurements or by use of national emission factors.

Emissions of SF_6, PFCs and HFCs are calculated separately, and are not included in the national inventory model.

The calculation of greenhouse gas emissions measured as CO_2 equivalents is based on data for global warming potential (GWP), calculated for a time horizon of 100 years, from IPCC Second Assessment in 1995.

6. Uncertainty

The reductions or increases of total GHG emissions (expressed in CO_2-equivalents) in percent relative to a base year, are very robust with respect to errors in level and trend of individual greenhouse gases. This is due to the fact that the same estimation methodology will be used for all years in a given time period. Exceptions are in cases where one significant pollutant or individual source shows a different trend compared to the remaining emissions. Even gases that constitute a rather small part of the total GHG emissions from Norway, like PFCs and HFCs, may be important for the trend determination as these emissions are changing rapidly. Generally, the trend from 1990 to 2010 will be more sensitive to errors than the trend from 1990 to 1996 (assuming that the uncertainty in future emission data is as in the historical). This is due to the fact that from 1990 to 2010 emissions of some pollutants will increase, while others will be substantially reduced.

Generally, the inventory is sensitive to errors in a particular gas or source if

1. The source or gas shows a different trend compared to the remaining inventory.
2. The error is large (the level of the gas or source is very uncertain).

The uncertainties in the level and trend of nitrous oxide, perfluorocarbons and methane are causing particular concern for the trend determination.

7. Verification

It is crucial for the success of the Kyoto protocol that the countries report high quality data. This could include routines for quality control as well as verification of the emission data.

Norway is making a survey to verify our national emission data (SFT 2000a; To be published). Statistic Norway (SN) on behalf of the Norwegian Pollution Control Authority (SFT) has done the verification. The method that has been used is comparing *emission intensity values* (EIV) (aggregated indirect emission factors) for Norway with values for Sweden, Canada and New Zealand. We have tested one method to check the *quality* of the Norwegian emission estimates reported to UNFCCC with the emission estimates from Sweden, Canada and New Zealand. These countries are chosen because they have common structural features; cold winters, scarcely populated areas, they produce electricity from hydropower and have some common industrial processes. We have also checked the *trend estimates* by comparing the emission intensity values for both 1990 and 1996.

Data used in the survey are the official emission estimates reported from the countries to UNFCCC and activity data (for example GDP, population, energy statistics or production) from official sources like OECD or UN. For each sector we have calculated emission intensity values of each pollutant per various type of activity data, for example emissions per TJ energy. Comparisons are made at different levels of aggregation of the IPCC summary tables.

Conclusions are made both on the suitability of this method for verifying emission data and on the conclusions that may be drawn for the reliability of the Norwegian reported data based on this study.

7.1 Suitability of method

In general this method seems suitable for detecting gross reporting errors. It is, however, likely to fit better for some source categories than other. It is also necessary in order to draw the correct conclusions to have certain knowledge of the countries included in the comparison. Furthermore it is important to compare countries that for each source category are expected to give similar results.

In this study we have concluded that one specific activity data usually is more suitable than the others for the purpose of verification. However, for a proper check of data it could be an advantage to compare more than one EIV. This would strengthen the conclusions made.

Energy
For combustion related emissions from energy (App. 2, Table 1A) we have tested activity data like GDP, population, energy consumption and transport activity (tonne-km or passenger-km). Energy use (from IEA statistics) was, not surprisingly, the most suitable activity data. This was the case for mobile combustion in transport and stationary combustion in energy and manufacturing industries and other sectors.

For the fugitive emissions from fuel (App. 2, Table 1B) energy use is not relevant. In the sector coal mining production of coal is probably the best (and maybe only) activity data, but our results were poor due to different types of mining (surface or underground mining). Oil and gas production is assumed to be the most suitable activity data to verify fugitive emissions from the oil and gas sector, but differences in production technologies had large impact on the results.

Industrial processes
For emissions from industrial processes, activity data like population and GDP are not relevant. For these emission sources relevant production data are the best activity data to be used for the verification. For emissions from metal production, the use of feedstock is also relevant. Emissions from metal production are in general difficult to compare among countries, due to inconsistent reporting of feedstock and emissions between energy sources and industrial processes/feedstock.

The activity data population and GDP were tested for the sector "Consumption of Halocarbons and Sulphur Hexacloride" which is included in App. 2, Table 2 Industry. Potential emission estimates were used in the comparison since few countries report actual emissions. These estimates are very rough and comparisons on actual emission estimates are needed to draw relevant conclusions.

Solvent and product use
Based on data from only Norway and Sweden it seems like the activity data population is relevant to check emission data for solvent and product use. This should, however, be tested for more countries.

Agriculture
The activity data animal population (cattle number), meat production, agricultural area, crop production, fertiliser consumption and agricultural output have been tested in this study.

For emissions from enteric fermentation the population of cattle seems to be the best activity data. But none of the proposed activity data assessed the emissions very well for the countries included in this study. An analysis on a more detailed level would make the use of more specific activity data possible.

For agricultural soils meat production at first glance seems to be a good activity data (with relatively small deviations between the countries). But since meat production does not include important sources like fertilisers, crop residues and animals kept for other purposes than production, the results seem coincidental. Possible future reporting of more detailed data will help to identify better activity data for comparison. More countries should be included in the study before any further conclusions can be drawn.

Waste
For emissions of CH_4 from waste disposal, number of tonnes municipal waste disposed of in landfills is a possible activity data for the verification.

7.2 Results for Norway

The project has identified several smaller reporting errors; especially emissions reported in another source category than it should according to the IPCC reporting instructions.

Energy
For most of the sectors listed in App. 2, Table 1 (Energy), the Norwegian emission estimates seem reasonable when comparing the activity data energy use. For fugitive emissions from coal mining and oil and gas extraction on the other hand, the emission estimates were not comparable with data reported from the other countries.

Industrial processes
For most of the industrial processes where we were able to test the activity data "production", we were able to verify the estimates. However, in some sectors we had problems because of differences between the sectors used for the production and emission data. Also, since the other countries do not have the same industrial activities as Norway, the foundation of comparisons were for some processes poor.

Solvent and product use
The Norwegian emission estimate for solvent and other product use (App.2, Table 3) seems reasonable. The activity data is based on population (emissions of CO_2 / million capita).

Agriculture
For agriculture there were large deviations from country to country. For enteric fermentation Norway have activity data values of the same magnitude as Canada and Sweden. The values for New Zealand are much higher. Taking the differences in the distribution of husbandry animals the Norwegian emission estimates seems reasonable. For manure management the percentage difference between the activity data values are too large to draw any conclusions.

Waste
The proposed activity data gives higher values for Norway than Sweden and Canada. Emission estimates for methane from landfills are uncertain, so differences between Norway, Canada and Sweden on 60 - 100 % could be expected.

7.3 Uncertainties/problems during the work

There are several issues that make this type of verification complicated and will contribute with uncertainties in the final conclusions:

- Different countries report emission data in different ways. Some countries report CO_2 emissions from production of metals as energy emissions, others as non-combustion emissions and others again something in-between.
- The OECD energy statistics first present preliminary figures that later are being revised. The figures for 1996 are only preliminary, but the emission figures from the UNFCCC are often based on revised energy figures. This leads to inconsistency in the data.

- To verify the emission data we need as disaggregated emission data as possible. Several countries (among them Norway) do only report a summary table over emissions in 1990 and detailed data for the latest year. For verification of trends we need detailed data for 1990 too.
- Inconsistencies between the sectors used in the emission reporting and reporting of the activity data, especially the energy data, has been a problem.
- OECD and UN do not list energy and production data for sectors with few companies. This means that for some sectors data is lacking.
- Not all countries have reported emissions of SF_6 and PFCs.
- More countries would be needed to verify the Norwegian emissions from industrial processes. For instance is Norway the only one of these four countries that produces carbide.
- Norway produces nitric acid as an intermediate product in the production of fertilisers. Norway does not report production of nitric acid to the UN production statistics, since this only is an intermediate and not an end product. We have therefore not found any suitable activity data for production of nitric acid.

7.4 Conclusions

We consider the method described in this report as appropriate for checking data for some sectors, but less promising for others. For energy use the method gives a certain verification of the Norwegian emission estimate for most of the sectors. For some of the industrial processes like iron and steel on the other hand, the method does not give a satisfactory result because of inconsistency between the sectors used in the international reporting of emission data and activity data.

To achieve better results from verifications like this, it is essential that the emission estimates must be reported according to the revised 1996 IPCC guidelines. Emissions from use of coal and coke used as reducing agents and not for energy purposes should for instance not be reported under Table 1: Energy but under Table 2: Industrial processes. Further, it is important that the countries report data on a detailed level, also for the base year according to the Kyoto protocol, 1990. The exercise of comparing the data has, however, been very useful for identifying errors in the reporting that are emissions reporting in an erroneous source category.

One lesson from this study is that a comparison should be performed between more than four countries. For several sectors only one country or no countries at all but Norway had reported emissions. Many of the industrial processes important for Norway are not important for the other countries chosen. This would have been an advantage if some countries were chosen because of their similarity to Norway in for instance transport and climate, while others were chosen because they report emissions from industrial processes relevant for Norway.

Another conclusion is that no distinction has been made between important and less important sources in the inventory. It is expected that the inventory quality is better for the important sources as frequently more sources are put into these estimates.

This method may be used by a neutral institution to check the emission estimates. To get a more conclusive verification of emission estimates from certain sectors (for instance the industrial process iron and steel), it can be necessary to contact the national focal points for supplementary information. It is also necessary with certain knowledge of national circumstances in order to interpret the results.

No large errors in the Norwegian emission inventory have been detected in this work. This process of verification has, however, revealed several smaller reporting errors, emissions that have been reported in other categories than they should according to the IPCC 1996 Revised Guidelines. These errors will be corrected before the next reporting to the UNFCCC.

Finally, it is important to realise that this method of verification only considers consistency compared to what other country report. It is not a verification of the scientific value of the inventory data themselves.

References

IPCC 1996: Intergovernmental Panel on Climate Change (IPCC) 1996: Revised Guidelines for National Greenhouse Gas Inventories.

SFT 1996: A balance of use of wood products in Norway, Kristin Rypdal et.al Stastistics Norway. SFT report 96:04

SFT 1999a: Evaluation of uncertainty in the Norwegian emission inventory. SFT report 99:01

SFT 1999b: Calculations of emissions of HFCs and PFCs in Norway-Tier 2-method. SFT report 99:03

SFT 2000a: Verification of the Norwegian Emission Inventory – Comparing emission intensity values with similar countries. To be published.

SFT/SN 2000b: The Norwegian Emission Inventory. Documentation of methodology and data for estimating emissions of greenhouse gases and lomg-range transboundary air pollutants. Statistics Norway/ Norwegian Pollution Control Authority. SN report 2000/1

Appendix 1: Comments to tables in appendix 2

The Common Reporting Format (CRF) is completed with emission and background data according to the UNFCCC reporting guideline on annual inventories adopted in November 1999 by decision 3/CP.5.

It has been resource demanding to fill in the CRF tables, but with a few adaptations we have managed to make use of the CRF. These adaptations, explanations to the provided national data and remarks to CRF tables are given below.

Explanations to the Norwegian emission inventory reported in the CRF tables:

- A full set of emission- and background data etc. has been given for 1990 while trend emissions are given for 1990-98
- Table 8 Recalculation: Only tables for 1990 and 1997 are filled in. However, the explanations of the differences are also valid for the years in between. It is a question of definition what is defined as recalculation. Is every minor change from the previous national report to UNFCCC recalculation? This should be clarified in the UNFCCC reporting guidelines.
- Cells (emission sources) are filled in with IE, NO, NE in Table 7 (Overview table for national greenhouse gas inventories (IPCC Table 8A)) only and not in every single table. Othervise empty cells indicate emission sources for which Norway has no data.
- In some of the shaded cells, Norwegian emission calculations are filled in and cell formulas are amended. Explanations are given as cell remarks and put in documentation boxes in the associated table. (These remarks are only visible in the electronic version of the tables).
- We have given some explanations to the reported figures as cell remarks.

Adaptations of the CRF:

- Land-use change and forestry (LUCF). In accordance with the recommendations of the Reporting Manual to the CRF, we have used our own reporting format for LUCF. See Appendix _Table 5.A
- Table 4.B(a) Sectoral background data for agriculture. In Appendix_Table 4.B(a) additional background data are given.

Preliminary remarks to the CRF:

- Countries with a well-established inventory system are able to fill in the CRF tables. But even these countries may face some difficulties delivering all the requested data. Consequently, one should evaluate which data are needed in for example a review of the reported national data to the UNFCCC
- Summary 3. Summary reports for methods and emission factors used. The countries should have the opportunity to inform whether they have used Tier 1, 2 or 3 emission factors when estimating the emissions.

Appendix 2

Reporting tables

http://www.sft.no/publikasjoner/luft/1742/ta1742_tables.xls