Norway's national communication under the Framework Convention on Climate Change - September 1994.

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Executive summary

This report is the first national communication presenting Norwegian climate policy according to the commitments under the Framework Convention on Climate Change.

Inventory of anthropogenic emissions and sinks of greenhouse gases in Norway

The following gases are included in the Norwegian inventory of emissions of greenhouse gases and biotic CO_2 sinks: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tetrafluoromethane (CF_4), hexafluoroethane (C_2F_6), sulphur hexafluoride (SF_6) and HFCs. Emission data for precursors (NOx, CO and NMVOCs) are also given. Emission figures for 1990 as well as historical trends are given for all greenhouse gases and precursors.

As a rule, the estimation methods follow the Draft Guidelines for national greenhouse gas inventories published by the Intergovernmental Panel on Climate Change (IPCC). However, where appropriate other estimation methods have been used to achieve a better and more complete presentation of our greenhouse gas emissions. The methodology is documented in the attached report by the Norwegian Pollution Control Authority (SFT report 94:02).

A greenhouse gas emission inventory for the period 1989 to 1993 is summarized in Table 1. The figures for CO_2 emissions in Table 1 are based on fuel sold. The figure for 1993 may be an overestimation because a major change was introduced in the tax system for diesel, making diesel for road traffic significantly more expensive and leading to an accumulation of stocks.

Table 1. Total emissions of greenhouse gases in Norway. 1989-1993 and percentage change from 1989-1993.
Sources: Statistics Norway and Norwegian Pollution Control Authority.

Year	CO_2 Mtonnes	CH_4 ktonnes	N_2O ktonnes	CF_4 tonnes	C_2F_6 tonnes	SF_6 tonnes	HFC_{134a} tonnes	HFC_{152a} tonnes	CO_2-equ. Mtonnes
1989	35.2	287	16	360	16	107.2	n.a.	n.a.	50.2
1990	35.6	289	16	369	16	91.5	0	3	50.2
1991	34.0	289	15	313	14	86.4	1	3	48.1
1992	34.3	293	13	242	11	28.9	2	3	46.4
1993 1)	35.5	294	14	254	11	31.3	31.2	1	48.1
1989-93	0.8%	2.4%	-14%	-29%	-30%	-71%	..	..	-4%

1) Preliminary figures

Figure 1 indicates historical trends from 1985 to 1993 in the emissions of greenhouse gases given as CO_2 equivalents, based on Global Warming Potential (GWP) values. CO_2 is by far the most important gas, accounting for approximately 70% of the total greenhouse gas emissions. Methane and nitrous oxide contribute about 13% and 8%, respectively. The "new" fluoridized gases (PFCs and SF_6) together contribute 8% of the total emissions. During the period from 1985 to 1993 total emissions peaked in 1986-1988, partly as a result of high SF_6 emissions.

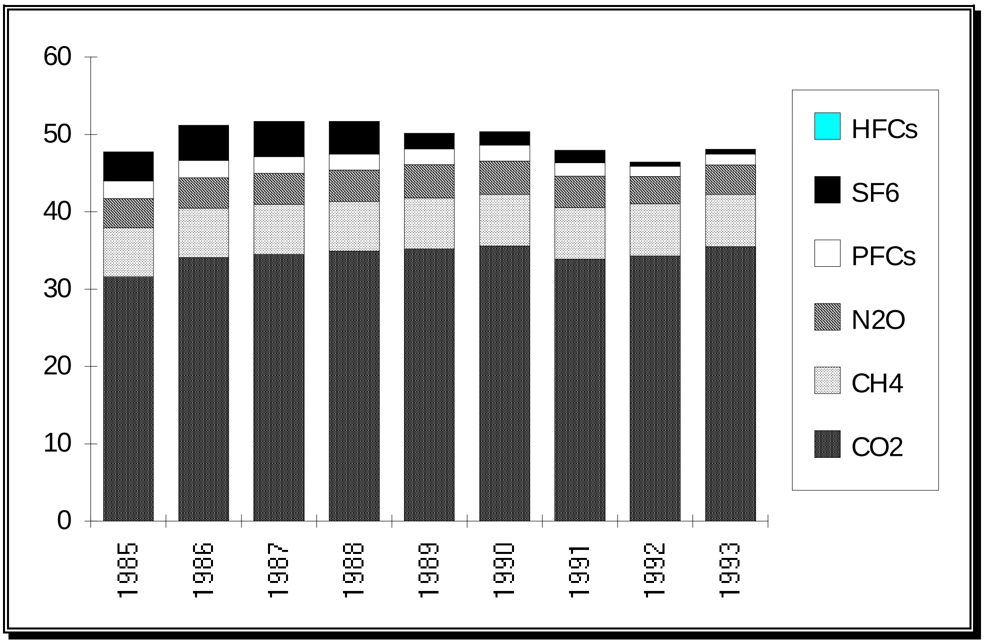

Figure 1. Greenhouse gas emissions in Norway. 1985-1993. Million tonnes CO_2 *equivalents.*
Sources: Statistics Norway and Norwegian Pollution Control Authority.

Mobile sources account for the largest proportion of CO_2 emissions in Norway. In 1993, road traffic contributed about 24 % of the total CO_2 emissions and coastal traffic and fishing about 10 %. Oil and gas production activities, including burning of oil and gas on stationary and mobile oil rigs, emissions from gas processing and leakage of hydrocarbons, accounted for about 23 %. Industrial processes, i.e. production of metals, carbides, cement etc., generated 18 % of the total CO_2 emissions.

It is estimated that, the annual net anthropogenic sink of CO_2 in forests in Norway is 12 million tonnes, corresponding to about 35% of Norway's total CO_2 emissions. This significant Norwegian sink is mainly caused by an annual increase in the standing volume of Norwegian forests.

Policies and measures

Norway's climate policy is founded on the ultimate objective of the Climate Convention and the scientific understanding of the greenhouse effect set out in the reports from the UN Intergovernmental Panel on Climate Change (IPCC). An important principle of Norwegian climate policy is that all policies and measures, at both national and international level, should be as cost-effective as possible. Coordinated international efforts and the development of formalized international mechanisms are essential in dealing with the greenhouse effect.

Norway ratified the Climate Convention on 9 July 1993. As the Convention is further developed, Norway will continue to advocate the need for new and more binding commitments, as well as flexible mechanisms for their implementation. There should be a special focus on the period beyond the year 2000, in order to develop policies in accordance with the objective of the Convention to stabilize the greenhouse gas concentrations in the atmosphere "at a level that would prevent dangerous anthropogenic interference with the climate system."

Norway's current target regarding national CO_2 emissions is as follows:
"CO_2 emissions are to be limited so that they do not exceed the 1989 level in the year 2000. This target is preliminary and will be considered in the light of further studies, technological advances, developments in the international energy markets and international negotiations and agreements."

Norway has been at the forefront of efforts to introduce economic instruments to limit emissions to air for a number of years. In 1991 the Government introduced a CO_2 tax on oil, natural gas and coal for energy use as a first step towards a comprehensive national climate policy. The CO_2 tax on petrol and natural gas used in petroleum exploration offshore was raised in 1992 and is now equivalent to about 20 dollars per barrel of oil. The Government is also promoting more efficient production and use of energy.

As a follow up of the commitments set out in the Climate Convention and the national target regarding CO_2 emissions, the Government is preparing a report to the Storting (the Norwegian national assembly) on policies and measures to limit emissions of greenhouse gases and enhance CO_2 sinks. The Government intends to present the report by the turn of the year. The report will contribute towards a more integrated climate policy, addressing all relevant greenhouse gases and economic sectors in accordance with the guiding principles of the Convention. Relevant measures, both economic and administrative consistent with the Governments overall economic strategy, will be considered with the aim of finding cost-effective ways of limiting net emissions of greenhouse gases in all sectors. Taxes on CO_2 are the most important means of limiting CO_2 emissions. The Government will intensify cooperation with the energy and industrial sectors, for instance by taking the initiative for voluntary agreements including surveys and declarations of intent to reduce emissions exempted from the CO_2 tax.

The Norwegian CO_2 tax scheme
The Norwegian environmental tax system consists primarily of product taxes, which in many instances may be a suitable approximation to emission taxes, e.g. for emissions of CO_2, SO_2 and lead. These emission components are already reflected in the tax system for fossil fuels. Both the petrol and the mineral oil tax contain a CO_2 element. A carbon tax has also been introduced for gas and oil combustion on the continental shelf, and from 1 July 1992 a carbon tax was introduced for certain applications of coal and coke. About 60% of the national CO_2 emissions are currently subject to such taxes. Table 2 shows the tax rates for petroleum products, gas, coal and coke as of 1 September 1994.

Norwegian CO_2 emissions increased substantially from 1960 to 1980. Throughout the 1980s, emissions were relatively stable. From 1989 to 1991 emissions were reduced by about 4 %, primarily because of a reduction in the consumption of gasoline and fuel oils and reduced production of metals. In addition to the CO_2 tax, implemented with effect from 1991, the ample supply of electric power and low economic activity contributed to this development. From 1991 to 1993, CO_2 emissions increased. This is mainly explained by increased oil and gas production and pipeline transport.

Table 2: Tax rates for petroleum products (NOK/l), gas (NOK/Sm^3) and coal and coke (NOK/kg).

	Basic tax	CO_2 tax	SO_2 tax	Total	CO_2 tax per kg CO_2 emitted
Unleaded petrol	3.12	0.82		3.94	0.35
Leaded petrol	3.78	0.82		4.60	0.35
Autodiesel	2.45	0.41	0.07	2.93	0.16
Mineral oil	0	0.41	0.07[1)]	0.48	0.16
Diesel, North Sea	0	0.82	0	0.82	0.31
Gas, North Sea	0	0.82		0.82	0.35
Pit coal	0	0.41		0.41	0.17
Coal coke	0	0.41		0.41	0.13
Petroleum coke	0	0.41		0.41	0.11

[1)] *The tax rate is 0.07 NOK per 0.25 per cent SO_2 content. (1 USD equals about 7 NOK).*

Energy policy and energy efficiency

A new Energy Act entered into force on 1 January 1991. The Act lays down general terms and conditions designed to ensure more efficient utilization of electricity, which is mainly produced using hydro power. The Act involves deregulation and keener competition in the electricity sector. The power market has seen considerable changes since the introduction of the new Energy Act. Growing competition has had a pronounced effect on electricity prices and has contributed to a switch from oil to hydro electricity for heating.

In 1993 Norway introduced a change in its energy efficiency policy based on a report to the Storting. Norwegian policy is now shifting away from extensive grant schemes towards more cost-effective measures. The main activities in the years to come in the field of energy efficiency will be information, education and the introduction of energy-efficient technology.

Energy production

Almost all electricity produced on the Norwegian mainland is based on hydro power, and most emissions of CO_2 from energy production are generated from offshore petroleum production and pipeline transport.

The use of more energy-efficient gas turbines has reduced emissions of CO_2 per unit of petroleum products produced. The efficiency of power generation in the petroleum sector has grown by 50% since 1975. Heat recovery systems have been installed on some offshore installations, thus improving energy efficiency. Flaring of gas has been reduced substantially compared to the level of production, and much less gas is flared in the Norwegian petroleum sector than in other comparable countries. The CO_2 tax applied to flaring and burning of natural gas and diesel in the petroleum sector is believed to have contributed to more energy-efficient production and has encouraged the development of projects and technical solutions to reduce CO_2 emissions offshore. These emissions increased by only 2.5% from 1990 to 1993, whereas petroleum production increased by 24% during the same period.

Transport
The CO_2 tax is the main instrument for limiting CO_2 emissions from the transport sector. However, the demand for transport oils is influenced by the total tax burden on these products, regardless of why they are imposed. Norwegian taxes on transport oils are among the highest in the world, currently 4.19 NOK/1 petrol and 2.93 NOK/l diesel. VAT is not included in these figures. Petrol taxes have been gradually increased throughout the 1990s and are now more than 50 per cent higher than in 1990.

The introduction of the CO_2 tax and the general growth in tax rates have contributed to a considerable reduction in petrol consumption, but a number of other transport policy measures described in the report also contribute to reductions of CO_2 emissions from this sector. The CO_2 emissions dropped by more than 5 per cent between 1990 and 1993.

In the *shipping sector*, domestic ferries and passenger ships have been subject to the CO_2 tax since 1992.

Industry
CO_2 emissions from energy use in industry have decreased considerably as a result of improved energy efficiency and changes in the energy mix. Emissions of perfluorized carbons (PFCs) from aluminium producers have been reduced by 43% since 1985. Emissions of sulphur hexafluoride (SF_6) dropped considerably from 1987 to 1992 as a result of reduced emissions from magnesium production. In 1986-87 these emissions were almost 10 times higher than in 1992. From 1990 to 1993, emissions of nitrous oxide (N_2O) were reduced by 12%, mainly by improvements in production processes.

Landfills
The Government has introduced new guidelines for discharge permits for landfills to control the extraction and combustion of methane. Eight plants were in operation in 1993, and these have reduced emissions of methane by a total of more than 10 000 tonnes.

Projections

Projections of CO_2 emissions
The projections of Norwegian CO_2 emissions are based on macroeconomic model projections supplemented with sectoral studies for some sectors (e.g. transport and petroleum production). Emissions of CO_2 are expected to rise by about 12% by the year 2000 taking the effects of the CO_2 tax into account, according to the Government's Long-term Programme 1994-1997. About 65% of this rise is due to the expected increase in gas production and transport, which is all exported.

Projections of emissions of non-CO_2 gases
Projections of emissions of CH_4 and N_2O are also based on the reference scenario in the Government's Long-term Programme 1994-97. Projections of emissions of the perfluorinated carbons (CF_4 and C_2F_6), sulphur hexafluoride (SF_6) and HFCs have been prepared on the basis of figures collected from the relevant branches and industrial enterprises.

Table 3 presents emissions and projected emissions of CO_2, methane, nitrous oxide, perfluorinated carbons, sulphur hexafluoride and HFCs.

Table 3. Emissions of the various greenhouse gases. 1989, 1990, 1993 and projections for 2000. Million tonnes CO_2-equivalents.

	1989	1990	1993[1)]	2000	Changes 1989-2000
Total	50.1	50.2	48.1	52.9	+6%
Carbon dioxide	35.2	35.6	35.5	39.5	+12%
Methane	6.6	6.7	6.8	6.4	-2%
Nitrous oxide	4.3	4.2	3.8	4.4	+4%
PFCs	2.0	2.1	1.5	1.4	-26%
Sulphur hexafluoride	2.0	1.7	0.5	0.6	-71%
HFCs	0.0	0.0	0.0	0.6	..

1) *Preliminary figures*

Vulnerability assessment and adaptation measures

Until now, most attention has been focused on effects on ecosystems and their vulnerability to climate change. The main findings are presented in chapter 4 of the report. In addition to climate change caused by increases in mean temperature, Norway may, because of its geography and long coastline, be particularly vulnerable to changes in the frequency of weather patterns and extreme events such as storms, floods and spring tides. Further investigations are needed, both on the possible relation between changes in the frequencies of such extreme events and global climate change on the ecological and socioeconomic impacts of such changes.

Research and systematic observation

A wide range of universities and research institutes from various disciplines have been engaged in different aspects of research related to climate change in Norway. The bulk of public and private funding goes into technological research and development, but there is also considerable activity in basic natural sciences, economics and social sciences. The Norwegian Climate and Ozone Research Programme was established in 1989, and is run by the Research Council of Norway. Several Norwegian research groups are collaborating to model atmospheric chemistry and the role of oceans. The Norwegian Institute of Air Research measures concentrations of greenhouse gases at the Arctic station in Ny-Ålesund on Svalbard. Norwegian institutes are doing research in several fields relevant to the objectives of the International Geosphere-Biosphere programme and other international global climate change programmes. Several Norwegian scientists have contributed to the IPCC assessments. The Centre for International Climate and Energy Research (CICERO) was established in 1990 to undertake climate-related research in all relevant disciplines. Policy-oriented studies related to the climate change issue also form a major part of a research programme named "Society, environment and energy" initiated by the Research Council of Norway. The Institute for Energy Technology (IFE) in Norway is participating in energy modelling work coordinated by the International Energy Agency (IEA). Norway has also strongly emphasized research on economic issues related to climate change, inter alia cost-effective mitigation measures.

Education, training and public awareness

The work of the World Commission on Environment and Development awoke public interest in issues related to climate change in Norway from the late 1980s. The attention focused on the importance of sustainable development and the need for all individuals to consider their own contributions to improvement of the environment have raised the level of awareness in many sectors of Norwegian society.

The negotiations on the Climate Convention are being followed closely by leading Norwegian newspapers and magazines. During the 1990s, the teaching of subjects related to environmental issues including climate change has been improved throughout the Norwegian educational system, from primary schools to universities.

The Norwegian Information Centre for Energy Efficiency (OFE) has during the 1990s arranged training courses and seminars in energy efficiency. The Government has also launched three large information campaigns on energy efficiency. Together with the other EU and EFTA countries, Norway will implement a system of energy labelling of electrical household appliances.

Joint implementation of measures to mitigate climate change

Joint implementation of climate measures with other Parties is an option under the Climate Convention. For Joint Implementation to become a fully operational mechanism under the Convention, there is a need to agree on criteria, inter alia to ensure the proper monitoring, verification, validity and long-term effectiveness of such measures, and to agree on institutional arrangements under the Convention for these purposes. To facilitate the development of such criteria there is a need to gain practical experience of Joint Implementation activities, including ways of designing Joint Implementation projects, types of agreements and standard methods of calculating emission reductions.

To this end, Norway, in cooperation with the Global Environmental Facility (GEF), Poland and Mexico, is currently running two pilot projects intended to demonstrate the potential for joint implementation of measures to mitigate climate change. The experience gained through such projects may prove valuable to the Conference of the Parties (COP) in the process of establishing operational criteria for joint implementation. In addition, Norway is taking part in several other international activities in the field of climate change, as described in chapter 8 of the report.

1. Inventory of anthropogenic emissions and sinks of greenhouse gases in Norway

1.1. Introduction

This section gives an outline of national emissions of greenhouse gases and biotic CO_2 sinks in Norway. The following greenhouse gases are included: 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 and HFC-152a). Emission data for precursors (NO_x, CO and NMVOC) are also given.

The emission Figures for 1990 are reported according to the IPCC guidelines for reporting national greenhouse gas emissions. In addition historical trends are given for all greenhouse gases and precursors.

1.1.1. Methods of estimation

Statistics Norway (SN) and the Norwegian Pollution Control Authority (SFT) cooperate to provide emission inventories for several air pollutants in Norway. SFT contributes emission factors for all sources and measured emission data from large industrial plants. SN has prepared 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 have been prepared in this way. The methodology is described in SN report 93/24: "Anthropogenic Emissions of the Greenhouse Gases CO_2 , CH_4 and N_2O in Norway." This report was an attachment to the Norwegian report to the Intergovernmental Negotiating Committee (INC) for a Framework Convention on Climate Change in August 1993, and is available on request. Figures for emissions of CF_4, C_2F_6, SF_6 and HFCs have been provided by SFT and the methodology is described in SFT report 94:02 "Greenhouse gas emissions in Norway. Inventories and estimation methods. September 1994".

As a general rule, the estimation methods follow the Draft Guidelines for national greeenhouse gas inventories published by the Intergovernmental Panel on Climate Change (IPCC). However, other methods have been used where necessary, as described in the SFT report. Greenhouse gas emissions are reported in "Minimum data Tables", where both activity data, emissions estimates and aggregated emission factors are given, as recommended by the IPCC.

In accordance with the IPCC Draft 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 Norwegian-owned coastal traffic, the fishing fleet and offshore oil and gas production activities. In Chapter 1.7. we also present some 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.

Some Figures for biotic CO_2 sinks have also been provided by SFT. These data include both emissions from fuelwood, wood waste etc. and annual CO_2 accumulation in Norwegian forests. However, in accordance with the IPCC Guidelines, these emissions are not included in the overall Norwegian greenhouse gas inventory.

1.1.2. GWP values used in the Norwegian calculations

Global Warming Potentials (GWP) can be used to compare the influence of other greenhouse gases on the climate with that of CO_2 on a weight- for-weight basis. The values calculated are uncertain, but this is nevertheless the best tool available for comparing the different greenhouse gases. As knowledge about atmospheric processes increases, the values are likely to change. In this Chapter we have included values calculated by Norwegian research institutions for SFT. These values have also been communicated to the IPCC, which will publish a supplementary report containing revised GWP values by the end of 1994. The IPCC will evaluate the calculations performed by others as well as other factors that may affect GWP values. The values given here may therefore differ from those given by the IPCC.

Greenhouse gases may be divided into three different categories. These are (1) gases which only have a direct influence on the climate, such as CO_2 , PFCs, SF_6 and HFC_2, (2) gases which influence climate both directly and indirectly, such as CH_4 and CFC, and (3) gases such as NO_x , CO and NMVOC which only have an indirect effect through their influence on other greenhouse gases, especially ozone. During the IPCC process, the uncertainties in the GWP values for direct effects have been reduced to an acceptable level, but Figures for indirect effects were withdrawn in the 1992 supplementary report. New calculations of indirect effects have been made for NO_x from aeroplanes, CO and CH_4 . However, we have chosen at this stage not to include the NO_x, CO and NMVOC Figures in the Norwegian greenhouse gas inventory, but merely conclude that their contribution to total emissions of greenhouse gases in Norway is very small.

In Norway the "new" fluorine-containing gases (PFCs and SF_6) account for a significant proportion of total emissions of greenhouse gases. We have therefore initiated calculations of their GWP values. All the values are given in Table 1.1.

Table 1.1. Global warming potential (GWP) calculated for a time horizon of 100 years. Direct GWP for all gases and indirect GWP for methane.

Gas	CO_2	CF_4	C_2F_6	SF_6	HFC_{134a}	HFC_{152a}	CH_4	N_2O
GWP	1	5 100[1]	10 000[1]	19 000[2]	1200[3]	150[3]	23	270[3]

1) J.S.Fuglestvedt et. al. 1994 2) F.Stordal et. al. 1993 3) IPCC, 1992.

The various gases have very different lifetimes in the atmosphere and the GWP values are dependent on the choice of integration period. We have chosen 100 years, which is close to the estimated mean lifetime of CO_2 . If a shorter integration period is chosen, the importance of gases with short atmospheric lifetimes (e.g. CH_4) is emphasized, and conversely a longer integration period emphasizes the importance of gases with longer lifetimes.

1.2. Total emissions of greenhouse gases.

This Chapter presents an overview of greenhouse gas emissions in Norway in 1990 and historical trends from 1985 to 1993. In Chapters 1.3 to 1.7 more details are presented for each pollutant separately.

1.2.1. Emissions in 1990.

Data on emissions of greenhouse gases in Norway in 1990 are given in Table 1.2. The source categories used follow the Norwegian standard. In the same Table, emissions are shown in CO_2 equivalents, using the GWP values quoted in Chapter 1.1.2. Table 1.2 also presents total emission Figures for each year in the period 1989-93. Table 1.3 shows greenhouse gas emissions by source as recommended by the IPCC draft reporting instructions.

The Tables show that CO_2 is by far the most important greenhouse gas in Norway, accounting for 70% of total greenhouse gas emissions. Methane (13%) and nitrous oxide (8%) are the next most important greenhouse gases in Norway, while the "new" fluoridized gases (PFCs and SF_6) together contribute about 8%. These new gases probably contribute more in Norway than in many other countries. Consumption of HFCs is so far insignificant in the context of climate change, but as mentioned in Chapter 1.4 their use is expected to increase significantly.

The industry and energy sector is the most important emission source and contributes 40% of total greenhouse gas emissions. Mobile sources accounted for about 30% of the total emissions in 1990.

1.2.2. Historical trends

A greenhouse gas emission inventory for the period 1985 to 1993 has been prepared on the basis of measurements and calculations, see Figure 1.1 and Table 1.4. During this period, total emissions peaked in 1986-88, partly as a result of high SF_6 emissions. From 1988 to 1992, total emissions were reduced by 10 % as emissions of SF_6, PFCs, N_2O and CO_2 dropped.

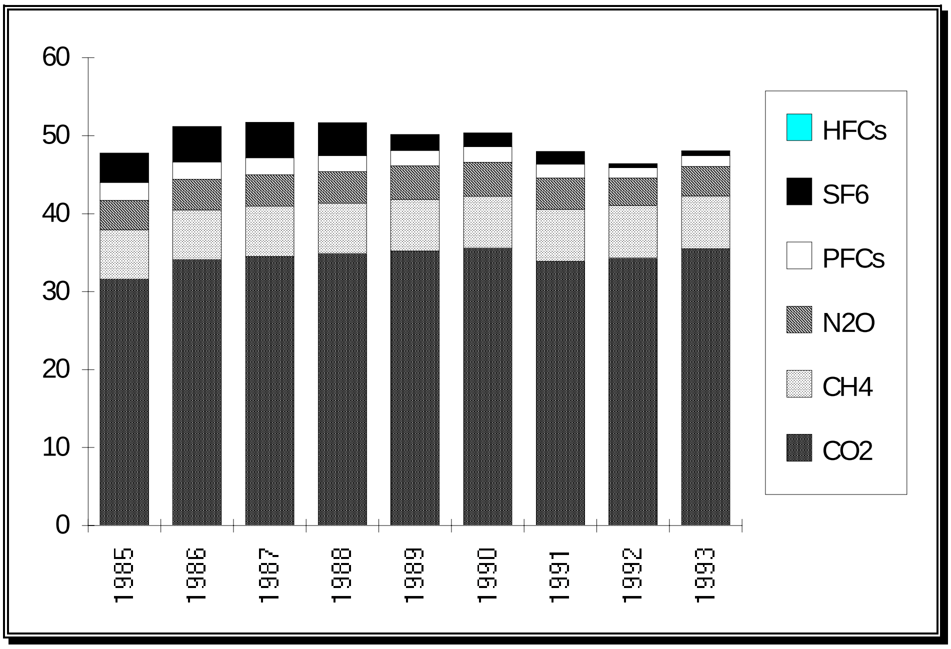

Figure 1.1. Greenhouse gas emissions in Norway. 1985-1993. Million tonnes CO_2 equivalents.

Table 1.2. Emissions of the greenhouse gases CO_2, CH_4, N_2O, CF_4, C_2F_6, SF_6, HFC 134a and HFC 152a in Norway in 1990 according to a national standard for division into source categories, and total emissions of greenhouse gases in the period 1989 to 1993. Sources: SN and SFT

	CO_2 Mtonnes	CH_4 ktonnes	N_2O ktonnes	CF_4 tonnes	C_2F_6 tonnes	SF_6 tonnes	HFC_{134a} tonnes	HFC_{152a} tonnes	CO_2-equ. Mtonnes
Total	**35.6**	**289.2**	**15.6**	**369**	**16**	**91.5**	**0.0**	**3.0**	**50.2**
Stationary combustion	**14.4**	**14.0**	**1.5**						**15.2**
Oil and gas production 1)	7.0	2.4	0.1						7.0
Industry 2)	4.8	0.5	0.8						5.0
Other sectors 3)	2.7	11.1	0.6						3.1
Processes	**7.2**	**272.2**	**13.1**	**369**	**16**	**91.5**	**0.0**	**1.0**	**20.8**
Oil and gas production 4)	0.3	7.9							0.5
Coal mining	0.0	5.5							0.1
Petrol handling 5)	0.0								0.0
Oil refineries	0.0								0.0
Fertiliser production	0.6		6.7						2.4
Carbide production	0.4	1.0							0.5
Petrochemical production	0.0	0.0							0.0
Cement production	0.7								0.7
Ferro alloy production	2.8								2.8
Iron production	0.2								0.2
Aluminium production	1.6			369	16				3.6
Magnesium production	0.1					89.4			1.8
Other metal production						0.3			0.0
Agriculture	0.2	91.1	6.5						4.0
Landfills	0.1	166.7							3.9
Other	0.1	0.0				1.8	0.0	1.0	0.2
Mobile combustion	**13.9**	**3.1**	**1.0**						**14.3**
Road traffic	8.1	1.9	0.6						8.3
Air traffic	1.3	0.0	0.1						1.3
Shipping 6)	3.7	1.0	0.2						3.8
Other mobile combustion	0.9	0.1	0.1						0.9
Total CO_2-eq. Mtonnes	**35.6**	**6.7**	**4.2**	**1.9**	**0.2**	**1.7**	**0.0**	**0.0**	**50.2**

Year	CO_2 Mtonnes	CH_4 ktonnes	N_2O ktonnes	CF_4 tonnes	C_2F_6 tonnes	SF_6 tonnes	HFC_{134a} tonnes	HFC_{152a} tonnes	CO_2-equ. Mtonnes
1989	35.2	287	16	360	16	107.2	n.a.	n.a.	50.2
1990	35.6	289	16	369	16	91.5	0	3	50.2
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1993 7)	35.5	294	14	254	11	31.3	31.2	1	48.1
1989-93	0.8%	2.4%	-14%	-29%	-30%	-71%	..	..	-4%

1) Natural gas in turbines, flares, diesel use.
2) Oil refineries, other industry.
3) Space heating, waste incineration.
4) Vent and leaks etc., oil loading offshore and onshore.
5) Loading and depots, tanking.
6) Coastal transport etc., fishing, mobile oil platforms.

7) Preliminary figures

Table 1.3. Emissions of greenhouse gases in Norway in 1990: sources according to IPCC draft reporting instructions. 1000 tonnes. Sources: SN and SFT

	CO_2	CH_4	N_2O	NO_X	CO	NMVOC
Total (Net) national emission	**35599**	**389**	**16**	**231**	**941**	**251**
I All energy (fuel combustion + fugitive)	**28649**	**30**	**2**	**221**	**881**	**216**
A Fuel combustion	26955	17	2	213	880	114
1 Energy & transformation industries	7481	3	0	21	5	2
2 Industry (ISIC)	3023	0	1	7	6	1
3 Transport	13249	3	1	168	738	101
4 Commercial/institutional	941	0	0	1	1	0
5 Residential	1416	11	0	2	125	9
6 Agriculture/forestry	612	0	0	8	4	1
7 Other	245	0	0	5	0	0
8 Biomass burned for energy	See Chapter 1.6. CO_2 sinks					
B Fugitive fuel emission	1694	13	0	9	1	102
1 Oil and natural gas systems	1651	8	0	9	1	93
2 Coal mining	15	5	0	0	0	NE
3 Distribution of oil products	28	0	0	0	0	9
2 Industrial Processes	**6494**	**1**	**7**	**9**	**60**	**3**
A Iron and steel	3019	0	0	6	0	1
B Non-ferrous metals	1699	0	0	1	20	0
C Inorganic chemicals	1083	1	7	2	40	0
D Organic chemicals	3	0	0	0	0	1
E Non-metallic mineral products	690	0	0	0	0	0
F Other	0	0	0	0	0	1
3 Solvent Use	**96**	**-**	**-**	**-**	**-**	**32**
A Paint application	72	-	-	-	-	24
B Degreasing and dry clining	1	-	-	-	-	0
C Chemical products manufacture/processing	6	-	-	-	-	2
D Other	18	-	-	-	-	6
4 Agriculture	**200**	**91**	**6**	**0**	**0**	**0**
A Enteric fermentation	0	76	0	0	0	0
B Animal wastes	0	15	0	0	0	0
C Rice cultivation	NO	NO	NO	NO	NO	NO
D Agricultural soils	200	NE	6	0	0	0
E Agricultural waste burning	NE	NE	NE	NE	NE	NE
F Savannah burning	NO	NO	NO	NO	NO	NO
5 Land use change & forestry	See Chapter 1.6. Biotic CO_2 sinks					
A Forest clearing						
B Grassland conversion						
C Abandonment of managed lands						
D Managed forests						
6 Waste	**81**	**167**	**0**	**0**	**0**	**0**
A Landfills	81	167	0	0	0	NE
B Waste water	0	0	0	0	0	NE
C Other						

NO= Not occuring, NE= Not estimated

1.3. Emissions of CO_2, CH_4 and N_2O

1.3.1. Emissions of CO_2

In 1993, Norwegian emissions of CO_2 totalled about 35.5 million tonnes. The largest CO_2 emissions in Norway are from mobile sources. In 1993, road traffic contributed about 24% of the emissions, while coastal traffic and fishing accounted for 10%. Oil and gas production, including burning of oil and gas on stationary and mobile oil rigs, emissions from gas processing and leakage of hydrocarbons, accounted for 23%. Emissions from industrial processes, i.e. production of metals, carbides, cement etc., constituted 18% of the total, see Figure 1.2.

Norwegian CO_2 emissions increased substantially from 1960 to 1980, only interrupted by the oil price increase during the early 1970s, see Figure 1.2. Throughout the 1980s, emissions have been relatively stable, despite a large increase in the consumption of natural gas by the oil industry. This is primarily explad by a considerable reduction in the use of fuel oil.

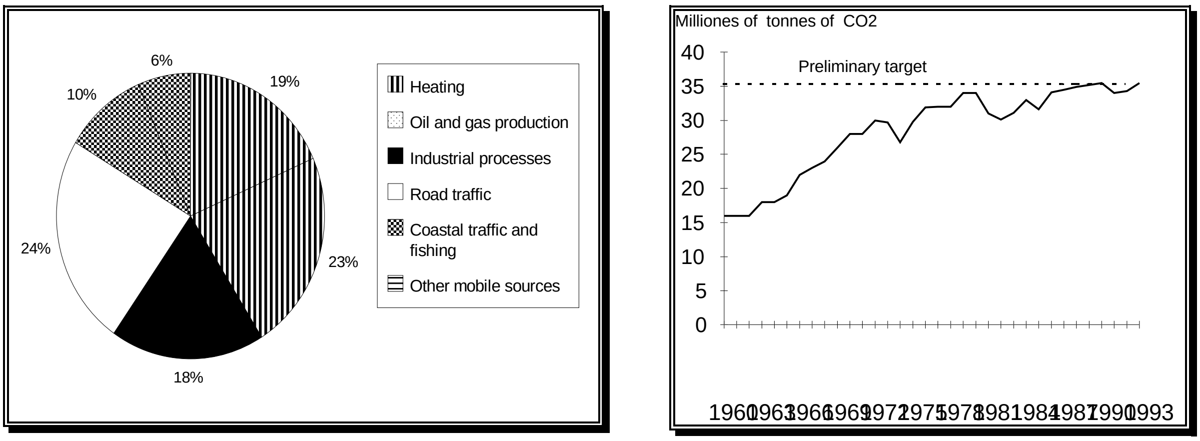


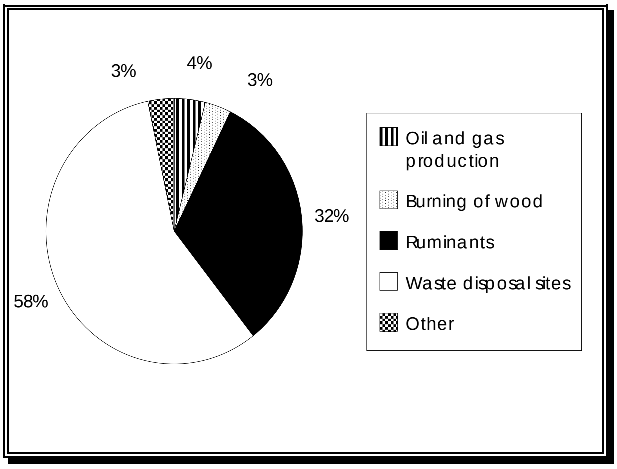
Figure 1.2. CO_2 emissions in Norway in 1993 by source and total emissions. 1960-93. Source: SN and SFT.

From 1989 to 1991, emissions were reduced by about 4%, primarily because of a reduction in the consumption of petrol and fuel oils and reduced production of metals.

From 1991 to 1993, CO_2 emissions have increased. This is partly explained by increased oil and gas production and pipeline transport. The figures for CO_2 emissions in the inventory are based on fuel sold. The figure for 1993 may be an overestimation because a major change was introduced in the tax system for diesel, making diesel for road traffic significantly more expensive and leading to an accumulation of stocks.

1.3.2. Emissions of methane

In 1993, Norwegian methane emissions were about 294 000 tonnes. The dominant sources of methane emissions are landfills and domestic animals, 58% and 32% respectively, see Figure 1.3. Methane emissions have probably more than doubled during the period from 1950 to the mid-1980s, primarily because growing amounts of waste have been deposited in landfills. During the past few years, however, emissions have probably been more stable.



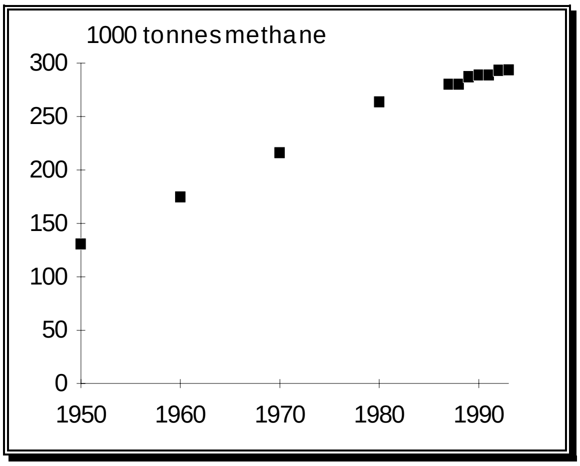
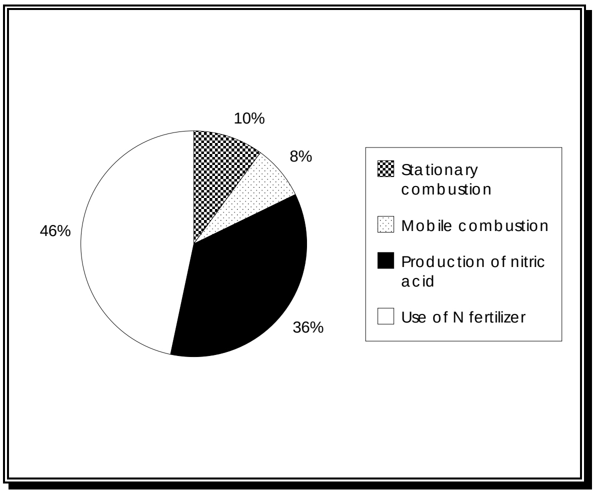


Figure 1.3. Emissions of methane in Norway in 1993 according to source and total emissions. 1950-93. Source: SN and SFT.

1.3.3. Emissions of nitrous oxide

Norwegian anthropogenic emissions of nitrous oxide in 1993 have been estimated at about 14 000 tonnes. There is a large degree of uncertainty in this estimate, especially as regards emissions from soil. The calculations indicate that the use of nitrogenous fertilizer accounts for almost 46% of the total, and the production of nitric acid for about 36%, see Figure 1.4.

Norwegian emissions of nitrous oxide have probably more than doubled during the period 1950-1989, primarily because of increased production and use of industrially produced fertiliser. From 1990 to 1993 emissions were reduced by 12% due to improved production processes and lower production of nitric acid.



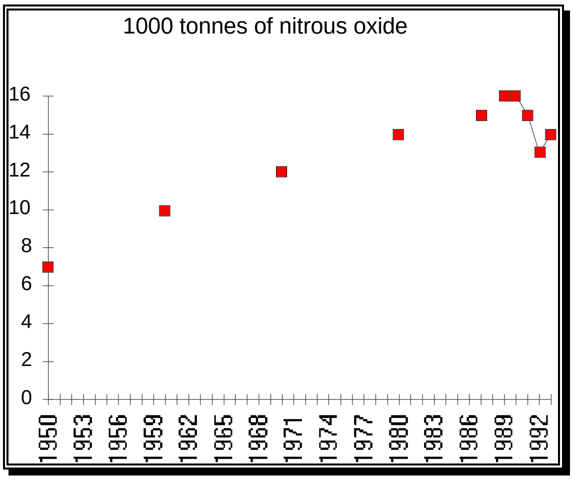


Figure 1.4. Emissions of nitrous oxide in Norway in 1993 according to source and total emissions. 1950-93. Source: SN and SFT.

1.4. Emissions of other greenhouse gases (PFCs, SF6 and HFCs)

1.4.1 Emissions of PFCs

Perfluoridized carbons (PFCs), e.g. tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6), are greenhouse gases with a very high global warming potential in addition to an exceptionally long lifetime in the atmosphere. Perfluoridized carbons are primarily formed through the production of aluminium.

On the basis of photoacoustic measurements carried out in 1992 by aluminium producers, emissions of PFCs (CF_4 + C_2F_6) in 1993 have been calculated to be about 266 tonnes. Around 4% of PFC emissions is estimated to be hexafluoroethane (C_2F_6), and the remainder is tetrafluoromethane (CF_4). The emissions per tonne of aluminium from Norwegian production plants are much smaller than those reported from other countries. The measurements and calculations also indicate that the emissions per unit produced have been reduced from about 0.6 to 0.3 kg PFCs per tonne aluminium during the past 5-8 years, partly as a result of reduced frequency of anode effects. As Figure 1.5 shows, there has been a reduction of 43% since 1985.

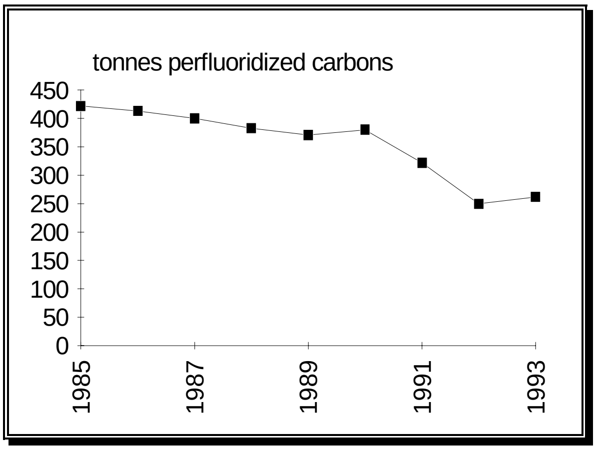


Figure 1.5. Emissions of PFCs from aluminium production in Norway. 1985 -1993. Source: SFT

1.4.2. Emissions of sulphur hexafluoride (SF_6)

Sulphur hexafluoride is another very potent greenhouse gas with a very high global warming potential. Norwegian emissions of SF_6 have been estimated by the Norwegian Institute of Air Research, NILU (Stordal et al. 1993). Consumption in 1993 is estimated to be approximately 46 tonnes and emissions 31.4 tonnes. The use of SF_6 as cover gas in magnesium production accounts for a large proportion of the consumption. However, a substantial amount is also used in electrical equipment, where most of it remains bound. This is why annual consumption is higher than emissions.

Figure 1.6 shows that emissions of SF_6 have been considerably reduced from 1987 to 1992, as a result of reduced emissions from magnesium production. Emissions in 1986-87 were almost 10 times higher than in 1992.

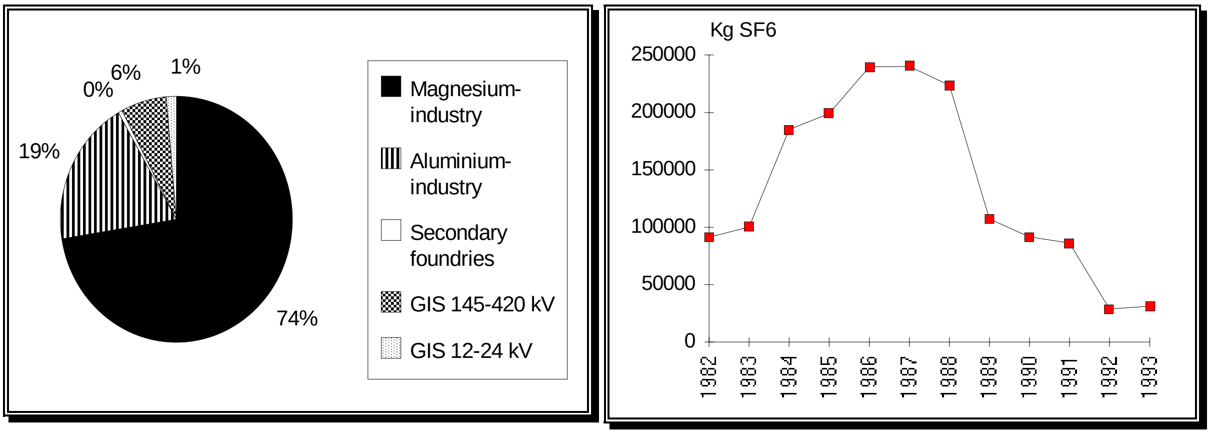


Figure 1.6. Emissions of SF_6 in Norway in 1993 according to source and total emissions 1982-1993. GIS: Gas insulated switch gear. Source: Stordal et. al. 1993.

1.4.3. Emissions of HFCs

HFCs are halogenized carbon compounds that do not contain bromine or chloride. HFCs are used in cooling installations and are very much in focus as substitute materials for CFCs and HCFCs. Consumption is modest at present, but is expected to increase as CFCs and HCFCs are phased out. A certain increase has been recorded: consumption increased from approximately 5 tonnes in 1992 to 32 tonnes in 1993, see Figure 1.7. However, this consumption is still relatively low measured as CO_2 equivalents, about 40 000 tonnes.

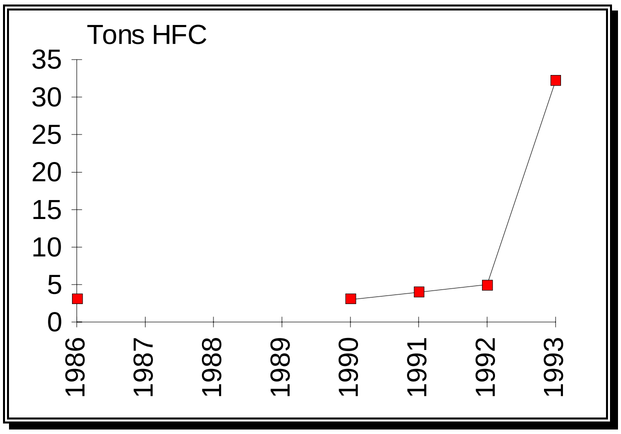


Figure 1.7. Consumption of HFCs in Norway. 1986 - 1993. Source: SFT.

1.5 Emissions of precursors (CO, NOx and NMVOC)

Emissions of NOx, CO and NMVOC in 1990 are shown according to the source categories defined in the IPCC Guidelines in Table 1.3, see Chapter 1.2.1. Mobile sources make the most important contribution to emissions of all these pollutants, especially as regards CO and NOx. Road traffic is the most important CO source, contributing 76% of the total emissions, while coastal traffic (including fishing boats) and road traffic account for about 35% each. In addition oil and gas production is an important source of NMVOC.

Emissions of CO and NOx have been reduced since 1989 mainly because of the introduction of catalytic converters in cars, see Table 4. However, emissions of NMVOC have increased in the same period because oil production has risen.

Table 1.4. Emissions of NMVOC, NOx and CO. 1989-1993. Source: SN and SFT.

Year	CO tonnes	NOx tonnes	NMVOC tonnes
1989	954	234	258
1990	941	231	251
1991	881	220	256
1992	851	220	265
1993	836	225	270
1989-1993	-12%	-4%	5%

1.6. CO_2-sinks

The net anthropogenic sink of CO_2 in the forest in Norway in 1992 is estimated at 12 million tonnes, see Table 1.5. This annual accumulation occurs mainly because the annual increment in the standing volume in Norwegian forests is larger than the sum of CO_2 emissions from wood harvested for industrial use and fuel. In addition, there is a net uptake in forest soil and sedimentation of carbon in fresh water and estuaries. The estimates are uncertain but the order of magnitude seems to be correct. The largest uncertainty is in the estimate of the net sink in forest soil. The net sink is equivalent to about 40% of the total emissions of CO_2 in Norway in 1992. The methods of calculation is described in SFT report no. 94:02 "Greenhouse gas emissions in Norway. Inventories and estimation methods. September 1994."

Harvesting from the forest has a long tradition in Norway, and up to the beginning of this century the annual harvest was larger than the gross increment. Since then there has been an increase in the standing volume of Norwegian forest. The estimate of standing volume (i.e. trunk volume without bark) is based on annual surveys of all forest made by the Norwegian Institute of Land Inventory. Research by Institute of Forestry at the Norwegian University of Agriculture (NLH), shows that roots, stumps, branches and bark contain only about half as much carbon as tree trunks (NLH, 1991).

The Institute of Forestry has also estimated the annual accumulation of CO_2 in humus and forest soils. The estimates are based on factors for respiration and washout derived mainly from experiments in other countries. The Norwegian Institute of Water Research (NIVA) has estimated the net accumulation of CO_2 in lakes and close coastal waters (SFT, 1993). The factors used to calculate net sedimentation are based on measurements and evaluation of both biological and chemical processes.

Carbon has been accumulating in soils and sediments since the last Ice Age, and the total amount of carbon in Norwegian soils is estimated to be one billion tonnes. We expect soils and sediments to continue to act as a net sink given the climatic conditions prevailing in Norway today. The standing volume of the forest is expected to level off, but no investigations have been made to determine when this is likely to happen.

Table 1.5. Biotic CO_2 emissions and sinks in Norway. All carbon is assumed to be emitted in the year when harvested. Million tonnes per year. (Source: SN, SFT)

Annual gross increment of roundwood cut [1]	29.1
Timber harvested for sawmills and wood industries [1] Of which wood waste burned as fuel: 0.9	-6.7
Timber harvested for pulp and paper industry [1] Of which black liquor and residues burned as fuel: 1.8	-5.9
Fuelwood harvested for private households [1]	-3.8
Logging waste	-0,5
Total anthropogenic sink	**12.2**
Accumulation in soil	2.8
Sedimentation in fresh water and estuaries	2.0
Natural losses	-2.0
Total natural sink	**2.8**
Net sink	**15**

[1] Including stumps, branches, bark, roots etc

1.7. International aviation and marine bunker fuels

In accordance with the IPCC Draft Guidelines, emissions from international aviation and marine bunker fuels are not included in the overall Norwegian greenhouse gas inventory, see also Chapter 1.1.1. In the following some separate emission data for these sectors are presented.

In 1990, CO_2 emissions from ships and aircraft in international traffic bunkered in Norway amounted to 1.8 million tonnes, see Table 1.6. Emissions of NO_x were relatively higher, totalling 32 000 tonnes, or 14% of all Norwegian NO_x emissions. From 1989 to 1993, emissions from ships in international traffic bunkered in Norway rose by about 50%, see Figure 1.8, whereas emissions from aircraft remained fairly stable.

Table 1.6. Emissions of CO_2, N_2O, CH_4 , NMVOC, NO_x and CO from ships and aircraft in international traffic bunkered in Norway in 1990. 1000 tonnes unless otherwise specified. Source: SN and SFT.

	CO_2 [1)]	N_2O	CH_4	NMVOC	NO_x	CO
International shipping	1.5	0.1	0.4	1.1	32.1	2.3
International aviation	0.3	0.0	0.0	0.1	0.7	0.6
Total	1.8	0.1	0.4	1.1	32.1	2.9

1) Million tonnes.

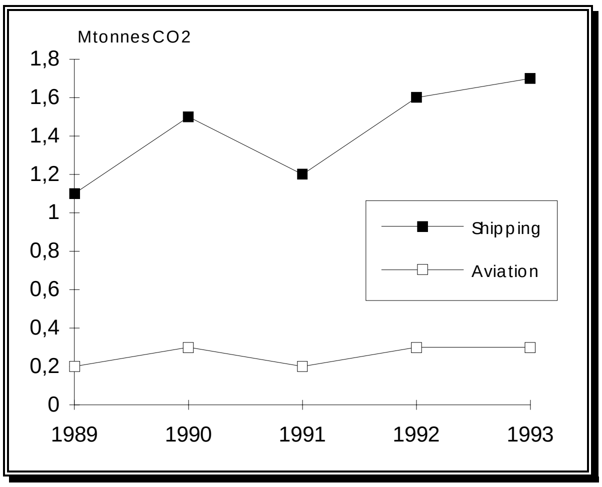


Figure 1.8. CO_2 emissions from ships and aircraft in international aircraft bunkered in Norway 1989-1993. Million tonnes. Source: SN and SFT.

2. Policies and measures

2.1 Overall policy context

Norway's climate policy is founded on the ultimate objective of the Climate Convention and the scientific understanding of the greenhouse effect set out in the reports from the UN Intergovernmental Panel on Climate Change (IPCC). An important principle of the Norwegian climate policy is that all policies and measures, at both national and international level, should be as cost-effective as possible. Coordinated international efforts and the development of formalized international mechanisms are essential in dealing with the greenhouse effect.

Norway ratified the Climate Convention on 9 July 1993. As the Convention is further developed, Norway will continue to advocate the need for new and more binding commitments, as well as flexible mechanisms for their implementation. There should be a special focus on the period beyond the year 2000, in order to develop policies in accordance with the objective of the Convention to stabilize the greenhouse gas concentrations in the atmosphere "at a level that would prevent dangerous anthropogenic interference with the climate system."

Norway's current target regarding national CO_2 emissions is as follows:
"CO_2 emissions are to be limited so that they do not exceed the 1989 level in the year 2000. This target is preliminary and will be considered in the light of further studies, technological advances, developments in the international energy markets and international negotiations and agreements."

As part of its effort to follow up the report of the World Commission on Environment and Development, Norway appointed a Green Tax Commission in 1992. Its tasks were, inter alia, to inquire into:

- How environmental policies could be integrated into economic and sectoral policies,
- How environmental policies could be made more cost-effective,
- How economic instruments could be used in environmental policies with an emphasis on reducing emissions to air.

The Commission published its recommendations in NOU 1992:3: "Towards More Cost-effective Environmental Policies in the 1990s: Principles and Proposals for Better Pricing of the Environment", and the Government adopted many of these principles in the Revised National Budget 1992. Based on preliminary reports from the Commission, CO_2 taxes were introduced in 1991, see 2.2.1 below. In the Government's Long-term Programme 1994-1997 long term policies towards the environment were given high priority. The Government is also promoting more efficient production and use of energy and energy conservation measures to achieve further limitations of emissions of CO_2.

Norway has introduced economic measures to limit emissions to air, particularly CO_2 taxes. In 1991 the Government introduced a CO_2 tax on oil, natural gas and coal for energy use as a first step towards a comprehensive national climate policy. The CO_2 tax on petrol and natural gas used in petroleum exploration offshore was raised in 1992 and is now equivalent to about

20 dollars per barrel of oil. The Government is also promoting more efficient production and use of energy.

As a follow up of the commitments set out in the Climate Convention and the national target regarding CO_2 emissions, the Government is preparing a report to the Storting (the Norwegian national assembly) on policies and measures to limit emissions of greenhouse gases and enhance CO_2 sinks. The Government intends to present the report by the turn of the year. The report will contribute towards a more integrated climate policy, addressing all relevant greenhouse gases and economic sectors in accordance with the guiding principles of the Convention. Relevant economic and administrative measures consistent with the Government's overall economic strategy, will be considered with the aim of finding cost-effective ways of limiting the net emissions of greenhouse gases in all sectors. Taxes on CO_2 are the most important means of limiting CO_2 emissions. The Government will intensify cooperation with the energy and industrial sectors, for instance by taking the initiative for voluntary agreements including surveys and declarations of intent to reduce emissions exempted from the CO_2 tax.

2.2. CO_2 emissions

2.2.1 Cross-sectoral

The Norwegian CO_2 tax scheme

Norway has for a number of years been at the forefront in introducing economic instruments to limit emissions to air. The Norwegian environmental tax system consists primarily of product taxes, which in many instances may be a suitable approximation to emission taxes, e.g. for emissions of CO_2, SO_2 and lead. These emission components are already reflected in the current tax system for fossil fuels. Both the petrol and the mineral oil tax contain a CO_2 element, and it should be emphasized that the Norwegian retail prices for petrol and mineral oil are among the highest in the world. A carbon tax has also been introduced for gas and oil combustion on the continental shelf, and as from 1 July 1992 a carbon tax was introduced for certain applications of coal and coke. About 60 per cent of national CO_2 emissions are currently subject to such taxes.

Table 2.1 shows the tax rates for petroleum products, gas, coal and coke as of 1 September 1994. Table 2.2 shows how the CO_2 taxes on petroleum products, gas, coal and coke have been increased during the last few years.

Table 2.1: Tax rates for petroleum products (NOK/l), gas (NOK/Sm³) and coal and coke (NOK/kg).

	Basic tax	CO_2 tax	SO_2 tax	Total	CO_2 tax per kg CO_2 emitted
Unleaded petrol	3.12	0.82		3.94	0.35
Leaded petrol	3.78	0.82		4.60	0.35
Autodiesel	2.45	0.41	0.07	2.93	0.16
Mineral oil	0	0.41	0.07[1]	0.48	0.16
Diesel, North Sea	0	0.82	0	0.82	0.31
Gas, North Sea	0	0.82		0.82	0.35
Pit coal	0	0.41		0.41	0.17
Coal coke	0	0.41		0.41	0.13
Petroleum coke	0	0.41		0.41	0.11

[1] The tax rate is 0.07 NOK per 0.25 per cent SO_2 content.

Table 2.2: Changes in CO_2 taxes on petroleum products (NOK/l), gas (NOK/Sm3) and coal and coke (NOK/kg), 1991-1994.

	From 1.1.91	From 1.1.92	From 1.7.92	From 1.1.93	From 1.1.94
Petrol	0.60	0.80			0.82
Mineral oil[2]	0.30			0.40	0.41
Gas, North Sea	0.60	0.80			0.82
Oil, North Sea	0.60	0.80			0.82
Coal and coke			0.30	0.40	0.41

2) From 1.1.91 the CO_2 tax was levied in addition to an already established fiscal duty of 0.32 NOK/litre. The fiscal duty was reduced to 0.17 NOK from 1.7.92 and to zero from 1.1.93. Total taxes on light fuel and diesel oils were reduced from 0.69 NOK/litre in 1991 to 0.48 NOK/litre in 1994 (including sulphur tax).

Exemptions from the CO_2 tax

Petrol: The petrol tax (basic tax and CO_2 tax) is levied on practically all domestic petrol use.

Mineral oil: Certain sectors exposed to international competition are exempted from CO_2 tax and SO_2 tax. The most important exemptions concern the consumption of mineral oil products in air transport, ships engaged in foreign trade, the supply fleet in the North Sea and fishing in distant waters. Through reimbursement schemes fuel consumption in coastal fishing and in coastal goods transport is virtually untaxed. Moreover, the pulp and paper industry and the fish meal industry pay a reduced CO_2 tax of 0.205 NOK/l. Fuel consumption in coastal passenger transport is taxed at the full rate.

Onshore use of natural gas: Not taxed (use negligible today).

Coal and coke: The CO_2 tax is not levied on coal and coke used as a reducing agent or as raw material in industrial processes. These processes account for nearly 90 per cent of all CO_2 emissions from coal and coke in Norway. In addition coal and coke used for energy purposes in the production of cement and LECA lightweight concrete are exempted.

Norwegian experience of carbon taxes
CO_2 emissions in Norway first dropped by about 5 per cent from 1989 to 1991 (mainly as a result of reductions in petrol consumption and metal production), and subsequently increased again, reaching the 1989 level in 1993. This is significantly different from the steady increase that was expected to continue into the 1990s. In addition to the CO_2 tax, which was implemented with effect from 1991, the ample supply of hydro-based electric power and low economic activity have contributed to this development. The main increase since 1991 has been in emissions from the petroleum industry as production and exports of natural gas increased.

From 1970 to1990 the consumption of *petrol* nearly doubled, and both the price and tax level in real terms were slightly lower in 1990 than at the beginning of the 1970s. Until the late 1980s the petrol tax was not deliberately used by the authorities to limit growth in consumption of petrol. Throughout the period, however, the tax level has been relatively high. It may therefore be assumed that petrol consumption and emissions after 1970 would have been substantially higher without a petrol tax or with a lower tax level. From 1990 to 1991, petrol consumption dropped for the first time since 1981. The introduction of the CO_2 tax has been a contributory factor.

The real price for most mineral oil products was slightly higher in 1991 than in the 1970s, but lower than at the beginning of the 1980s. The periodic fluctuations in consumption seem to be related to fluctuations in real prices for heating oils and trends in relative real prices for heating oils and electricity.

The CO_2 taxes introduced 1 January 1991 are high compared to similar taxes that have been introduced or proposed in other countries. The development of Norwegian CO_2 taxes provides a good illustration of the problems a small open economy faces in trying to be in the forefront with respect to introducing instruments aimed at limiting global environmental problems. The lack of international implementation and coordination of instruments may lead to leakage effects, so that a country incurs substantial costs without reducing overall emissions. So far, there are few indications that the taxes have had significant adverse effects on the competitive position of Norwegian industry.

Current national carbon taxes are not fully differentiated according to carbon content. It has been emphasized that the tax basis should be as broad as possible and that the rates should reflect CO_2 emissions. The Government has advocated this principle in several national budgets and in the Long-term Programme 1994-1997.

Energy policy and energy efficiency

In Norway, almost all electricity is generated by hydro power. A new Energy Act that entered into force on 1 January 1991 lays down general terms and conditions designed to ensure more efficient utilization of hydro power. The Act involves deregulation and keener competition in the power sector. The power market has seen considerable changes since the introduction of the new Energy Act. Growing competition has had a pronounced effect on electricity prices and has led to reductions in the price of power for several categories of customers.

In 1993 Norway introduced a change in the energy efficiency policy based on a report to the Storting. Norwegian policy is now shifting away from extensive grant schemes towards more cost-effective measures. The main activities in the years to come in the field of energy efficiency will be information, education and the introduction of energy-efficient technology.

In 1994 the Government has allocated NOK 56 million for energy efficiency activities, NOK 36 million for information and educational measures and NOK 20 million for the introduction of energy-efficient equipment and systems and new renewable energy sources. The Government will also strengthen information and educational resources, while encouraging the establishment of regional energy-saving centres.

2.2.2 Energy and transformation industries

Electricity production on the mainland

Almost all electricity produced on the Norwegian mainland is hydro power, and nearly all emissions of CO_2 from energy production are generated in connection with offshore petroleum production.

Offshore petroleum sector

More energy-efficient gas turbines have reduced the emissions of CO_2 per unit of petroleum products produced. The efficiency of power generation in the petroleum sector has grown by 50% since 1975. Heat recovery systems have been installed on some installations.

Flaring of gas has been reduced substantially compared to the level of production, and much less gas is flared in the Norwegian sector than in other comparable countries. In spite of a 24% increase in oil and gas production, the amount of gas flared was reduced by approximately 45% from 1990 to 1992. A minimum level of gas flaring is necessary for safety reasons. Flaring of gas is regulated by the Petroleum Act.

The carbon tax covers flaring and burning of natural gas and diesel in the petroleum sector. The tax rates are currently 0.82 NOK/m^3 and 0.82 NOK/litre respectively. The tax is believed to have contributed to more energy-efficient production and has encouraged the development of projects and technical solutions to reduce CO_2 emissions offshore.

Considerable technological improvements have made it possible to achieve energy-efficiency gains in both the production and transport of petroleum. One example is the proposal for redevelopment and reconstruction of the EKOFISK transport system, which, as the proposal stands, will give a reduction of 900 000 tonnes of CO_2 emissions per year.

The Norwegian Oil Association's (OLF) environmental programme, which has been conducted as a joint effort between the authorities and OLF, has made an important contribution to an improved understanding of the connection between costs and environmental gains in the petroleum sector. A decision has been taken to continue the environmental programme as a formal cooperative effort between OLF and the authorities.

2.2.3 Transport

CO_2 taxes

The CO_2 tax is the main instrument for limiting CO_2 emissions from the transport sector (cf. Chapter 2.2.1). The tax rates are currently 0.82 NOK/1 petrol and 0.41 NOK/1 diesel.

The demand for transport oils is influenced by the total taxes on these products, regardless of why they are imposed. Norwegian taxes and retail prices on transport oils are among the highest in the world, currently 4.19 NOK/1 petrol and 2.93 NOK/l diesel. VAT is not included in these Figures. Petrol taxes are more than 50 per cent higher in 1994 than in 1990.

The introduction of the CO_2 tax and the general growth in tax rates have contributed to a considerable reduction of petrol consumption. The consumption dropped by more than 5% between 1990 and 1993. Other factors than taxation may also have had some impact, especially the general decline in economic growth over the same period.

In the shipping sector, domestic ferries and passenger ships are affected by the CO_2 tax. These ships have been taxed since 1992.

Other measures

The CO_2 tax is, as mentioned above, the main policy instrument used to control CO_2 emissions. However, a number of other transport policy measures also contribute to reductions of CO_2 emissions from the transport sector.

The purchase taxes for cars are among the highest in the world, and they are differentiated according to the value and weight of different kinds of cars. The weight element is an incentive to buy lighter, more energy-efficient cars.

The maximum speed limits in Norway are low by international standards, thus contributing to relatively low fuel consumption.

A survey of the possibility of introducing alternative fuels in the transport sector in Norway has been carried out, with a special focus on natural gas. The survey included international experience, the gas market in Western Europe, distribution conditions, infrastructure and the potential for the use of natural gas in Norway. To encourage research and development activities in this field in Norway, funds have in recent years been allocated to projects concerning the use of natural gas in buses and the development and testing of electric vehicles. In the future other fuels and means of transport might also be of interest.

The Ministry of Transport and Communications is investigating the possibility of implementing road pricing, which is regarded as an efficient instrument for reducing local transport and environmental problems. Road pricing could also make a certain contribution to the reduction of CO_2 emissions from the transport sector. There are toll rings around the largest cities, and these may be used to some extent to reduce congestion and adverse environmental effects.

In the longer term regional and local land-use and transport planning may have some influence on the development of transport needs. The recently adopted national policy guidelines on integrated land-use and transport planning (under the Planning and Building Act) define limitation of the need for transport and increased use of environmentally sound modes of transport as two important objectives for planning at local and regional level.

Subsidies to expand public transport may under certain circumstances limit CO_2 emissions from the transport sector. However, it is difficult to evaluate the net environmental effect of such subsidies. The effect of a given level of subsidies varies according to the strategies followed in the transport sector. The Government gives high priority to public transport, especially railway transport, as set out in the transport plans for the period 1994-97, which have been adopted by the Storting. The Government has established a special programme to support the country's four largest cities in building infrastructure for public transport.

Norway will implement the EU vehicle inspection system during the period 1994-98. This is expected to give some improvements in average energy efficiency.

2.2.4 Industry

CO_2 emissions from energy use in industry have decreased considerably as a result of improved energy efficiency and changes in the energy mix. Energy efficiency has been improved by general capital replacement and operational changes, which were to some extent supported by an earlier grant scheme for energy efficiency measures. In the industrial sector, electricity and biological fuels have to a large extent replace mineral oils as an energy source. This has been especially pronounced in the pulp and paper industry, which is increasingly using bark and other biological spill products as fuel. These changes took place in the early 1980s, mainly because measures were introduced to regulate emissions of such spill products. The price of mineral oil has been higher than that of electricity, and this has also been of importance in changing the energy mix. The introduction of a CO_2 tax on mineral oils from 1 January 1991 and the abolition of the excise tax on electricity for manufacturing industries from 1 January1993 have also made mineral oils relatively more expensive.

The network for energy use in Norwegian industry has continued to grow since its start in 1989. The network now represents 70 percent of total energy use in Norwegian domestic industry. In addition to collection of energy and production data, the network also offers development of energy efficiency analysis methods for the different trade groups.

The Norwegian Government will intensify its cooperation with the energy and industrial sector and take the initiative for voluntary agreements on, for example, surveys and declarations of intent to reduce emissions exempted from the CO_2 tax.

Ammonia production

In 1992, emissions of CO_2 from ammonia production were estimated at about 0.7 million tonnes per year (around 2% of Norway's total emissions). The emissions are caused by the use of NGL as raw material for hydrogen production, and amount to just under 2 tonnes of CO_2 per tonne of ammonia produced .

Oil refineries

In 1992, Norway's three refineries emitted a total of approx. 2 million tonnes of CO_2, corresponding to about 6% of the country's total emissions. Of this, 90-95% is generated by energy consumption during the production process and 5-10% by flaring of refinery gas. A number of projects have been implemented internally at the refineries to reduce energy consumption, especially through regeneration of heat.

Cement production

Emissions of CO_2 from Norwegian cement production are estimated to be about 1.3 million tonnes per year, corresponding to about 1 tonne CO_2 per tonne cement. Of this, 50 - 60% is generated by the decomposition of limestone during the production process. Decomposition is a necessary part of the manufacturing process, and the emissions are therefore directly dependent on the production volume. The remaining 40-50% of the emissions originate from the sources of energy, which are coal, waste oil and liquid organic hazardous waste.

Metals manufacturing

In 1991, metals manufacturing as a whole accounted for 12-13% of total emissions of CO_2 in Norway. The largest emissions originate from the ferro-alloys industry, which alone accounts for about 7%. The manufacture of aluminium accounts for 4-5%. CO_2 emissions during metals manufacturing derive from the use of coal and coke as a reducing agent, and are therefore primarily dependent on the volume of production. Hydro power is used as a source of energy, and this does not cause emissions of CO_2.

Ferro-alloys

Ferro-alloys are manufactured by direct carbothermal reduction in electric smelting furnaces. It does not appear to be feasible to use other reducing agents than carbon. The carbon used is usually in the form of coal or coke but, for technical reasons, a small proportion of granulated wood is used for some alloys. It is technically feasible to use charcoal instead of fossil carbon, but this is economically possible only in places where charcoal is available in sufficient quantities (e.g. in Brazil). The Ferro-alloy Industry's Research Fund has now started a project entitled "Environmental declarations", which is expected to provide some data on possible CO_2 abatement measures. The planned project period is 1993-1995.

Primary aluminium

Primary aluminium is manufactured by a combination of smelting and electrolysis, i.e. the raw material, aluminium oxide, is placed in a salt smelter that is electrolyzed. The aluminium is then precipitated as molten metal, and the oxygen combines with the carbon at the anode, generating CO_2 .

Extensive research is being carried out on the development of inert anodes, i.e. anodes made of a material which does not combine with oxygen in the reactive form in which it is found. The oxygen can then be removed as oxygen gas. It is still very uncertain when such a system may become technically feasible. One obstacle at present is that energy consumption has been shown to be much higher than when carbon anodes are used. Thus, if the electrical energy is produced using fossil fuel, the benefit obtained by not using carbon anodes could be reduced or even outweighed by the increase in CO_2 emissions from energy production.

Reduced energy consumption through recycling
Production based on recycled resources is generally less energy- consuming. The largest potential for use of recycled materials is in the production of metals, but a certain potential also exists in the paper, plastics and glass industries. Waste can also be used as a source of energy in production, or as fuel in a waste-burning hot water generator.

Projects involving sorting municipal waste at the source are currently in progress. Grants have been made for a number of projects to develop methods to reduce waste generation and increase recycling. Burning car tyres during the production of cement, and in other applications are examples of such projects.

The Norwegian authorities are actively seeking agreements with trade and industry to increase the amounts of waste recycled .

2.2.5 Residential and Commercial

There has been a steady decrease in CO_2 emissions in the commercial and the residential sectors, mainly as a result of the continued shift from oil to electricity based on hydro power. The significant change in the mix of energy carriers is related to the trend in energy prices. The CO_2 tax on fossil fuels for energy purposes was introduced in 1991, and raised the price of heating oil in relation to that of electricity. It is assumed that the increased taxes on fossil fuels will contribute to a further reduction in energy for heating oil consumption and further substitution of electricity.

In 1991 the Government launched a grant scheme for the residential sector. Grant schemes for industry and commercial buildings already existed. However, all these schemes were discontinued in 1993 after an assessment showed a large percentage of free riders. Efforts are being made to develop new methods of promoting energy efficiency in various industries and in large building complexes, including state-owned buildings.

To follow up a report to the, Storting the Government decided to promote the establishment of regional energy efficiency centres. These will serve local building owners and households. The first centre was opened in August 1994. Activities in the centres are mainly financed by an increase of NOK 0.02 per/kWh in the transport tariffs for electricity, which provides a total revenue of NOK 100-150 mill. The centres will mainly cooperate with local energy utilities, but will also be open for participation from other companies in the sector like oil companies, consultants and suppliers of energy efficient equipment.

For some years, the utilities have included energy efficiency services as part of their business strategy. Some, mostly in the large cities (Oslo and Bergen) have run extensive grant and loan schemes, whereas other have not been active in this field. The establishment of the regional centres will ensure a more uniform supply of energy efficiency services to the public.

2.3 CO_2 sinks

Long-term fixation of carbon in biomass can be achieved by forest growth. The standing volume of Norwegian forests has been steadily increasing in recent years, and is now estimated to total about 600 million m^3, corresponding to a carbon stock of about 800 million tonnes CO_2 .

One of the main objectives of Norwegian forestry policy is to maintain and enhance forestry resources, both because this permits continued exploitation of the natural resource base for forestry purposes and because it has a favourable effect on climate.

Norwegian forests are very important as a carbon sink. Current forestry policy emphasizes the conservation, development and utilization of natural resources, and has, as described above, resulted in a steady increase in forest biomass and thus the fixation of large amounts of CO_2 . It is also possible to increase the yearly net fixation of CO_2 in Norwegian forests through specific measures designed to stimulate forest growth further. A number of measures to increase the production of forest biomass have been evaluated, and may be of interest in an integrated system of forest management. Continuous evaluation will be required to find the right balance locally between forestry and climate policy on the one hand and local environmental effects related to biodiversity, recreational value, etc, on the other.

2.4. Methane emissions

2.4.1. Waste management

About 1.5 million tonnes of waste are deposited in landfills in Norway each year, corresponding to 70% of all municipal waste. In 1992, emissions of methane from landfills were estimated at 166 000 tonnes.

During the last 5-6 years, emissions of methane have been reduced at several landfills by extracting the landfill gas for energy purposes. Eight plants were in operation in 1993, and have altogether reduced emissions of methane by more than 10 000 tonnes. The extraction also has an effect on the local environment by reducing smell and seepage from the landfills. Five new plants are now being built or planned.

2.4.2 Agriculture

Methane emissions from the agricultural sector constitute about 30 % of total methane emissions and about 4 % of Norway's total emissions of greenhouse gases measured in CO_2 equivalents. Most of this is generated as an inevitable by-product of digestion in ruminants, (and also represents a loss of energy during the process.) However, there are ways of reducing methane production by altering the composition of animal fodder, for instance by increasing the amount of fat or other additives.

2.4.3 Fugitive fuel emissions

Petroleum sector
Venting of gas without combustion is sometimes an alternative to flaring. Both flaring and venting of gas are regulated by the Petroleum Act. For safety reasons flaring is preferred to venting.

Emissions of methane from loading from oil fields to ships and further to terminals can be reduced by installing recovery systems. Pilot projects have been started to test recovery systems on both ships and terminals. The technology for such systems is under development, and experience from the pilot projects will be very useful. The main intention of the projects has been to reduce emissions of non-methane volatile organic compounds (NMVOC). Optimized loading routines have also helped to reduce emissions.

2.5. Nitrous oxide emissions

2.5.1. Industry (non-energy)

Nitrous oxide (N_2O) from nitric acid production
Nitrous oxide is generated during production of nitric acid. In 1990 emissions of nitrous oxide from this source amounted to about 6 700 tonnes per year, corresponding to 1.8 million tonnes of CO_2. After reconstruction of some of the plants in 1991, emissions dropped to about 5 000 tonnes in 1993, but are expected to increase to 6 000 - 7 000 tonnes by the year 2000 if the production capacity is fully exploited.

2.5.2. Industry (energy-related)

Emissions of N_2O from stationary combustion in industry are estimated at 900 tonnes, i.e. about 6% of total emissions of N_2O in Norway. This estimate is very uncertain, however. It is estimated that about 30-40% of these emissions are associated with the use of wood, bark and black lye in the pulp and paper industry. Except for the reduction obtained by generally more effective use of energy, the possibility of reducing emissions has not been investigated further.

2.5.3. Agriculture

Emissions of N_2O from agriculture were estimated at 6 500 tonnes in 1990, and have probably remained unchanged since 1980. This Figure coresponds to about 3% of total emissions of greenhouse gases in Norway. The emissions are mainly a result of increased addition of nitrogen to the soil. The processes controlling the production of N_2O in the soil are not fully understood.

Emissions can be reduced by careful spreading of nitrogenous fertilizer, and by spreading it at specific times during the growing season when the crops make best use of the nitrogen. This may reduce the amount of fertilizer needed as well as the generation of N_2O. These and other routines for irrigating and preparing the soil have been published by the Norwegian fertilizer manufacturer and distributed to farmers. The manufacturer is continuing research on how to reduce emissions of N_2O. Research is also being carried out on the pathway followed by nitrogen from anthropogenic input to final deposition, where N_2O is one of the components. The aim is to identify possible reductions and evaluate costs.

2.5.4. Transport

Mobile sources contribute about 1 000 tonnes of N_2O emissions, corresponding to 7% of the total. The main source is road traffic. A report published by SFT in 1993, "Emissions from Road Traffic in Norway", shows that emissions from passenger cars with a catalytic convertor are 3-4 times higher than emissions from cars without such convertors. No measures have been evaluated.

2.6. Other greenhouse gases

A report to the Storting on policies to limit emissions of NO_X is being prepared. Instruments and measures to reduce emissions of NMVOC in accordance with the commitments set out in the VOC protocol will be elaborated.

2.6.1. Industry (process and energy-related)

PFC emissions from aluminium production
Aluminium production is the only known significant anthropogenic source of emissions of the perfluorinated carbons tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6). Fluorinated carbons are formed by a reaction between carbon and fluorine in electrolytic cells for aluminium manufacture where carbon is the anode or reduction material. On the basis of measurements, emissions of PCFs are estimated to have been 284 tonnes in 1992, corresponding to 1.5 million tonnes of CO_2 . The uncertainty is roughly -30 to +50%.

Emissions were probably reduced by about 40% between 1985 and 1992. Emissions can be further reduced in three different ways: 1) by converting Søderberg furnaces to prebake furnaces, 2) by reducing the anode effect frequency in Søderberg furnaces (partly by means of point suppliers) and 3) by reducing the frequency of anode effect in prebake furnaces.

SF_6 emissions from magnesium production
The gas is used as an additive to air that covers the surface of liquid magnesium during the casting process. The covering gas is emitted to air after use. The amount of SF_6 emitted has been reduced from about 90 tonnes in 1990 to about 23 tonnes in 1992, both as a result of reduced production levels and improved routines and maintenance. However, since the GWP value for SF_6 is estimated to be 19 000, this is equivalent to 0.4 million tonnes of CO_2 .

There is limited scope for further reductions by means of more stringent routines, and the gas cannot be separated and reduced with the open casting equipment in use today. The only alternative to SF_6 is SO_2 , which was used before 1982. However, SO_2 causes health problems and is not regarded as a realistic alternative.

2.6.2. Residential and commercial

Emission standards for residential woodburning stoves

Emission standards for residential woodburning stoves will be introduced to reduce emissions of particles/PAHs, because woodburning stoves make a major contribution to local pollution problems. Neither emissions of CO_2 from woodburning stoves nor CO_2 uptake during regrowth of wood are included in the greenhouse gas inventory. The energy efficiency of most stoves that comply with the new emission standards will be improved, but this effect is not taken into account in the emission reductions. Emission standards will also reduce methane emissions, thereby reducing the greenhouse effect.

The emission standards will be voluntary from 1995 and mandatory from 1997. In the year 2000, methane emissions are expected to be reduced by 1 500 tonnes, or 0.3 ktonnes of CO_2 equivalents.

2.6.3. Solvent and other product use

Emissions of NMVOC

The carbon content of NMVOC emissions is included in the CO_2 emission inventory in Norway as recommended by the IPCC. This is because the lifetime of NMVOC is short and CO_2 is the end product of the chemical reactions. The ECE agreement on 30% reduction of NMVOC emissions, which Norway has ratified, will thus contribute to a reduction of CO_2 emissions. The indirect effect of NMVOC as an ozone precursor is not included. The reduction will be completed by 1998 and will reduce CO_2 emissions by 300 ktonnes.

Use of HFCs

HFCs are halogenated carbon compounds that do not contain bromine or chlorine. They are not regulated directly by the Montreal Protocol as substances that deplete the ozone layer. Various HFC compounds are relevant as substitutes for CFCs and HCFCs, the use and production of which are to be phased out completely in countries complying with the Montreal Protocol. Today's consumption of HFCs is moderate but, unless new measures are initiated, is expected to increase gradually as CFCs and HCFCs are phased out. The consumption of HFC-134a increased from 5 tonnes in 1992 to 32 tonnes in 1993. This corresponds to 40 000 tonnes of CO_2 equivalents, assuming that the GWP of HFC-134a is 1200.

SF_6 used in electrical equipment

In 1992, emissions of SF_6 from gas insulated switchgear in Norway totalled 2.2 tonnes. Emissions occur only as a result of leakages or accidents, or if installations are destroyed without recovering the gas. The emission Figure is based on the assumption that 1% of the gas in installed equipment is emitted every year.

3. Projections and assessment of effects of measures

Emissions of CO_2 are closely related to the use of fossil fuels, which in turn is related to the level of economic activity. Analyses of these relationships and projections of CO_2 emissions have been an important basis for implementing Norwegian climate policy since the late 1980s, and were a central in the discussion of climate-related issues in the following documents:

- SIMEN - studies of industry, environment and energy up to the year 2000 (1989)
- The report from the Interministerial Climate Group (1991)
- The Green Tax Commission (NOU 1992:3)
- The Government's Long-term Programme 1990-1993
- The Government's Long-term Programme 1994-1997

In the following, projections of both CO_2 emissions and emissions of other important greenhouse gases in Norway are presented.

3.1 Projections of emissions of CO_2

Methodology and key assumptions
The emission projections for Norway are based on macroeconomic model projections supplemented with sectoral studies for some sectors (e.g. transport and petroleum production). For medium-term projections, up to ten years, the macroeconomic model MODAG is used. For longer-term projections a general equilibrium model, MSG, is used. A description of the models, and some important assumptions underlying the projections, is given in Annex 1. This means that emission projections are consistent with overall macroeconomic developments and policies in Norway for the period in question. Emission and energy scenarios have also been studied using other models such as Markal models. Such studies serve as background information for the macroeconomic analyses.

Table 3.1 shows the development of key macroeconomic aggregates in the baseline scenario. The gross domestic product in mainland Norway is projected to grow at an annual rate of just above 2 per cent until the year 2000. However, production in the petroleum and ocean transport sectors is assumed to grow at a rate of 4.2 per cent per year due to expansion of offshore petroleum activities. The growth of private and government consumption is expected to be about 2 per cent per year. Gross capital formation for mainland Norway is expected to grow at an annual rate of about 4 per cent during the period, starting from a relatively low level. Exports of other goods than oil and gas are assumed to increase by just above 3 per cent per year and imports by about 2 1/4 per cent per year.

Table 3.1. Development of key macroeconomic variables and energy use in the baseline scenario.

	1991 Billion NOK, constant 1991 prices	Annual average growth rate 1991-2000	
Gross domestic product	686.7	2.6	
Mainland Norway	563.8	2.1	
Manufacturing	94.3	2.2	
Petroleum and ocean transport	122.9	4.8	
Domestic use of goods and services	626.3	2.1	
Private consumption	349.7	1.8	
General government consumption	147.5	2.0	
Gross fixed capital formation[1])	136.8	2.5	
Mainland Norway	89.7	4.1	
Petroleum and ocean transport[1])	47.1	-1.2	
Export	307.5	3.3	
Oil and natural gas	96.7	6.0	
Other goods	112.5	3.2	
Import	247.1	2.2	
Number of persons employed (1000)	2034	0.9	
Net domestic energy use[2]):			
Petroleum products (1000 tons)	6005	0.8	
Mineral oil	3778	0.7	
Petrol	2227	1.0	
Electricity (TWh)	99	1.7	

1) Includes oil rigs under construction
2) Data from MODAG

Total energy use is projected to grow by about 1 per cent per year, use of electricity by 1.7 per cent and use of petroleum products by 0.8 per cent. A continuous improvement of energy efficiency for the various sectors is assumed in the projections. The rate of autonomous energy efficiency improvement varies between sectors, but is on average assumed to be about 1 per cent per year.

Emissions of CO_2

Table 3.2 shows the resulting projections for gross emissions of CO_2 in the period 1991 to 2030 based on current policies, i.e. including the present CO_2 taxes.

Table 3.2 Gross emissions of CO_2 in Norway by sector. Million tonnes.

	Petroleum sector	Domestic transport *1)*	Manu-facturing	House-holds *2)*	Other sectors	Total emissions *3)*
1989	7	4	11	6	6	35
1990	8	4	12	6	6	36
1991	7	4	11	6	6	34
1992	8	4	11	6	6	34
1993 4)	8	5	11	6	6	36
1994	8	5	11	6	6	36
1995	9	5	11	6	5	36
1996	9	5	11	6	6	37
1997	9	5	12	6	6	37
1998	9	5	11	6	6	38
1999	10	5	12	6	6	39
2000	10	5	12	6	6	39
2001	10	6	12	6	6	40
2010	9					41
2030	7					41

1) Excl. own transport in industries and households
2) Incl. transport by private car
3) Numbers may not add because of rounding errors
4) Preliminary figures

Emissions of CO_2 are expected to rise by about 12% by the year 2000 taking the effects of the CO_2 tax into account, according to the Governments Long-Term Programme 1994-1997. About 65% of this rise is due to the expected increase in gas production and transport, which is all exported.

Total emissions of CO_2 are estimated to grow by 1.7 per cent per year, emissions from the petroleum sector by 3.4 per cent and emissions from other sectors by 1.2 per cent in the period 1991-2000.

One of the main reasons for the large rise in emissions from the petroleum sector is a substantial increase in production and transport of natural gas. The gas is transported to the continent by pipeline, and pipeline compressors are very energy-intensive. The electricity used to run the compressors is produced from natural gas.

It should be noted that because of developments in the petroleum sector, total CO_2 emissions are expected to increase in the 1990s and largely stabilize thereafter. In this context it should also be noted that CO_2 emissions are not expected to increase much in a long-term perspective (i.e. 15-35 years from now) if current policies are maintained.

Uncertainty
Uncertainty in model projections has several causes. The first type of uncertainty is connected to assumptions about variables such as real oil price, petroleum extraction, energy efficiency and international economic growth . Fluctuations in oil prices and estimates of oil and gas extraction represent sources of uncertainty for projections of the development of the Norwegian economy, energy use and emissions of CO_2 .

When assessing the uncertainty of model projections, it is particularly important to consider possibilities for energy substitution. The estimates of elasticities of substitution between fossil fuels and electricity are particularly important, since Norway's electricity is produced by hydro power. If the proportion of total energy demand covered by electricity grows while all other factors remain unchanged, CO_2 emissions will therefore be reduced.

Long-term projections
The long-term projections are based on a general equilibrium model called MSG. In the MSG model, economic growth is determined by technological change, the growth of the capital stock and the supply of labour, and the availability of raw materials and natural resources. Supply and demand are assumed to be equal in all markets, and consumers and producers utilize all the existing resources. This means in particular that the specified supply of labour is fully employed. The model is therefore not used for analyses of short-term adjustment problems or the development of unemployment. The classification of sectors is the same in MSG as in the MODAG model.

As noted above, CO_2 emissions are not expected to increase significantly from 2000 to 2030 since the amount of petroleum extracted is expected to decrease after 2000. It is assumed that petroleum extraction will drop from 184 mtoe in 2001 to only 87 mtoe in 2030. Assuming that there will be moderate economic growth and a continued increase in energy efficiency in all sectors, CO_2 emissions are estimated to total about 41 million tonnes in 2010 and about 40 million tonnes in 2030. The low growth of emissions from other sectors than petroleum in 2010-2030 is mainly explained by the assumtion that private consumption will grow more slowly.

Electricity production in Norway is currently based on hydro power. However, this source provides only limited scope for expansion, and production of electricity from natural gas might be an option in the future. The long-term projections do not include power plants based on natural gas, because it is assumed that expansion and upgrading of the existing hydro power system will take place. These assumptions are uncertain.

Sinks
The projections of emissions do not include estimates of removal of CO_2 by sinks. However, the timber volume in Norwegian forests has been increasing for many years. As described in Chapter 1.6, the net sink of CO_2 in forest, soil and aquatic ecosystems in Norway in 1992 is estimated at 12 million tonnes.

Sensitivity analysis
Sensitivity analyses illustrate that it is relatively costly to reduce CO_2 emissions in Norway, for the following reasons:

- Electricity production in mainland Norway is almost entirely based on hydro power. Thus, Norway cannot reduce emissions from coal- and oil-based power plants as many other countries can. Heating of houses and other buildings is already largely based on electricity.

- A major source of CO_2 emissions in Norway is the transport sector. Norway is among the OECD countries with highest petrol prices, and price elasticities in the transport sector are relatively small. This makes it difficult to achieve further substantial reductions in emissions from the transport sector in a short period of time.

3.2. Projections of emissions of other greenhouse gases

Projections of emissions of CH_4 and N_2O are based on the updated reference scenario based on the Government's Long-term Programme 1994-97, which is described in more detail in Chapter 3.1 above. The updated projections of emissions from the petroleum sector published by the Ministry of Industry and Energy have also been incorporated. In addition, emissions from the transport sector have been adjusted on the basis of the prognoses of emissions from road traffic, railways, coastal shipping and aircraft made by the Ministry of Transport and Communications.

Projections of emissions of the perfluorinated carbons (CF_4 and C_2F_6), sulphur hexafluoride (SF_6) and HFCs are prepared by the Norwegian Pollution Control Authority (SFT) on the basis of Figures collected from the relevant branches and industrial enterprises. The projections for these gases are highly uncertain.

Table 3.3 shows emissions and projected emissions of methane, nitrous oxide, perfluorinated carbons, sulphur hexafluoride and HFCs, together with the Figures for CO_2 . The GWP values used in the Table are given in Chapter 1.1.

Total emissions of greenhouse gases are expected to increase only slightly, by 6% from 1989 to the year 2000. One of the main reasons is that emissions of CF_4, C_2F_6 and SF_6 are expected to decrease over the period. Consumption of HFCs is expected to increase as CFCs are phased out. In SFT reports 93:16 and 93:17 on phasing out HCFCs and HFCs, it is predicted that consumption of HFCs will reach 460 tonnes in the year 2000, provided that no new regulations are introduced. This is equivalent to 0.5 million tonnes CO_2, assuming that only HFC-134a is used. Emissions of methane and nitrous oxide are expected to remain relatively stable throughout the period.

Table 3.3. Emissions of the various greenhouse gases in 1989, 1990, 1993 and projections for 2000. The Figures are given in million tonnes CO_2-equivalents (direct GWP, direct and indirect GWP for methane).

	1989	1990	1993	2000	Changes 1989-2000
Total	50.1	50.2	48.1	52.9	+6%
Carbon dioxide	35.2	35.4	35.5	39.5	+12%
Methane	6.6	6.7	6.8	6.4	-2%
Nitrous oxide	4.3	4.2	3.8	4.4	+4%
PFCs	2.0	2.1	1.5	1.4	-26%
Sulphur hexafluoride	2.0	1.7	0.5	0.6	-71%
HFCs	0.0	0.0	0.0	0.6	..

4. Vulnerability assessment and adaptation measures

The Intergovernmental Panel on Climate Change predicts that the global mean surface temperature will increase by 3.0 ± 1.5 ºC as a consequence of a doubling of the atmospheric CO_2 concentration (IPCC 1992). It is anticipated that the elevated temperature will produce a substantially wetter atmosphere, giving higher precipitation. The effects of global warming are expected to be greatest in northern and high altitude areas (Monserud et al. 1993). The climatic scenario for Norway if the atmospheric concentration of CO_2 doubles is expected to involve a temperature increase of 2 ^{0}C in the summer and 3-4 ^{0}C in the winter towards 2030. Precipitation is expected to increase by 5-15%, and most of the increase is assumed to occur in spring in the western parts of the country. Eastern Norway and the county of Finnmark may become dryer because of increased evapotranspiration (c.f. Holten & Carey 1992). However, considerable uncertainty still surrounds the predictions of climate change provided by regional models (IPCC 1992). This must also be taken into account when considering climate change and its impacts in Norway.

Until now, most attention has been focused on effects on ecosystems and their vulnerability to climate change. In addition to climate change caused by increase in mean temperature, Norway may, because of its geography and long coastline, be particularly vulnerable to changes in the frequency of weather patterns and extreme events such as storms, floods and spring tides. Further investigations are needed, both on the possible relation between changes in the frequencies of such extreme events and global climate change on the ecological and socioeconomic impacts of such changes.

4.1 Impacts of climate change on terrestrial ecosystems

Soil processes
In temperate, boreal and arctic ecosystems, a temperature rise is expected to speed up the decomposition and mineralization rates of detritus by stimulating the activity of micro-organisms in soil throughout the year. However, decomposition and mineralization can only proceed faster if the soil moisture level is maintained. Enhanced microbial activity during the winter season may lead to more leaching of mineralized nutrients from the soil, and over a period of time also reduce the content of organic carbon (Anderson 1991).

Biota
In plants native to the boreal zone a rise in temperature may lead to a greater rise in respiration and photorespiration rates than in the photosynthesis rate. Thus, the rise in the photosynthesis rate caused by a higher CO_2 concentration (Woodward et al. 1991) may be outweighed by the effects of a higher temperature (Salisbury & Ross 1985). It is difficult to predict where the equilibrium between these two opposing processes will lie. Gauslaa (1984) has showed that in alpine plants, a temperature rise may reduce the higher capacity for growth and reproduction resulting from an increase in the respiration rate.

A temperature rise can lead to a shift of climate zones both in altitude and latitude. Higher plants migrate more slowly than the rate at which the climate is predicted to change. As a consequence, plant species may be exposed to a climate to which they are not adapted. Over time it is therefore expected that climate change may cause changes in the species composition, abundance and distribution of plants (Graham & Grimm 1990, Woodward 1992, Urban et al. 1993) invertebrates (Solbreck 1993) and vertebrates (Holten 1990*b*). This is also supported by experiments and palynological data (Bazazz 1990, Huntley 1991). Extreme climatic events such as storms, drought and episodes of frost in spring might be as significant as the rate of climate change as regards alterations in species composition, competition and ecosystem processes (Holten & Carey 1992, Urban et al. 1993). The varied topography of Norway makes it possible for some species of plants and animals to migrate short distances in altitude and thus follow the climatic conditions to which they are adapted. Species with a higher temperature optimum that migrate upwards may outcompete nature alpine species. As a result of climate change and differences in species' capacity for migration, the distribution and population size of species native to alpine forests and other alpine habitats may decrease (Holten 1990*a*).

It is assumed that climate change may have a severe impact on the flora and fauna of bogs and marshes in Norway. In Eastern Norway and Finnmark, such habitats may change character through species migration and the influence of changed precipitation patterns and higher temperatures, which may slow down their formation and speed up decomposition. Suitable habitats for species that are dependent on bogs and marshes may therefore become much more patchily distributed than is the case today.

Alpine areas, bogs and marshes are expected to alter most during changes in the climatic conditions as described above. Because of the scarcity of alternative habitats, a warmer climate may therefore endanger species found in such areas.

Most invertebrates are capable of migration, have an extensive distribution, and can probably cope with climate change as indicated through adaptation. However, climate change will expose insects adapted to cold environments to warmer conditions which may alter their development. Vertebrates have generally good dispersal abilities and presumably tolerate a wide range of climatic conditions. They are able to migrate faster than vegetation in response to climate change. Nevertheless, it is difficult to predict the extent to which vertebrates will become established in newly formed habitats created by climate change.

Interactions between trophic levels

In most species of higher plants, the photosynthesis rate is found to rise with CO_2 concentration, which results in a lower carbon-to-nitrogen ratio in tissue grown at elevated CO_2 concentrations (Conroy & Hocking 1993). Insect performance and fitness is impaired if the nitrogen content of the leaves that form their diet is reduced, and increases of 20-80% in consumption rate have been measured as a response to poorer tissue quality (Eamus & Jarvis 1989, Bazazz 1990). In a high-CO_2 environment, the decomposition rate and nitrogen mineralization rate in litter may be slower as a result of the lower nitrogen content. However, it is difficult to predict where a balance will be found between a higher decomposition rate caused by elevated temperatures and a lower decomposition rate caused by poorer litter quality. Plants may also become threatened by pests, pathogens and herbivores whose distribution was formerly limited by low temperature, if their migration rate is slower than that of the invading species, so that they are no longer geographically separated. In conclusion, the current knowledge makes it difficult to predict the effects of higher temperature, alterations in precipitation patterns and elevated CO_2 concentration on ecosystem processes and dynamics in Norway.

4.2 Impacts of climate change on fresh water ecosystems

The predicted temperature rise will probably not lead to a loss of species diversity in Norwegian fresh water ecosystems, but some species may disappear from certain localities. Higher nitrogen concentrations caused by increased runoff from soil, changes in physiochemical and hydrological conditions, and a higher carbon dioxide concentration may lead to changes in competition between some species of primary producers and consumers (Schindler et al. 1990, Hessen & Wright 1993). For specialized species of phytoplankton, zooplankton, vertebrates and cold stenothermic glacial relicts, the forecasted climate change could be critical in some localities (Aagaard et al. 1989). Fresh water systems are isolated, and some species of fish and crustaceans may be unable to migrate to alternative habitats (Holten 1990*b*).

4.3 Impacts of climate change on marine ecosystems

There is no indication that the expected climatic change is critical for marine ecosystems. Most marine species are capable of moving quickly to favourable growing and spawning areas. Climate change may however result in changes in the distribution and stock size of most fish species. A general northward shift in the distribution of fish stocks may be expected. A higher sea temperature may lead to immigration of new marine species, but the overall effects of this on marine ecosystems are not easily predicted. The immigration of new phytoplankton species may cause toxic algal blooms. In the Barents Sea, higher sea temperature and a smaller area of ice in summer may contribute to greater biological production.

4.4 Adaptation measures

Protected areas are important for monitoring and research on the effects of climate change on ecosystems. Because of the expected shift of climate zones, areas that are protected may change character in the future. It may therefore be necessary for example to protect new areas or enlarge those already established in order to ensure that a representative sample of the variety of habitats found in the country is protected. This is essential to preserve species and genetic variability within species, maintain biodiversity and establish migration corridors to enable species to follow the climate to which they are adapted.

Discussion of how the management of protected areas can be adapted to cope with a changing climate has already started. To be better prepared for this situation, Norway is focusing on ways of improving the knowledge of the impact of climate change on ecosystems, for example by expanding research activities. A report describing the effects of climate change on Norwegian ecosystems was published in 1994 by the Directorate for Nature Management. Storms and servere weather conditions may occur more frequently as a result of climate change, and work has been started to clarify the consequences of such episodes for environmental management.

5. Research and systematic observation

Research related to climate change involves a range of disciplines in various programmes and projects carried out in Norway. The bulk of public and governmental funding goes into technical R&D, but there are also substantial contributions from the basic natural sciences, economics and social science. CICERO (Centre for International Climate and Energy Research - Oslo) was established in 1990 to form a part of the world wide effort in support of climate and energy related multilateral cooperation. This institute carries out approximately 20 man-years of climate related R&D in most relevant disciplines. In addition, climate change research is supported through the general allocations to universities and research institutes.

The Norwegian Climate and Ozone Research Programme was established in 1989, and is run by the Research Council of Norway. Scientists at both Norwegian universities and other research institutes are funded by this programme.
Research on the following topics is given priority:

1) Monitoring greenhouse gases and tropospheric composition,
2) The role of the ocean and the biosphere in climate change,
3) Development and application of general circulation models,
4) Palaeoclimatological research,
5) Monitoring total ozone and stratospheric ozone,
6) Development and application of numerical models for atmospheric chemistry and
7) Impact of climate change and stratospheric ozone depletion.

Some of the projects funded by the programme and/or by other means are described in more detail below.

5.1 Modelling and prediction, including global circulation models

Atmosphere
Several Norwegian research groups are collaborating to model atmospheric chemistry. These include the geophysics departments at the Universitites of Oslo and Bergen and the Norwegian Institute of Air Research (NILU). The focus is on two-dimensional models of the global troposphere and stratosphere from pole to pole, which are used to investigate the effects of altering emissions of greenhouse gases and other trace gases such as NO_2 and SO_2 on ozone, methane and other trace gases. A global 3-D model of the troposphere, driven by meteorological data generated by a general circulation model (GCM), is being used at the University of Oslo to study global ozone distribution. There are plans to couple the 3-D atmospheric model with a simple ocean model to study the global CO_2 cycle.

Global circulation models have not been much used in Norway previously, but scientists at the Universities of Oslo and Bergen are now applying international GCMs. They will be studying the effects on atmospheric circulation of changes in radiative forcing caused by changes in greenhouse gas concentrations (particularly ozone) and changes in the aerosol load.

Different ways of describing clouds in GCMs are also being studied. Some of this work is being carried out on a Nordic basis.

Ocean
Oceanic models are being used in Norway to study the north Atlantic and the response of the circulation to small changes in boundary conditions, e.g. solar radiation at the surface (Nansen Environmental Remote Sensing Centre, Bergen). The circulation in the Weddell Sea and its sensitivity to the amount of heat and fresh water exchanged at the surface are being studied using an oceanic model (University of Bergen).

5.2 Climate process and climate system studies

Ocean
The formation of cold bottom water is the subject of extensive studies both in the Greenland-Iceland-Norwegian (GIN) Seas and in the Weddell Sea in Antarctica. Norway has a long tradition of Antarctic research, in which oceanography has been a strong component. The CO_2 balance in the GIN seas is being studied in a major international project to which Norway is making a substantial contribution (including the use of an oceanographic research vessel). A major sink of atmospheric CO_2 is thought to have been found in the northern Atlantic. This project is partly funded by the Norwegian authorities and partly by the Nordic Council of Ministers and the European Commission. It is hoped that measurements of the carbon balance in surface water and in the atmosphere above the ocean surface, together with other parameters describing the transfer of material from the atmosphere to the ocean and within the ocean, will provide a more detailed picture of the CO_2 budget in the GIN Seas.

Another oceanography project is a Nordic extension of the World Ocean Circulation Experiment. Its aim is to quantify the flow of warm, saline water into the GIN Seas and the return flow of cold, less saline water. This is being organized as a joint Nordic project funded partly at Nordic level and partly through national contributions. About seven acoustic doppler current meters are deployed at strategic locations to study the climatology of the ocean currents.

Palaeoclimatology
Several Norwegian research groups are working on aspects of palaeoclimatology, including studies of ocean floor sediment cores and glaciers, tree ring studies and investigations of written historical material. The incorporation of such groups into climate research has proved very fruitful, and has yielded much historical information and time series on past climate change. Material of this kind can be used to test GCMs and other models with input conditions quite different from those prevailing today. For instance, interesting results have been obtained concerning the relationship between the rise in CO_2 and the temperature rise through late-glacial climate reconstructions in Western Norway (University of Bergen). Some of the projects are Norwegian contributions to international programmes organized by bodies such as the European Science Foundation.

Biosphere-atmosphere interactions
Biosphere-atmosphere interactions are also being studied, in particular how fertilization of forest soils increases emissions of N_2O and slows down methane oxidation in soils, i.e. the positive feedback link between the two processes. In one project, the production and release of greenhouse gases in aquatic systems are being studied. Another area of potential interest in Norway is to detect whether there are sometimes sudden bursts of hydrated methane at high latitudes on Svalbard or the northern part of the mainland.

Stratospheric ozone
Norwegian scientists were among the first to publish calculations of the ozone balance in the stratosphere (around 1970), and there are several long time series of Dobson measurements from Norway, although there are some gaps in the records (Oslo, Tromsø and Longyearbyen). These measurements have been reported to the WMO Ozone data center in Toronto. There was a strong Norwegian component in the European Arctic Stratospheric Ozone Experiment (EASOE) which ran from November 1991 to March 1992. The EASOE was funded both by CEC and by the national authorities. Norway also provided part of the funding for data the analysis. Norway ia also participating in the Second Stratospheric Arctic and Middle latitude Experiment (SESAME).

5.3 Data collection, monitoring and systematic observation, including data banks.

Atmosphere
The Norwegian Institute for Air Research (NILU) has the main responsibility for climate gas obervations in Norway, often in collaboration with other institutes in Norway or abroad. Both ozone and carbon dioxide concentrations are measured at the Arctic atmospheric chemistry baseline station in Ny-Ålesund on Svalbard, which will also be used by the Network for Detection of Stratospheric Change (NDSC), a new international programme. The effects of clouds and aerosols on ozone concentrations are being studied in another project.

Ozone concentrations are also measured using sondes launched from Bear Island between the Norwegian mainland and Svalbard. Methane and ozone have been measure at a rural site in Southern Norway for a number of years.

Norway is also participating in the North Atlantic Climatological Dataset, a project intended to produce a consistent climate database covering the entire North Atlantic, the North Sea and the Baltic Sea.

Oceanography
On the weathership Polarfront at approx 66^{o}N and 0^{o} longitude, temperature and salinity records have been maintained since just after the Second World War, and studies document highly significant but slow changes in deep ocean temperatures.

Terrestrial
As a part of the programme for terrestrial monitoring (TOV), a project involving the monitoring of vegetation in permanent plots was started in 1990. The aim of the project is to detect environmental impacts of pollution at an early stage, and to study changes in ecosystems over time. Some of the methodological parameters used in relation to the project will be able to show environmental impacts by climate changes as well.

Tree limits and the occurrence of lichens are two of the environmental indicators monitored in order to measure the impacts of climate change on terrestrial ecosystems. For instance, a study of the growth rate of the lichen *Hypogymnia physodes*, including monitoring in four reference areas in Norway, is in progress.

5.4 Research on impacts of climate change

Until recently, impact studies have been given low priority within the Climate and Ozone Research Programme. Some projects on the effects of climate change, increased UV-radiation and higher CO_2 concentrations are in progress. One of the projects within the International Tundra Experiment (ITEX) is to test experimentally how alpine plant performance is affected by experimentally induced warming.

The CLIMEX project (Climate Change Experiment) is a whole-ecosystem experiment in which ambient atmospheric and climatic conditions are manipulated using a large (1200 m^2) greenhouse. The project is addressing the effects of increased atmospheric CO_2 concentration and higher temperature on natural vegetation/soil/water systems. The project receives both national and EU funds.

In some other projects, the impacts of climate change are being investigated by studying responses to climate change in the past, e.g. vegetational development during the late glacial period.

5.5 Socio-economic analysis

Various Norwegian institutes and sponsors have been involved in policy-oriented studies on climate change over a number of years. Particularly in the field of economics, there has been a great deal of activity on climate change issues since the late 1980s, as mentioned in Chapter on projections. A major effort was sponsored by the Interministerial Climate Group (1989-91) to provide a basis both for domestic policy and for Norwegian contribution to the then forthcoming negotiations. More than half of CICERO's output.

The Research Council for Norway is financing projects in this field through its programmes 'Economy and Ecology' and 'Society, Environment and Energy'. Projects related to energy are clearly dominant, and a large part of the effort is concerned with CO_2 and economy.

The Institute for Energy Technology (IFE) in Norway is participating in energy modelling work coordinated by the International Energy Agency (IEA). More efficient use of energy, transition to less CO_2 -intensive energy sources and renewable energy are among the topics under consideration.

The Research Council of Norway has recently established a working group to evaluate research needs and priorities related to the human dimension of global environmental change.

5.6 Technology

The development of energy-related technology has been the main area of research related to reductions of greenhouse gas emissions. In 1993, the Norwegian Government's expenditure on energy-related R&D amounted to about NOK 160 million. This included programmes on energy efficiency, the development of renewable sources of energy, the development of technology for improved utilization of major hydro power plants, and the demonstration of new technology.

The development of new and more efficient technologies will be of the utmost importance in establishing benign forms of energy production and use. In 1993, funds allocated to this field totalled NOK 70 million, including NOK 35 million for demonstration purposes. The current strategy for the development of renewable sources of energy has three goals. In addition to the reduction of greenhouse gas emissions, these are to develop viable long-term alternatives to our present energy mix, and to develop new industry based on technological innovations. Government funding for this area in 1993 was about NOK 40 million, including NOK 15 million for demonstration purposes.

Norway produces about 110 TWh of electricity annually using hydro power. Given the importance of this resource, small improvements in hydro power technology will yield considerable results. Better utilization of this natural resource will also reduce the need to develop new watercourses for electricity production. A major R&D programme in this field started in 1992 and was allocated NOK 50 million by the Government in 1993.

In addition to these programmes, several smaller R&D projects in the petroleum sector and in the industry are related to climate change. Some examples that are also receiving public funding are described below.

In the petroleum sector, a light, compact system for separating CO_2 from exhaust gas emitted from gas turbines is currently being developed for testing in one project. In a second project, different methods of sequestering CO_2 in oil and gas reservoirs are being studied. Another interesting study is entitled "Separation and deposition of CO_2 in the ocean", and the possible biological effects of sequestering CO_2 in the deep oceans have been investigated. One institute is studying catalytical processes that can be used to develop liquid fuel based on CO_2. The light metal industry is running a project to reduce emissions of CF gases. In 1993, the Government allocated funds to a project to develop a lightweight electric car that can be 100% recycled. This is a joint project involving industry in Switzerland, Austria and Norway.

In addition to activities sponsored by the Government, the petroleum and hydro power sectors allocate substantial resources to R&D efforts. In other sectors, the Government is trying to promote more emphasis on R&D.

5.7 Norwegian contributions to international global change programmes

5.7.1 The International Geosphere-Biosphere Programme (IGBP):

Norway has been a member of the IGBP since 1989. Norwegian scientists are doing research in several fields which are relevant to the objectives of the IGBP Core Projects. However, many of the projects are not formally affiliated with the IGBP. The Norwegian IGBP committee is trying to promote closer links between national research and IGBP Core Project research.

In order to initiate IGBP-related research and to coordinate Norwegian contributions, the Norwegian IGBP committee arranged two IGBP workshops in 1992. A workshop on Land-Ocean Interaction in the Coastal Zone (LOICZ) is planned for 1994. The workshops are supported by the Research Council of Norway .

Global Change and Terrestrial Ecosystems (GCTE)
A workshop was held in March 1992 to promote Norwegian participation in the GCTE. It was attended by 20 scientists from Norwegian research institutions. The discussion gave an overview of current Norwegian research relevant to the GCTE. An international GCTE conference, Global Change and Arctic Terrestrial Ecosystems, was arranged by the GCTE Core Project Office and the Norwegian Institute for Nature Research (NINA) in Oppdal, Norway, in August 1993. The conference was attended by 166 participants from 15 countries.

Past Global Changes(PAGES)
A workshop was held in November 1992 to promote Norwegian participation in PAGES. It was attended by 20 scientists from Norwegian research institutions and showed that Norwegian scientists are interested in participating in the Core Project research.
The discussion gave an overview of current Norwegian research relevant to PAGES. A report has subsequently been published. Norwegian scientists are active in several national and international research programmes which are relevant to all parts of PAGES.

International Global Atmospheric Chemistry Project (IGAC)
Norwegian scientists are involved in two IGAC sub-projects. Three research groups will participate in modelling studies forming part of the North Atlantic Regional Experiment (NARE) in summer 1994, and a scientific secretariat for the sub-project Global Emissions Inventory Activity (GEIA) has been established at the Norwegian Institute for Air Research (NILU).

Biospheric Aspects of the Hydrological Cycle (BAHC)
Norwegian researchers participate in BAHC through NOPEX, which is a Nordic hydro-meteorological pilot experiment for studies of areal evapotranspiration and interactions between the land surface and the atmosphere. It is intended to improve our understanding of climatic processes. The project is mainly funded by the Nordic Council of Ministers.

Land-Ocean Interaction in the Coastal Zone (LOICZ)
A number of current Norwegian research projects are relevant to the LOICZ. The Norwegian IGBP committee plans to arrange a workshop this autumn (1994) to promote participation by Norwegian scientists in the Core Project research. The Norwegian research includes a wide range of topics related to the coastal zone and the fjords; the interplay of freshwater and marine systems, the carbon budget in coastal systems, causes of plankton blooms, biochemical cycles in coastal waters and sediment-water interactions.

Research related to Focus I, "The effects of changes in external forcing and boundary conditions on coastal fluxes", and Activity 3.1, "Cycling of organic matter within coastal systems", will probably be of most interest to Norwegian scientists.

Joint Global Ocean Flux Studies (JGOFS)
CARDEEP is a Norwegian-based research programme designed to improve understanding of the role deepwater-forming regions of the GIN seas play in global oceanic CO_2 uptake. The programme is supported by the EU (MAST), the Nordic Council of Ministers and the Research Council of Norway. CARDEEP is accepted as 'core project research'.

5.7.2 The World Climate Research Programme (WCRP).

Norway is participating in the World Ocean Circulation Experiment (WOCE), which is organized under the WCRP, through the Nordic World Ocean Circulation Experiment . This project is an extension of the WOCE into the Greenland-Iceland-Norwegian Seas, and is run according to WOCE guidelines.

5.7.3 Contribution to IPCC

Several Norwegian scientists from various institutes have contributed to the IPCC assessments as lead authors, writing contributors and peer reviewers. Contribution by CICERO and the NILU to the 1994 assessment of "radiative forcing" and CICERO's involvement in Working Group III should be especially noted.

5.7.4 Capacity building in developing countries

Two programmes run by the Research Council of Norway make funds available for Norwegian scientists for projects involving collaboration with colleagues from developing countries. These are "Supporting Norwegian collaborators in developing countries", where funds are earmarked for researchers from developing countries, and "Environmental capacity building". Until now, few projects related to climate change have been funded through these programmes.

6. Education, training and public awareness

The work of the World Commission on Environment and Development awoke public interest in issues related to climate change in Norway from the late 1980s. The attention focused on the importance of sustainable development and the need for all individuals to consider their own contributions to improvement of the environment have raised the level of awareness in many sectors of Norwegian society.

The negotiations on Agenda 21 and the Rio Declaration on biodiversity and climate change were followed closely by leading Norwegian newspapers and magazines. The UNCED and subsequent efforts to follow up its decisions also gave rise to a wide range of activities throughout the Norwegian educational system, from primary schools to universities.

The text of the Climate Convention refers directly to the issue of education, training and public awareness, and encourages all Parties to promote activities designed to give the general public a better understanding of climate change and its effects. This in turn should result in support for policy measures to deal with climate change and also encourage public participation in climate-related measures.

In 1990, the Norwegian Government decided to establish the Centre for International Climate and Energy Research (CICERO), linked to the University of Oslo. The new institution was charged, inter alia, with *1)* developing the basic knowledge required to contribute to national and international policies on climate; and *2)* keeping the country's politicans, public authorities, industry, educational institutions, media and public opinion informed about development trends with regard to international policy on climate issues.

The main vehicle for information on international climate issues in Norway is a bimonthly publication from CICERO. Research on issues related to climate change and energy is an integral part of the work of many departments of Norwegian universities. Large-scale international research cooperation has also been initiated.

A discussion forum for climate-related issues for representatives of academic institutions, industry and the public administration was established this year. Posters and educational material have been developed and produced in cooperation with the industrial sector.

The annual publication "Pollution in Norway", produced by the State Pollution Control Authority, gives an updated review of emissions of pollutants, the state of the environment and anticipated developments. Great emphasis has been put on making the report readily accessible to the the general public and politicians. The publication is free of charge and is widely used by students at various levels. Detailed Figures and analyse are also published by Statistics Norway, especially in the annual "Natural Resources and the Environment".

The Norwegian Information Centre for Energy Efficiency (OFE) has for some years now arranged training courses and seminars in energy efficiency. The target groups are consultants, caretakers, maintenance personnel and architects. In 1993, the OFE arranged more than 300 days of seminars, each with between 15 and 30 participants.

The Government ran two major information campaigns on energy efficiency in 1992, and one in 1993. Their goals were to promote the use of energy-efficient equipment in households. The first campaign increased sales of energy-efficient shower fittings by more than 150 000.

Together with the other EU and EFTA countries, Norway will implement a system of energy labelling of household electrical appliances. From 1 January 1995 all refrigerators, freezers and combined refrigerators will carry a label showing their energy efficiency class and energy consumption per year. Energy efficiency labelling is an important means of increasing public awareness of energy consumption of different appliances.

Information and educational activities together with the introduction of energy-efficient technology will be the main elements of the Government's energy efficiency policy in the years to come.

7. Joint implementation of measures to mitigate climate change

Article 4.2 of the Climate Convention states that the Annex 1 Parties "shall adopt national policies and take corresponding measures on the mitigation of climate change". Moreover, Article 4.2 states that "these Parties may implement such policies and measures jointly with other Parties".

Currently, the Climate Convention does not include legally binding quantitative emission targets. However, most Annex 1 Parties have established national targets regarding stabilization of greenhouse gas (GHG) emissions.

In short, this means that there are currently no quantitative commitments under the Climate Convention towards which emission reductions may be credited, whether such reductions are achieved domestically or in cooperation with other Parties.

All emission reductions, irrespective of where and how they are achieved, may be counted against the ultimate goal of the Climate Convention, to mitigate climate change. The climate effect of any reduction of emissions of greenhouse gases or any growth of carbon sinks is the same no matter where abatement takes place. Ideally, abatement measures should be achieved where they produce the greatest reduction in GHG emissions. Joint implementation should be seen as a cost-effective step towards achieving this objective.

For Joint Implementation to become a fully operational mechanism under the Convention, there is a need to agree on criteria, inter alia to ensure the proper monitoring, verification, validity and long-term effectiveness of such measures, and to agree on institutional arrangements under the Convention for these purposes. To facilitate the development of such criteria there is a need to gain practical experience of Joint Implementation activities, including ways of designing Joint Implementation projects, types of agreements and standard methods of calculating emission reductions.

To this end, Norway, in cooperation with the Global Environmental Facility (GEF), Poland and Mexico, is currently running two pilot projects intended to demonstrate the potential for joint implementation of measures to mitigate climate change. The Scientific and Technical Advisory Panel to the GEF (STAP) has described the two projects as examples of measures that are particularly suitable for implementation in developing countries and in coal-dependent economies in Central and Eastern Europe. The experience gained through such projects may prove valuable to the Conference of the Parties (COP) in the process of establishing operational criteria for joint implementation. In particular, the projects illustrate the problems involved in the determination of incremental costs as well as the measurement and verification of net emission reduction. The project in Mexico focuses on improving energy efficiency by introducing compact fluorescent lamps in two major cities. The project is estimated to result in net annual emission reductions of 101 000 tonnes of CO_2 and 216 tonnes of methane. The project in Poland covers the conversion of a number of coal-fired boilers to gas, and is linked to several World Bank loans to the environment/energy sector in Poland. The estimated emission reductions are 6 659 tonnes of CO_2 per year. Together with a thorough description of the projects, these issues were examined in detail in a paper which was made available to INC 9 [1].

The Norwegian contribution to these projects, the equivalent of NOK 30 million, is additional to official development assistance allocations (ODA) and also to our contribution to the GEF. Norway has not foreseen any crediting for the emission reductions achieved through these projects, nor have they been linked with our national stabilization target.

The projects further illustrate how joint implementation may provide developing countries and countries with economies in transition with access to new and additional financial resources and environmentally benign technology. The transfer of environmentally sound technology is an important vehicle for promoting sustainable development in accordance with the objectives of Agenda 21. Thus Joint Implementation is also an important mechanism for achieving some of the broader objectives of UNCED.

During the process[2] of arriving at a standardized, well-functioning system for implementing cost-effective measures across borders to fulfil the objectives of the Climate Convention, the Norwegian Government will encourage and promote initiatives to investigate and demonstrate the scope of joint implementation.

8. Other international activities

Cooperation with countries with economies in transition.
A bilateral agreement on environmental cooperation between Norway and Hungary was signed in 1991. One of the activities under this agreement is joint work on Hungary's national communication according to the Climate Convention, which was initiated earlier this year by the ministries of the environment in the two countries. This includes cooperation between CICERO (The Centre for International Climate and Energy Research, Oslo) and Hungarian counterparts, including the Technical University of Budapest and Eötvös Lóránd University.

The cooperation will include the development of GHG inventories and will focus on the effects of measures to reduce emissions, a description of national policies, programmes and measures, and projections of national GHG emissions and sinks. It might also be extended to include methodology for the valuation of effects and for ranking measures on the basis of net benefits or cost/benefit ratios.

Two trust fund agreements have been established between Norway, the World Bank and the European Bank for Reconstruction and Development (EBRD) in the energy/environment area. Under these agreements projects related to energy efficiency and reduction of pollution from the energy sector are being financed.

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[1] This paper was prepared by an economist at the World Bank, Mr. Robert J. Anderson Jr.

[2] The important point is not whether or not this is called a pilot phase. Joint implementation can in any case only become an operational mechanism under the Convention once the Parties have agreed only legally binding, quantified emission targets. In Norway's view, it is imperative to use the period before such targets are established to generate information and thereby facilitate confidence-building as regards the concept of joint implementation.

Cooperation with developing countries

A memorandum of understanding on environmental cooperation has been signed by the governments of Indonesia and Norway. A feasibility study under its toms is to investigate the impact of reforestation of the extensive grasslands in Indonesia on the local environment and in terms of fixation of carbon dioxide, and its significance for local and regional economic and social development. Studies carried out under the agreement indicate that there is an economically interesting potential for further carbon sequestration.

An interesting joint project on fuel switching, run by Brazil and Norway, is nearing completion. The potential global and national benefits of switching from diesel generation to biomass fuel are being studied.

Annex 1

Models used and key assumptions in the Norwegian projections of CO2 emission

MODAG is a Keynesian-type macroeconomic model that is basically demand driven. The model is constructed and updated by Statistics Norway, and its main user is the Ministry of Finance. The model is used regularly as an analytical aid in preparing the National Budget and the Government's Long-term Programme, which present overall government policy in the form of reports to the Storting (national assembly). The Norwegian national accounting system forms the conceptual framework and the empirical basis of the model. Nearly all parameters are estimated econometrically and the model is re-estimated every year. The model is relatively disaggregated with 28 production sectors, 40 commodities and 14 categories of private consumption. Activity in the petroleum sector, which is very important for the Norwegian economy and for emissions of CO_2 , is exogenous to the model.

Total energy demand is proportional to gross output by industry, and is an aggregate composed of electricity and petroleum products. The decision to use electricity or petroleum products depends on the relative prices of electricity and fuels and a trend variable. A rise in fuel prices results in reduced demand for fossil fuels and increased demand for electricity, but total energy demand remains unchanged.

The trend variable is a proxy for omitted and partly unobservable variables, such as increased use of electricity-specific equipment and high installation costs for oil heaters combined with uncertainty about the future oil price. If relative prices remain constant, the effect of the trend variable is to cause electricity to make up a gradually increasing share of total energy demand.

One of the main advantages of using macroeconomic models for emission projections is that they provide consistency between macroeconomic forecasts, expected growth in energy use and the resulting emissions to air. Synergistic (indirect) effects, like the effects of CO_2 taxes on other pollutants, are also captured by the model.

It should be noted that there is no substitution between total energy and other input factors. The effects of relative price changes can to some extent be adequately reflected by adjusting energy efficiency parameters exogenously. Furthermore, the sectoral composition of the model is not specifically designed for environmental purposes, e.g. the transport sector is rather aggregated. However, for medium-term projections (up to the year 2000) the model is considered to be quite satisfactory for energy and environmental purposes as well.

Emissions from four types of sources are calculated in a supplementary model to MODAG. Emissions from industry and private households due to *stationary combustion* are associated with the use of fuel oils, *mobile combustion* emissions are associated with the use of petrol, *process emissions* are associated with the use of intermediate materials other than energy commodities, and *evaporation* is associated with industrial use of materials (proxy for use of solvent), total demand for petrol (evaporation from storage and handling of petrol) and private consumption (proxy for use of paints etc.).

Key assumptions

Emission coefficients by source and sector are calibrated to a base year, and are projected by taking into account environmental instruments or policies that have already been implemented or decided. No further measures to reduce emissions are introduced in the baseline scenario. The projections presented therefore represent future developments based on present economic and environmental policies and future economic developments. The projections also depend on many uncertain assumptions concerning key variables and parameters.

The assumptions of the baseline scenario reported are similar to those of the "Solidarity alternative" in the Government's Long-term Programme 1994-97, which represents medium-term Government economic policies. Important exceptions from this are the assumptions for the petroleum sector, which have been updated and revised in connection with a more recent Government report to the Storting on petroleum policy.

The projection presented is based on the measures implemented in 1994, i.e. a CO_2 tax of 0.82 NOK/litre for petrol and 0.41 NOK/litre for mineral oil and autodiesel, and a CO_2 tax of 0.82 NOK/Sm^3 , and 0.82 NOK/litre fuel for the petroleum sector (offshore).

The development of the petroleum market is highly uncertain. The baseline scenario is based on a technical assumption that the price of crude oil will remain constant at about 17 US dollars per barrel until the year 2000, measured in 1994 prices. An exchange rate of 7 NOK/USD has been used. The price of oil has various implications for Norwegian emissions of CO_2 . In addition to its influence on the domestic use of oil products, it affects the level of activity in the petroleum industry and thus emissions from this industry. Neither coal nor natural gas is used in significant amounts on the Norwegian mainland, and price assumptions for these commodities therefore have little effect on emissions. Norwegian petroleum production is assumed to increase from 119 million tonnes of oil equivalents (mtoe) in 1991 to about 184 mtoe in 2001.

The projection is based on the following economic assumptions:

- There will be a consensus on wage formation and incomes policies that generates an improvement in the competitiveness of Norwegian industry up to 1998.

- There will be a redistribution of public expenditure from transfers to industry and households to public purchases of goods and high priority services with a view to increasing employment.

- The annual rate of GDP growth in trading partner countries will be 2 1/2 per cent.

- The annual increase in consumer prices in trading partner countries will be 3 per cent.

- There will be a broadly unchanged level of direct and indirect taxes.

- The household savings rate will be roughly unchanged.

- The entire electricity supply will be based on hydro power.

It is also assumed that energy-intensive manufacturing industries will keep their existing power contracts at the same real prices as today, and that it will not be profitable for such industries to expand production by buying additional electricity at market prices. If energy-intensive industries expand production significantly more than assumed, emissions of CO_2 and possibly other greenhouse gases from these industries will increase more than specified in Table 3.2 in Chapter 3.

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