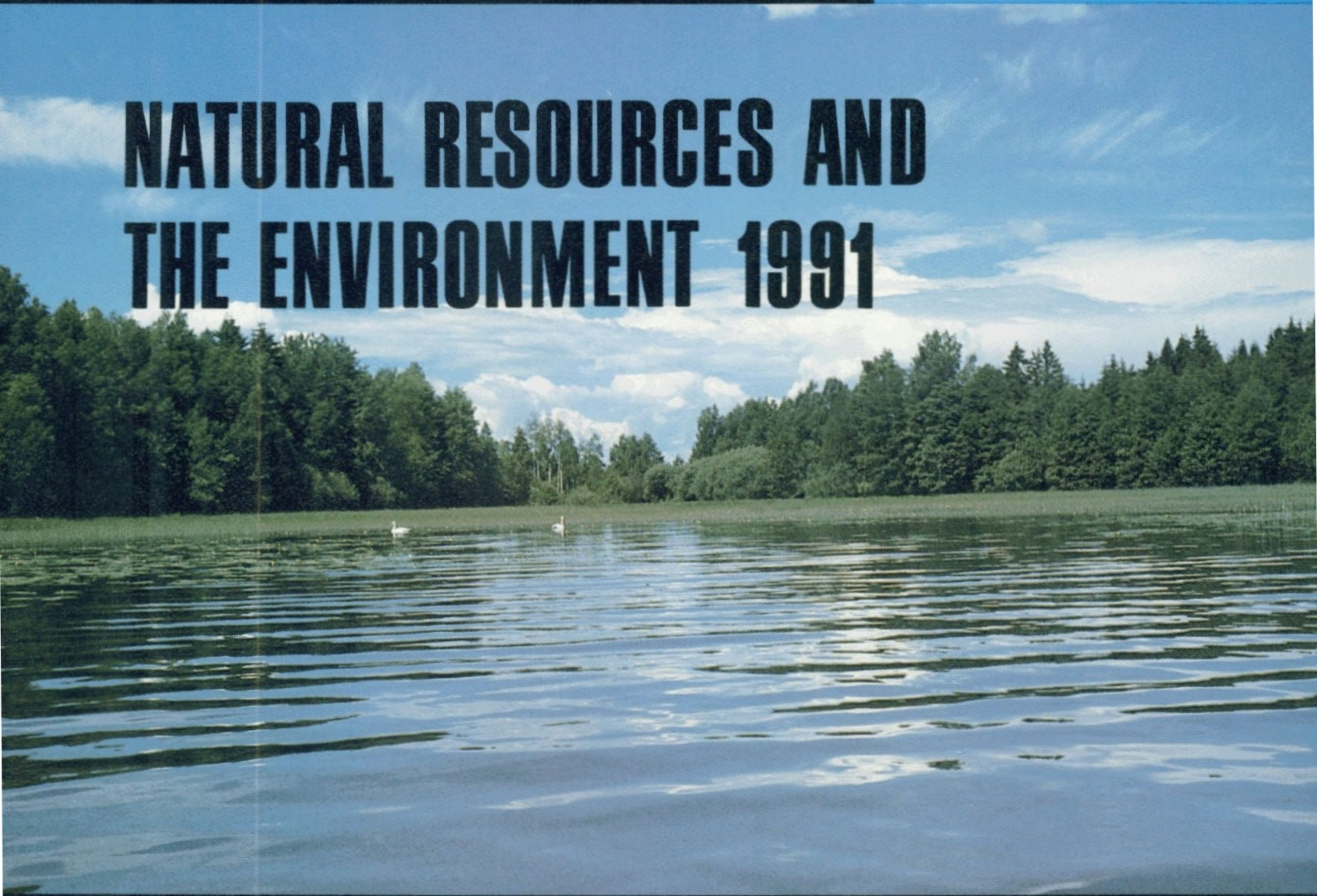
RAPPORTER

92/1A

NATURAL RESOURCES AND THE ENVIRONMENT 1991



STATISTISK SENTRALBYRÅ
CENTRAL BUREAU OF STATISTICS OF NORWAY

RAPPORTER FRA STATISTISK SENTRALBYRÅ 92/1A
REPORTS FROM THE CENTRAL BUREAU OF STATISTICS

NATURAL RESOURCES AND THE ENVIRONMENT 1991

ENERGY, AIR, FISH, FORESTS, AGRICULTURE,
MUNICIPAL WASTE WATER, WASTE,
ENVIRONMENTAL INDICATORS

RESOURCE ACCOUNTS AND ANALYSES

STATISTISK SENTRALBYRÅ
CENTRAL BUREAU OF STATISTICS OF NORWAY
OSLO-KONGSVINGER 1992

ISBN 82-537-3668-1
ISSN 0332-8422

EMNEGRUPPE
10 Ressurs- og miljøregnskap og andre generelle ressurs- og miljøemner

EMNEORD
Forurensning
Naturmiljø
Miljøøkonomi
Utslipp

Photo: Front cover: Frode Brunvoll. Back cover: Hans Viggo Sæbø

GRYTTING AS ORKANGER

PREFACE

The Central Bureau of Statistics (CBS) elaborates statistics on the state of the environment as well as accounts for a number of important resources. CBS also develops methods and models to analyze the interrelationships between socio-economic conditions, resource use and environmental conditions. The publication *Natural Resources and the Environment* presents an annual survey of this work.

Natural Resources and the Environment 1991 presents updated resource accounts for energy and fish, accounts for emissions to air, and the results of analyses based on these accounts. The report also presents analyses of agricultural pollution, forest damage, municipal waste water treatment plants and waste. The final chapter of this year's report deals with environmental indicators.

The Central Bureau of Statistics wishes to thank all the institutions that have supplied data for *Natural Resources and the Environment 1991*.

The publication, prepared jointly by the Division for Resource Accounts and Environmental Statistics, Department of Economic Statistics, and the Natural Resources Division, Research Department, has been edited by Senior Executive Officer Frode Brunvoll. Mary Bjærum has translated the Norwegian version into English.

Central Bureau of Statistics, Oslo 28 April 1992

Svein Longva

CONTENTS

Explanation of symbols in tables:

.	Category not applicable
..	Data not available
-	Nil
0	Less than 0.5 of unit employed
0,0	Less than 0.05 of unit employed
*	Provisional or preliminary figure

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1. INTRODUCTION AND SUMMARY

Introduction

This report provides important information on natural resources and the natural environment in Norway in the form of statistics and results of analyses. The main emphasis is on statistics elaborated by the Central Bureau of Statistics, but data have also been obtained from other sources. An attempt has been made to throw some light on interesting features of development in the areas dealt with in the report, and the reasons for any changes. In some cases the effects of possible future measures are also analyzed.

Examples of relevant environmental issues elucidated in the report are global climate change, air pollution and discharges to the North Sea. A fundamental question is whether Norway will be able to achieve the goals fixed for emissions of gases such as CO_2 and NO_x, and to what degree the measures introduced in order to achieve these goals will affect other goals for economic activity and employment. Another question is whether Norway will be able to meet her obligations under the so-called North Sea Declaration, i.e. to reduce Norwegian discharges of nitrogen and phosphorus to the North Sea by 50 per cent by 1995, with 1985 as base year.

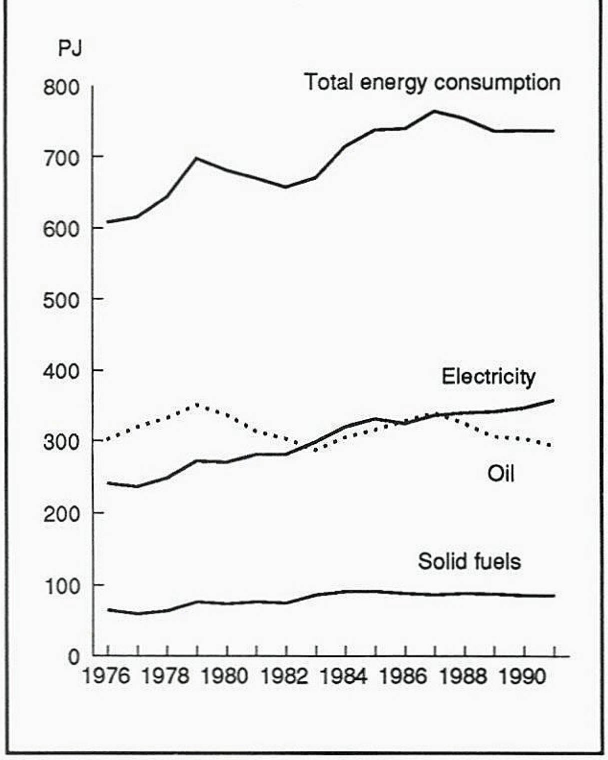
One way of focusing the main characteristics of the status of the environment is to present a set of *environmental indicators*. An environmental indicator is a figure which gives a simple indication of the status of a specific condition in the environment, and any changes in such. Work is currently being done on environmental indicators in international organizations such as the OECD, and in a number of countries. In Norway, a reference group has been appointed to develop a set of environmental indicators, under the leadership of the Ministry of Environment. The Central Bureau of Statistics is represented in this group and is also doing independent work on environmental indicators. The status of this work is summed up in this report.

Summary

Chapter 2 describes Norwegian energy reserves, domestic extraction and use of energy and recent years' trends in energy prices. It also includes an overview of the international oil and gas market, as well as a description of changes in energy consumption in Europe.

Total energy consumption in Norway, the energy sectors and ocean transportation excluded, increased by average 1.5 per cent annu-

Figure 1.1. Use of energy sources outside the energy sectors and ocean transportation. 1976-1991. Petajoule



ally during the period 1976-1989. According to the preliminary figures, total energy consumption has remained the same during the last two years. Electricity consumption increased by average 2.7 per cent per year during the period, i.e. more than the total energy consumption. Oil consumption decreased during the last part of the period.

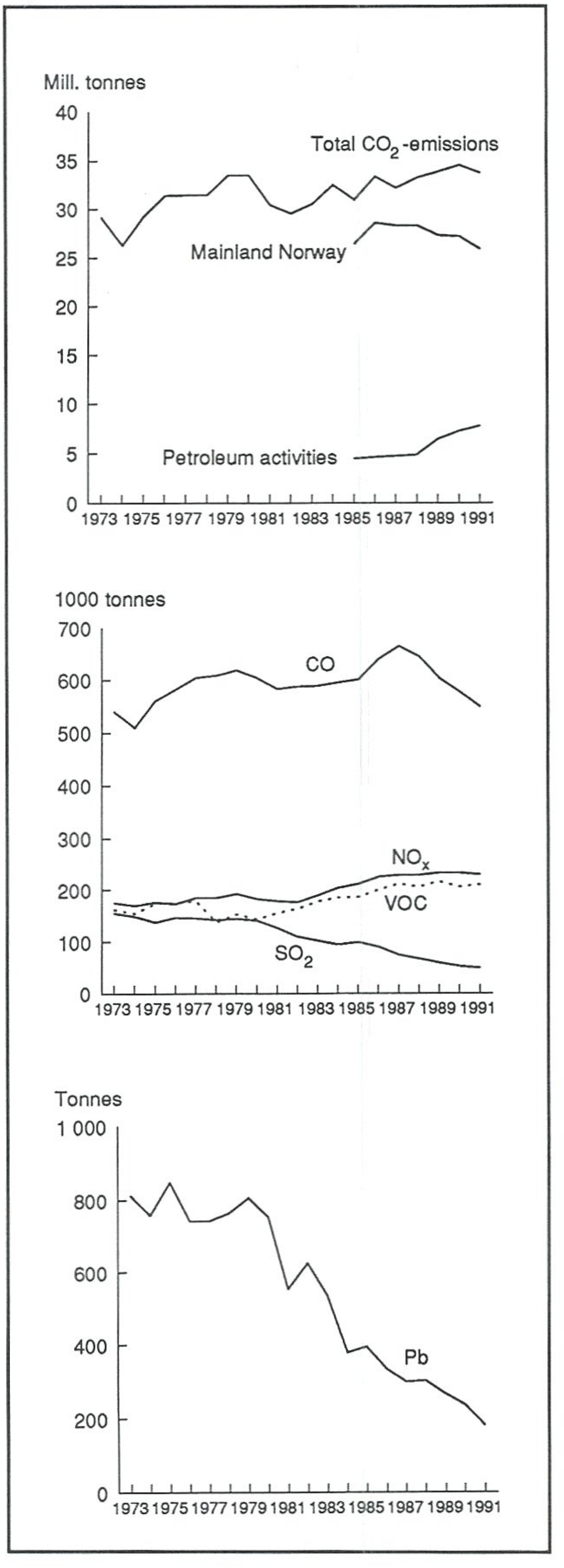
After a marked increase also in the domestic temperature-adjusted demand for electricity throughout the 1980s, preliminary figures for 1991 show a slight decline in demand. The strong increase in the 1980s was due to a high level of economic growth and a change from use of oil to electricity due to rising oil prices and the higher cost of installing oil-based equipment. During the last five years, there has been a decline in economic growth without a corresponding decline in electricity consumption. The reason is the continued shift from use of oil to use of electricity. In the last few years, however, this shift seems to have stopped, regardless of the fact that oil has again become more expensive than electricity. This may be because consumption of light heating oils in Norway is now low, and it would be relatively expensive to substitute much of the remaining oil consumption by electricity.

Hydropower production in Norway in 1991 (110.4 TWh) returned to almost normal level, after three years with a level of production 10 per cent higher than normal. The decline in production was due to less precipitation and thus less flow of water to the reservoirs, and led to a decrease in net export of power from about 16 TWh in 1990 to about 3 TWh in 1991.

Total oil and gas production increased by 9 per cent from 1990 to 1991. Total extraction in 1991 amounted to about 120 million tonnes oil equivalents (mtoe) divided between 27 mtoe gas and 93 mtoe oil.

Chapter 3 presents inventories of Norwegian emissions of several polluting compounds, and comments on changes in emission levels over time. In the 1970s, the level of emissions of most compounds changed in step with oil consumption. There was a slight decrease in emissions in the early 1970s due to a marked rise in the price of oil and lower oil consumption. This decrease was followed by a steady increase in

Figure 1.2. Emissions to air. 1973-1991



emissions up to around 1980, when a new rise in oil prices again led to a decrease in emissions. In the 1980s, two different groups of emissions have followed different paths. The one group, consisting of NO_x, VOC, CO and CO_2, continued to follow oil consumption. A specific cause of larger emissions of these compounds is higher consumption of transport fuels. In recent years, however, the increase in emissions has been much diminished by a lower rate of economic growth, and therefore less consumption of oil. As for the second group, consisting of SO_2 and lead (Pb), emissions have been reduced substantially; the present level of emissions is less than half the level in the early 1970s. This is a direct result of an active environmental policy directed at these compounds. Requirements regarding cleaning of emissions and the composition of heating oils have obviously led to a significant decline in air pollution from sulphur and lead.

The emission figures for recent years have been affected by a gradual decrease in use of petroleum products in mainland Norway, which has helped to reduce emissions. However, much of this reduction was counteracted by increased emissions due to a higher level of activity in the North Sea.

Preliminary figures for 1990 and 1991 indicate a decreasing trend for emissions of SO_2, Pb and CO. Only small changes have occurred since the end of the 1980s in emissions of CO_2, NO_x, particulates, N_2O, VOC and CH_4.

The fact that a reduction in emissions has also led to improved air quality is also confirmed by comparing data on emissions with measurements of pollution concentrations, particularly in towns and urban areas. Good spreading conditions have also contributed to the low level of pollution in Norway in recent years.

Measures to reduce emissions of greenhouse gases, e.g. higher prices for fossil fuels, also affect emissions of other polluting substances and therefore influence other environmental problems, such as acidification and injuries to health. At the same time, such measures also lead to other benefits in addition to those connected to a better environment, such as less wear and tear on roads, less noise from traffic and less accidents.

Methane is an important greenhouse gas. Per molecule, methane is about 26 times more effective as a greenhouse gas than CO_2. The direct and indirect effects of methane on global climate are described at the end of the chapter.

Chapter 4 presents the resource account for fish, including information on changes in fish stocks, quotas and the size of the catch, as well as figures for exports of fish products and reared salmon. The spawning stock of Norwegian spring spawning herring is still totally dominated by the year class from 1983, but the year class from 1991 is expected to provide good recruitment to the stock. There was a strong increase in the stock of Barents Sea capelin in 1989, and fishing of this stock was permitted in 1991 for the first time since 1986. A positive development has been observed in the stock of North-East Arctic cod. The size of the cod stock in 1991 is estimated to 1.2 million tonnes.

From 1990 to 1991, the total catch in Norwegian fisheries increased by 360 000 tonnes to 2.1 million tonnes. The first-hand value was NOK 5.6 billion, an increase of NOK 800 million from 1990. The export value of fish products increased by about 12 per cent compared to 1990, to just under NOK 15 billion. The exported quantity and export value of reared salmon decreased in 1991 for the first time. This occurred regardless of the fact that production of salmon in 1991 reached a record level of between 150 000 and 160 000 tonnes. Total exports of salmon amounted to 127 000 tonnes in 1991, to a value of NOK 4.5 billion.

Chapter 5 describes the status of Norwegian forests, and also presents some figures for forest health status in other European countries.

The annual amount of cut roundwood has increased in recent years, but the amount of wood cut has been less than the new growth.

Only small changes in forest status occurred in Norway from 1990 to 1991. For spruce, the average crown density decreased, but no change was observed from 1990 to 1991 in the crown density of pine. Many European countries report declining forest health status in 1990, and the situation seems to be particularly serious in Eastern Europe.

Chapter 6 describes agricultural land use and pollution from agriculture. The total area of agricultural land in Norway increased by about 4 per cent from 1979 to 1989, and now accounts for about 3 per cent of Norway's total land area. Runoff of nutrients (nitrogen and phosphorus) from agriculture is a major source of water pollution. An increase in the area of fully cultivated land and a decrease in the area of surface cultivated land may have caused more runoff of nutrients from agricultural land. This effect is counteracted to some extent, however, by reduced quantities of manure, lower concentrations of domestic animals and less extreme use of commercial fertilizers. Measures such as spreading manure during the growth season, spreading fertilizers in several doses, as well as less or later soil preparation also help to reduce runoff and erosion caused by farming practices.

The pressure to use cultivated and cultivable land (i.e. arable land that is not cultivated) for purposes other than agriculture has increased along with increasing urbanization and the growth of other industries. Annual transfers of agricultural land to other purposes decreased during the 1970s, but tended to increase again towards the end of the 1980s. About 500 km^2 of agricultural land has been transferred to other purposes since 1967, and most of this land has been lost for later agricultural production.

Chapter 7 presents the results of a survey of municipal waste water treatment plants. A total of 1387 such plants were registered in 1990, with a combined capacity of 3.9 million population units and a load of 2.9 million population units. This is about 100 more plants than registered in 1988, and the capacity has increased by about 0.5 million population units. A marked increase in capacity, 0.3 million population units, was registered for *chemical plants*. The highest capacities were recorded in Eastern Norway, where most of the waste water is treated in so-called "high grade" plants (i.e plants with biological and/or chemical phases). Mechanical plants dominate in Western Norway and northwards. Fjords are the recipients of the dis-charges from about 65 per cent of the total capacity of the plants.

Chapter 8 presents an overview of quantities of waste and waste management in Norway. Environmentally hazardous waste was found or suspected to exist in more than 70 per cent of the sites registered in a survey of waste disposal sites and contaminated ground carried out by the Norwegian Geological Survey.

About 200 000 tonnes of hazardous waste is generated in Norway every year. About 90 000 tonnes of this waste is treated internally by the companies where the waste occurs. The remaining 110 000 tonnes is treated externally in more or less controlled form. The quantity of waste delivered to approved systems of collection has increased during the last 5 years, and amounted to 66 000 tonnes in 1991. Oily waste is quantitatively the most dominating type of delivered hazardous waste.

About 2 million tonnes of municipal waste was produced annually at the end of the 1980s. Approximately 40 per cent of this waste comes from private households.

In 1990, around 40 per cent of Norwegian households sorted out one or more types of waste, most frequently batteries.

Chapter 9 presents the main features of the work being done by the Central Bureau of Statistics to develop environmental indicators. Environmental indicators are intended to provide a simple picture of important aspects of the state of the environment, and any changes that are taking place. The set of environmental indicators developed so far includes indicators of the following environmental effects and conditions: Climate change, depletion of the ozone layer, health, noise, eutrophication, damage to forest, damage to fish, contamination, recreation, wilderness and biological diversity. This main set of *response indicators* (indicators of effects) will be supplemented by a set of *stress indicators* (indicators of causes) which will include, inter alia, important figures for emissions.

In recent years, various circles have expressed a wish for calculation of a GDP adjusted for environmental impacts, i.e. a "green GDP". This would include not only purely economic conditions but also damage to the environment and depletion of resources. The set of indicators being prepared at present does not include any indicators of this type, but a GDP adjusted for changes in the environment is discussed in the final section of this chapter.

2. ENERGY

In 1991, hydropower production was back to normal after being 10 per cent above this level for the three preceding years. The large decrease in production of 11 TWh from 1990 to 1991 was due to less precipitation and reduced flow of water to the reservoirs. The lower level of production led to relatively little export to Sweden and Denmark. At the same time the increase in production capacity is very small, approximately 0.3 TWh from 1991 to 1992. The introduction of an electricity market based to a greater extent on market price mechanisms means that overdevelopment involves greater risk for the investors. Moreover, production has been high for some years, with very low purchaser prices in some sectors of the market. These two factors combined have led to greater caution in becoming involved in new hydropower development projects.

Following substantial growth in the domestic demand for electricity for a couple of decades, demand now seems to be levelling out. The marked growth in the past was caused partly by strong economic growth and partly by the change from oil to electricity as a result of large increases in oil product prices and the higher cost of installing oil-based equipment. During the past five years the decrease in economic growth has not been accompanied by corresponding decrease in the growth of electricity consumption. The main reason is the shift from oil to electricity. In recent years, however, this shift seems to have diminished, in spite of the fact that oil has again become more expensive than electricity. A possible explanation is that the consumption level of light heating oils is now low in Norway, and it would be relatively expensive to replace much of the remaining oil consumption by electricity.

A large amount of exploration for new oil and gas fields is taking place on the Norwegian continental shelf and investments in field development, extraction and pipeline systems were almost 40 per cent higher in 1991 than in 1990. Estimates of investments in 1992 show a planned nominal increase of about 12 per cent from 1991 to 1992. Thus activity on the continental shelf has reached a higher level than ever before, and from September 1991 average production was 2.1 million barrels a day. In 1991 the value added for oil and gas was about NOK 92 billion, or 13 per cent of the gross domestic product. Preliminary estimates show that the oil rent was about NOK 41 billion in 1991, or NOK 10 000 per capita.

2.1. The Norwegian energy market

Supply

Hydropower reserves

The hydropower reserves can be placed into four categories:

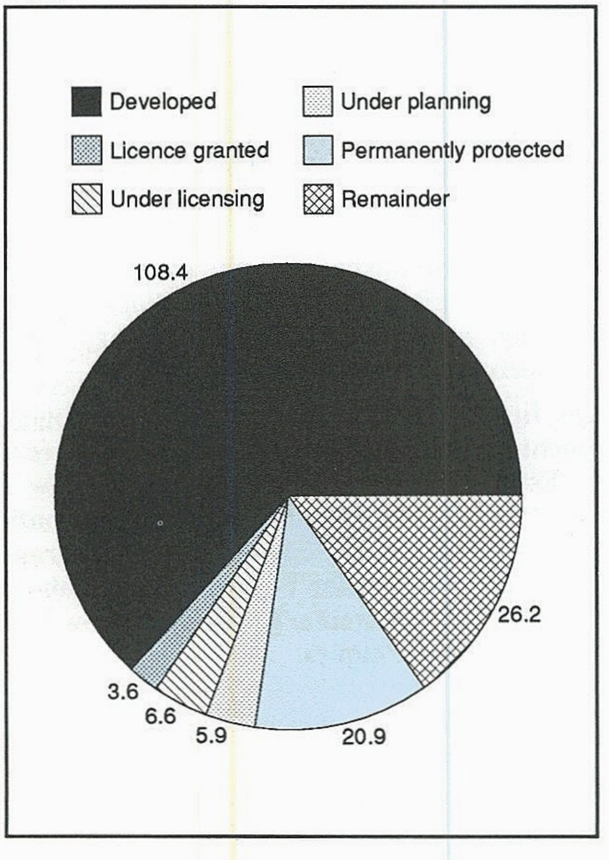
- Watercourses that have been developed for hydropower
- Watercourses that are under construction or under licensing
- Remaining watercourses in the "Master Plan for Water Resources"
- Protected watercourses.

Figure 2.1 shows that, per 1 January 1992, Norway's total economically exploitable water resources amounted to 171.6 TWh. This figure includes permanently protected watercourses with a power potential of 20.9 TWh. Per 1 January 1992, hydropower resources had been developed with an average power potential (the production capacity of the power stations in a year with normal precipitation) of 108.4 TWh.

This is 0.3 TWh higher than at the turn of the year 1990/91. Undeveloped hydropower resources, excluding permanently protected watercourses, amounted to 42.3 TWh per 1 January 1992. Of this amount, about 16 TWh was under construction, under licensing or under planning.

At the turn of the year the total reservoir capacity in the Norwegian hydropower system was 56 TWh. Throughout 1991, the reservoirs were filled to a higher level than the average for the last ten years. At the turn of the year 1990/91, the reservoir holding was 61 TWh. Thus, in the course of the year, the reservoir capacity was reduced by about 5 TWh.

Figure 2.1. Exploitable hydropower 1 January 1992. TWh



Hydropower production

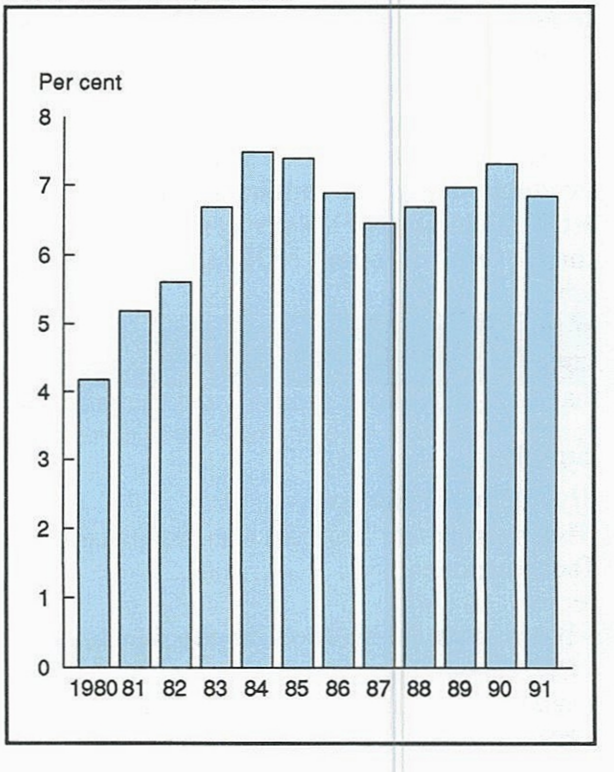
In 1991, production of electricity reached 110.9 TWh, a reduction of 10.7 TWh compared with 1990. The decrease was a result of less precipitation and flow of water to the reservoirs in 1991 than during the year before. The total production includes 0.5 TWh thermal power, the rest is hydropower. The production of electricity was lower than the year before for the first time since 1986, see table 2.21 (in appendix of tables). In 1990, water equivalent to 7.5 TWh bypassed the available production capacity. In 1991, this hardly occurred.

The hydropower rent and return on capital

The hydropower rent can be estimated as the return over and above normal return on capital (7 per cent). Such a surplus return is achieved in the event of increasing construction costs for extensions to the production system. The long-term potential hydropower rent is realized if the market price of electricity is equal to the long-term marginal cost of new development. In the Norwegian power market, the average price of electricity is lower than the long-term marginal cost. This means that the long-term potential hydropower rent in the hydropower sector is not realized. The hydropower rent is described in more detail in *Natural Resources and the Environment 1990*.

The Norwegian Water Resources and Energy Administration (NVE) calculates the long-term marginal cost of new power. Estimated in

Figure 2.2. Rate of return on capital in the electricity sector 1980-1991. Per cent



terms of 1991 prices this is estimated to be 41 øre per kWh for regular consumption (delivered to consumer exclusive VAT) and about 29 øre per kWh for energy-intensive industry. Given electricity prices equal to marginal cost, sales of firm power equivalent to the firm power production capacity in 1991, and sales of surplus power equivalent to the difference between the average annual production capacity and firm power production, the operating surplus potential in the electricity sector, including the tax on electricity, is calculated to NOK 20.2 billion. Assuming a normal return of 7 per cent on a capital of NOK 193 billion, the rent is thus estimated to NOK 6.7 billion. This illustrates the long-term potential rent in the electricity sector at present capacity, assuming a high enough demand to keep the market in equilibrium.

Preliminary estimates for 1991 give an operating surplus of about NOK 13.2 billion in the electricity supply, including the tax on electricity. This gives a return on capital of about 6.8 per cent in the sector. Thus the electricity sector gave no rent in 1991. Figure 2.2 shows the realized return on capital in the electricity sector during the period 1980-1991. The rate of return on capital is calculated on the basis of the operating result plus the tax on electricity as a percentage of the amount of real capital in the electricity sector.

Owning to varying flow of water to the reservoirs, the rate of return will vary. The rate of return increased steadily during the first part of the period, the reason being the strong increase in the price of electricity delivered to regular consumption. Since 1984, the rate of return has remained stable, taking into account variations in flow of water. The main reason why the observed rate of return on capital is not higher is that energy-intensive industry and the pulp and paper processing industry have long-term contracts for purchase of power at low prices.

Reserves of oil and natural gas

The share of the total proven resources that can be extracted at today's prices and by known technology is referred to as reserves. If prices rise, or production technologies improve, the share of the profitable resources (reserves) will increase. In the case of oil, about 1/3 of the proven resources are reserves, and to these must be added the potential resources in unexplored parts of the continental shelf. The Petroleum Directorate (1991) estimates a reserve potential of 5 500 million tonnes oil equivalents (mtoe) south of Stad as of 31 December 1990. Of this amount, 4 520 mtoe have been discovered. Development licences have been obtained for 3 160 mtoe, of which 880 mtoe has been extracted. In addition to the reserves south of Stad, proven resources are estimated to be 470 mtoe on Haltenbanken and 270 mtoe on Tromsøflaket. This gives a total estimated reserve of 5 260 mtoe. Nearly all these estimates are higher than those of the previous year.

According to preliminary estimates at the end of 1991, the total discovered reserves on the Norwegian continental shelf have increased to 5 400 mtoe, of which about 1 000 mtoe have been extracted. This is mainly due to new discoveries, and reflects a high "success ratio". In 1991, reserves were discovered in 4 out of 10 wells, which is a very good result.

Tables 2.17 and 2.18 in the appendix of tables show changes over time in the estimated reserves for all development licences. In 1991, the oil reserves in these fields increased, partly owing to revaluation of the remaining reserves in "old" fields, but mainly as a result of new licenses. The new licences referred to Heidrun, Lille Frigg, Loke and Tordis. The growth in reserves yet again exceeded extraction. Gas reserves also increased, and the addition from new fields and revaluations combined equalled more than twice the amount extracted. The largest upward revaluation referred to reserves in the Ekofisk and Valhall fields. The reserves in Embla were substantially reduced.

At the present rate of extraction, the oil reserves in developed fields and in fields to be developed will last just over 12 years, while the gas reserves will last for 47 years. If the reserves in fields that are not yet licensed are added, the oil reserves will last for 18 years and the gas reserves for 100 years, at the present rate of extraction. Since oil and gas production will increase as new fields are taken into operation, the R/P rate (ratio between reserves and production) will be fall considerably towards the turn of the century if no new reserves are discovered. It is unlikely, however, that lack of reserves will limit the petroleum activities before far into the next century. The reason is the assumed increase in degree of utilization due to technological advances and expectations of new finds.

Oil and gas extraction in 1991

According to figures from the quarterly national accounts, value added for oil and gas extraction increased by 10.2 per cent from 1990 to 1991. Much of the increase from 1990 to 1991 was due to a strong increase in production towards the end of 1990.

According to the production statistics, which show the trend in Norwegian oil and gas production in terms of physical units, total production increased by 9 per cent from 1990 to 1991. Oil production increased by as much as 13 per cent, but natural gas production decreased by 2 per cent during the period, see figure 2.3. In 1991, total production amounted to 119.9 million tonnes of oil equivalents, distributed between 27.3 mtoe gas and 92.6 mtoe oil. The largest contributors to the increased production were the Gullfaks and Oseberg fields. The fairly small fields Gyda and Hod, where production started in the second half of 1990, as well as the Ula field, also contributed to the high level of production in 1991. The decrease in gas production was due mainly to less production on the Frigg, Ekofisk and Tommeliten fields. This decrease was only partly compensated by increased production of gas on Gullfaks and Veslefrikk, and start of production on Gyda and Hod.

In September 1991, Norwegian oil production reached a level of more than 2 million barrels a day for the first time ever, with an average production of 2.1 million barrels per day. Production was somewhat lower during the fourth quarter, however, owing to a partial stop of production on Statfjord A. In December, average production amounted to 2.0 million barrels of oil per day.

Figure 2.4 shows oil and gas production for the largest fields in 1991. *The Statfjord field* still accounts for the largest share, 31 per cent, of total Norwegian oil production. In spite of

Figure 2.3. Oil and gas production on the Norwegian continental shelf. 1971-1991. Mtoe

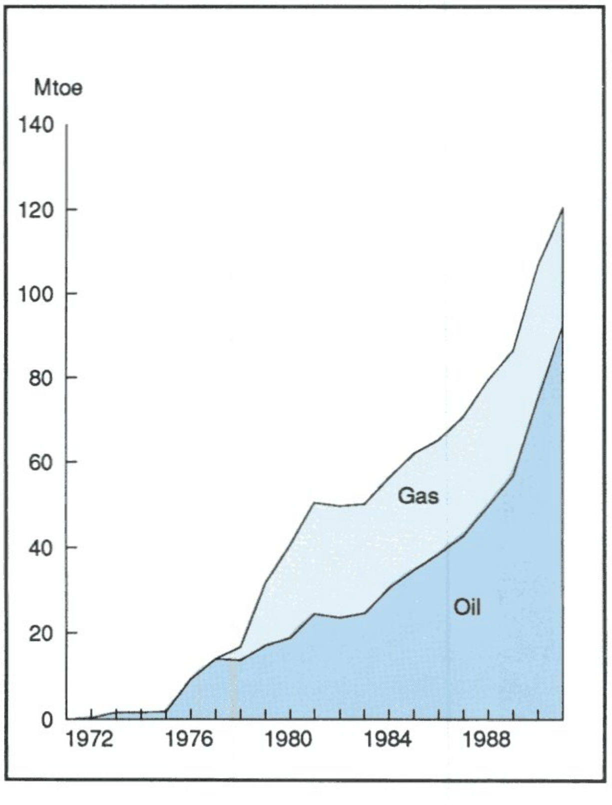
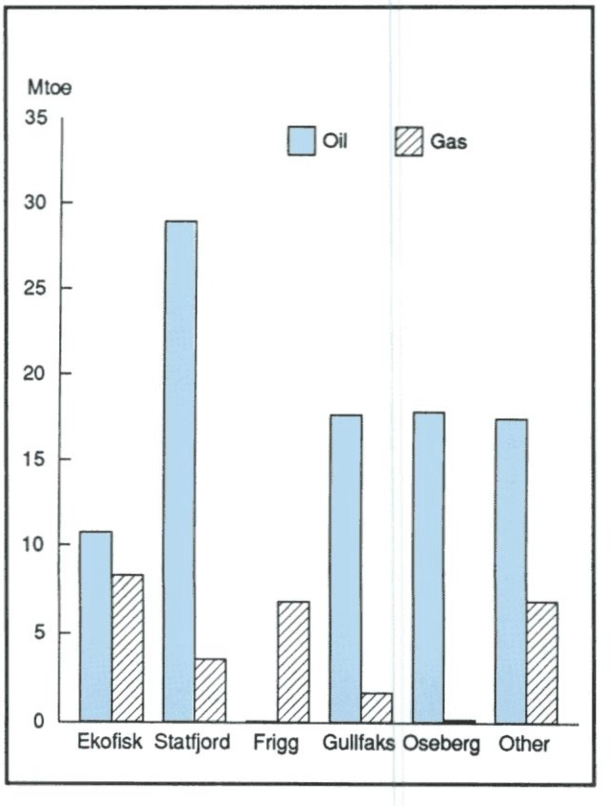


Figure 2.4. Oil and gas production from the largest fields in 1991. Mtoe



low production during the fourth quarter owing to a fairly long stop in production for maintenance reasons, followed by a further stop due to irregularities in the technical processes, production on this field increased by 2 per cent from 1990 to 1991. In December, average production was 544 000 barrels of oil per day. The Statfjord field is divided between Norway and Great Britain. As a result of new information on the reserves, Norway's share has increased by more than one percentage point to 85.24 per cent from the original 84.09 per cent. This re-evaluation applies retrospectively for the accumulated production, implying a return of oil to Norway amounting to 33 000 barrels a day for a two-year period. Britain started to return this oil on 1 September 1991. On the other hand, the owners of the Statfjord field must pay back NOK 538 million to the British for investment costs.

The Oseberg field accounted for 19 per cent of the total oil production in 1991. Production increased by 21 per cent from 1990 to 1991. Growth in production was highest during the last half of the year compared with the same period the year before, mainly due to start of production on Oseberg C (2 September) and on the satellite field Gamma Nord (9 October). Development of the Oseberg field is now regarded as completed for the time being. Total investments in the field are estimated to NOK 44 billion in 1990 kroner. The Oseberg C platform has a capacity of 110 000 barrels of oil per day, increasing the field's capacity by about 30 per cent. Gamma Nord is a subsea installation connected to the C platform. To start with, the satellite will produce oil, while gas is re-injected into the Oseberg field in order to increase production of oil. In December, the Oseberg field produced an average of 448 000 barrels of oil per day (not including Gamma Nord).

After technical production problems on *the Gullfaks field* were solved towards the end of 1990, production was maintained at a high level throughout 1991. Production increased by 32 per cent from 1990 to 1991, accounting for 19 per cent of total oil production in 1991. In December the field produced an average of 388 000 barrels per day.

In 1991, production from *the Ekofisk field* amounted to almost 12 per cent of Norway's total oil production. Production was the same in 1990 and 1991, about 40 per cent above 1987-level, before water injection was started at the turn of the year 1987/88. In December, average daily production was 224 000 barrels per day.

About 87 per cent of Norwegian oil production was exported in 1991.

The Ekofisk field accounts for 30 per cent of the total production of natural gas. Production of gas from this field fell by 5 per cent from 1990 to 1991.

Production of gas from *the Frigg field* decreased by 10 per cent from 1990 to 1991. This field used to be the largest supplier of Norwegian gas, but in 1991 its share was reduced to 25 per cent. The main reservoir on this field, where production started in 1977, is almost empty. The production now comes from smaller satellites in the area.

Norwegian gas production will remain at about the present level until the mid-1990s. Sleipner and Troll will contribute to a new increase in production.

Except for the gas used on the platforms themselves, domestic consumption of Norwegian gas is so far nil. In the quarterly national accounts, consumption on the platforms is not included in the production figure, implying that, per definition, gas exports are the same as production. According to the quarterly national accounts the export index for natural gas increased by 22.7 per cent from 1990 to 1991. Thus, in spite of a fall in production, the value of Norwegian gas exports increased by 18.9 per cent from 1990 to 1991. The price of Norwegian gas is fixed in long-term sales contracts, adjusted for changes in the price of oil. Thus gas prices follow changes in oil prices, with a certain time lag.

Oil investments in 1991

In the investments survey carried out by CBS in the 4th quarter of 1991, accrued investment costs for extraction of crude oil and natural gas are estimated to NOK 39.2 billion in 1991, see table 2.1. According to this estimate, accrued investment costs in the extraction sector increased by 33.6 per cent (nominal) from 1990

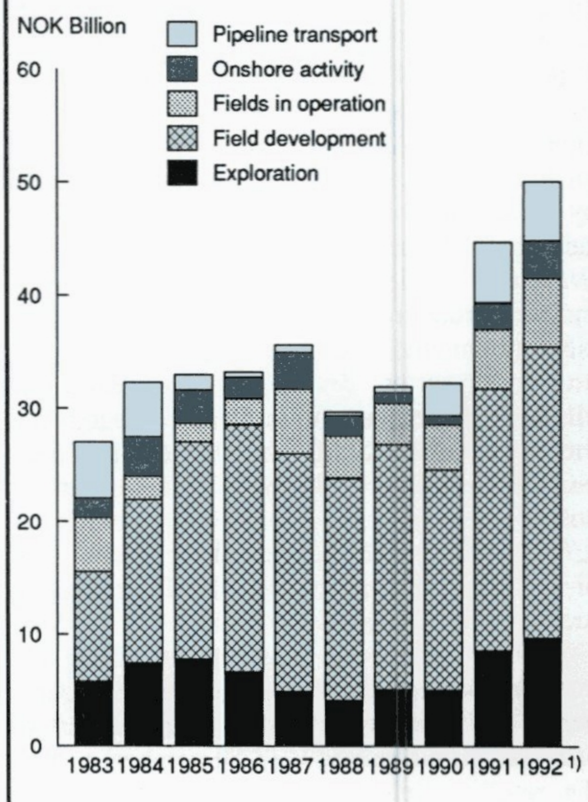
Table 2.1. Executed and assumed investments in oil extraction and pipeline transport. 1990-1992. NOK billion, current prices

	1990	1991	1992
Oil sector as a whole	32.2	44.6	49.9
Extraction of oil and gas ..	29.3	39.2	44.7
Exploration	5.1	8.6	9.7
Field development	19.5	23.1	25.7
Goods	12.6	13.0	14.6
Services	5.6	8.2	9.1
Production drilling ..	1.4	1.8	2.1
Fields in operation	4.0	5.3	6.1
Goods	0.8	0.8	1.0
Services	0.8	1.2	1.2
Production drilling ..	2.4	3.3	3.8
Onshore activity[1]	0.7	2.3	3.3
Pipeline transport	2.9	5.4	5.2

Investment survey estimates (CBS) for 1992.

[1] Including office buildings, bases and terminal buildings on land.

Figure 2.5. Accrued investments in the petroleum sector. 1983-1992. NOK billion



[1] Estimated for 1992.

to 1991. The increase in costs is especially large for investments in onshore activities and exploration.

In the most recent investment survey, the accrued investment costs for *field development* were estimated to NOK 23.1 billion in 1991, an increase in current value of 18.2 per cent compared with 1990. Field developments that weighed heaviest were Snorre, Sleipner, Draugen, Oseberg C and Brage. Except for Oseberg, all these fields were in the building phase for large parts of 1991. Therefore, seen as a whole, investments in materials were relatively high in 1991. In recent months, the materials share has gradually decreased, however, while more money has been spent on services for production drilling. This reflects, among other things, completion of building on the Oseberg field, with start of production in September 1991, and on Snorre, with start of production in summer 1992.

Accrued investment costs for *fields in operation* are estimated in the survey to NOK 5.3 million in 1991, a current value increase of 33.8 per cent from 1990 to 1991. The greater share of these costs refers to production and water injection drilling.

According to the investment survey, *exploration costs* increased substantially from 1990 to 1991. Estimated exploration costs increased by 66.4 per cent to NOK 8.6 billion in 1991. As many as 46 wells were drilled for appraisal in 1991 - an increase of 28 per cent compared with 1990. The activity was at 1986-level, before the fall in oil prices.

Investment costs in *the pipeline sector* are estimated to NOK 5.4 billion for 1991, an increase of 88.3 per cent compared with 1990.

The high level of investment is due to work on the Zeepipe pipelines, and to a lesser extent Europipe. The decision to build the Europipe pipeline was taken in 1991. The line connects the Troll and Sleipner fields to Nordemey, near Emden.

For *the total oil sector*, i.e. the oil extraction sector plus pipeline transport, accrued investment costs for 1991 are now estimated to NOK 44.6 billion - a nominal increase of 38.5 per cent compared with 1990. Figure 2.5 shows accrued investment costs during the period 1983-1992.

The investments survey for the fourth quarter of 1991 also asked for estimates of investments in the petroleum sector in 1992. According to the survey, accrued investment costs are estimated to NOK 44.7 billion, a 14.1 per cent nominal growth compared with 1991 distributed fairly evenly between the different cost items. It must be noted, however, that estimates of investments are very uncertain at such an early stage.

Accrued investment costs for field development are estimated to increase by 11.5 per cent from 1991 to 1992, to NOK 25.7 billion. The main projects in 1992 are Heidrun and Troll. Other fields of importance for the high level of investment are Sleipner, Draugen, Snorre and Brage. It is estimated that the distribution between materials and services will be about the same as in 1991.

It is estimated that exploration costs will increase by 12.9 per cent in 1992, to NOK 9.7 billion. This estimate may be too high, if oil prices remain low or decrease further in the course of 1992.

It is estimated that NOK 6.1 billion will be invested in fields in operation - an increase of 13.9 per cent compared with 1991.

The construction of onshore installations for processing of natural gas from Troll and Sleipner gives an estimated increase of 46 per cent from 1991 to 1992 for investments in onshore activities. This brings these investments up to NOK 3.3 billion.

According to the investments survey, investments in the pipeline sector will decrease by 4.5 per cent from 1991 to 1992, to NOK 5.2 billion.

Petroleum revenues

The petroleum activities are a source of excess return or rent, compared with other industrial activities. The oil rent is calculated as the total income from production of oil and gas after subtracting production costs and a normal return on invested productive capital (7 per cent rate in our calculations). The method of calculation ignores that several of the input factors used in the extraction of oil and gas probably receive a higher return than in other industry. Therefore, to some degree, they can be said to receive part of the oil rent.

Theoretically the oil rent can be traced back to three conditions, ignoring a possible reward for risk. The *resource rent* arises because petroleum can be regarded as a non-renewable resource, where the return on the petroleum wealth is the resource rent. The *classic rent* arises because some reserves are cheaper to extract than others, giving an excess rent in all cases where the extraction costs are not the highest in the market. The *monopoly rent* arises under conditions of imperfect competition, when some producers are able to influence the market.

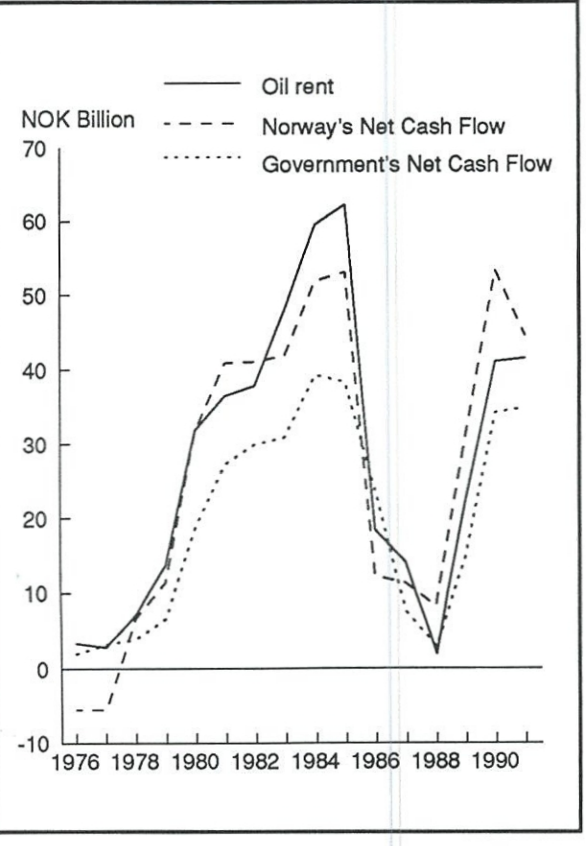
In theory, the components of the rent cannot be considered independently, and no attempt has been made to calculate the different components of the oil rent. There are grounds to assume, however, that the monopoly rent was moderate in 1991, even if there were examples of market influence both in the oil and in the natural gas market. The real price of oil is less than half of the 1985 level, when the oil rent was at its peak. On the other hand, there are large cost differences between the different fields. In 1990, there may have been a certain risk premium on account of the Gulf war, while before 1986 the monopoly rent was more important. Thus, as of the early nineties, the oil rent seems less exposed to a price plummet .

Norway's net cash flow from the petroleum activity is calculated as the operating result plus capital depreciation and royalties minus accrued investments. Thus the sum of Norway's net cash flow over the whole production period is the total net income from the petroleum activity. The present value of the cash flow is almost equal to the present value of the total oil rent and the value of the capital stock

Table 2.2. Petroleum revenues and the oil rent. 1976-1991

Year	Value added in petroleum extraction	Oil rent	Oil rent as a share of gross domestic product
	NOK billion		Per cent
1976	6.1	3.3	1.9
1977	7.4	2.8	1.5
1978	12.8	7.0	3.3
1979	20.8	13.7	5.7
1980	41.0	31.8	11.2
1981	50.0	36.5	11.1
1982	55.3	37.8	10.4
1983	66.9	48.0	11.9
1984	83.4	59.5	13.1
1985	89.7	62.3	12.4
1986	51.0	18.3	3.6
1987	51.8	14.1	2.5
1988	44.4	1.9	0.3
1989	69.8	22.1	3.5
1990	90.5	41.0	6.2
1991	91.8	41.5	6.0

Figure 2.6. Oil rent, Government net cash flow and Norway's net cash flow. NOK billion



on the continental shelf, when the discount rate is the same. The national wealth of the oil reserves can be defined as the present value of the oil rent. Figure 2.6 shows the course of development of the oil rent and Norway's net cash flow. In years with large investments and low income, Norway's net cash flow may be negative, as in the years before 1978. The oil rent is only slightly influenced by fluctuations in investments, because "normal capital cost" is calculated on the basis of the total capital stock.

The value added of extracted oil and gas also increased in 1991, to almost NOK 92 billion, see table 2.2. Oil production increased by more than 10 per cent, but this was still not enough to compensate for the lower average price of oil and increased input of materials, implying a decrease in added value in terms of current prices. The value of gas exports increased, after a decrease in production which was more than compensated by higher average price. Preliminary calculations show that the oil rent for 1991 was about the same as in 1990, just over NOK 41 billion, or almost NOK 10 000 per capita. In terms of real value, both the added value and the oil rent were slightly lower in 1991 than in 1990. Norway's net cash flow decreased from NOK 53.3 billion in 1990 to NOK 44.5 billion in 1991, due to increased accrued investments of almost NOK 10 billion. For the period 1976 to 1991 the present value of the oil rent (calculated in 1991 terms) was almost NOK 950 billion 1991-kroner. The present value of Norway's net cash flow was 87 per cent of this sum. This is explained by large investment expenditures (negative cash flow) during the development phase, which weigh heavily in the calculations of present value. In recent years the cash flow has been somewhat higher than the calculated oil rent. This is because capital depreciation has become equal to the sum of gross investments and the higher value of the capital stock, implying that the capital value has levelled off. The difference between Norway's net cash flow and the oil rent is then the normal return on the capital stock, when both quantities are calculated on the basis of the same definition of real capital.

When comparing the two concepts of income, oil rent and cash flow, note that the calculations employ two different investment concepts. When calculating Norway's net cash flow the concept used is accrued investments, which is the only relevant concept in this connection. On the other hand, the calculations of the capital stock in the national accounts apply the concept of productive investments. This means that the investment is entered into the accounts when the platforms are towed out to the field. In this case some of the accrued investments then appear as inventory, implying that the capital stock is underevaluated in the calculation of the oil rent. If the calculations are corrected for this condition, the oil rent for 1991 is decreased to about NOK 39 billion, owing to a very large inventory at the end of the year.

A third term used in connection with the income from petroleum is *the Government net cash flow* from petroleum activity. Government net cash flow is used to "oil-adjust" the balance of the State Budget, and is entered as income to a petroleum fund established by the Storting (the Norwegian National Assembly) as from 1990. Up to 1985, Government net cash flow consisted mainly of income from taxes. From that year onwards, the Government has been a direct shareowner, so that Government net cash flow is calculated as the sum of income from taxes, income from the Government's direct involvement and dividends from Statoil, minus the Government's share of investments in licences. The income from taxes consists of post-paid tax on income and a special petroleum tax, as well as royalties and various minor items. The royalties ensure some income to the Government regardless of operating result, so that Government cash flow fluctuates less than the two other incomes. The decreasing contribution of taxes to the Government net cash flow implies that the Government is more exposed to risk. Post-payment of tax means that Government net cash flow lags behind Norway's net cash flow and the oil rent.

In the National Budget, Government net cash flow is estimated to NOK 34.9 billion for 1991, while the estimate for 1992 is NOK 36.4 billion, assuming an average price of 21 dollars per barrel. An objective of the Government's tax policy has been to ensure that as much as possible of the rent is used to benefit society. Since the Government net cash flow includes all the tax income from the petroleum activity, it includes a component which cannot be said to originate from the oil rent, but from "the normal capital cost". This, and certain other conditions, make it difficult to compare the two incomes. Figure 2.6 shows, however, that a substantial part of the oil rent goes to the oil companies, and that this share increases with the size of the rent. From 1976 to 1991 the present value of the Government net cash flow amounted to 69 per cent of the present value of the oil rent.

The difference between the two cash flow terms - Government net cash flow and Norway's net cash flow - can be interpreted as a direct measure of the fiscal effect of the Government's tax and participation policies on the total income. So far, the Government has collected 80 per cent of the present value of the cash flow.

Energy production 1930-1991

Table 2.3 shows changes in extraction of energy sources from 1930 up to the present time. Up to the beginning of the 1970s, hydropower accounted for the greater part of primary energy production in Norway. After production of crude oil and natural gas started in the mid-1970s, these sources of energy have taken over a steadily increasing share of the total energy production. Coal production in Svalbard has remained at about the same level since 1950. Extraction of the other energy sources has increased substantially. The increase has been particularly marked for crude oil, where production has increased nearly four-fold during the 10-year period 1981 to 1991. Hydropower production was about 19 per cent higher in 1991 than in 1981. The total extraction of energy sources has more than doubled since 1980, and is more than 20 times greater than in 1970.

Figures from the Energy Accounts show a total production of energy in Norway of 5 041 PJ in 1990. The primary supply, that is to say, the gross supply of energy for use in Norway,

Table 2.3. Extraction of energy sources in Norway. 1930-1991. PJ

Year	Total	Hydro power	Crude oil	Natural gas	Coal
1930 ..	37	31	-	-	6
1939 ..	47	39	-	-	8
1950 ..	82	61	-	-	11
1960 ..	122	111	-	-	11
1970 ..	220	206	-	-	14
1972 ..	324	243	68	-	14
1974 ..	362	276	72	-	14
1976 ..	904	295	584	10	14
1978 ..	1 562	291	718	541	11
1980 ..	2 289	301	1 034	944	8
1981 ..	2 291	336	992	952	11
1982 ..	2 412	334	1 036	1 029	12
1983 ..	2 717	382	1 289	1 032	14
1984 ..	2 959	383	1 467	1 096	13
1985 ..	3 096	371	1 622	1 089	14
1986 ..	3 282	349	1 799	1 122	12
1987 ..	3 676	374	2 098	1 193	11
1988 ..	3 990	394	2 380	1 208	7
1989 ..	4 840	427	3 156	1 248	10
1990* .	5 041	436	3 466	1 129	9
1991* .	5 465	398	3 949	1 108	10

is 1 074 PJ. This comprises 21.3 per cent of the total production. Norway is a net importer of coal and coke and a net exporter of oil, gas and hydropower.

Use of energy sources

The hydropower balance

In 1991, gross domestic consumption of electricity amounted to 108.1 TWh, of which 28.6 TWh was used in energy-intensive industry, 62.0 TWh in regular consumption and 7.2 TWh as surplus power to electric boilers. About 9.5 TWh was lost in the transmission and distribution networks. About 0.7 TWh was used in pumping stations. Export of electricity decreased from 16.2 TWh in 1990 to 6.0 TWh in 1991. During the same period, import increased from 0.3 TWh in 1990 to 3.2 TWh in 1991, see table 2.4. Thus the export surplus of electricity in 1991 was reduced by as much as 13.1 TWh compared with 1990. The value of the export surplus decreased from about NOK 900 million in 1990 to about NOK 300 million in 1991.

Table 2.4. Observed production and consumption of electricity, and estimated firm power production and demand given normal temperature and normal flow of water. 1990 and 1991. TWh

	1990 observed	1990 "normal year"	1991 observed	1991 "normal year"
Overflow	7.5	-	0	-
Production	121.6	108.1	110.9	108.4
Export	16.2	-	6.0	-
Import	0.3	-	3,2	-
Domestic consumption	105.7	108.1	108.1	108.4
Loss + power to pumping stations .	10.5	9.9	10.2	9.5
Surplus power ...	5.8	4.5	7.2	5.6
Energy-intensive industry	29.7	30.0	28.6	30.0
Regular consumption	59.7	63.7	62.0	63.3

In 1991, the Norwegian hydropower system had an average annual production capacity of about 108.4 TWh. This means that with the installed capacity in 1991, and given normal precipitation and flow of water, production would have been 2.0 TWh lower than the actual production in 1991. The temperature-adjusted net domestic consumption of firm power for regular consumption was just over 63 TWh, i.e. 1 TWh higher than the actual consumption. With normal temperature and flow of water, and good economic conditions for industry, Norwegian hydropower production would have been more or less equal to the demand, and the net export would have been almost nil.

The main reason for the strong reduction in surplus power on the Norwegian hydropower market in 1991 was much less flow of water to the reservoirs than during the period 1988 to 1990. There was practically no overflow (water that passes outside the production system) in 1991, as against 7.5 TWh the year before.

In 1991, power consumption in energy-intensive industry was 1.1 TWh lower than in 1990.

Regular consumption, on the other hand, used as much as 2.3 TWh, or about 4 per cent, more electricity in 1991 than in 1990. In 1990 the average price per unit of utilized energy was lower for oil than for electricity. Due to the rise in the price of crude oil in 1990, which did not affect the prices of oil products until 1991, and a substantial increase in environmental taxes on petroleum products in 1991, the price of oil was higher in 1991 than the price of electricity.

Investments in new hydropower projects were low in 1991. The Svartisen and Meråker watercourses are under development. These two developments combined will increase production capacity by 2-3 TWh.

Use of energy

The Energy Accounts follow the energy sources from extraction via conversion to use within the different production sectors and in private households. In the accounts, the energy sectors consist partly of extraction sectors, partly of conversion sectors. The extraction sectors are coal mining, hydropower plants and extraction of crude oil and natural gas. The conversion sectors include coke plants (Norsk Koksverk was closed down at the end of 1988), oil refineries, thermal power stations and district heating plants. So far, Energy Accounts have been prepared for the years 1976-1990. Table 2.19 and 2.20 show the preliminary accounts for 1990, see section 2.9, appendix of tables.

In 1990 the energy used outside the energy sectors was 1 044 PJ, see table 2.5. This is an increase of 7.9 per cent from 1989 to 1990. The increase occurred mainly in ocean transportation (foreign trading) where there has been a large increase in the fleet registered in NIS (The Norwegian International Ships Register). Domestic use of energy remained unchanged from 1989 to 1990. Use of energy in energy-intensive industry increased by 3.1 per cent from 1989 to 1990, but consumption in other manufacturing decreased by 2.7 per cent. During the same period, use of energy increased by 3.2 per cent in agriculture and fisheries, but decreased by 2.6 per cent in other industries. Private households used 0.5 per cent more energy in 1990 than in 1989.

Preliminary figures for 1991 show stable total energy consumption outside the energy sectors and ocean transportation during the last two years, see table 2.6.

Table 2.5. Use of energy[1] outside the energy sectors by industry. 1990*. Changes 1976-1990

Industry	1990 PJ	Average annual percentage change	
		1976-89	1989-90
Total	1 044	0.3	7.9
Ocean transportation	309	-2.4	32.6
Domestic use	736	1.5	0.1
Agriculture and fisheries	32	0.3	3.2
Energy intensive industry	200	1.4	3.1
Other manufacturing and mining	109	-0.8	-2.7
Other industries	190	2.7	-2.6
Private households	204	2.2	0.5

[1] Includes use of energy sources as raw materials.

Table 2.6. Use of energy outside the energy sectors and ocean transportation (foreign trading), by source of energy. 1991*. Changes 1976-1991

Energy source	1991 PJ	Average annual percentage change	
		1976-89	1989-91
Total	736	1.5	0.1
Electricity	356	2.7	2.3
Firm power	330	2.5	1.6
Regular consumption	224	3.5	2.3
Energy intensive industries	106	0.8	-
Surplus power	26	6.3	14.0
Oil total	292	0.1	-2.2
Oil other than transportation	54	-6.5	-9.5
Oil for transportation	187	2.6	-2.3
Liquefied gas	51	33.6	8.9
District heating	3	.	-
Solid fuels	85	2.3	-1.2
Coal, coke	50	0.6	-1.0
Fuelwood, paper waste, other solid waste	36	5.5	-

Table 2.7. The electricity balance[1] 1991*. Changes 1975-1991

	1991 TWh	Average annual percentage change 1975-1990	1990-1991
Production	110.9	3.0	-8.8
+ Import	3.2	7.6	966.7
- Export	6.0	7.2	-63.0
= Gross domestic consumption	108.1	2.6	2.3
- Consumption in pumping plants	0.7	7.6	133.3
- Surplus power	7.2	4.0	24.1
- Losses in exports and surplus power	0.9	4.3	-40.0
= Gross firm power consumption	99.3	2.5	1.2
Energy intensive ind.	29.5	0.8	-3.6
Regular cons.[2]	69.8	3.4	3.4
- Losses in the transm. lines, cons. in the power stations, statistical diff.	8.6	2.2	-1.1
= Net firm power consumption	90.7	2.5	1.5
Energy intensive ind.	28.6	0.8	-3.7
Regular cons.[2]	62.0	3.6	3.9
Regular cons.[2], temperature adjusted	63.3	3.8	-0.6

[1] The definitions in the table follow the definitions of the Electricity Statistics. The figures are preliminary.
[2] Firm power consumption outside energy intensive industries.

Gross domestic consumption of electricity was 108.1 TWh in 1991. Power to pumping stations and surplus electricity accounted for 7.9 TWh, and losses in the transmission and distribution network for 9.5 TWh. Net firm power consumption was distributed as follows: 28.6 TWh to energy-intensive industry, and 62.0 TWh for other purposes, see table 2.7. Of a total production of 110.9 TWh in 1991, 6.0 TWh was exported. 3.2 TWh was imported. The value of the export surplus was about NOK 300 million.

Figure 2.7 and table 2.21 show an increase of about 4 per cent per year in the temperature-adjusted regular consumption of electricity in Norway at the start of the 1980s. At the end of the 1980s the average rate of increase was about 3 per cent per year. From 1990 to 1991 the increase in consumption was nil.

The strong increase in consumption at the start of the 1980s was connected partly to relatively strong growth in the Norwegian economy. Another reason was the shift from use of oil to use of electricity following the strong increase in oil prices after OPEC II in 1979. After 1985, the growth in the Norwegian economy declined, and the growth in private consumption stopped. In spite of this development, the strong growth in electricity consumption continued, if not at quite the same pace as before. This growth was due to the continued shift from oil to electricity. For the same period, the growth in total energy consumption was moderate.

The change from oil to electricity took place in spite of a decrease in the price of oil relative to the price of electricity throughout large parts of the 1980s. This may have been connected to the high investment cost of new oil-based installations, as well as high maintenance costs and depreciation of existing installations.

Figure 2.8 shows a dramatic decrease in total sales of heating oils and kerosene in Norway from 1978 to 1991. In 1978, these oil sales, calculated in TWh utilized energy, accounted for about 30 TWh, while the corresponding figure for 1991 is 10 TWh.

The dramatic change from 1990 to 1991 in the rate of growth in the temperature-adjusted electricity consumption was partly due to weak economic development (zero growth in private consumption), but also indicates that it is now difficult or expensive to achieve an even more rapid shift from oil-based to electricity-based installations (the decrease in sales of heating oils from 1990 to 1991 was about equal to the increase in sales of surplus electricity). The introduction of flexible tariffs in the electricity market and environmental taxes in the oil market has meant that electricity has become cheaper in recent years relative to oil, but this does not seem to have had any marked effect on the change from oil to electricity.

Figure 2.7. Net regular consumption of firm power. 12 monthly gliding sum. 1978-1991. TWh

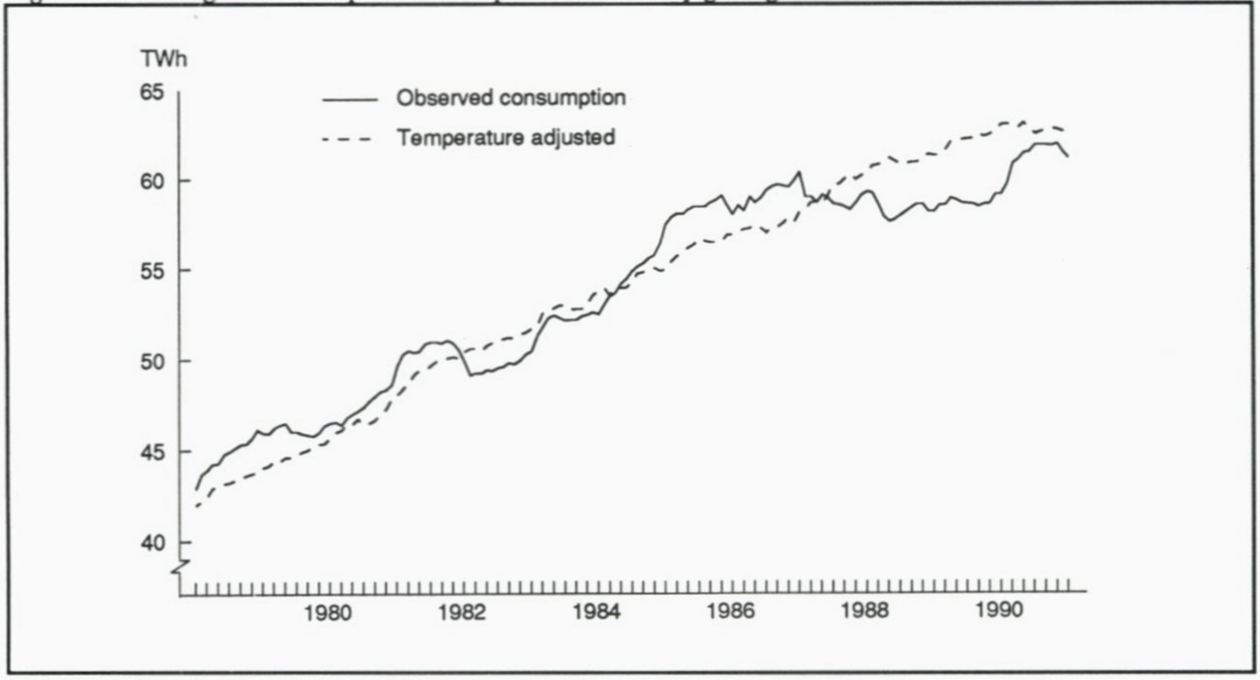
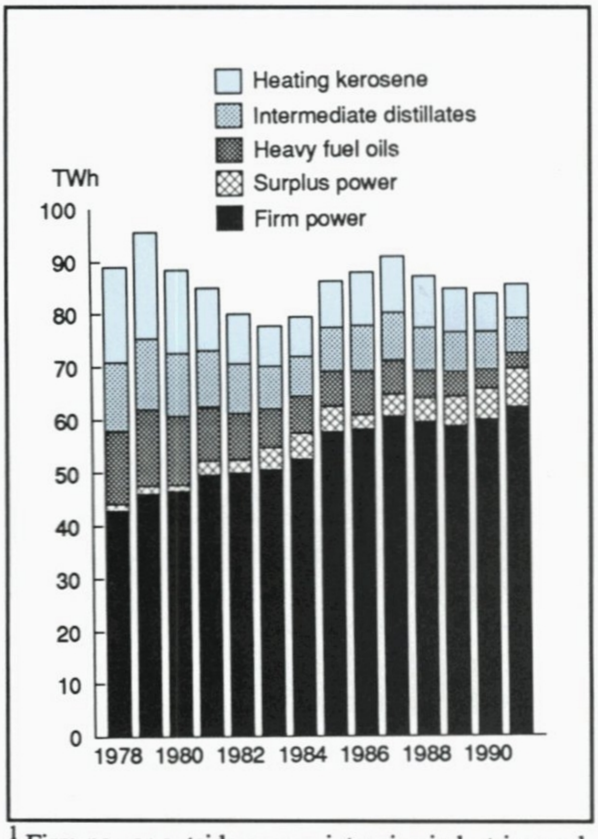


Figure 2.8. Regular electricity consumption[1] and sales of heating oils and kerosene. Utilized energy. 1978-1991. TWh



[1] Firm power outside energy intensive industries, and surplus power.

Energy prices

Large quantities of the electricity produced in Norway are sold through fixed contracts, partly through long-term contracts with energy-intensive industry, and partly through medium-term contracts to regular consumption. The price for electricity paid by energy-intensive industry is about a third of the price paid in regular consumption. Part of this price difference can be explained by differences in utilization time, and in transmission and distribution costs. In 1991, companies in energy-intensive industry and pulp and paper manufacturing renewed long-term contracts (1976 contracts) for yearly deliveries of power amounting to 7 TWh at prices far lower than the cost of developing new power as indicated by cost estimates prepared by the Norwegian Water Resources and Energy Administration (NVE).

The terms of the 1976 contracts apply up to the end of 1995. Afterwards, there will be two alternative types of contracts for fixing future prices. A company will be able to choose product-related prices, where the price of electricity is regulated in step with the price of the company's products. Alternatively, a company will be able to choose real price contracts. These are described in more detail in the section 2.3, Energy policy.

Sales of surplus power, i.e. sales without a delivery guarantee, take place on an electricity spot market. In this market the price of electricity is decided from hour to hour depending on supply and demand. Before, only actors who produced electricity themselves had access to this market. As from 1 May 1991 the market was made accessible to everyone upon payment of a one-time fee of NOK 50 000 in order to participate.

Table 2.8 shows the estimated prices of electricity among different user groups in 1990 and 1991. The average price of electricity exported from Norway increased from 6.0 øre per kWh in 1990 to 10.6 øre per kWh in 1991. Thus in 1991 the price of electricity for export was almost as high as that for permanent deliveries to energy-intensive industry (12.0 øre per kWh).

Figure 2.9 shows the prices of electricity and oil products per unit of energy (converted to utilized energy) measured in fixed 1980 prices. Figure 2.10 shows changes in the price of fuel oils.

On average, the nominal price of electricity to private households increased by about 3 per cent from 1990 to 1991, which implied a reduction in the real price of about one half per cent. The main reason for this reduction was the introduction of flexible tariffs to households in some regions. The average price to private households was 42.2 øre/kWh.

The price of petroleum products increased substantially throughout 1991. The (nominal) price of heating kerosene increased by almost 26 per cent, and the price of the other petroleum products increased by about 20 per cent. This means that, in the course of 1991, the price of heating kerosene became higher than the price of electricity, calculated in terms of utilized energy. The price of heating oil is slightly lower than the price of electricity, calculated in terms of utilized energy. One reason for the marked rise in the price of petroleum products is that the rising price of crude oil throughout 1990 did not affect the price of products until 1991. A second is the increase in environmental taxes on petroleum products.

The price of non-leaded gasoline rose by 14.1 per cent from 1990 to 1991, or somewhat more than 10 per cent in real terms. By comparison, the price of leaded high-octane gasoline rose by 15.2 per cent during the same period. The reason for the different percentage increases is that, in 1991, the tax on leaded gasoline was increased by 10 øre per litre more than the tax on non-leaded gasoline.

Table 2.8. Average electricity prices in different user groups, electricity tax included (VAT excluded). Øre/kWh

	1990	1991
Export	6.0	10.6
Import	..	..
Domestic consumption (excl. loss)	27.9	29.4
Surplus power	6.0	12.0
Energy int. industry	11.7	12.0
Regular consumption	38.3	39.4

Figure 2.9. Calculated prices for utilized energy. 1973-1991. Fixed 1980 prices. Øre/kWh. All taxes included

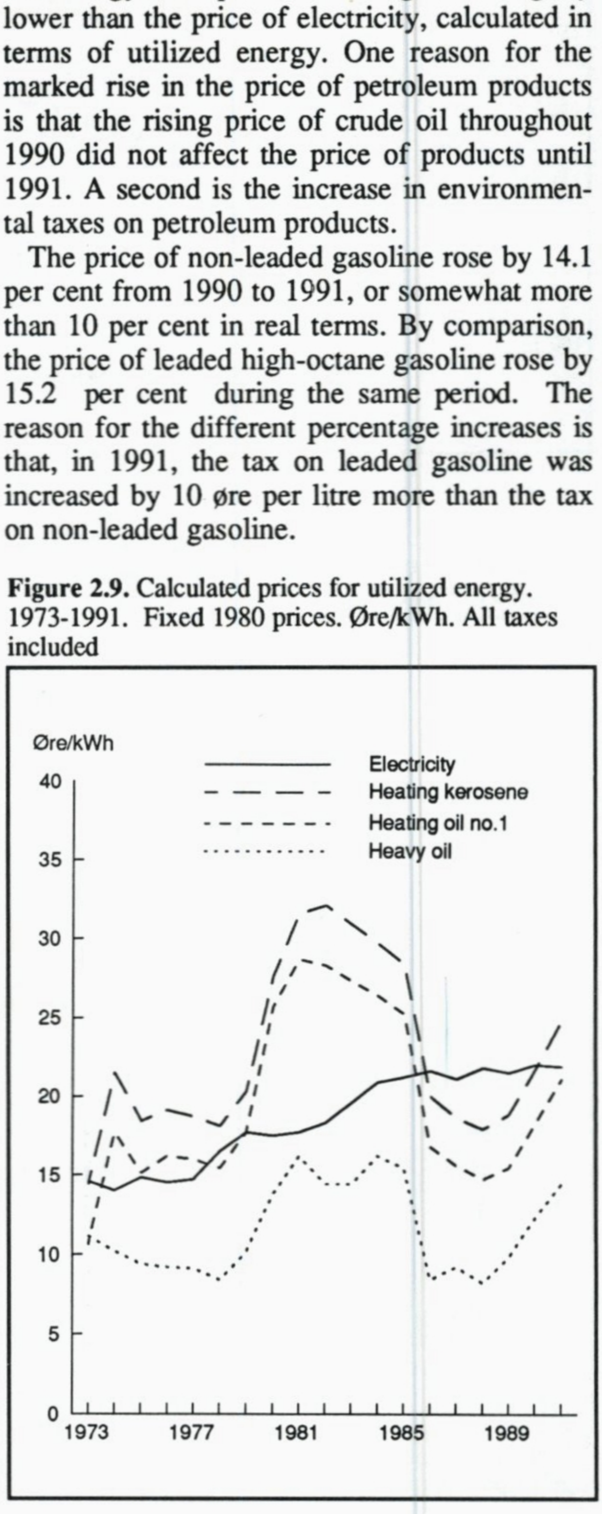


Figure 2.10. Prices of fuel oils. 1973-1991. Fixed 1980-prices. Øre/litre

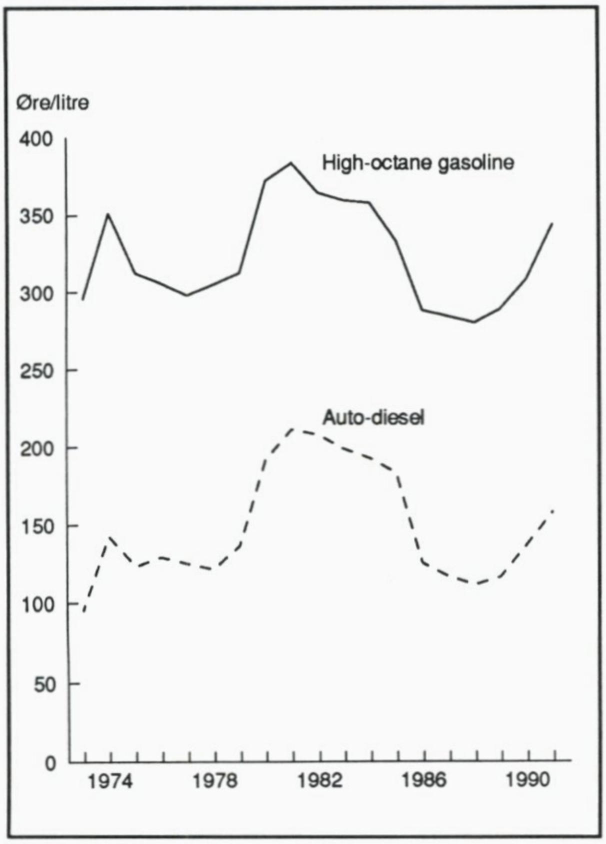
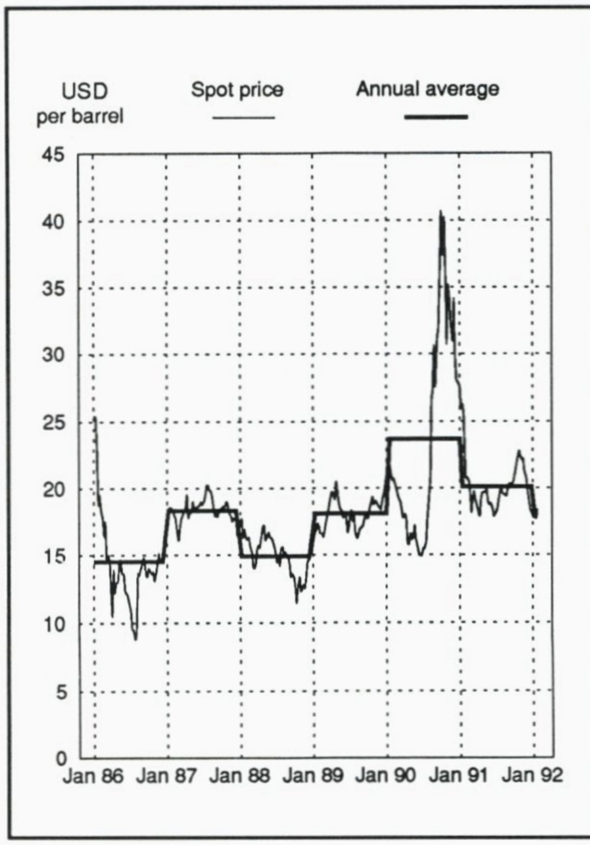


Figure 2.11. Spot price of Brent Blend



2.2. The world market

The oil market

At the start of 1991 the spot price of Brent Blend was about USD 26 per barrel. The start of the Gulf War on 17 January caused an immediate substantial drop in the price of crude oil. Up to June, the price of Brent Blend fluctuated around 19 dollars per barrel. From a record low of USD 17.85 per barrel in the middle of June, the price of crude oil started to rise again, and Brent Blend reached its highest price since the Gulf war, 23 dollars a barrel, in mid-October. At the end of 1991, however, the price of crude oil had almost returned to the June level. The main reason for the price drop towards the end of 1991 was a weaker growth in demand than expected, leading to build-up of stocks, and an anticipated further drop in prices.

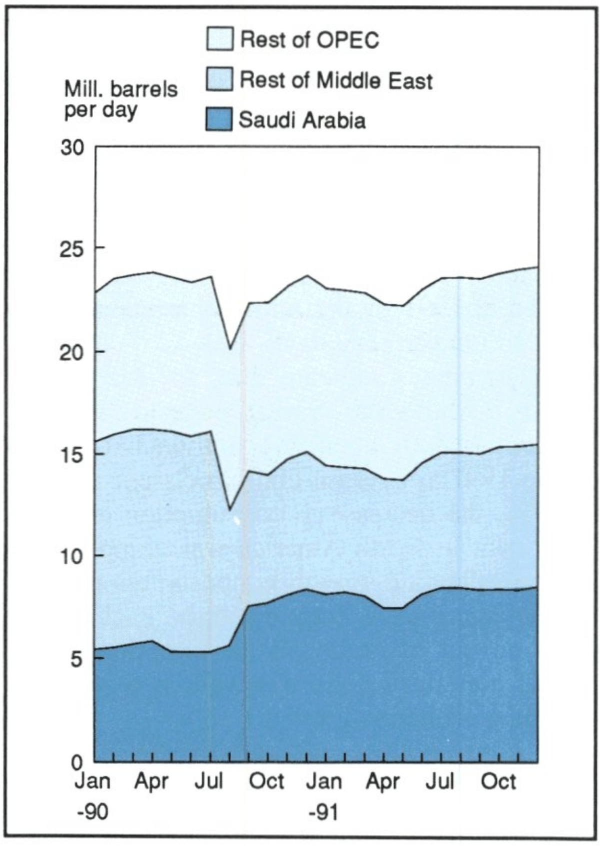
According to preliminary estimates from the IEA, the total world demand for crude oil increased in 1991 by 0.1 million barrels a day to 66.3 million barrels a day.

The estimates indicate that, for the OECD area as a whole, the average demand for crude oil decreased by about 0.1 million barrels per day in 1991 to 37.9 million barrels per day. As in 1990, the decrease in consumption of about 2 per cent in North America was compensated by corresponding growth in consumption in the OECD countries in Europe and the Pacific. The levelling out of crude oil consumption in the OECD area during the past year is a result of declining economic growth.

Oil consumption was also reduced in the earlier East block countries in 1991. The main reasons for the decreased demand were the collapse of the COMECON trade cooperation, and adjustment to crude oil prices on the world market. The reduced demand in these countries was compensated, however, by increased consumption of oil in other countries outside the OECD. The growth in consumption of crude oil in 1991 was especially strong in Asia (6 per cent), Latin America (3 per cent) and Africa (2 per cent). Average consumption of crude oil in countries outside the OECD increased in 1991 by a total of 0.2 million barrels a day to 28.4 million barrels a day.

Preliminary figures indicate that stocks of crude oil in the OECD area amounted to 475 million tonnes at the end of 1991, or 97 days' consumption. Therefore the stocks in the OECD area remain at the relatively high level built up in the fourth quarter of 1990. At the start of 1991, the amount of unsold crude oil under transit was abnormally high. During the third quarter, however, this stock was brought down to almost the same level as before the Gulf crisis.

Figure 2.12. OPEC's oil production. Mill. barrels per day



During the first five months of 1991, OPEC's production of crude oil decreased from almost 23 million barrels per day to 22.2 million barrels per day, see figure 2.12. The decrease was followed by a strong growth in production in the Middle East, especially in Saudi Arabia, of 1.3 million barrels a day from early July. A steady growth in production during the second half of the year meant that, during December 1991, the organization equalled its production record of 24.2 barrels per day, registered in March 1990. Average production for 1991 is estimated to 23.2 million barrels per day, the highest level for 11 years. With a capacity utilization of 97 per cent during the 4th quarter of 1991, OPEC exceeded its limits on production during the second half of the year, most recently fixed at 24 barrels per day during the OPEC meeting on 26 November. At the same time, during the 4th quarter, the price of crude oil fell below the goal of 21 dollars a barrel.

After the oil fires in Kuwait were extinguished, the country produced 400 000 barrels per day at the turn of the year. Production and export from Kuwait is expected to increase substantially this year. The embargo on Iraq is still effective, so that Iraq's production is restricted by its domestic refining capacity and exports to Jordan, and amounts to about 500 000 barrels per day. What will happen in future is very uncertain, both as regards the embargo and the development of Iraq's production capacity. In October last year, the United Nations sanctioned sales of a limited quantity of Iraqi oil under strong control and management by the UN. In the last few months, the possibility of Iraq accepting the UN demands has been strongly influenced by developments on the market, most recently in early January this year, when a meeting between the UN and Iraq caused a drop of 1 dollar per barrel in the price of Brent Blend.

Within the OECD there was only a slight increase in production in the course of 1991. Denmark became self-sufficient in oil for the first time since Danish production started.

In the earlier Soviet Union, production of oil and natural gas decreased by just over 10 per cent in 1991 compared with the year before. The reduction was 3 per cent in 1989 and 6 per cent in 1990. Almost the entire reduction of 1.1

million barrels per day in 1991 occurred in Russia, which accounted last year for almost 90 per cent of the total production of 10.4 million barrels per day in the earlier Soviet Union. The decrease in oil exports continued in 1991, and in the period September - October 1991 amounted to just under 2 million barrels per day. Developments during the second half of the year tend to indicate, however, that the drop in exports is slowing down. However, uncertainty concerning developments in the new independent republics makes it difficult to predict the trend in exports from this area.

IEA's forecasts of supply and demand for crude oil in the present year are based on an economic growth of just over 2 per cent in the OECD area during the first half of 1992 and a price for crude oil of about 20 dollars a barrel. According to the estimates, a relatively strong increase in demand in North America will be compensated by stagnation and decreasing demand in the rest of the world. Even with an assumed decrease in production outside the OPEC area in the first half of 1992, if OPEC maintains the same level of production as in December last year, i.e. 24.1 million barrels a day, this will lead to a large excess supply in the crude oil market during the period. This surplus may be further increased by an expected increase of production to 800 000 barrels a day in Kuwait during the first half of the year, and possible export from Iraq.

The communique from the OPEC meeting in the middle of February stated that OPEC's production during the 2nd quarter of the year would be restricted to 23 million barrels a day. Moreover, an extraordinary meeting of the OPEC countries will be convened if Iraq starts to export again. The consequence of the OPEC meeting was an immediate and relatively strong drop in the price of crude oil. Therefore, even with no further restrictions on production by OPEC, most of the factors that influence the market tend to indicate that the price of crude oil will remain low during the first six months of 1992.

Table 2.9 shows proven reserves of oil and natural gas.

The gas market

Table 2.9 shows proven reserves of natural gas. The world's total reserves increased by almost 4 per cent from the end of 1990 to the end of 1991, in spite of extractions during the year. The greatest increase was in Africa and the earlier Soviet Union, but reserves also increased in Western Europe. More than 80 per cent of the world reserves are owned by Russia and countries in the Middle East. At the end of

Table 2.9. World reserves[1] of oil and gas

	Reserves 1990		Reserves 1991		Changes in reserves from 1990 to 1991	
	Oil	Gas	Oil	Gas	Oil	Gas
	Bill. toe		Bill. toe		Per cent	
Asia-Pacific	6.8	7.7	6.0	7.6	-12.3	-1.0
Western Europe	2.0	4.5	2.0	4.5	0.2	1.7
Eastern Europe and Soviet	8.0	41.3	8.0	45.1	-0.1	9.1
Middle East	90.1	33.8	90.0	33.6	-0.1	-0.4
Africa	8.1	7.4	8.2	7.9	1.0	7.3
America	20.8	12.9	20.6	12.9	-0.9	-0.4
The world	135.9	107.6	134.8	111.7	-0.8	3.8
OPEC	105.2	44.5	104.6	44.2	-0.6	-0.6
Norway	1.0	1.7	1.0	1.7	0.0	0.1

[1] The term "reserves" as used in this table is not the same as the term used in the account figures in tables 2.17 and 2.18.

Source: Oil and Gas Journal, 1991.

1990, the reserves would have lasted for 58 years, without addition of new ones. When interpreting these facts it is important to note that the average figures conceal large regional differences. This means that if no new reserves are found in the regions with large consumption, it will cost more to deliver the gas to the consumer, since the greater part of the reserves are located far away from the consumer regions. Nevertheless, the United States is the only country that can expect a scarcity of gas within the next 10-20 years.

World gas consumption increased by 2 per cent to 1738 mtoe from 1989 to 1990. The growth was strongest in the developing countries. Consumption in Western Europe, the market for Norwegian gas, increased by 1.7 per cent to 227 mtoe. Although the market is fairly well developed, the share of the energy consumption covered by gas is much lower than in Eastern and Central Europe and North America. Gas is expected to increase its share of the market at the expense of electricity in particular. Norwegian producers expect substantial growth in the European gas market.

The European gas market is a negotiating market dominated by large purchasing companies with almost national monopolies. The EC Commission wants to regulate the market in order to avoid discrimination and increase cost-efficiency. The principle of third-party access is fundamental in the EC, and will also apply to a European Economic Area (EEA). In the long term, this can be expected to limit the market influence of the transmission companies and increase the number of participants in the market. This will probably reduce the final price to consumers and make gas attractive in several segments of the market. See Bjerkholt & Gjelsvik (1991) for a more detailed analysis of this problem.

2.3. The energy policy

Report to the Storting (1990-91) - Reorganization of Statkraft (Norwegian State Power Board)

One of the main intentions of the Energy Act (Proposition No. 43 (1989-1990) to the Odelsting (one of the chambers of the Norwegian Storting)), which entered into force on 1 January 1991, was to try to distinguish between those units of the power supply that can exist in a free market, i.e. the production enterprises, and the units that must be regarded as natural monopolies, i.e. the transmission and distribution companies. A combination of competitive activity (production plants) and monopoly functions (transmission network) can lead to unfortunate cross-subsidizing and exploitation of the power to influence the market. To follow up the Energy Act it was proposed in Proposition No. 100 (1990-1991) to the Storting "Reorganization of Statkraft" that two new companies be established to replace the earlier Statkraft. The production plants were to be collected in a new production company, Statkraft SF, and transmission activity combined in a network company, Statnett SF.

Splitting Statkraft into two companies, a production company and a network company, seems to be a natural consequence of the reorganization of the Norwegian power market to comply with the intentions of the Energy Act. It is assumed that all actors in the power market will have access to the network through the new network company, and that Statkraft SF will have to compete on equal terms with other suppliers for use of the network. Given effective monopoly control of the network, the conditions should promote good utilization of existing capacity and more optimal development of new capacity. The question arises, however, whether Statkraft SF will be able to compete on equal terms with other power production companies. Proposition No. 104 to the Storting, see below, makes it clear that the Government still wants to make active use of the company in its industrial and employment policies by requiring the company to enter into special types of contracts with favourable terms for energy-intensive industry in particular.

Proposition No. 104 (1990-1991) concerning renewal of Statkraft's industrial contracts and the terms in the contracts concerning reversion

In the 1990s, some of Statkraft's contracts with energy-intensive industry and pulp and paper manufacturing industry expire. It was decided already in autumn 1991 to renew these contracts and to revise the terms in the contracts referring to prices and reversion. According to Proposition No. 104, contracts covering a total of 7.7 TWh are to be renewed. The Government proposed that the new contracts fix a price, excluding taxes, of 13 øre/kWh in 1996 (1991 prices), rising to 18 øre/kWh in the year 2010. The electricity tax, which is currently 4 øre/kWh, is added to the price. The major-ity in the Storting elected to give industry two alternative systems of prices to choose from. In the one alternative, a company can choose product-related prices, i.e. the price of power will vary with the price of the company's products. The lowest price was fixed at 13 øre/kWh (1991 prices). Alternatively, a company can choose real price contracts, where the price will be regulated from 13 øre/kWh in 1996 to 16 øre/kWh in 2010 (1991 prices). Thus the Storting fixed lower prices than proposed by the Government.

It is stated in the Proposition that the situation in the Norwegian power market is very uncertain, and that it has therefore been difficult to calculate the economic consequences of the proposed contract terms. However, several methods can be used to calculate the costs connected to the actual contracts.

A measure of the value of the actual amount of power in different applications can be obtained by inviting tenders for the quantity of power concerned, and allowing all purchasers, including foreign purchasers, to compete for the contracts.

Another measure can be obtained by reviewing the costs of ongoing hydropower development projects. As an alternative to developing new hydropower to cover the demand in regular consumption, it is possible to refrain from requiring Statkraft to enter into long-term contracts with industry at low prices. The electricity thus made available can be used instead to cover the demand in the regular consumption, at a higher price. For the Government, which owns Statkraft, this is a cheaper solution than developing new hydropower capacity in order to meet the increased demand from this group. The Norwegian Water Resources and Energy Administration (NVE) has estimated the marginal cost of new hydropower development for delivery to energy-intensive industry to be 25 øre/kWh, delivered from power station as per 1 January 1990. This corresponds to about 26 øre/kWh in 1991 prices. If a reallocation of power removes the need for extensive new hydropower development, the long-term marginal cost will remain almost constant in future. Thus the gain to be obtained by not entering in to the power contracts outlined in Proposition No. 104 can be calculated as the quantity of power multiplied by the difference between long-term marginal cost and contract price. This gain is estimated to about NOK 700 million in 1996 and about NOK 300 million in 2010.

Protection Plan IV

In 1991, the "Mellquist Committee" published its report "Verneplan for Vassdrag IV" (Protection Plan IV for Watercourses). The committee considered 207 of a total of 350 proposed objects, and unanimously proposed protection of 114 objects, with a hydropower potential of about 6 TWh. The views of the committee were undecided as regards how many of 15 other objects should be protected. The total hydropower potential of these objects is 8.2 TWh. The committee are in agreement concerning protection of 2 TWh of these, agree that 0.5 TWh should not be protected, but have not reached consensus on protection of 5.7 TWh. One of the guiding principles of the committee was to propose protection of a number of watercourses so that, all in all, Protection Plan IV would preserve a cross-section of Norwegian watercourses with both typical and unique natural characteristics. Emphasis was also placed on distributing the protected water-courses between regions and according to patterns of settlement.

If the committee's recommendations are followed (where agreement has been reached) Protection Plan IV will imply an increase of 40 per cent in protected hydropower potential, compared with Protection Plans I-III. Thus, the combined protection measures initiated through Protection Plans I-IV, and through national parks and landscape protected areas in the Saltfjell/Svartisen area, will imply protection of between 30.3 and 36 TWh of an estimated exploitable hydropower potential of 171 TWh.

As long as there is no way of calculating the value of untouched nature, every protection plan will obviously be a subject of debate. By and large, it seems as if the committee has tried to take this debate into account by adopting a middle line in relation to the protection proposals presented before it started its evaluations.

Protection Plan IV is a direct follow-up of Protection Plans I-III. Since the first of these protection plans was presented, we have seen steadily increasing international concern about the problems connected to combustion of fossil fuels. In the future, the discussions on how to counteract these global climate problems will give greater attention to the question of increased and more effective use of a clean source of energy such as hydropower. It is fairly reasonable to assume that commercial production of hydropower would increase the economic value of the watercourses, but this is not reflected in the submitted proposals.

Proposition No. 108 (1991-1992) concerning transport of gas from the Heidrun field to land, establishment of a methanol factory, etc.

In this proposition the Government proposes laying a pipeline for natural gas from the Heidrun oil and gas field to Tjeldbergodden, at Aure, in the county of Møre og Romsdal. It is also proposed to build a methanol factory to utilize the gas from the field.

In spring 1991 it was decided to develop the Heidrun oil field on Haltenbanken. This implied solving the problem of what to do with the associated gas from the field. Two real alternatives were relevant: *Reinjecting* the gas into the field for extraction at a later date, and then connecting this gas to other gas fields on Haltenbanken and further to gas fields in the North Sea, or *transporting the gas to shore* and using it in onshore industrial activity.

Many calculations have been carried out of the profitability of the two alternatives. The conclusion in the proposition is that the present value of transporting the gas to land is about NOK 300 million more than for reinjection. Compared with earlier calculations showing that the present value of the reinjection solution was NOK 950 million more than if the gas were to be transported to shore, the new calculations have increased the prognosis of the price of methanol from 136 USD/tonne to 165 USD/tonne (1990 prices), and increased the estimated investment costs for reinjection by 560 million 1990-kroner (more than twice the previous estimate). In the profitability assessment, the total costs of the pipeline have been charged to the landing/methanol factory alternative. This means that the profitability of this alternative improves the more the pipeline is utilized. The methanol factory will require only 20 per cent of the pipeline capacity.

When weighing up the two alternatives it was decided to ignore the implicit socio-economic costs implied by the fact that the methanol factory is exempted from CO_2-tax. This tax is estimated to NOK 800 million given today's rate of tax on CO_2 in Norway. It is also stated in the proposition that the national goal of stabilizing CO_2 emissions by the year 2000 remains firm. The reinjection solution would thus be socio-economically profitable.

This conclusion can be reversed, however, with greater utilization of the capacity of the pipeline. There are three possible ways to achieve this extra utilization of capacity; further development of gas-fired power stations in the area, sales of gas from Haltenbanken to Sweden through a pipeline passing through mid-Norway, and establishing other industrial activity in the region to exploit the gas (including a possible extension of the methanol factory).

However, in this connection it is stated in the proposition that it is not considered relevant to base the supply of new power on the construction of gas-fired power stations to enable the gas from Heidrun to be used on shore. It is claimed that the question of gas-fired power stations must be decided in the light of the Government's policy on climate at the time in question. Thus the possibility of better utilization of the pipeline capacity is limited to either use in new industry, or exports. The proposition says nothing about whether new industrial activity would also be exempted from the CO_2-tax in future, or whether it would be treated according to the same terms as a possible gas-fired power station. Gas exports to Sweden would reflect the shadow price of the gas used to produce methanol.

All the considered solutions are associated with a large degree of uncertainty. One of the solutions, namely reinjection, seems to stand out as a possible way of postponing the final decision. This means that a certain aversion to risk would appear to favour this alternative. However, The Storting decided on 3 February 1992 to build a methanol factory.

2.4. Analysis: Energy consumption in households

In Norway, use of energy for stationary purposes in the household sector has shown a steadily increasing trend from 1980 to 1990, except during the last three years, which were particularly mild. The composition of the energy consumption has also changed. In 1980, consumption of liquid fuels accounted for 26 per cent, and electricity for 61 per cent, of the total energy consumption in the household sector. In 1990 the figures were 14 for liquid fuels and 72 per cent for electricity.

Common explanations of the increase in total energy consumption are an increase in the number of households, that each household has acquired more electrical equipment, or that they maintain a higher average temperature in the home than they did before. Economic models traditionally explain changes in energy consumption by changes in income, relative prices and composition of sectors. These factors were not found adequate to explain the changes in energy consumption in private households. For this reason, an attempt has been made to connect the changes in consumption to other underlying factors such as type of dwelling, size of household and living area. The connection between such variables and energy consumption is emphasized in the Energy Survey 1990 (Ljones et al., 1992).

Figure 2.13. Average energy consumption per household per year by type of building and living area. kWh

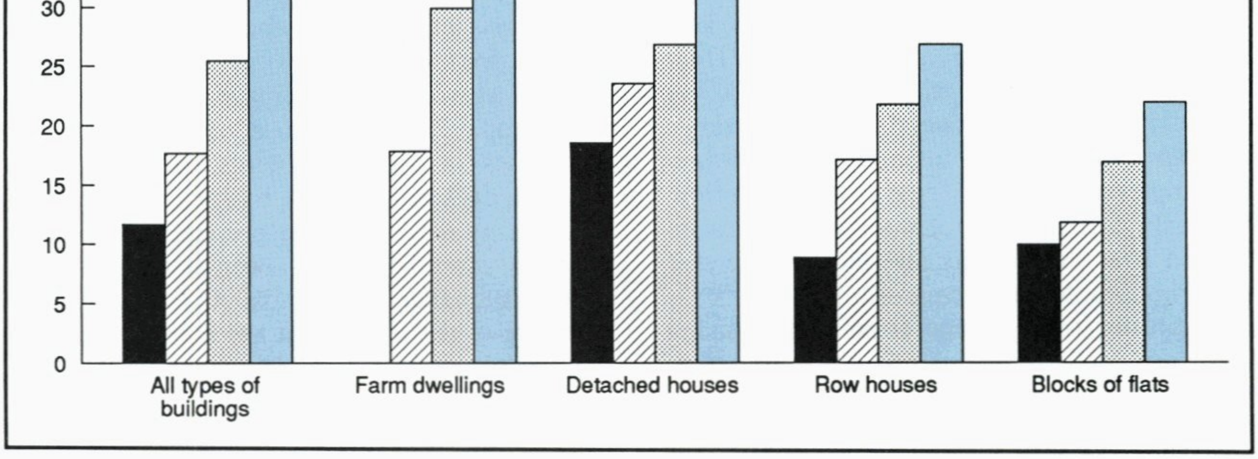


Figure 2.14. Average energy consumption per household per year by type of building and size of household. kWh

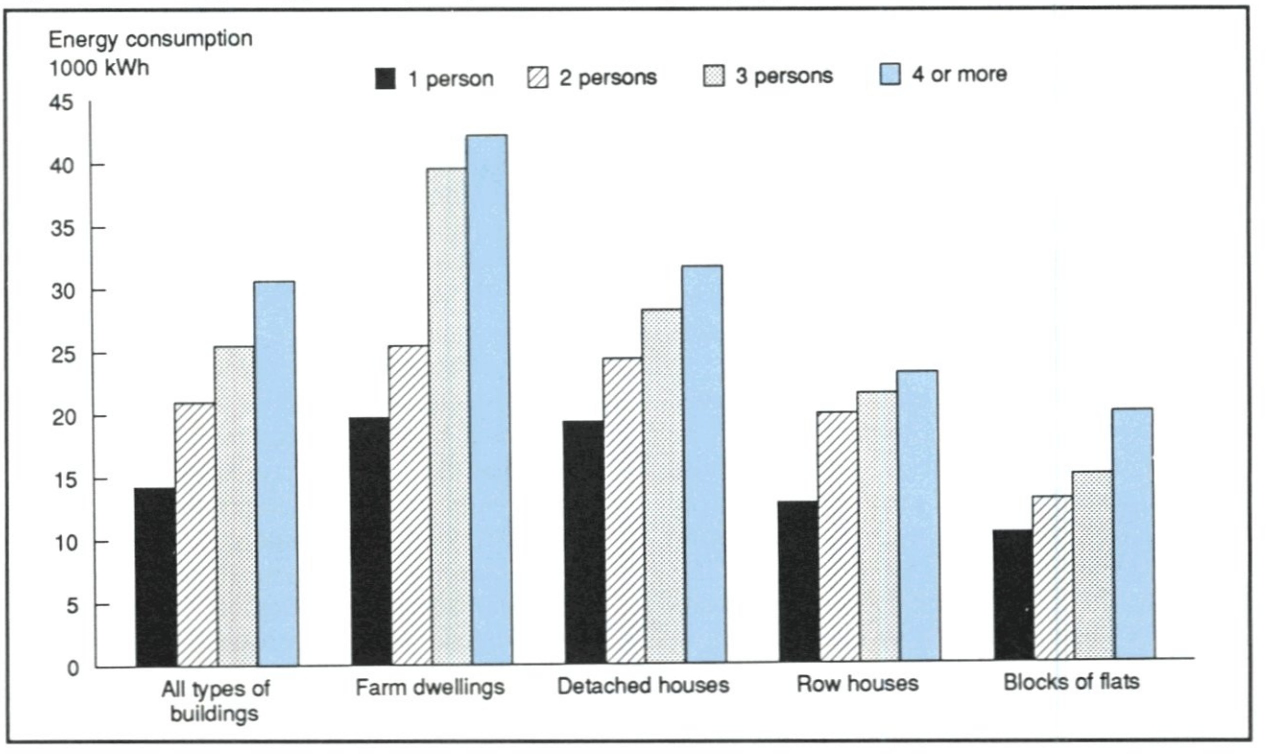
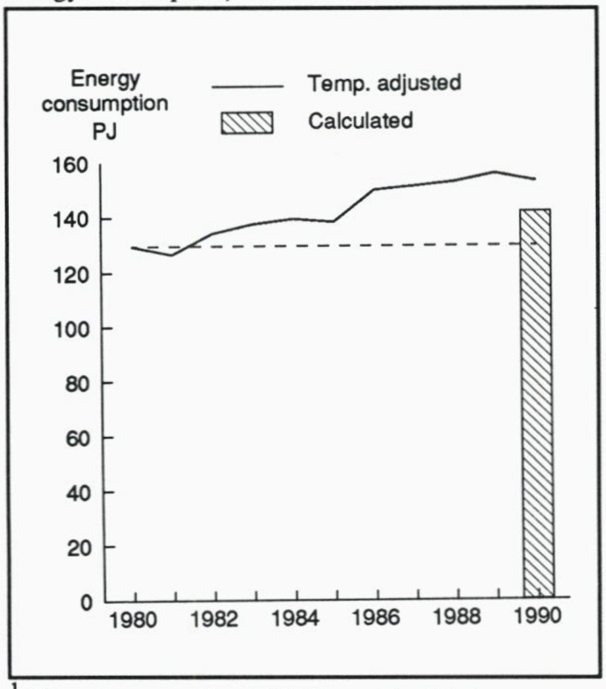


Figure 2.13 shows that the type of building is an important determining factor for energy consumption. Energy consumption is highest in farm dwellings and detached houses, and even in terms of energy consumption per m^2, there are large differences between the different types of buildings. One of the reasons is that the two types of buildings mentioned above do not have the same protection against cold as blocks of flats or row houses. The Population and Housing Censuses in 1980 and 1990 (CBS, 1982 and 1991) show only slight changes in the composition of the housing mass from 1980 to 1990. The number of dwellings with an area exceeding 100 m^2 increased to over 40 per cent, however, in 1990, compared with 30 per cent in 1980. A trend towards a larger average area per dwelling is an important factor in explaining the increased energy consumption. While the average area of the dwelling has increased over the last decade, the average size of the household has decreased.

According to the Population and Housing Censuses in 1980 and 1990, the number of dwellings increased by about 16 per cent during the period. The number of residents per dwelling decreased by 11 per cent. In 1980, 28 per cent of the households consisted of one person, while in 1990 this figure was 36 per cent. The number of households consisting of 4 persons or more has decreased from 30 to 23 per cent, while the percentage of households with 2 or 3 persons has remained relatively stable over time.

Figure 2.14 shows a clear association between energy consumption and size of household. A single-person household uses about 14 000 kWh per year. If the size of the household is increased by one person the energy consumption increases by about 7 000 kWh. A further increase in the size of the household causes steadily less increase in energy consumption. This is because, as the household increases in size, the energy used for space heating does not increase to the same extent as the energy used for other purposes. During the last 10 years there has been a marked trend towards smaller households. At the same time, the size of the population has increased, as has the number of households. This has led to an increase in energy consumption in the house-

Figure 2.15. Total, temperature-adjusted energy consumption in the household sector (stationary energy consumption)[1] 1980-1990. PJ



[1] The column on the right shows calculated energy consumption in 1990 based on the same composition and number of households as in 1980.

hold sector in spite of a decrease in energy consumption per household per year.

All in all, temperature-adjusted energy consumption for the household sector increased by 18 per cent from 1980 to 1990, see figure 2.15. This is equivalent to an average annual increase of 1.7 per cent.

Calculation of the total energy consumption in 1990 as it would have been if the composition and number of households had been the same as in 1980 gives a much lower result than the actual energy consumption in 1990, see column to the right of the figure. This shows that a change in the composition and number of the households does much to explain the increase in energy consumption in the household sector during the last ten years. Average consumption for the different types of households has also changed over the period due to changes in other variables.

The change in average living area and the change in the size of households both contributed to the higher energy consumption in 1990 than in 1980. These two variables are correlated, so it is difficult to isolate the effect of one from the other. It can be shown, however, that, for a given living area group, energy consumption increases with the number of persons in the household.

Although type of dwelling, living area and size of households are emphasized as explanatory factors, it must be pointed out that energy consumption may also be affected by several other factors. Such variables can be type of heating equipment, geographical location, year of building and standard of insulation.

Changes in the *composition* of the energy consumption from 1980 to 1990 may be connected, inter alia, to changes in the composition of the heating equipment. A comparison of results from the Energy Survey in 1983 (Ljones, 1984) with those of the Energy Survey in 1990 show that, in 1983, 38 per cent of the households had stoves based on liquid fuel. The corresponding share in 1990 was 29 per cent. The proportion of households using oil/kerosene has decreased from 30 to 25 per cent during the same period.

48 per cent of the households used electricity as the main source of heating in 1983. Seven years later the corresponding figure was 57 per cent, and use of liquid and solid fuels had decreased. However, consumption of solid fuels accounts for the same share of energy consumption in 1983 and 1990. The reason is more use of wood for supplementary heating.

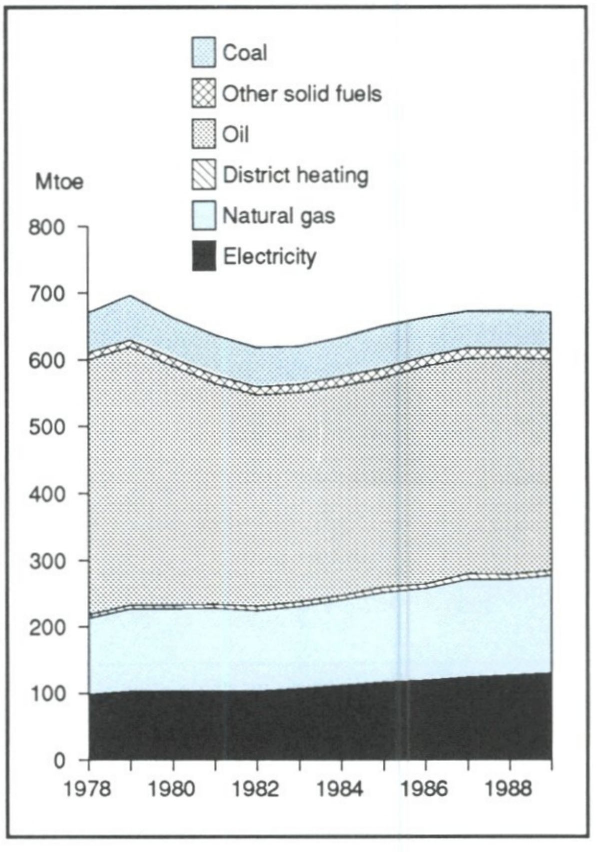
In 1976 an analysis was carried out to show the distribution of energy consumption between different purposes, inter alia, for households (Sæbø, 1979). The energy survey in 1990 also shows the energy consumption by purpose. The results of these analyses show that electricity used for lighting and electrical equipment accounted for a larger share of the total energy consumption in 1990 than in 1976. There seems to have been little change, however, in the share of the total energy consumption referring to electricity-based space heating. The figures indicate that changes in the relation between consumption of oil and electricity in the 1980s are due mainly to reduced use of liquid fuels for heating purposes and more use of electricity for purposes other than heating.

2.5. Analysis: Energy consumption in Western Europe

Studies of energy consumption in Western Europe are interesting for several reasons. Norway is a net exporter of oil and gas, and it is important to acquire information on nearby markets. Such information is also necessary in order to shed light on the change towards a more integrated energy market in Western Europe, and for analyses connected to international agreements to limit air pollution.

For these reasons, the Central Bureau of Statistics has developed a multi-sectoral energy demand model for 9 West European countries: the 4 large countries (Germany (West), Great Britain, France and Italy), the "gas" country Netherlands, and 4 Nordic countries (Sweden, Denmark, Finland and Norway), see Birkelund et al. (1991). Analyses of future energy consumption and air pollution are being done based on simulations with the model. Before doing such analyses it is useful to study energy consumption in the model area, as demonstrated in recent years. In this section, the description of energy consumption in the 9 abovementioned countries is based OECD data for energy prices, energy consumption and economic activity.

Figure 2.16. Final consumption of energy sources in 9 West European countries combined. 1978-1989. Mtoe



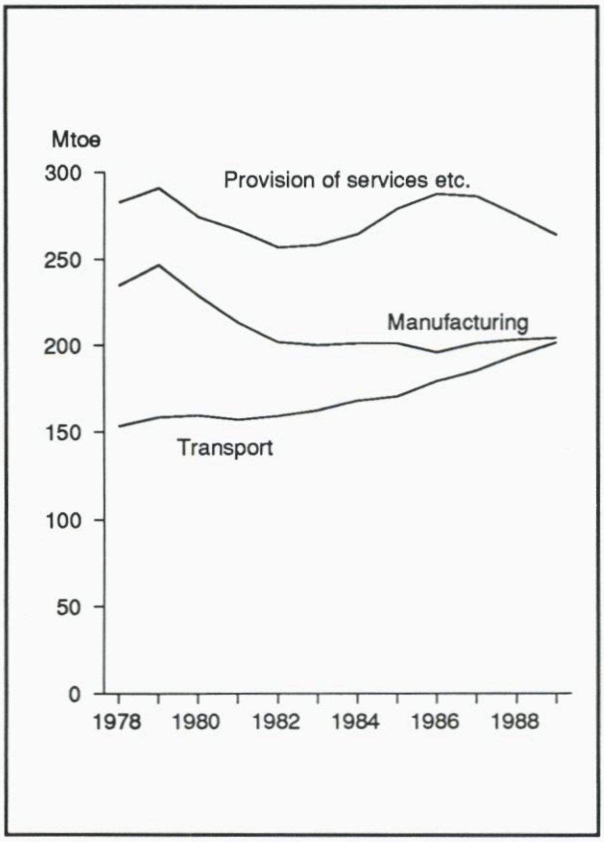
Final consumption of energy

The data from OECD show that, in 1989, the total final consumption of energy, i.e. excluding the energy sector, in the 9 countries accounted for about 4/5 of the total energy consumption in OECD, Europe. Figure 2.16 shows changes in consumption during the period 1978-1989.

The figures show delivered energy in mtoe and do not include use of sources of energy in industrial processes. The increase in energy consumption at the end of the 1970s was followed by a decrease in consumption from 1979 to 1982. During the latter half of the 1980s, energy consumption first increased slightly, and then levelled out towards the end of the period. The level of consumption was lower in 1989 than in 1979, in spite of a real increase in GDP throughout the period. This development is connected to changes in energy prices, distribution between sectors, and technology. Certain aspects of these conditions are discussed later in this section.

The reduction in energy consumption during the period 1979-1982 can be related to, inter alia, the second large price hop for oil in the 1970s, OPEC II. This is indicated by the changes in the consumption of the different energy sources, as shown in figure 2.16. There was a marked decrease in consumption of oil during the period. In spite of this decrease, oil was still the most used source of energy in 1989. The least used sources are district heating, coal and other solid fuels. The growth in energy consumption from 1984 to 1987 was caused mainly by an increase in consumption of electricity and natural gas. There was a steady increase in the use of these two sources of energy throughout the 1980s. The main reason for the increase in consumption of

Figure 2.17. Final consumption of energy by sector in 9 West European countries combined. 1978-1989. Mtoe



natural gas was improved availability following development of the networks.

Figure 2.17 shows changes in consumption of energy in the different sectors. Since the OECD statistics lack information on the distribution between private households, the service sector and primary industries, these sectors are combined in the figure. Energy consumption for purposes of transportation comprises a separate sector, and here the consumption of energy, mainly in the form of petroleum products, increased fairly steadily during the 1980s. The main reason was growth in the level of activity and in income in the different countries. The decrease in energy consumption during the period 1979-1982 occurred in the stationary sectors, in manufacturing in particular. The consumption of energy for manufacturing levelled out during the latter half of the decade. At the start of the period, about 50 per cent more energy was used for manufacturing than in the transportation sector, but in 1989 the consumption in the two sectors was the same. Energy consumption in households, the service sector and the primary industries combined showed a slight increase during the period 1982-1986, followed by a decline.

The decrease in energy consumption during the period 1987-1989 seems to be related to the higher winter temperature during these years. Several countries experienced an increase in electricity consumption and a decrease in oil consumption in private households and the service sector during a period with higher electricity prices and lower prices for oil. This is connected to the tendency to use more electricity-specific equipment in these sectors (Bye & Mysen, 1991).

Figure 2.18 shows that, although changes in energy consumption in each of the 9 countries follow the same course as the combined energy consumption shown in figure 2.16, there are some deviations from the general pattern. Certain countries, such as Italy, Finland and Norway, experienced a slight, but steady increase in consumption throughout the 1980s. In several countries energy consumption decreased towards the end of the decade. Figure 2.18 also shows that, not surprisingly, the largest amount of energy is used in countries with the highest level of economic activity and the largest population, headed by Germany (West). Other reasons for the different levels of consumption may be differences in climate, transport distances, technology, distribution between sectors, and energy prices. This results in different energy intensities, defined as energy consumption per GDP.

Figure 2.19 shows changes in energy intensities for the 9 countries during the period 1978-1988. A falling trend was experienced in all countries. The reduction during the period was in the order of 15-25 per cent. The reduction was greatest in Denmark and least in Norway. An American survey of manufacturing industry in 8 OECD countries indicates that the reduction in energy intensity was due mainly to technological progress in the different sectors, and less to a move towards less energy-intensive production (Howarth et al., 1991). However, the comparatively high level of energy-intensities in countries such as Netherlands, Sweden,

Figure 2.18. Final consumption of energy in 9 West European countries. 1978-1989. Mtoe

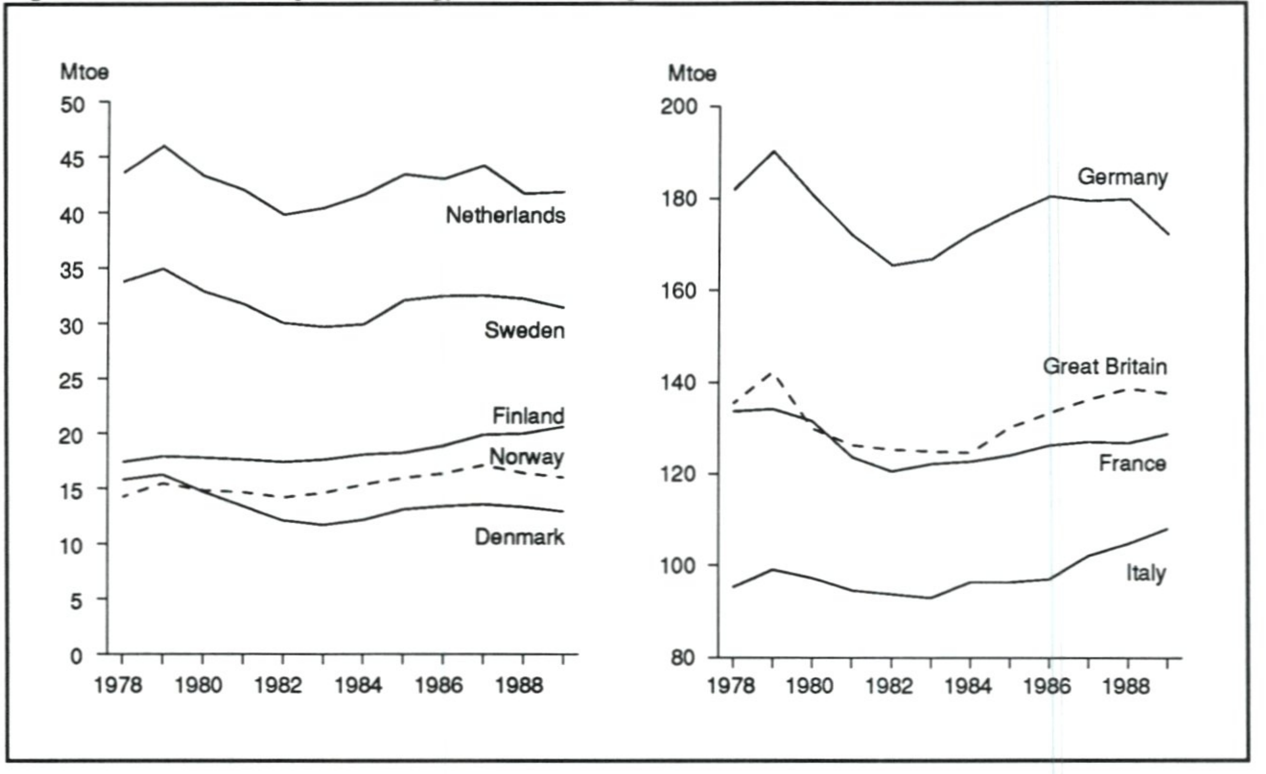


Figure 2.19. Energy intensities in 9 West European countries. 1978-1988. 1 000 toe/GDP (fixed 1988 US dollars)

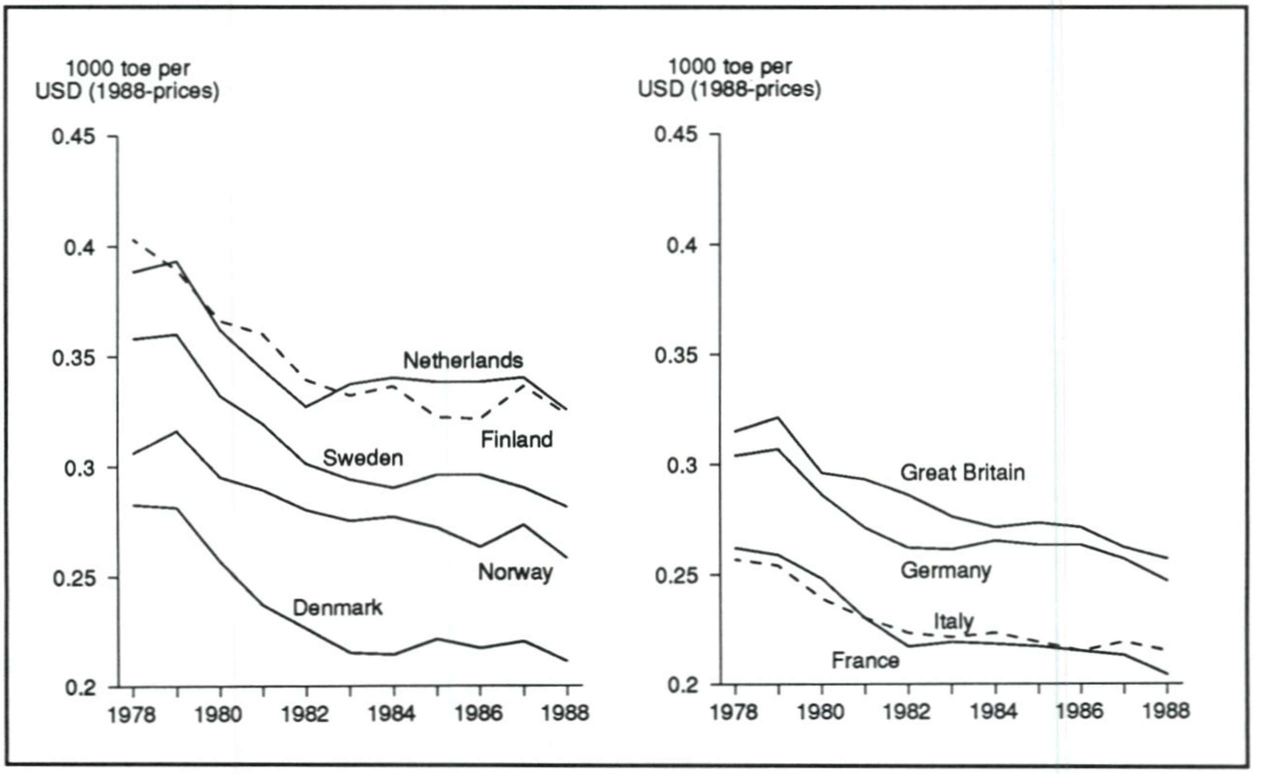


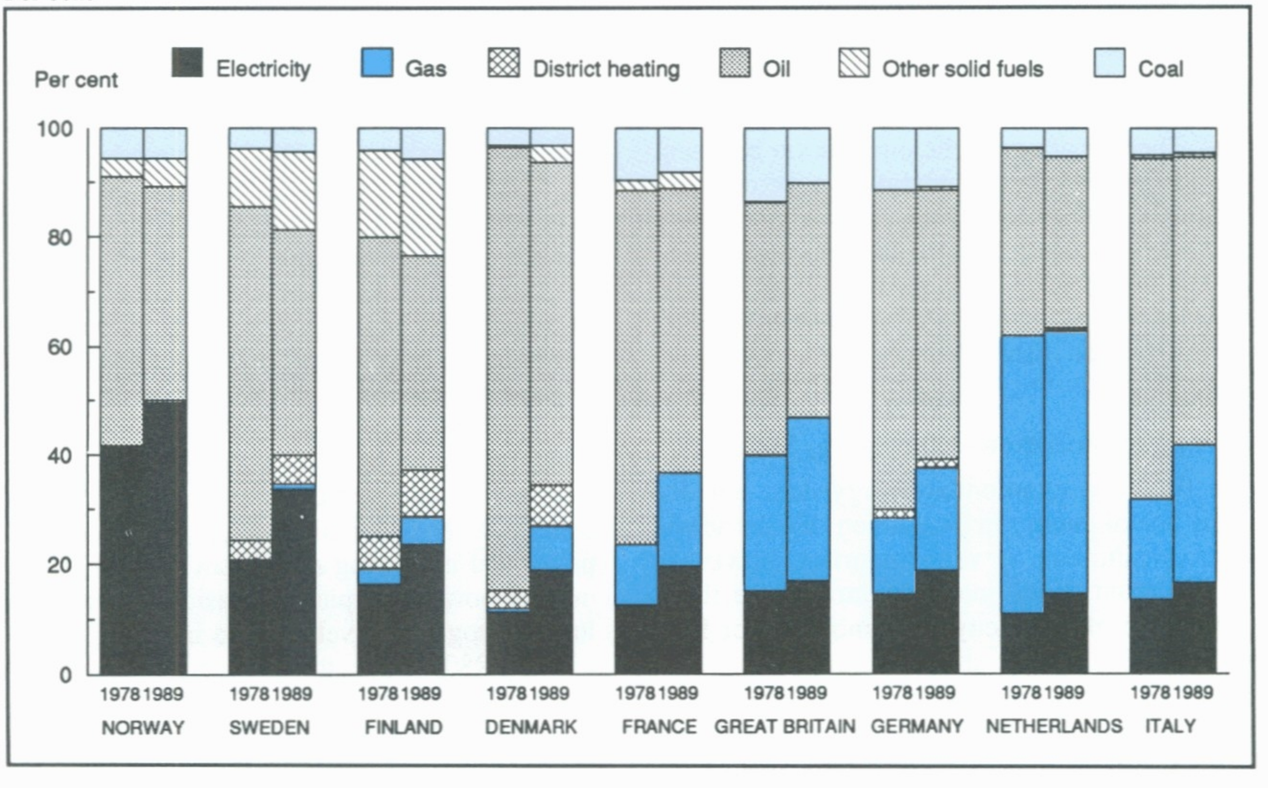
Table 2.10 a. Average annual changes in energy-intensity in 9 West European countries. 1978-1982 and 1982-1988. Per cent

	Denmark	Finland	Norway	Sweden	Great Britain	Germany West	France	Nether-lands	Italy
1978-82	-6.58	-4.69	-2.65	-4.81	-3.20	-3.73	-4.37	-3.50	-3.75
1982-88	-1,14	-0.77	-1.33	-1.15	-1.76	-0.93	-1.04	-0.12	-0.64

Table 2.10 b. Average annual changes in real price of energy in 9 West European countries. 1978-1982 and 1982-1988. Per cent

	Denmark	Finland	Norway	Sweden	Great Britain	Germany West	France	Nether-lands	Italy
1978-82	15.85	6.48	5.70	10.72	6.30	9.30	9.02	11.93	9.68
1982-88	-5.32	-6.54	-1.40	-3.06	-4.01	-7.45	-5,66	-6.33	-5.43

Figure 2.20. Energy consumption distributed by energy sources in 9 West European countries. 1978 and 1989. Per cent



Finland and Norway can be put down to a relatively energy-intensive economic structure.

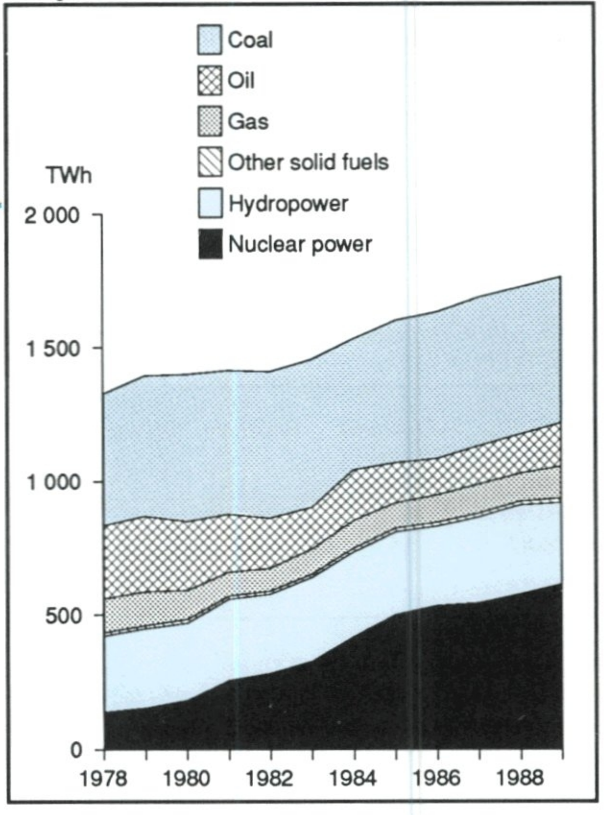
Tables 2.10 a and b tend to show that the changes in energy intensities were also related to some extent to changes in the price of electricity relative to the price of other production factors and goods, here indicated by the real price of energy. The tables show average annual percentage changes in respectively energy intensities and real price indices for energy for the periods 1978-1982 and 1982-1988. The percentage reduction in energy-intensities was much larger during the first period with rising energy prices, than in the second period when the price of energy decreased.

There are large differences in the pattern of energy consumption among the countries. Figure 2.20 shows the different energy sources' share of the total final energy consumption in 9 countries in 1978 and 1989. Oil was the most used source of energy except in Norway and Netherlands. Electricity consumption is relatively high in Norway and Sweden, while gas accounts for a large share of the total consumption in Netherlands, Italy and Great Britain. The share of oil has decreased in all countries, while the share of electricity has increased. Several countries also experienced a growth in the share of natural gas. In Sweden, Finland and Denmark, there was a slight increase during the 1980s in the shares accounted for by district heating and of solid fuels other than coal. These changes in the distribution between the different sources of energy may be connected to some degree to changes in relative prices, but may also related to a trend in time towards use of more electricity-specific equipment and the building of infrastructure for natural gas and district heating.

Energy consumption in the energy sectors

The final consumption of energy does not include use of energy in production of electricity. This consumption is very important, however, for pollution, since many countries base their production of electricity on combustion of fossil fuels. Figure 2.21 shows the composition of the total power production, and changes over time, in the same nine countries discussed in the previous section.

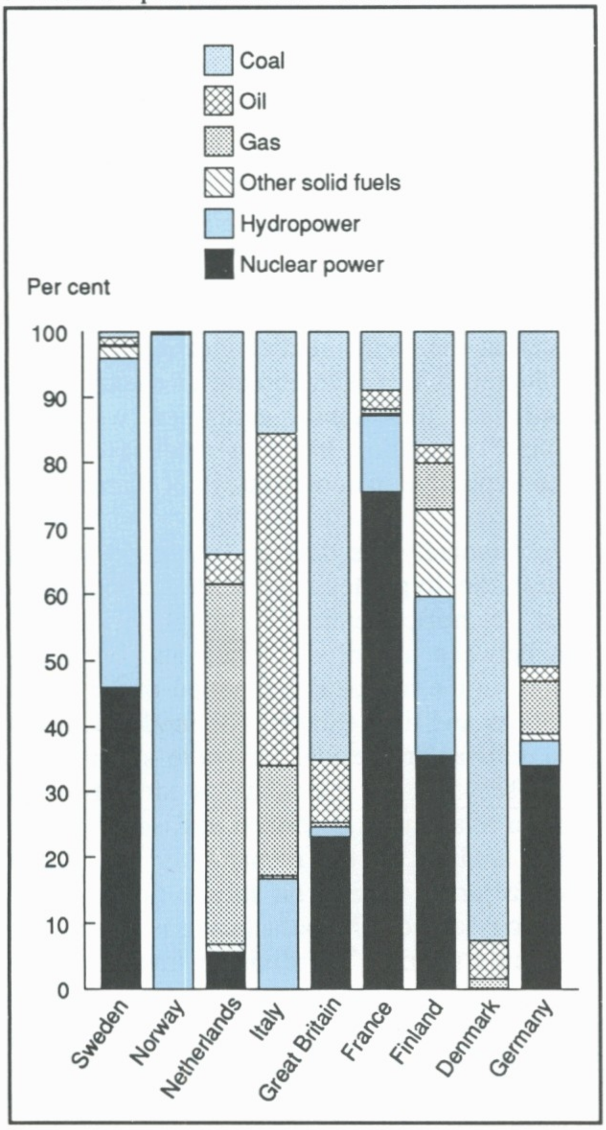
Figure 2.21. Total electricity production in 9 West European countries combined. 1978-1989. TWh



Power production increased by 33 per cent during the period 1978-1989. During the same period, oil-based production of power decreased by 40 per cent and gas-based production by 5 per cent in the area. The lower production of oil-based power and gas-based power was more than compensated by extensive development of nuclear power in several countries. Production of coal-based electricity and hydroelectricity also increased, but contributed less than nuclear power to the increase in total power production.

Some production of electricity from alternative sources of energy such as geothermal heat, wind power and biomass was started in the 1970s. The main reasons were uncertainty concerning reserves of oil and gas, rising energy prices and increasing scepticism towards use of nuclear power. In spite of considerable technological progress, developments in energy prices in the 1980s made the alternative sources of energy commercially unprofitable. Therefore the increase in production of power from these sources during the period 1978-1989 is largely

Figure 2.22. Composition of electricity production in 9 West European countries. 1989. Per cent



a result of subsidized research activity in the different countries.

Figure 2.22 shows large variation in the composition of the power production in the different countries. However, a common feature of several countries is to depend on few sources of energy for their power production. The reason, apart from the question of profitability, is a wish to use their own energy resources. This is most obvious in Norway, where power production is based almost exclusively on hydropower. In the other countries, the potential for further hydropower development is almost exhausted, or such development has been stopped, as in Sweden. Countries with large resources of coal, such as Germany (West) and Great Britain, base more than 50 per cent of their power production on coal, while Netherlands bases most of its power production on natural gas.

The increase in the real price of oil has led to greater use of coal and gas in power production, at the expense of oil, in all countries except for Italy. The change from oil to coal was especially marked in Denmark and Netherlands where, during the 1980s, oil's share of the market dropped by 40 percentage points and 35 percentage points respectively to 6-7 per cent of the market. The reason why substitution reached a higher level in these countries than in others was the large proportion of dual-fuel capacity, leading to lower cost of adjustment than in other countries.

Formal agreements linking the price of gas to the price of oil meant a rise in the price of gas in step with the price of oil. This may explain some of the decrease in the use of gas to produce electricity in Germany (West) and Great Britain. In Finland, Italy and Netherlands, on the other hand, there was a moderate increase in gas-fired production. This is due to conditions specific to each of these countries.

Netherlands has a very well developed network for distribution of gas, which meant relatively low transmission costs. While the other countries use oil and gas as peak-load power (reserve capacity to cover peak demand), gas-based power is used both to cover peak and ordinary demand in Netherlands. As far as Finland is concerned, trade agreements with the earlier Soviet Union were a deciding factor in initiating use of gas in Finland in the 1980s.

The largest change from 1978 to 1989 in the composition of the electricity production occurred as a result of extensive development of nuclear power. For the area as a whole, production of nuclear power has increased by just over 340 per cent in the course of twelve years. The greatest increase has occurred in France, where the share of the market covered by nuclear power increased from 13 to 75 per cent. The low price of electricity in France led to increased demand. The increased demand was covered by an almost 10-fold increase in nuclear power production during the period. There was also a strong increase in nuclear power production in Germany (West) and Great Britain, so that the share of the market covered by this form of power increased by 10 per cent and 13 per cent respectively at the end of the 1970s to 33 per cent and 23 per cent respectively in 1989. Sweden and Finland also contributed to the increase in nuclear power production during the first half of the period, but production in these countries has since stabilized.

The reason for the levelling out of nuclear production in Sweden and Finland, and the stable production in Netherlands, with a market share of 7-8 per cent throughout the relevant period, is a preliminary stop in the development of nuclear power plants as a result of political pressure. Italy stopped nuclear power production in 1986 for the same reason.

2.6. Analysis: Energy demand in the Nordic countries

In connection with the development of an energy model for the Nordic countries, an analysis has been carried out of the demand for energy in these countries (Johnsen & Mysen, 1992). The following are some results for the manufacturing and transportation sectors.

Energy demand in the manufacturing sectors

A characteristic feature of changes in the consumption of the different sources of energy in the Nordic countries during the last 20 years is increased consumption of electricity and decreased consumption of oil. Up 1982/83, when the price of oil increased relative to the price of electricity, a change to electricity at the expense of oil seems reasonable. Since 1982/83, however, the relation between the price of the two forms of energy has moved in the opposite direction, but electricity consumption has continued to increase relative to consumption of oil.

There are several explanations of this apparently paradoxical development. Firstly, in recent years, there has been an increase in use of electricity for electricity-specific equipment. Secondly, the capital cost of installing oil-based heating equipment has become very high compared with the corresponding cost of equipment based on electricity. A third reason may be uncertainty about the future development of the price of oil. For example, the oil price may rise as a result of environmental taxes on fossil fuels.

Another factor which may have contributed to the growth in electricity consumption relative to consumption of oil is that the oil price shock- in the 1970s led to technological develolopments that favoured use of electricity. A requirement for cleaning equipment with "end of pipe" regulation has also made use of oil more expensive in some sectors of manufacturing.

Unfortunately the data are not good enough to test the hypothesis presented above in a strict, scientific manner. To simplify, the relation between use of electricity and oil is described in the model as a function of the relative prices and time (trend). The model does not give satisfactory results for some sectors. For these sectors the calculations are based on simpler relations as described in Risø (1986).

The analysis of the demand for energy for manufacturing focuses on substitution between electricity and oil. Manufacturing is aggregated into three sectors. The division into sectors is slightly different for Denmark than for Norway and Sweden.

A main result of the estimates is that the trend parameter, which shows how much the

Table 2.11. Estimated results for substitution between electricity and oil in manufacturing sectors

Sector	Parameter	Denmark	Norway	Sweden
Metals	Subst.elast.	0.29		0.28
	Trend	0.14		0.06
Pulp and paper processing	Subst.elast.		1.64	0.08*
	Trend		0.24	0.17
Other manufacturing	Subst.elast.		0.41	0.19*
	Trend		0.09	0.13

* Not significant at five per cent level (one-tailed t-test).

relation between electricity and oil changes in the course of a year (assuming that the relative prices remain unchanged), is significantly greater than 0 in all sectors. This means that a change from oil to electricity has occurred which cannot be explained by changes in prices. Another important result is that the substitution elasticities, which show the percentage change in the relation between electricity and oil after a change of one per cent in relative prices, are relatively low.

Table 2.11 shows that in *metals manufacturing* the possibility for substitution between oil and electricity after a change in the relative factor price is about the same in Denmark and Sweden. This is evident from the fact that the estimated substitution elasticities are about the same size. The trend towards increased consumption of electricity seems to be more marked in Denmark than in Sweden. In other words, the price-dependent substitution from oil to electricity seems to take place more rapidly in the metals manufacturing sector in Denmark than in the same sector in Sweden.

In the case of the *pulp and paper processing industry*, it is worth noting that the estimated substitution elasticity is much higher in Norway (1.64) than in Sweden (0.08). The trend is somewhat stronger in Norway than in Sweden. In *other manufacturing* the estimated substitution elasticity in Norway (0.41) is about twice as high as in Sweden (0.19). The trend in other manufacturing seems to be somewhat more marked in Sweden than in Norway, but is generally not as great as in the pulp and paper processing sector.

To sum up, it can be said that the results, which show a significant trend for almost all sectors, indicate that the hypothesis presented above is relevant, but better data are needed in order to study these conditions in more detail. Another important point is that the relatively low substitution elasticities will result in taxes on fossil fuels having low effect in a model simulation of these energy relations. On the other hand, energy equations with a trend roughly implying an annual increase of 10 per cent in the relation between electricity and oil, give a reference path with higher electricity consumption and lower oil consumption than energy equations without such a trend. From the point of view of the environment, a reference path of this kind, with low oil consumption, would be favourable.

Demand for energy in the road transport sector

One of the intentions of the analysis was to compare price and income elasticities in the different Nordic countries. In order to obtain relevant information, an economic model was developed for energy consumption in road transport. A comparison of price and income elasticities in the different countries provides an indication of how much the tax on gasoline, for example, must be increased in order to achieve a certain percentage reduction in emissions.

Energy consumption for road transport both accounts for a large share of the total energy consumption and also increases much more than energy consumption for other purposes. This means that road transport is one of the main sources of emission of various air pollutants. The different pollutants cause different degrees of injury to health. A large share of the total emissions from road transport consist of NO_x, and these emissions occur most frequently in towns, where they affect a large number of persons. It is therefore important to know to what degree a tax on fuel will affect the demand for fuel, and thus also emissions, in the different countries.

Table 2.12 shows energy consumption in the road sector in relation to total energy consumption in the Nordic countries Denmark, Finland, Norway and Sweden. The table shows that, in Denmark, road transport accounts for 18 per cent and in Sweden 19 per cent of the total energy consumption. The corresponding figure for Norway is 14 per cent and for Finland 15 per cent. The reasons for the variation are to be found in the different economic structures of the different countries. Compared with the other countries, Denmark has little energy-intensive industry, while a large share of the total energy consumption in Norway and Finland goes to manufacturing.

Table 2.12 also shows the average annual rate of growth for energy consumption for road transport during the period 1970-1988. The lowest annual growth occurred in Denmark (1.9 per cent) and Sweden (2.6 per cent). The rate of growth was higher in Finland (3.7 per cent) and Norway (3.5 per cent).

In all the Nordic countries the increase in energy consumption for road transport was much higher during the period than the increase in total energy consumption, but the rates of growth differed. A possible reason may be differences in economic growth. Growth in GDP was lowest for Denmark and Sweden during the period, and these countries also showed the lowest increase in energy consumption both in the road sector and as a whole. The growth of GDP was much stronger in Norway and Finland, as was the increase in energy consumption in these two countries.

The model for road transport is based on a method used by Pindyck (1979) and Kouris (1983). This method determines energy consumption as a function of the number of vehicles, average distance driven per vehicle, and fuel efficiency.

The reason for modelling demand in this way is that demand for fuel originates from the demand for transport services. Therefore the consumption of fuel for road transport is strongly linked to the size of the vehicle park, use of the vehicle park (driven distance) and efficiency. By simulating the model with a reference path and an alternative path where the price of fuel and income are both increased by one per cent, we derived the price and income elasticities shown in table 2.13.

The table shows that the long-term price elasticity is largest in Denmark and Sweden. In Norway and Finland the long-term price elasticity is less than 1. This implies that a 1 per cent increase in the price of gasoline will cause a greater reduction in consumption in Denmark and Sweden than in Finland and Norway. The reason may be the denser population in Sweden and Denmark compared with Norway and Finland, so that public transport may be an alternative to private transport. It should be emphasized that all estimates of elasticities are associated with some uncertainty.

The income elasticity is greater than 1 for all countries except Norway. An income elasticity of more than 1 implies that a 1 per cent increase in income will increase consumption by more than 1 per cent.

In all analyses of energy demand an important factor is substitution between different forms of energy. As far as road transport is concerned, only two forms of energy are relevant, namely gasoline and diesel. In all the Nordic countries, price trends for both these forms of energy have been such that any substitution between the two cannot be put down to changes in the price of fuel. Substitution between gasoline and diesel is more likely to depend on conditions such as different price trends with regard to gasoline-driven and diesel-driven cars, different developments in the kilometer tax (a tax on the distance driven) or different levels of comfort.

Table 2.12. The share of the total energy consumption used in the road sector, growth rates of energy consumption and GDP in the Nordic countries. Per cent

	Road sector's share of total energy consumption (1988)	Annual growth rate in energy consumption in the road sector 1970-1988	Annual growth rate in total energy consumption 1970-1988	Annual growth rate in GDP 1970-1988
Denmark	19	1.9	-0.5	2.1
Finland	15	3.7	1.7	3.4
Norway	14	3.5	1.9	4.0
Sweden	18	2.6	0.1	2.0

Source: OECD (1970-88).

Table 2.13. Long-term price and income elasticities for gasoline

	Price	Income
Denmark	-1.39	1.67
Finland	-0.70	1.36
Norway	-0.86	0.84
Sweden	-1.48	1.06

2.7. Analysis: Model for the power sector in Norway

The macroeconomic model MSG has been made more suitable for analyzing problems connected to energy and the environment by improving the modelling of the power sector and the power market in Norway.

Relevant problems

Pollution problems connected to combustion of fossil fuels can initiate measures to reduce use of these forms of energy. Relevant instruments are quotas, direct regulation, standards and taxes. Measures directed at reducing combustion of fossil fuels will turn the demand for energy in the direction of hydropower.

The Energy Act which entered into force on 1 January 1991 is intended to promote more market-based sales of electricity in Norway. The Act requires the power companies to distinguish between production units and transmission and distribution units. In 1991 it was also decided to divide Statkraft into two public companies; a production company and a company producing transmission services. These reforms require better modelling of behaviour, cost conditions and mechanisms in the power market.

Production of electricity from gas-fired power stations is becoming a steadily more relevant issue. There are large reserves of gas in the North Sea, and the use of natural gas to produce electricity is one of several proposed applications. Introduction of electricity based on gas will influence the supply of electricity. The localization of a possible gas-fired power station will affect the demand for transmission services, and production of such.

Cooperation and exchange of power between participants in the national power markets in the Nordic countries is being steadily extended. Greater potential for Norwegian export of power could increase the alternative value of Norwegian electricity production. It can in-fluence profitability in the Norwegian electricity sector and help to change the distribution between export and domestic use of electricity. Increased trading will also improve the possibilities of importing power in periods with low domestic production of electricity.

Changes in the Norwegian industrial structure will affect production in the different parts of the power sector. Deliveries of power to energy-intensive industry require fewer distribution services than deliveries to the service sector, for example. An economic development where power consumption in the service sector increases more rapidly than the consumption in energy-intensive industry will imply having to extend production of distribution services at a faster rate than the electricity production itself.

In Norway, the price of electricity is different for different groups of consumers. Some of this difference can be explained by variations in utilization time and transmission and distribution costs. However, some price differences cannot be explained by differences in costs. These are assumed to be a result of price discrimination between different groups of purchasers of electricity. The costs differences in the transmission and distribution networks are of major importance in analyses of the effects of changes in price discrimination in the power market.

Main features of the model

In the empirical model developed for the power sector, see Johnsen (1991), the power sector is defined as consisting of four production sectors: *hydropower, gas-based power, transmission services and distribution services.* The model specifies cost functions for each of these sectors. Would-be purchasers of electricity are grouped into sectors corresponding to the sectors in MSG.

The reason for choosing to establish a power sector model as part of MSG is because, in certain analyses, it will be interesting to study the interaction between the power market and the rest of the economy. Power development requires large investments, and it is often interesting to study the macroeconomic consequences of increased demand from the power sector for capital. On the other hand, the price of power decided in the power sector model will be important for the future structure of industry.

Each sector's demand for power can be decomposed into firm and surplus power. The distribution between firm and surplus power determines each sector's demand for distribution and transmission services. The total demand for electricity delivered from the power station is obtained by adding up all the sectors' demand for power, and adding the calculated loss in the transmission and distribution networks.

The purchaser price of electricity to a particular sector consists of the price of electricity delivered from the power station, the price of transmission services, the price of distribution services and an electricity tax, and also VAT for sectors where VAT is not refunded. In principle, the price of electricity delivered from the power station is the same for all users. Given realized purchaser prices, taxes and transmission and distribution costs during the base year, a price discrimination coefficient is calculated for each sector. This coefficient is included as a sector-specific variable in the comparisons of purchaser prices.

The power sector model is linked to MSG as a special block. MSG's figures for electricity demand are used in the power sector model to determine prices of electricity that give equilibrium between demand and supply in the power market. It is also checked whether the equilibrium price is high enough to make it profitable to extend production capacity for hydropower or electricity based on gas. In this way, the model is used to calculate an equilibrium solution where supply and demand for power are in balance.

The power sector model can also be used more passively/partially. For example, it is possible to define the different sectors' demand for electricity in advance (exogenous variables). The model can then be used to calculate what electricity must cost to make it profitable to produce and make available the amount of electricity demanded.

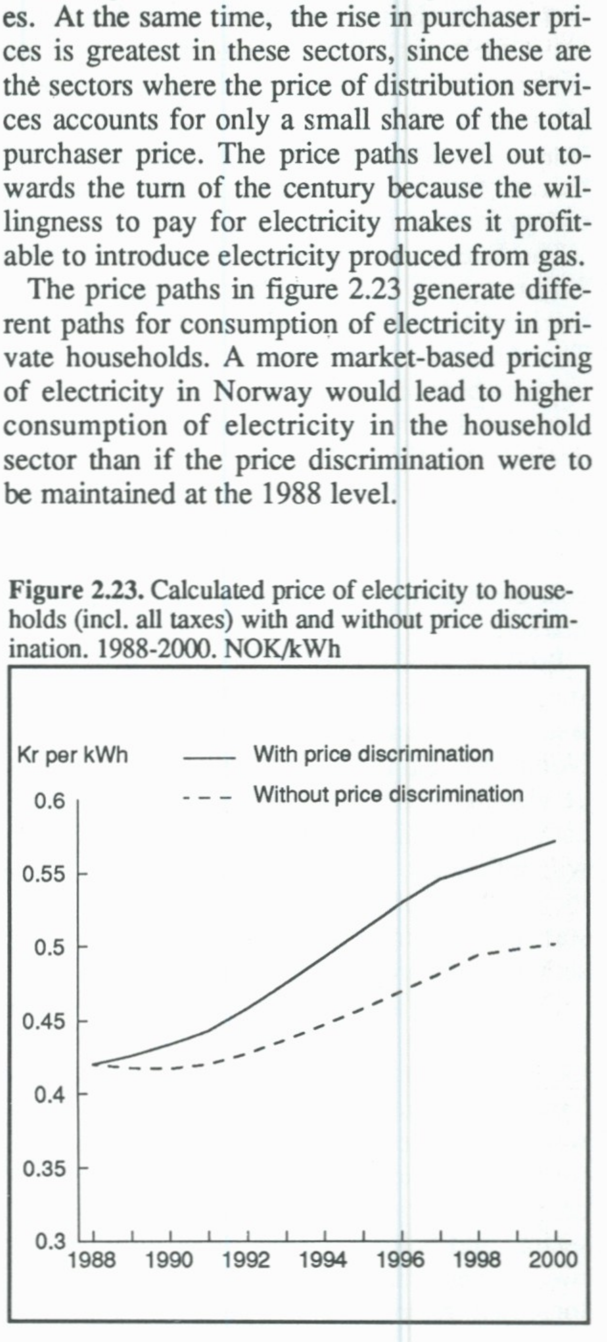
Examples of use of the model

The power sector model has not yet been used for detailed analyses. However, figure 2.23 illustrates the type of result to be obtained from the model. The figure shows changes in purchaser prices of electricity to households given two different assumptions about price discrimination in the power market. In the first case, the price discrimination in the Norwegian power market is removed, while the other path is based on price discrimination at the 1988 level.

If the price discrimination in the power market is removed, the change is moderate. This is due to a greater decrease in demand in the sectors which ordinarily have much to gain from price discrimination, than in the sectors where the price of electricity is high. Price sensitivities are higher in sectors where the price increases. At the same time, the rise in purchaser prices is greatest in these sectors, since these are the sectors where the price of distribution services accounts for only a small share of the total purchaser price. The price paths level out towards the turn of the century because the willingness to pay for electricity makes it profitable to introduce electricity produced from gas.

The price paths in figure 2.23 generate different paths for consumption of electricity in private households. A more market-based pricing of electricity in Norway would lead to higher consumption of electricity in the household sector than if the price discrimination were to be maintained at the 1988 level.

Figure 2.23. Calculated price of electricity to households (incl. all taxes) with and without price discrimination. 1988-2000. NOK/kWh



2.8. Units and conversion factors

Table 2.14. Average energy content, degree of efficiency and density, by source of energy

Energy source	Theoretical energy content	Unit	Fuel efficiency			Density
			Manuf. Mining	Trans-port	Other use	
Coal	28.1	TJ/ktonnes	0.80	0.10	0.60	..
Wood[1]	8.4	TJ/kfm^3	0.65	-	0.65	0.5 tonnes/fm^3
Paper waste (dry matter)	12.6-15.5	TJ/ktonnes	..	..	..	..
Wood waste (dry)	15.0-18.5	TJ/ktonnes	..	..	..	..
Crude oil	42.3	TJ/ktonnes	..	..	..	0.85 tonnes/m^3
Natural gas	40.6	TJ/MSm^3	..	..	..	0.77-1.07kg/Sm^3
Liquid propane and butane (LPG)	46.0	TJ/ktonnes	0.95	-	0.95	0.53 tonnes/m^3
Gasoline	44.0	TJ/ktonnes	0.20	0.20	0.20	0.74 tonnes/m^3
Kerosene	42.7	TJ/ktonnes	0.80	0.30	0.75	0.79 tonnes/m^3
Diesel-, gas-, heating oil 1 and 2	42.3	TJ/ktonnes	0.80	0.30	0.70	0.83 tonnes/m^3
Heavy oil	41.9	TJ/ktonnes	0.90	0.30	0.75	0.95 tonnes/m^3
Electricity	3.6	TJ/GWh	1.00	0.95	1.00	

[1] fm^3 = m^3 solid wood.

Table 2.15. Energy units[1]

	PJ	TWh	quad (oil)	Mtoe (oil)	Mbarrel (oil)	GSm^3 (bcm) (gas)	GScuft (gas)
1 PJ	1	0.278	9.50x10^{-4}	0.024	0.175	0.025	0.83
1 TWh	3.60	1	3.42x10^{-3}	0.085	0.629	0.088	3.00
1 quad (oil)	1053	292.5	1	24.9	184.1	25.6	877.5
1 Mtoe (oil)	42.3	11.8	0.04	1	7.4	1.03	35.3
1 Mbarrel (oil)	5.72	1.59	5.4x10^{-3}	0.135	1	0.141	4.8
1 GSm^3 (bcm) (gas)	40.6	11.3	3.9x10^{-2}	0.97	7.1	1	33.7
1 GScuft (gas)	1.20	0.33	1.1x10^{-3}	0.028	0.21	0.03	1

[1] 1 quad = 10^{15} Btu (British thermal units).
1 Mtoe = 1 mill. tonnes of (crude) oil equivalents.
1 Mbarrel=1 million barrels crude oil (1 barrel=0.159 m^3).
1 GSm^3 = 1 billion standard cubic meters natural gas.
1 GScuft = 1 billion standard cubic feet natural gas.
(1 Scuft = 0.0283 Sm^3).

Table 2.16. Prefixes

Name	Symbol	Factor
Kilo	k	10^3
Mega	M	10^6
Giga	G	10^9
Tera	T	10^{12}
Peta	P	10^{15}
Exa	E	10^{18}

2.9. Appendix of tables

Table 2.17. Reserve accounts for crude oil. Developed fields and fields to be developed. 1986-1991. Million tonnes of oil equivalents

	1986	1987	1988	1989	1990	1991
Reserves per 1/1	733	838	870	1028	916	1094
New fields	29	60	156	-	105	94
Re-evaluation	118	22	59	-38	155	11
Extraction	-42	-49	-57	-75	-82	-93
Reserves per 31/12 ...	838	870	1028	916	1094	1107
R/P-rate	20	18	18	12	13	12

Source: OD, CBS.

Table 2.18. Reserve accounts for natural gas. Developed fields and fields to be developed. 1986-1991. Million tonnes of oil equivalents

	1986	1987	1988	1989	1990	1991
Reserves per 1/1	387	1259	1247	1267	1258	1230
New fields	893	8	17	-	19	54
Re-evaluation	7	10	33	22	-18	19
Extraction	-28	-30	-30	-31	-28	-27
Reserves per 31/12 ...	1259	1247	1267	1258	1230	1275
R/P-rate	45	42	43	41	44	47

Source: OD, CBS.

Table 2.19. Extraction, conversion and use[1] of energy sources. 1990*. PJ

	Total	Coal	Coke	Fuelwood, paper waste, other solid waste	Crude oil	Natural gas	Petroleum products[2]	Electricity	District heating
Extraction of energy sources	5041	9	-	-	3418	1129	48	436	-
Energy use in extraction sectors	-87	-	-	-	-	-79	-2	-6	-
Imports and Norwegian purchases abroad	559	20	28	0	69	-	442	1	-
Exports and foreign purchases in Norway	-4378	-7	-4	0	-2897	-1030	-380	-58	-
Stocks (+Decrease, -Increase)	-61	0	-1	.	-62	.	1	.	-
Primary supply	1074	21	23	0	527	20	109	373	-
Petroleum refineries	-35	-	6	-	-539	0	500	-2	-
Other energy sectors, other supply	43	-1	-	36	-	-	3	0	5
Registered losses, statistical errors	-38	0	0	-	12	-20	-1	-26	-2
Registered use outside energy sectors	1044	21	29	36	-	-	610	346	3
Ocean transport	309	-	-	-	-	-	309	-	-
Domestic use	736	21	29	36	-	-	302	346	3
Agriculture and fishery	32	0	-	-	-	-	28	4	0
Energy intensive manufacturing	200	13	24	0	-	-	54	109	0
Other manufacturing and mining	109	7	5	17	-	-	24	56	0
Other industries	190	-	-	-	-	-	117	71	1
Private households	204	0	0	19	-	-	78	106	1

[1] Including energy goods used as raw materials.

[2] Including liquefied gas. Coke includes petrol coke.

Table 2.20. Extraction, conversion and use[1] of energy sources. 1990*

	Coal	Coke	Fuelwood, paper waste, other solid waste	Crude oil	Natural gas	Petroleum products[2]	Electricity	District heating
	1000 t	1000 t	1000 toe	1000 t	Mill. Sm^3	1000 t	GWh	GWh
Extraction of energy sources	311	-	-	80812	27817	1050	121137	-
Energy use in extraction sectors	-	-	-	-	-1942	-54	-1554	-
Imports and Norwegian purchases abroad	713	901	0	1623	-	10380	283	-
Exports and foreign purchases in Norway	-254	-119	0	-68493	-25380	-8800	-16233	-
Stocks (+Decrease, -Increase)	-9	-15	.	-1473	.	42	.	-
Primary supply	762	767	0	12469	495	2618	103633	-
Petroleum refineries	-	161	-	-12743	0	11651	-449	-
Other energy sectors, other supply	-23	-	844	-	-	66	114	1435
Registered losses, statistical errors	-5	-7	-	274	-496	-14	-7298	-552
Registered use outside energy sectors	734	922	844	-	-	14316	96000	883
Ocean transport	-	-	-	-	-	7353	-	-
Domestic use	734	922	844	-	-	6963	96000	883
Agriculture and fishery	6	-	-	-	-	652	1223	3
Energy intensive manufacturing	458	779	3	-	-	1182	30160	106
Other manufacturing and mining	263	142	401	-	-	565	15438	109
Other industries	-	-	-	-	-	2764	19737	349
Private households	7	1	440	-	-	1800	29442	316

[1] Including energy goods used as raw materials.

[2] Including liquefied gas. Coke includes petrol coke.

Table 2.21. Electricity balance[1]. 1975 - 1991. TWh

	1975	1980	1985	1986	1987	1988	1989	1990*	1991*
Production	77.5	84.1	103.3	97.3	104.3	110.0	119.2	121.6	110.9
+Import	0.1	1.8	4.1	4.2	3.0	1.7	0.3	0.3	3.2
-Export	5.7	2.3	4.6	2.2	3.3	7.4	15.2	16.2	6.0
=Gross domestic consumption	71.9	83.6	102.7	99.3	103.9	104.4	104.3	105.7	108.1
-Consumption in pumping plants	0.1	0.5	0.8	0.9	0.7	1.0	0.4	0.3	0.7
-Surplus power	3.2	1.2	4.8	2.7	4.1	4.5	5.6	5.8	7.2
-Losses in exports and surplus power	0.8	0.3	1.0	0.3	0.5	0.8	1.5	1.5	0.9
=Gross firm power consumption	67.7	81.6	96.2	95.4	98.6	98.1	96.9	98.1	99.3
Energy intensive industries	27.0	28.7	30.9	29.2	29.8	30.5	30.5	30.6	29.5
Regular consumption[2]	40.7	52.9	65.3	66.2	68.8	67.6	66.4	67.5	69.8
-Losses in the transmission lines, consumption in the power stations, statistical differences[3]	6.3	7.7	8.7	9.1	9.2	9.2	8.8	8.7	8.6
=Net firm power consumption[3]	61.4	73.9	87.5	86.4	89.3	88.9	88.1	89.4	90.7
Energy intensive industries	26.2	27.9	30.0	28.4	28.9	29.6	29.6	29.7	28.6
Regular consumption[2]	35.2	46.0	57.5	58.0	60.4	59.3	58.5	59.7	62.0
Regular consumption[2], temperature adjusted	36.3	45.1	55.0	57.1	58.6	60.2	61.7	63.7	63.3
Average annual change, per cent		4.4	4.0	3.8	2.6	2.7	2.5	3.2	-0.6

[1] The definitions in the table follow the definitions of the Electricity Statistics. The figures are preliminary.

[2] Firm power consumption outside energy intensive industries.

[3] In the Electricity Statistics the sum of losses and statistical differences is registered. From 1983 losses are estimated as the difference between gross and net electricity consumption in energy intensive industries plus an estimated loss in regular consumption of 14 per cent (from 1989 13.5 per cent). Net consumption appears as the difference between gross consumption and estimated losses. This estimation procedure implies a slight deviation between the figures for regular consumption and those of the Electricity Statistics.

Tabell 2.22. Use of energy sources outside the energy sectors and ocean transport[1]. 1976-1991. PJ

Energy source	1976	1980	1984	1985	1986	1987	1988	1989	1990*	1991*
TOTAL	607	680	714	735	739	764	753	735	736	736
Electricity	241	269	319	329	324	335	339	340	346	356
Firm power	232	265	302	312	315	321	323	320	325	330
Surplus power	9	4	17	17	10	15	16	20	21	26
Oil total	301	336	304	315	327	339	323	305	302	292
Oil other than transportation	159	138	76	81	91	84	77	66	60	54
Gasoline	9	3	0	0	0	0	0	0	0	0
Kerosene	17	16	7	9	10	11	10	8	7	6
Medium distillates	66	63	41	43	43	45	42	39	37	34
Heavy fuel oil	66	56	28	29	37	29	25	19	16	14
Oil for transportation	141	157	178	182	197	200	194	196	194	187
Gasoline, gasoline type jet fuel, kerosene type jet fuel	74	82	89	92	100	102	103	103	103	99
Medium distillates	64	71	81	83	89	90	85	87	86	85
Heavy fuel oil	3	5	8	7	8	7	6	6	4	3
Liquefied gas	1	41	50	52	40	56	52	43	49	51
District heating	.	.	.	.	.	3	3	3	3	3
Solid fuels	65	74	91	91	88	86	88	87	85	85
Coal, coke	47	49	60	57	53	51	53	51	50	50
Fuelwood, paper waste, other solid waste	18	25	31	34	34	35	34	36	36	36

[1] The time series has been adjusted.

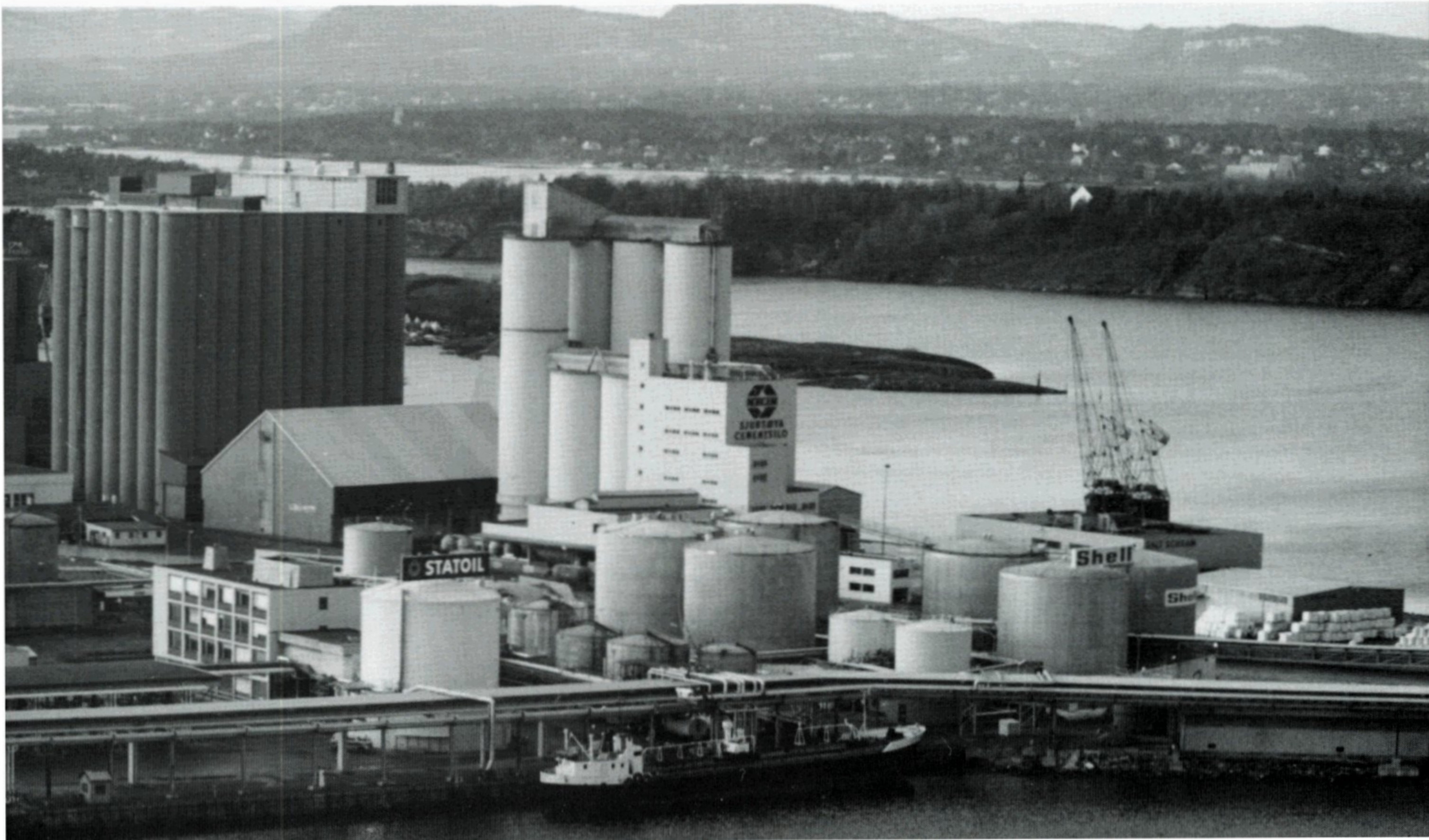
Tabell 2.23. Average prices[1] of electricity[2] and selected petroleum products. Delivered energy. 1981-1991

Energy source	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990*	1991*
Heating products:											
Price øre/kWh											
Electricity[3]	20.1	23.2	26.9	30.5	32.7	35.6	37.9	41.7	43.0	45.9	47.3
	(17.5)	(20.2)	(23.4)	(26.5)	(28.5)	(31.6)	(34.3)	(37.2)	(38.6)	(41.4)	(42.2)
Heating kerosene .	26.9	30.5	31.8	32.5	32.8	24.8	25.0	25.7	28.3	33.9	40.1
Fuel oil no. 1	22.8	25.1	26.2	26.9	27.2	19.4	19.6	19.7	21.6	26.6	31.9
Fuel oil no. 2	21.7	23.8	25.0	25.7	25.7	18.1	18.3	18.8	20.7	25.7	30.8
Heavy fuel oil ...	13.8	13.7	14.8	17.7	17.8	10.4	12.4	11.7	14.7	19.1	23.3
Transportation products:											
Price øre/litre											
Super gasoline ...	435.0	460.5	492.5	520.9	512.8	476.0	510.0	536.0	578.5	642.8	741.0
Regular gasoline .	427.0	451.7	480.2	505.3	501.8	.	.	.	.	.	.
Unleaded gasoline	.	.	.	.	521.2	457.0	489.0	503.0	540.5	596.9	681.2
Auto diesel	240.0	262.7	272.3	280.3	282.0	207.6	210.0	214.0	233.0	285.9	341.0

[1] All taxes included.

[2] Households and agriculture.

[3] The figures in parentheses comprise the variable part of the price (the energy part of the H4-tariff).



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3. AIR

Each year CBS, in cooperation with the State Pollution Control Authority (Statens Forurensningstilsyn - SFT), prepares inventories of Norwegian emissions of several polluting compounds. The emission figures for the last couple of years reflect a gradual reduction in the use of petroleum products in "Mainland-Norway" but, at the same time, more activity in the North Sea. The figures have also been influenced by improved combustion technology and quality criteria for oil products. Emissions of some components (SO_2, Pb and CO) have shown a tendency to decrease, while only small changes have been experienced in emissions of other components (NO_x, CO_2, particulates, N_2O, VOC and CH_4). Changes in emissions help, in their turn, to explain changes in the concentrations of air pollutants. The inventories are part of the overall monitoring of the environment and provide a basis for forecasts of future emissions to air and analyses of the effects of various pollution control measures. These measures normally represent a cost to society, but can also lead to benefits in the form of reduced harm to human health and damage to nature and various materials.

In recent years the importance of methane for changes in the greenhouse effect has been the object of increased research. This chapter includes a brief review of the importance of methane as a greenhouse gas.

3.1. Air pollution - some sources and effects

There are three main sources of emissions to air in Norway: stationary combustion, mobile combustion and so-called process emissions. In stationary combustion, coal, coke and oil products are burned in small or large stoves, furnaces, turbines or flares. The purpose is usually to provide heat or power for industrial processes and other forms of heating. Emissions from mobile combustion are characterized by use of fossil fuels to drive an engine. Examples are motor vehicles, boats, aircraft and motorized tools. Process emissions are characterized as originating from processes other than combustion. A major part of these emissions originate from industrial processes, but emissions from other activities such as domestic animal husbandry/manuring and deposition of waste are also categorized as emissions from processes. Use of coal or coke as a reducing agent in the production of metals is also regarded as a process. Solvents and distribution of oil products create emissions by evaporation. It is important to classify the emissions by source in order to be able to evaluate countermeasures. The measures can be directed at both combustion conditions (furnaces and engines) and the sources of energy (energy carriers). Examples of measures are catalytic converters in cars, more stringent quality criteria for oil products and/or taxes to reduce use of especially polluting products. The emissions can also be reduced by cleaning or by modifying production and/or distribution routines.

Air pollution in Norway is caused partly by Norwegian emissions from industry, transport and heating systems, and by long-range transported pollution from other countries (transboundary pollution). *Norwegian emissions* are the main source of the local pollution which impairs health and damages materials, while *transboundary pollution* is the main source of acidification of the environment. The damaging effects may be difficult to predict. They depend on the concentration of the different polluting components and the duration of exposure of humans and the environment. The concentration is determined by the intensity and location of the emissions, weather, and other conditions which can affect spreading and transformation of the emissions. In the case of some components the damage does not occur until the concentration exceeds a certain critical level. For other components even low concentrations involve risk of damage. This applies in particular to emissions with carcinogenic properties.

In recent years, global environmental problems due to increased emissions to air have been the subject of marked attention. The global thermal balance is dependent, inter alia, upon the chemical composition of the atmosphere. Without the atmosphere, the global mean temperature would have been about 32 degrees centigrade lower than it is today. The atmosphere absorbs some of the heat radiated from the earth, but lets through almost all the radiation from the sun. It is this that is called *the greenhouse effect.* Many people fear that increased emissions of certain components during the last century are destroying the natural thermal balance, and thus causing a change in the earth's climate. The most important greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), freons, ozone (O_3) and water vapour. Emissions of other components can influence the thermal balance of the globe indirectly through chemical reactions in the atmosphere.

Human beings and the natural environment are protected from the harmful effects of ultraviolet radiation by ozone, which functions as a filter in the stratosphere (the layer of the atmosphere roughly 15-50 km above the earth). Several measurements indicate that this ozone layer has become thinner in recent years. This may be due to increased emissions of pollutants. Emissions of chlorofluorocarbons (CFCs) and halons are regarded as particularly harmful, because these classes of chemical compounds have a very long lifetime (100-200 years) in the troposphere (roughly the lower 0-15 km of the atmosphere). When they reach the stratosphere, on the other hand, they decompose, and may start chain reactions where each molecule can contribute to the destruction of thousands of ozone molecules.

The effects of air pollution are sometimes due to secondary pollutants. These are substances generated, for instance, during oxidation of the original emissions. An example: Emissions of the base ammonia (NH_3) has a net acidifying effect on the earth by oxidation.

$$NH_3 + \text{oxidizing agent} \Rightarrow NO_3^- + H^+$$

Ozone is formed in the troposphere through reactions between nitrogen oxides (NO_x) and hydrocarbons or carbon monoxide (CO) under the influence of solar radiation. Increased concentrations of ozone in the troposphere are damaging to humans and the natural environment. Sulphate (SO_4^{2-}) is formed by oxidation of sulphur dioxide (SO_2) or other sulphur compounds.

Table 3.1 shows some sources, effects and critical levels associated with the most important air pollution problems. Limit for health damage ("critical level") means the level of pollution to which a population can be exposed without risk of damage to health.

Table 3.1. Sources, damage and critical levels associated with some polluting compounds

Compound	Source	Damage	Critical level
Sulphur dioxide	Combustion of oil Transportation Process emissions: - Refining - Manuf. of basic metals - Silicon carbide - Paper and paper products	*Health:* SO_2 together with dust increases the risk of respiratory diseases. *Nature:* Damage to vegetation. Acidification of water and soil. Corrosion. Influences global thermal balance	Health: 100-150 $\mu g/m^3$ (day) 40-60 $\mu g/m^3$ (half year) Vegetation: 30 $\mu g/m^3$ (half year)
Nitrogen oxides	Transportation Combustion of oil Process emissions: - Manuf. of fertilizers - Manuf. of basic metals	*Health:* Increase the risk of respiratory diseases. NO_2 more harmful than NO. *Nature:* Contribute to acidification of water and soil. Produce ozone through reaction with VOC or CO under influence of solar radiation. Corrosion (only to a limited degree). Influence the oxidation capacity of the atmosphere.	Health (NO_2): 200 $\mu g/m^3$ (hour) 100-150 $\mu g/m^3$ (day) 75 $\mu g/m^3$ (half year)
Carbon monoxide	Transportation Burning of wood Combustion of oil Process emissions: - Silicon carbide - Metal production	*Health:* CO adheres to red blood cells and reduces the uptake of oxygen. Effects: - Increased risk of cardiac spasm - Reduced activity for healthy people - Lower birth-weight of children *Nature:* Influences the oxidation capacity of the atmosphere. Produces ozone through reactions with NO_x under influence of solar radiation	Health: 25 mg/m^3 (hour) 10 mg/m^3 (8-hours)
Volatile organic compounds	Transportation Burning of wood Combustion of oil Solvents Filling stations Oil loading Oil and gas extraction Refining	*Health:* Might contain carcinogenic substances like PAH and benzene *Nature:* Produces ozone through reaction with NO_x under influence of solar radiation. Influences the oxidizing capacity of the atmosphere	
Polycyclic aromatic hydrocarbons	Burning of wood Aluminium plants	*Health:* PAH in air might cause cancer in the respiratory system	
Ammonia	Use of commercial fertilizers and manure Ammonia production	*Nature:* Contributes indirectly to acidication of water and soil. Direct damage to vegetation near sources of emission	
Soot	Burning of coal Burning of wood Transportation	*Health:* Soot together with SO_2 can cause respiratory diseases. Soot is often a carrier of carcinogenic substances (Lead, PAH)	Health: 100-150 $\mu g/m^3$ (day) 40-60 $\mu g/m^3$ (half year)
Dust	Burning of coal Dust from roads (studded tyres)	*Well-being:* Dust cover on vegetation and constructions in the vincinity of the emission sources	
Lead	Gasoline-driven cars	*Health:* Increased risk of coronary diseases and spontaneous abortion. Altered behavioural pattern and reduced intelligence and fertility. Anemia	Health: 1.5 $\mu g/m^3$ (half-year)
Photo-chemical oxidants (Ozone, PAN)	Formed in the atmosphere by reactions with NO_x, CO, hydrocarbons under the influence of solar radiation	*Health:* Can cause respiratory diseases. *Nature:* Damage to forests and other vegetation *Materials:* Damage to for example rubber and plastics	Vegetation: 200 $\mu g/m^3$ (hour) Health: 100-200 $\mu g/m^3$ (hour) measured as O_3 concentration

Table 3.1 continued

Compound	Source	Damage	Critical level
Carbon dioxide	Fossil fuels Deforestation/landuse changes, burning of biomass Manufac. of cement	Contributes to increased greenhouse effect	
Methane	Domestic animals/ manure Deposition of waste Extraction: oil, gas, coal Oil loading Burning of wood Fossil fuels	Contributes directly to increased greenhouse effect, entails tropospheric ozone production and alteration of the characteristics and composition of the atmosphere. (Methane also affects stratospheric ozone.)	
Nitrous oxide	Fossil fuels, burning of biomass, fertilizers, microbiological processes	Contributes to increased greenhouse effect. Reduces the stratospheric ozone layer.	
Chlorofluoro-carbons	Refrigeration installations, chemical cleaning, aerosols Foam plastic production	Reduces the stratospheric ozone layer. Contributes to the greenhouse effect.	
Halons	Fire extinguishers	Reduces the stratospheric ozone layer	

Source: CBS.

Sulphur dioxide	SO_2
Sulphate	SO_4^{2-}
Nitrogen oxides	NO_x(NO and NO_2)
Carbon monoxide	CO
Carbon dioxide	CO_2
Lead	Pb
Ozone	O_3
Methane	CH_4
Nitrous oxide	N_2O
Chlorofluorocarbons	CFC
Halons	$Br_xCl_yF_zC$
Ammonia	NH_3
Volatile organic compounds (not including methane)	NMVOC

Box 3.1. Some chemical formulas and abbreviations

3.2. Emissions to air in Norway

Inventories of emissions to air have been compiled for sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), non-methane volatile organic compounds (NMVOC), particulates and lead (Pb) for the years 1973-1989. Inventories have been compiled for methane (CH_4) and nitrous oxide (N_2O) for the years 1987-1989. Emissions of ammonia (NH_3) have been calculated for 1988 and 1989. The State Pollution Control Authority (SFT) has estimated preliminary figures for 1990 and 1991. Cruder estimates also exist for some components for the period 1960-1972. In general, the inventories for earlier years are less detailed and more uncertain than those for later years. The emission inventories for more recent years have been calculated on the basis of surveys of energy consumption (Resource Accounts for Energy, and Manufacturing Statistics from the Central Bureau of Statistics). Consumption of the different forms of energy is distributed between the different assumed purposes within each economic sector (MODIS IV).

The consumption is multiplied by emission coefficients connected to source of combustion, form of energy and type of industry. The calculations also take into account information on companies with a discharge permit from SFT, in which case the estimated figures are replaced by reported and/or measured values. Process emissions and emissions caused by evaporation are estimated on the basis of information on the different activities. This includes data reported to SFT, conclusions in relevant reports and specific emission coefficients connected, for example, to volume of production. The figures for fuel consumption, the emission coefficients, distribution by source and other parameters are all associated with a degree of uncertainty. Least uncertainty is connected to the emission coefficients for CO_2, Pb and SO_2. Here the emission coefficients refer respectively to the carbon, lead and sulphur content of the fuel. Emissions of other components from fuel consumption are determined to a large extent by the combustion conditions. Greatest uncertainty is connected to the emission coefficients for NMVOC, N_2O, and CH_4. Process emission figures that are not connected to industrial enterprises are generally uncertain.

The emission coefficients are adjusted somewhat from year to year depending on changes in the chemical composition of the fuels, changes in combustion technologies and new knowledge. The historic figures for NMVOC from several sources, NO_x in connection with petroleum activities, methane from wood heating, and nitrous oxide from gasoline-driven cars have been changed this year in the light of new knowledge on emission coefficients. New sources or new methods of calculation have also been taken into account, mainly for emissions in the category process emissions/evaporation. Here too the historic emission figures have been updated. This applies to process emissions of lead, NMVOC from gasoline distribution and oil refineries, methane and NMVOC from oil extraction, and methane from coal extraction and domestic animal hus-

Table 3.2. Emission coefficients for NO_x, NMVOC, CO and particulates. 1989

	NO_x	NM-VOC	CO	Particulates
	kg/tonne			
Stationary combustion				
Natural gas				
Industry	13.3	0.5	1.8	0.00
Heating kerosene				
Households	2.5	0.6	6.5	0.30
Industry	3.0	0.4	2.0	0.25
Heating oil				
Households	2.5	0.6	6.5	0.30
Industry	3.0	0.4	2.0	0.25
Heavy oil				
Households	4.2	0.3	0.4	1.30
Industry	5.0	0.3	0.2	1.30
Coal				
Households	1.4	10.0	10.0	8.50
Industry	4.5	0.8	3.0	1.40
Wood				
Households	0.7	6.9	100.0	10.00
Industry	0.9	1.3	15.0	2.40
Mobile sources				
Marine fuels				
Ocean transport	70.0	2.5	5.0	1.20
	g/km			
Road traffic				
Light vehicles				
Gasoline	1.97	1.60	15.5	0.05
Diesel	1.40	1.00	2.0	0.41
Heavy vehicles				
Gasoline	7.00	4.60	44.4	0.13
Diesel	12.7	1.38	2.4	0.78

Source: CBS, SFT.

Table 3.3. Emission coefficients for SO_2 and CO_2.1989

	Kg SO_2/tonne energy source	Tonnes CO_2/tonne of energy source[1]
Natural gas	0.0	2.75
LPG (propane)	0.0	3.00
Kerosene	0.4	3.15
Gasoline	0.6	3.15
Heating oils	3.4	3.15
Diesel	3.4	3.15
Marine fuel	3.4	3.15
Special distillate	7.0	3.15
Heavy oil LS	18.2	3.15
Heavy oil NS	39.4	3.15
Coal, industry	16.0	2.42
Coal, households	20.0	2.42
Wood	0.4	-[2]

[1] The emission coefficients for CO_2 are based on total carbon content of the fuels; i.e. the carbon in other emitted substances containing carbon are included in the coefficients for CO_2.
[2] Renewable source of energy, emissions included in the natural carbon cycle.
Source: NP, SFT, CBS.

bandry, as well as from several industrial sources. The estimates of emissions from use of solvents are very uncertain. These emissions are estimated to range from 30 000 to 50 000 tonnes per year. The calculation routines for estimating emissions from aircraft have been changed this year. The emissions are now calculated on the basis of fuel consumption by Norwegian aircraft and specific emission coefficients estimated from work carried out by the Norwegian Institute for Air Research (Norsk institutt for luftforskning - NILU). The emission figures cover emissions from Norwegian aircraft in Norway during all phases of the flight. Except in the case of CO_2, CH_4 and N_2O, the calculations were previously based only on number of take-off and landing cycles. The energy consumption used as a basis for calculating emissions from coastal sea transport have also been adjusted downwards, and now agree with the statistics on sales of petroleum products.

Tables 3.2 and 3.3 show some of the emission coefficients used to calculate emissions from fuel combustion.

The emission inventories give some indication of the pollution load. They thus provide a basis for assessing where to introduce various pollution control measures and show the effects of any measures introduced. They also provide the necessary data to make forecasts of emissions to air, and thereby to find out whether or not Norway is fulfilling national objectives and international agreements on reductions of emissions to air.

Emissions to air by economic sector and source of emission

Table 3.4 shows emissions of SO_2, NMVOC, CO, CO_2, particulates, Pb, CH_4, N_2O and NH_3 in 1989, distributed by economic sector. Table 3.5 shows the same emissions distributed by source of emission. In table 3.6 the emission figures for some of the main economic sectors are distributed between stationary and mobile sources and emissions from industrial processes/evaporation. Emissions from evaporation of solvents are only roughly distributed between sectors. The summary does not include emissions from foreign ships in Norwegian waters.

Table 3.4. Emissions to air by sector. 1989. 1 000 tonnes unless otherwise specified

Sector	SO_2	NO_x	CO	CO_2	NM-VOC	Particulates	Pb	CH_4	N_2O	NH_3
				Mill. tonnes			Tonnes			
Total	59.4	232.9	603.4	33.9	216.2	20.9	265.3	288.4	16.7	36.7
Energy sectors	7.3	45.6	9.5	7.8	103.0	1.0	1.7	33.5	0.6	-
Extraction of oil and gas[1]	1.3	41.9	4.9	6.4	95.9	0.3	0.0	27.2	0.4	-
Extraction of coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	-
Oil refineries	5.1	2.1	0.0	1.1	6.4	0.1	0.0	0.1	0.1	-
Electricity and water supply[2]	0.9	1.6	4.6	0.2	0.7	0.6	1.7	0.1	0.1	-
Manufacturing and mining	36.0	25.0	73.7	10.1	21.0	1.9	12.3	1.5	8.1	0.6
Pulp and paper industry	3.8	1.4	2.1	0.3	0.2	0.4	0.1	0.2	0.3	-
Manufacture of industrial chemicals	7.5	5.3	43.5	1.7	1.6	0.1	0.0	1.0	7.4	-
Manufacture of mineral products	3.4	5.4	0.7	1.7	0.3	0.3	0.1	0.0	0.1	-
Manufacture of iron, steel and ferro-alloys	11.6	6.4	0.1	3.1	1.8	-	10.0	0.0	0.0	-
Manufacture of other metals	5.3	1.6	20.2	2.0	0.1	0.1	0.0	0.0	0.1	-
Manufacture of metal products, boats, ships and platforms	0.4	1.0	1.0	0.2	7.2	0.1	0.5	0.0	0.0	-
Manufacture of wood, plastic, rubber, graphic and chemical products	1.6	1.4	4.8	0.3	8.4	0.7	0.6	0.1	0.1	-
Manufacture of consumer goods	2.5	2.6	1.3	0.7	1.5	0.3	0.6	0.0	0.1	-
Other	16.0	162.3	520.1	15.9	92.3	18.0	251.1	253.5	7.9	36.1
Building and construction	0.5	6.8	3.6	0.5	4.3	0.5	1.2	0.1	0.0	-
Agriculture and forestry	0.8	6.5	11.6	0.8	2.9	0.9	2.0	81.0	6.5	36.1
Fishing and hunting	1.9	31.4	2.8	1.4	1.2	0.6	0.4	0.4	0.1	-
Land transport, domestic	2.1	27.3	17.5	2.0	4.9	2.1	7.2	0.2	0.2	-
Sea transport, domestic	5.7	27.5	2.4	1.2	1.0	0.5	0.4	0.4	0.1	-
Air transport, domestic	0.1	3.0	2.6	1.0	0.5	0.1	2.1	0.0	0.1	-
Other private services	1.2	16.8	81.7	2.1	20.4	0.7	55.0	0.7	0.2	-
Public activities (municipal)[2]	0.4	0.3	0.5	0.3	0.1	0.0	0.2	158.4	0.0	-
Public activities (state)	0.5	6.2	2.5	0.8	0.5	0.2	0.7	0.1	0.1	-
Private households	2.8	36.4	395.0	5.7	56.5	12.5	181.3	12.3	0.6	-

[1] Includes gas terminals. [2] Includes emissions from waste incineration plants.
Source: CBS, SFT.

Table 3.5. Emissions to air by source. 1989. 1 000 tonnes unless otherwise specified

Source	SO_2	NO_x	CO	CO_2	NM-VOC	Par-ticu-lates	Pb	CH_4	N_2O	NH_3
				Mill. tonnes			Tonnes			
Total	59.4	232.9	603.4	33.9	216.2	20.9	265.3	288.4	16.7	36.7
Stationary combustion	14.7	41.7	130.0	13.2	12.5	13.8	1.8	14.8	2.0	-
Boilers and direct-fired industrial furnaces	10.2	11.9	6.7	4.4	1.0	1.7	0.4	0.5	0.9	-
Gas turbines	0.0	20.1	2.9	4.6	0.8	0.0	-	1.4	0.3	-
Flares	0.0	5.4	0.6	1.2	1.9	0.0	-	2.7	0.1	-
Non-industrial boilers and small stoves	4.0	3.4	119.5	2.9	8.5	12.1	0.1	10.1	0.7	-
Incineration of waste	0.4	1.0	0.2	0.1	0.3	-	1.3	-	-	-
Mobile combustion	14.1	180.4	410.1	14.1	61.8	7.2	253.3	4.4	0.9	-
Road traffic	3.8	83.1	364.3	8.0	42.1	4.0	243.3	3.2	0.5	-
Light vehicles	1.4	44.0	330.3	5.5	35.5	1.8	224.3	2.7	0.3	-
Gasoline	1.0	41.5	326.9	5.0	33.7	1.1	224.2	2.7	0.2	-
Diesel	0.5	2.4	3.4	0.4	1.7	0.7	0.0	0.0	0.1	-
Heavy vehicles	2.4	39.1	34.0	2.6	6.6	2.2	19.1	0.4	0.2	-
Gasoline	0.1	4.3	27.4	0.4	2.8	0.1	19.0	0.2	0.0	-
Diesel	2.3	34.8	6.6	2.2	3.8	2.1	0.1	0.2	0.2	-
Motorcycles, two-stroke engines, tractors and motor-driven tools ...	0.7	10.1	35.6	0.8	15.1	1.5	7.1	0.1	0.0	-
Railways	0.1	0.5	0.2	0.1	0.1	0.1	0.0	0.0	0.0	-
Air traffic	0.2	4.1	3.5	1.4	0.6	0.2	2.1	0.0	0.1	-
Ships and boats	9.3	82.6	6.5	3.8	3.9	1.4	0.6	1.1	0.2	-
Processes and evaporation	30.6	10.7	63.3	6.6	142.0	-	10.0	269.2	13.7	36.7
Domestic animals and manuring ...	-	-	-	-	-	-	-	80.9	6.4	36.1
Liming	-	-	-	0.2	-	-	-	-	-	-
Biological degradation of waste	-	-	-	0.0	-	-	-	158.4	-	-
Evaporation, solvents	-	-	-	-	31.6	-	-	-	-	-
Gasoline distribution	-	-	-	-	9.4	-	-	-	-	-
Oil loading	-	-	-	-	82.7	-	-	6.3	-	-
Refining, crude oil and natural gas .	4.2	-	-	-	6.6	-	-	0.4	-	-
Extraction: crude oil, natural gas and coal	-	-	-	-	8.6	-	-	22.2	-	-
Transformation of nitrogen to artifical fertilizers	-	3.9	-	0.4	-	-	-	-	7.3	0.6
Reduction of iron ore to metals and alloys	15.6	6.8	20.0	4.7	1.3	-	-	-	-	-
Use of coke and coal for production of carbides	4.9	-	43.3	0.4	-	-	-	1.0	-	-
Transformation of gas to basic plastic	-	-	-	-	0.8	-	-	-	-	
Use of sulphurous solutions, manufacture of cellulose	2.1	-	-	-	-	-	-	-	-	-
Transformation to mineral products	0.9	-	-	0.8	-	-	-	-	-	-
Other industrial processes[1]	2.8	-	-	-	0.8	-	10.0	-	-	-

[1] Production of sulphuric acid (SO_2), anode mass (SO_2), titanium dioxide (SO_2), fermentation processes (NMVOC), processing of sulphurous ore (SO_2) and recycling of scrap iron (Pb).
Source: CBS, SFT.

Table 3.6. Emissions to air in 1989 by main source of emission and main sector. 1 000 tonnes unless otherwise specified

Sources and sectors	SO_2	NO_x	CO	CO_2	NM-VOC	Par-ticu-lates	Pb	CH_4	N_2O	NH_3
				Mill. tonnes			Tonnes			
Stationary combustion	14.7	41.7	130.0	13.2	12.5	13.8	1.8	14.8	2.0	-
Energy sectors	1.9	30.9	7.6	7.1	3.5	0.7	1.2	4.3	0.6	-
Primary industries	0.4	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0	-
Manufacturing and mining	9.2	7.7	6.5	3.3	0.8	1.6	0.4	0.4	0.8	-
Supply of services	1.3	0.8	0.7	1.0	0.1	0.1	0.1	0.0	0.2	-
Private households	1.9	2.1	115.1	1.6	8.0	11.3	0.0	10.0	0.4	-
Mobile combustion	14.1	180.4	410.1	14.1	61.8	7.2	253.3	4.4	0.9	-
Energy sectors	1.2	14.6	1.9	0.7	1.5	0.3	0.5	0.2	0.0	-
Primary industries	2.3	37.7	14.2	1.8	4.0	1.4	2.5	0.5	0.1	-
Manufacturing and mining	0.4	6.6	3.9	0.4	0.9	0.3	1.9	0.1	0.0	-
Supply of services	9.3	87.1	110.1	7.0	16.9	3.9	67.0	1.5	0.5	-
Private households	0.9	34.4	280.0	4.1	38.5	1.2	181.3	2.2	0.2	
Processes/evaporation	30.6	10.7	63.3	6.6	142.0	0.0	10.0	269.2	13.7	36.7
Energy sectors	4.2	-	-	-	98.0	-	-	28.9	-	-
Primary industries	-	-	-	0.2	-	-	-	80.9	6.5	36.1
Manufacturing and mining	26.4	10.7	63.3	6.4	19.3	-	10.0	1.0	7.3	0.6
Supply of services	-	-	-	0.0	14.7	-	-	158.4	-	-
Private households	-	-	-	-	10.0	-	-	-	-	-

Source: CBS, SFT.

Emissions in Norway 1973-1991

The historical trend in emissions to air can be explained mainly by changes in economic activity, use of energy, technology and measures to reduce emissions. Changes in the use of the different forms of energy are described in more detail in Chapter 2. This section describes the most important trends in emissions of SO_2, NO_x, CO, NMVOC, particulates, lead and CO_2 during the period 1973-1991. Inventories are available for methane (CH_4) and nitrous oxide (N_2O) for the last three years only. Ammonia emissions have been estimated for 1988 and 1989 only. The figures for 1990 and 1991 are preliminary estimates by SFT, and are not distributed by sector or by source.

There was a marked reduction in **emissions of SO_2** during the period 1973-1991, see figure 3.1. Emissions from stationary combustion decreased from 73 000 tonnes in 1973 to 15 000 tonnes in 1989, and emissions from processes from 67 000 tonnes to 31 000 tonnes during the same period. The reductions in SO_2-emissions can be put down to several factors:

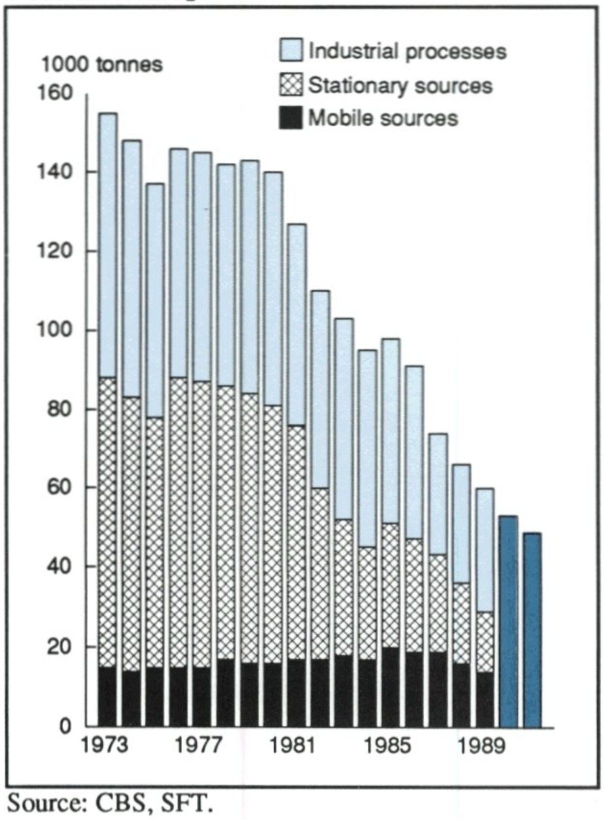
– The sulphur content of several oil products has been reduced. Regulations concerning the sulphur content of heavy oil entered into force in 1977 in the coastal counties of Southern Norway, and were made more stringent in the 13 southernmost counties in 1986.

– A ten-year programme to clean up older polluting industry was started in 1974. The programme involving granting permits for emissions and instructions to install cleaning equipment in a number of undertakings.

– There was a good supply of cheap surplus power in the 1980s. This led to reduced consumption of oil, in the pulp and paper processing industry in particular.

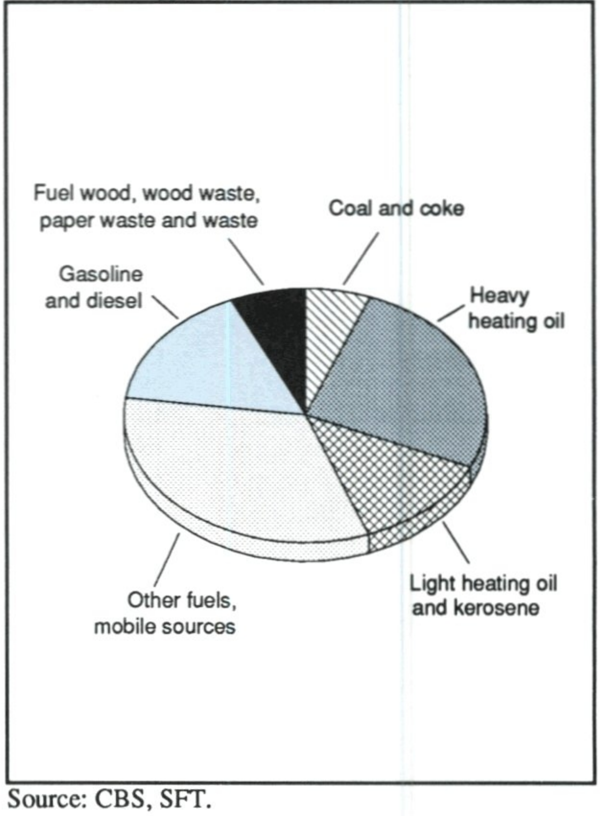
– There were several mild winters at the end of the period, which led to less use of energy for heating.

Figure 3.1. Emissions of SO_2 by source. 1973-1991*. 1 000 tonnes SO_2



Source: CBS, SFT.

Figure 3.2. Emissions of SO_2 from combustion by source of energy. 1989



Source: CBS, SFT.

Due to the factors described above, total emissions during the period were more than halved.

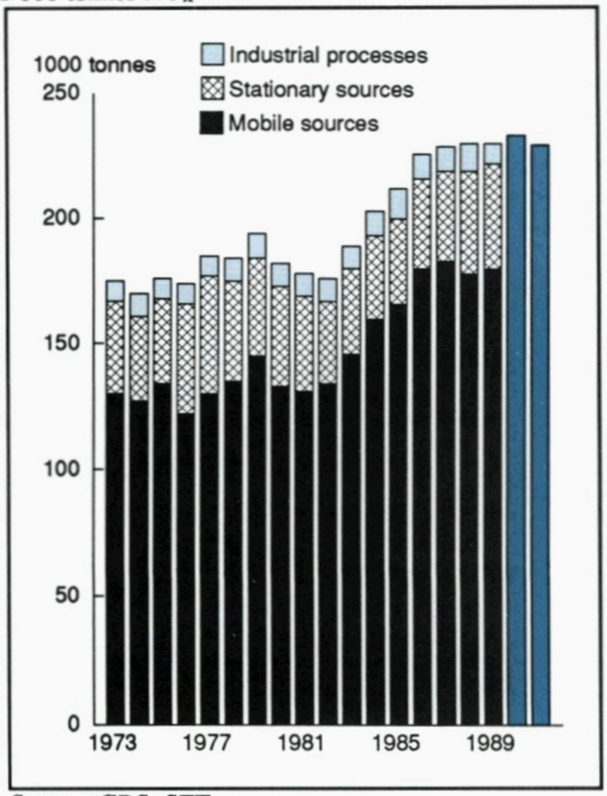
The largest reductions in emissions occurred in the pulp and paper processing sector, from 33 000 tonnes in 1976 to 3 800 tonnes in 1989. This sector is the largest consumer of surplus power. The smelting works at A/S Sulitjelma mines were closed down in 1987, leading to a substantial reduction in SO_2-emissions from industrial processes. Only small changes in emissions from industrial processes occurred from 1988 to 1989. Emissions from stationary sources were reduced by about 5 000 tonnes from 1988 to 1989. Emissions from mobile sources were reduced by about 1 000 tonnes during the same period. Total SO_2-emissions were reduced by 10 per cent, and the reduction from 1989 to 1990 is also expected to have been about 10 per cent. Preliminary estimates indicate that a somewhat lower reduction can be expected from 1990 to 1991.

About half the SO_2-emissions in Norway originate from industrial processes. The remaining emissions are equally distributed between stationary and mobile sources. Figure 3.2 shows emissions from fuel combustion in 1989 distributed between the different sources of energy.

Industrial activities were the cause of 61 per cent of the total emissions of SO_2. About half this amount originated from manufacture of metals. In this case, the SO_2-emissions are normally connected to both the sulphur content of the coal or coke, and sulphur in the ore. Other industries causing substantial emissions are manufacture of industrial chemicals, oil refining, and domestic sea transport.

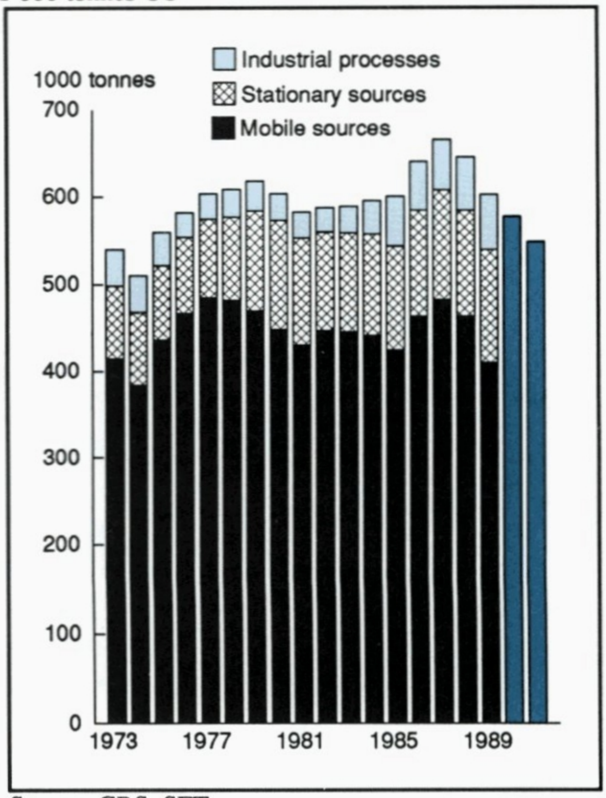
There was a substantial increase in **emissions of NO_x** during the first half of the 1980s, but in recent years these emissions have remained almost unchanged, see figure 3.3. The main reason for the strong increase in the 1980s was increased use of private cars. Mobile combustion was the cause of 77 per cent of the emissions in 1989, the dominating sources being ships and road traffic. For private cars, emissions of NO_x per unit of fuel have increased

Figure 3.3. Emissions of NO_x by source. 1973-1991*. 1 000 tonnes NO_x



Source: CBS, SFT.

Figure 3.4. Emissions of CO by source. 1973-1991*. 1 000 tonnes CO



Source: CBS, SFT.

due to higher energy efficiency in new cars. As from 1989, catalytic convertors were made mandatory in new cars run on gasoline. About 18 per cent of the total emissions refer to stationary combustion. These emissions have been reduced during the period due to reduced consumption of heating oils. Emissions from industrial processes have remained relatively stable.

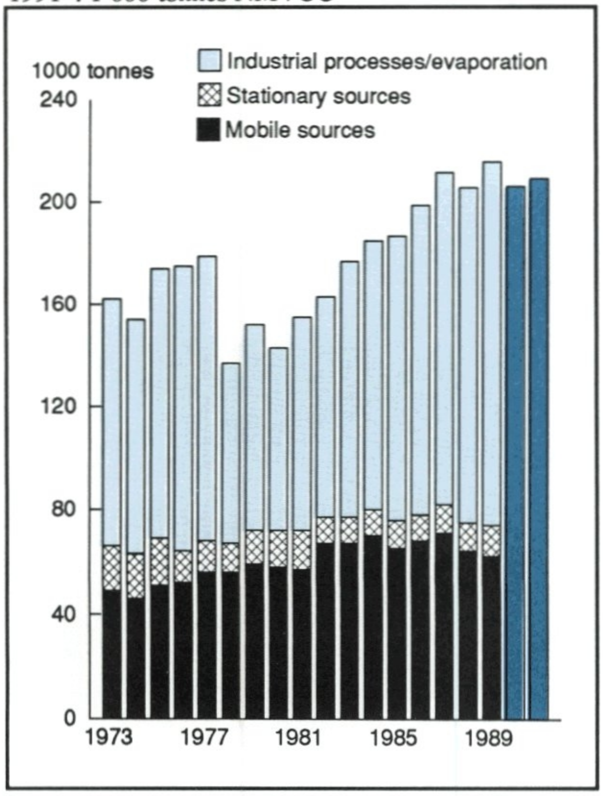
The largest emissions of NO_x are connected to extraction of oil and gas, fisheries, transport and private households.

Emissions of CO remained relatively stable in the 1980s up to 1985, increased slightly up to 1987, and then decreased, see figure 3.4. The increase from 1985 to 1987 was due to larger sales of gasoline. Almost 64 per cent of the total emissions of CO originates from combustion of gasoline. The increase in use of private cars in the 1980s had a stronger impact than improvements in combustion technology. During the last two years, the sale of transport oils (including gasoline) has decreased slightly. In recent years the reduction in emissions has been particularly marked for mobile sources. Private cars are responsible for about 62 per cent of the emissions from mobile sources.

Emissions of CO from industrial processes have remained stable in recent years. The most important sources of these emissions are manufacturing processes for magnesium, and especially carbides. About 10 per cent of the total emissions came from industrial processes. Stationary combustion was the cause of 22 per cent of the total emissions. 92 per cent of this 22 per cent came from combustion of wood, mainly for heating purposes in private households. Emissions from stationary sources increased slightly during the 1980s, due to more use of wood for fuel. The estimates of wood consumption are based, however, on rather uncertain data.

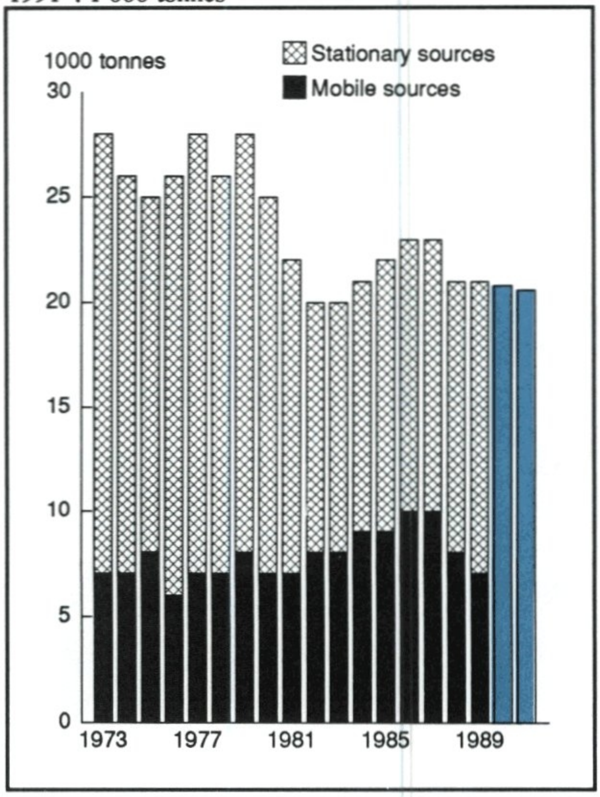
Emissions of NMVOC increased around the mid-1970s due to a higher level of activity in the oil sector. Emissions from this sector decreased again with the change to other methods of landing the oil. The increase in total emissions up to 1987 can be put down partly to

Figure 3.5. Emissions of NMVOC by source. 1973-1991*. 1 000 tonnes NMVOC



Source: CBS, SFT.

Figure 3.6. Emissions of particulates by source. 1973-1991*. 1 000 tonnes



Source: CBS, SFT.

landing of gas from new fields, and partly to a higher level of emissions from mobile sources, see figure 3.5. The figures for NMVOC emissions in general are associated with a high degree of uncertainty.

The main sources of emissions of volatile organic compounds (NMVOCs) are evaporation, distribution of oil products and processes connected to extraction of oil and gas. About 66 per cent of the NMVOC-emissions refer to evaporation or processes. Emissions from oil activities (including gas terminals and transport of crude oil) accounted for almost 45 per cent of the total emissions in 1989. The decidedly largest source was transport of crude oil. Emissions from use of solvents accounted for about 15 per cent of the total emissions of NMVOC, but as mentioned above, the figures are very uncertain. This year's estimate of emissions from use of solvents is much lower than assumed before. It is likely that emissions of solvents have decreased in recent years. After more information has become available on the health hazards connected to inhalation of solvents, many industries and private households have probably changed over to water-based products.

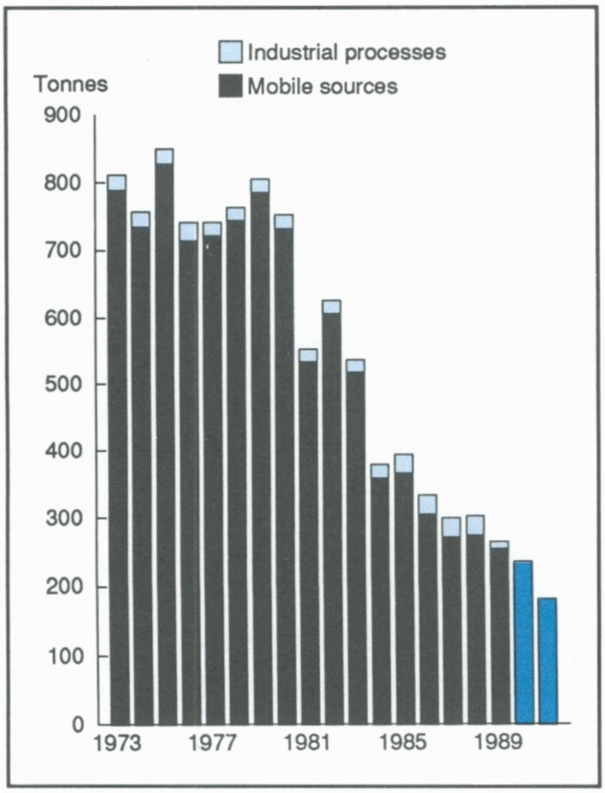
Incomplete combustion in mobile sources accounted for about 29 per cent of the total emissions. Use of private cars in particular, but also two stroke-engines, were important in this connection. Stationary combustion was the cause of only 6 per cent of the NMVOC emissions in 1989, the most important source being burning of wood in private households.

Emissions of particulates decreased from 1973 up to 1983, see figure 3.6. This was mainly due to less stationary combustion of heavy oil. The decrease was followed by an increase up to 1987, due to higher consumption of wood in private households in addition to increased use of private cars. No marked changes have occurred in emissions of particulates since 1988.

34 per cent of the total emissions originated from mobile sources, with 57 per cent of this amount from diesel-driven engines.

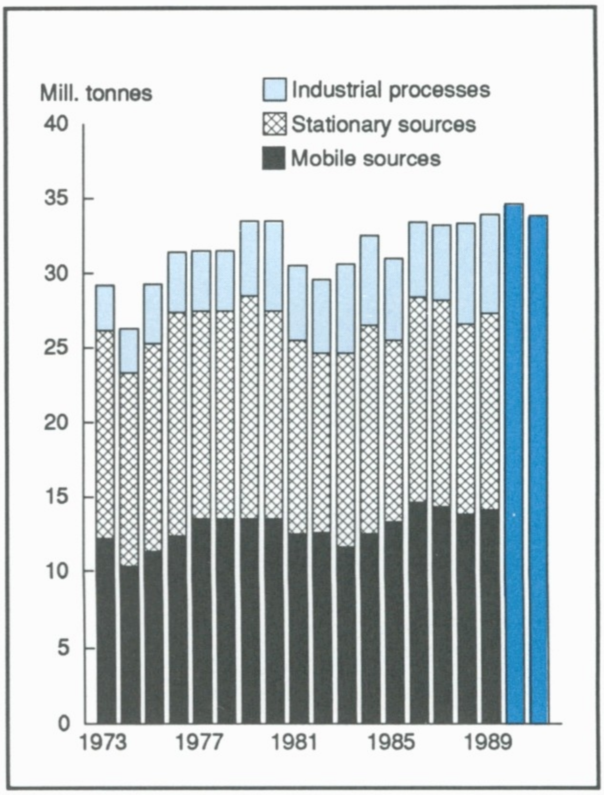
In 1989, private households accounted for 60 per cent of the total emissions of particulates.

Figure 3.7. Emissions of lead by source. 1973-1991*. Tonnes lead



Source: CBS, SFT.

Figure 3.8. Emissions of CO_2 by source. 1973-1991*. Million tonnes CO_2



Source: CBS, SFT.

The main cause was heating with wood, but private cars were another important source of these emissions. Domestic transportation accounted for 13 per cent of the emissions in 1989.

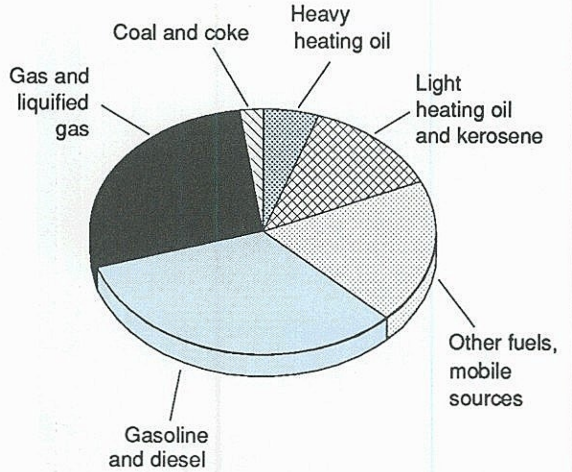
Emissions of lead have decreased in recent years, see figure 3.7. This is due to a lower content of lead in gasoline (the regulations entered into force in 1980 and 1983), in addition to the introduction of non-leaded gasoline in 1986. In 1989, sales of non-leaded gasoline accounted for 30 per cent of total sales. A/S Christiania Spigerverk was closed down in 1989. This is the main reason for decreased emissions of lead from industrial processes from 1988 to 1989. The figures for process emissions of lead have been adjusted considerably, also historically. Only 4 per cent of the total emissions came from industrial processes, and only 0.5 per cent from incineration of waste and oil.

More than 95 per cent of the emissions of lead in 1989 originated from mobile sources, and were almost entirely due to the content of lead in gasoline. Private households, supply of services and domestic road transport were the most important sectors of emissions.

Emissions of CO_2 have varied somewhat during the period. Figure 3.8 shows marked decrease in emissions from 1973 to 1974, followed by an increase up to 1979/80. Emissions decreased again up to 1982, after which there was a slight rise up to 1986. The reason for the two distinct reductions in emissions was reduced consumption of oil products due to higher prices in 1973-74 and 1979-80. Preliminary figures indicate that CO_2-emissions have remained stable during the period 1988-1991. There has been a slight general decline in the consumption of petroleum products, but combustion connected to extraction and processing of oil and gas has increased. Figure 3.9 shows the connection between emissions of CO_2 and use of the different forms of energy in 1989.

Mobile and stationary sources each accounted for about 40 per cent of the carbondioxide emissions in 1989. The remainder were generated by industrial processes (19 per cent), where

Figure 3.9. Emissions of CO_2 from combustion of different forms of energy. 1989



Source: CBS, SFT.

the main source was metals manufacturing. Extraction of oil and natural gas accounted for the largest share of the total emissions (19 per cent), followed by private households (17 per cent), metals production (15 per cent) and transportation (13 per cent).

Emissions of methane have increased slightly in Norway from about 277 tonnes in 1987 to about 288 tonnes in 1989. The two most important sources of methane emissions were domestic animal husbandry/manuring and deposition of waste, which accounted respectively for 28 per cent and 55 per cent of the total emissions in 1989. 10 per cent of the emissions of methane came from activities connected to extraction of oil and gas (including shipping of crude oil and the gas terminal at Kårstø). Stationary combustion accounted for 5 per cent, and mobile combustion for 1.5 per cent of the total emissions, with the largest contribution again coming from heating with wood in private households.

There are two main sources of **emissions of N_2O**. These are use of manure and commercial fertilizer in agriculture, and production of nitric acid. These sources accounted for respectively 39 and 44 per cent of total emissions of nitrous oxide in 1989. 12 per cent came from stationary sources, and 5 per cent from mobile sources. Emissions of nitrous oxide in Norway have remained fairly constant throughout the period.

Emissions of NH_3 amounted to 36.6 tonnes in 1988 and 36.7 tonnes in 1989. These emissions depend to a large extent on the number of domestic animals and the spread of manure (79 per cent), as well as the use and composition of commercial fertilizers (21 per cent). A very small proportion of the emissions came from production of ammonia. The emission figures for ammonia are very uncertain.

Emissions of CFCs and halons

SFT has collected figures for import of CFCs and halons as raw materials in 1986, 1989, 1990 and 1991. The time series is shown in table 3.7. There are no reliable figures for annual emissions of these compounds but, averaged over time, the import statistics also indicate changes in the level of emissions. The import figures for CFC compounds have decreased by 66 per cent from 1986 to 1991.

It has been shown to be difficult to replace halons in fire-extinguishers, but in spite of this, imports have decreased by 40 per cent since 1986. Especially the activities in the North Sea make it difficult to reduce consumption of halons in Norway. New regulations banning the use of CFCs in Norway entered into force on 1 July 1991. However, dispensation from the ban has been granted in some cases. Today, it is possible to use hydro-chloro-fluorocarbons, so-called HCFCs, as a substitute for CFCs. Most of these will also have an ozone-depleting effect, but not as great as that of CFCs. Hydrofluorocarbons (HFC), not containing chlorine, are now used in refrigeration plants. These compounds have no known damaging effects on stratospheric ozone, but are less reliable in use and are more expensive. However, all these substitutes for CFC are regarded as greenhouse gases.

Table 3.7. Raw materials import of CFC and halons to Norway in 1986, 1989, 1990 and 1991[1]. Tonnes

	1986	1989	1990	1991
Total import of CFCs	1 411	990	773	478
CFC-11 ($CFCl_3$)	680	418	314	97
CFC-12 (CF_2Cl_2)	311	234	200	169
CFC-113 ($C_2F_3Cl_3$) ..	350	262	194	129
CFC-114 ($C_2F_4Cl_2$) ..	-	1	1	1
CFC-115 (C_2F_5Cl) ...	70	75	64	89
Total import of halons	151	90	136	90
Halon 1211 (CF_2BrCl) .	13	4	4	3
Halon 1301 (CF_3Br) ..	136	86	132	87
Halon 2402 (C_2F4Br) .	2	-	-	-

[1]Import of products is not included.

Source: SFT.

Emissions to air in other countries

Table 3.8 shows emissions of SO_2, NO_x, NMVOC and CO_2 in certain OECD countries. The table also shows emissions per inhabitant and per gross domestic product. USA and Canada stand out as producing large amounts of emissions, also on a relative scale. Some countries, however, have not included large sources of emissions in the total estimate, such as boat traffic, offshore activities and emissions from certain industrial processes. Therefore the emission figures in this table are not necessarily directly comparable.

Long-range transported air pollution

Through EMEP (European Monitoring and Evaluation Programme), a cooperative programme for monitoring and evaluation of long-range transported air pollution in Europe, Norway's own contributions of oxidized sulphur and nitrogen, and the amounts of these components received from other countries,

Table 3.8. Emission to air. Selected countries. 1988 unless otherwise specified

	SO_2	NO_x	NM-VOC	CO_2[1]	SO_2	NO_x	NM-VOC	CO_2[1]	SO_2	NO_x	NM-VOC	CO_2[1]
	Total emission				Emission per inhabitant				Emission per GDP			
	1 000 tonnes			10^6 tonnes C	kg			tonnes C	1000 tonnes/ 10^9 US$			1 000 tonnes C/10^9 US$
Canada	3800	1959[4]	2315[4]	131.1	146.4	75.5	89.2	5.1	8.7	4.5	5.3	301
USA	20700	19800	18500	1463.9	84.0	80.4	75.1	5.9	4.7	4.5	4.2	331
Japan	835[2]	1176[3]	..	280.2	6.8	9.6	..	2.3	0.5	0.7	..	171
Austria	121	213	466	16.7	15.9	28.0	61.4	2.2	1.4	2.4	5.4	192
Belgium	414[2]	297[2]	..	33.0	41.9	30.1	..	3.3	3.6	2.6	..	286
Denmark	242	249	146[4]	17.7	47.2	48.5	28.5	3.5	3.7	3.8	2.2	270
Finland	302	276	181[4]	17.8	61.1	55.8	36.6	3.6	4.8	4.4	2.9	283
France	1223	1656	1877[8]	106.1	21.9	29.6	33.6	1.9	1.7	2.4	2.7	152
Germany (West)	1237	2859	2603	198.0	20.3	46.8	42.7	3.2	1.6	3.6	3.3	248
Ireland	174[2]	115[2]	108[2]	7.9	49.2	32.5	30.5	2.2	6.6	4.4	4.1	299
Italy	2006	1705	827	112.4	34.9	29.7	14.4	2.0	2.9	2.5	1.2	164
Luxembourg ...	12	22[4]	20[4]	2.5	32.0	58.7	53.3	6.7	2.2	4.1	3.7	462
Netherlands	259	585	396	53.3	17.5	39.6	26.8	3.6	1.5	3.4	2.3	307
Norway	67	225	248	8.8	15.9	53.4	58.9	2.1	1.1	3.7	4.0	143
Portugal	205	122	156	10.5	19.9	11.8	15.1	1.0	3.4	2.0	2.6	173
Spain	2156[4]	826[4]	843[5]	58.5	55.3	21.2	21.6	1.5	6.4	2.4	2.5	172
Sweden	213	396	440	22.1	25.2	46.9	52.1	2.6	1.9	3.5	3.8	193
Switzerland	74	194	311	12.6	11.1	29.1	46.6	1.9	0.7	1.9	3.1	124
UK	3813	2642	2013	164.9	66.1	46.3	35.3	2.9	5.4	3.7	2.8	232

[1] CO_2 emissions from energy use. [2] 1987. [3] 1986. [4] 1985. [5] 1983.

Source: OECD, 1991.

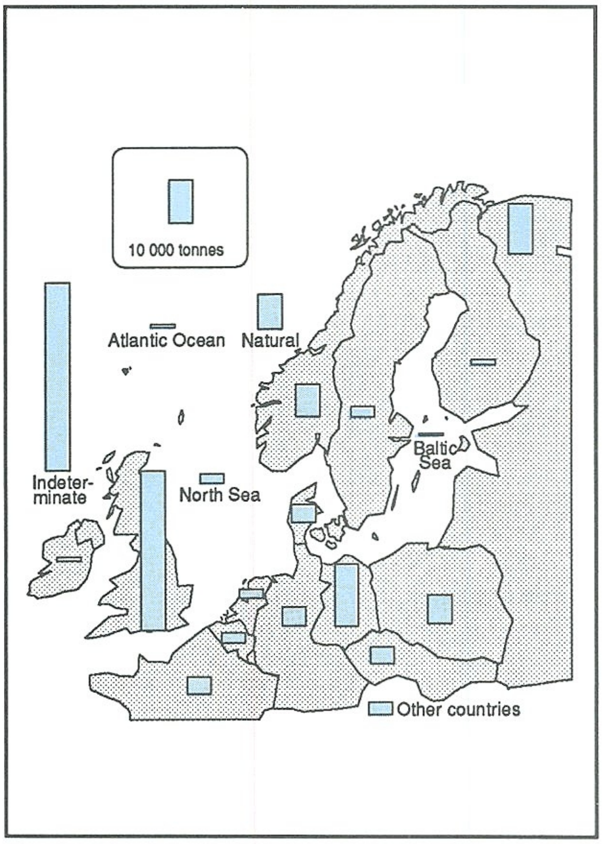
have been calculated for the years 1985, 1987, 1988, 1989 and 1990. The calculations include only contributions from European countries. The calculations are based on reported and estimated emissions figures coupled with meteorological, physical and chemical data in order to model horizontal transport in the atmosphere. The calculated concentrations are compared with observed values. Oxidized nitrogen occurs mainly in the form of NO_2 and NO_3^-, and oxidized sulphur as SO_2 and SO_4^{2-}. Figures 3.10 and 3.11 show the results of the calculations for 1990. The overview includes only countries that affect Norway to any significant degree. The item "Other countries" represents the sum of small contributions from Hungary, Italy, Rumania, Spain and Yugoslavia. Sea areas where emissions both occur and are received are the Baltic Sea, the North Sea and the Atlantic. Some of the emissions of sulphur dioxide originate from natural sources, mainly marine biological processes.

Norway is the recipient of 160 000 tonnes oxidized sulphur (measured as S) and 98 000 tonnes oxidized nitrogen (measured as N). Only 5 per cent of the sulphur and 6 per cent of the nitrogen originate in Norway. The main contributors of this pollution are Great Britain, Germany, Poland and the previous Soviet Union. The calculations also show large differences within Norway itself. The southernmost counties of Norway are exposed to the greatest load of pollution. The Norwegian emissions are deposited mainly in immediate sea areas. Sweden and the previous Soviet Union are also important recipients.

Agreements

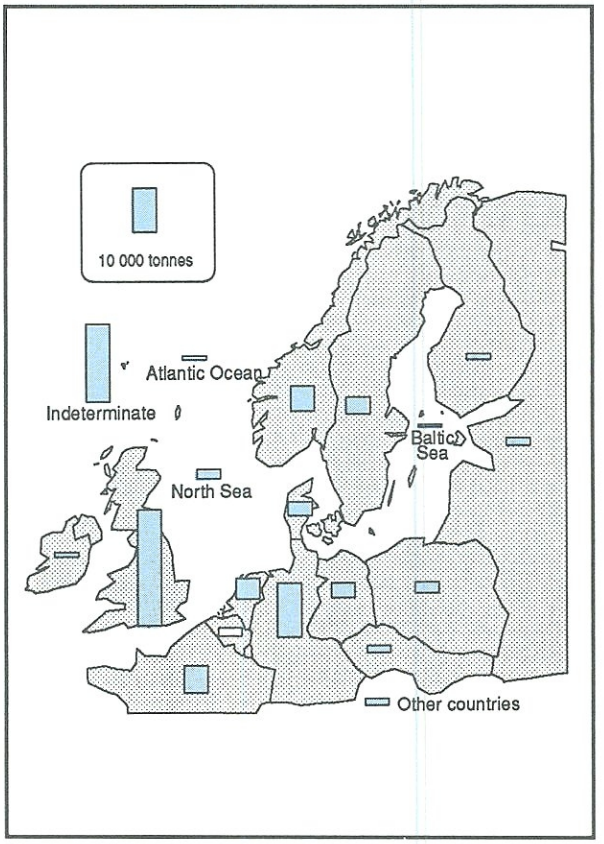
Norway has undertaken to reduce emissions of certain components. Box 3.2 gives an overview of these agreements and national objectives. The most recent agreement (1991) refers to reduction of emissions of non-methane volatile organic compounds (NMVOC).

Figure 3.10. Supply of oxidized sulphur (measured as S) to Norway from European countries and ocean areas. 1990



Source: EMEP.

Figure 3.11. Supply of oxidized nitrogen (measured as N) to Norway from European countries and ocean areas. 1990



Source: EMEP.

International environmental agreements can take many forms and are committing to a greater or lesser degree. The most important categories of agreements are:

Declarations, most of which are political statements of willingness, often somewhat vaguely formulated.

Conventions, which specify general commitments and objectives in relation to a group of environmental problems for the different partners to the agreement.

Protocols which usually contain specific commitments for the different countries.

In principle, Conventions and Protocols are legally binding, but as yet no sanction mechanisms have been established to ensure that the commitments are met. As an appendix to international agreements, or preceding negotiations on such agreements, it is not unusual for the different countries to publicly announce national targets for stabilizing or reducing various kinds of environmentally harmful emissions.

The following is a short list of some international agreements which Norway is party to. The brackets show the year the agreement was signed. The agreements may include other provisions and requirements than those stated below.

Declarations		
North Sea Declaration (1987)		
	Micropollutants	50 per cent reduction by 1995 with 1985 as base year. 70 per cent for cadmium, mercury, lead and dioxins
	Nutrients	50 per cent reduction
	PCB	Cease all use by 1995
Conventions		
ECE (1979)	Limits on long-range transboundary air pollution	
Vienna (1987)	Protect the stratospheric ozone shield	
Protocols		
Helsinki (1985)	Sulphur	30 per cent reduction by 1993 with 1980 as base year
Sophia (1988)	NO_x	Stabilization at the 1987 level by 1994.
Montreal (1987)	CFCs	Reduce use of CFCs by 50 per cent by 1998 with 1986 as base year.
	Halons	Stabilize use at the 1986 level by 1992.
London (1990)	CFCs	With 1986 as base year: 20 per cent reduction by 1993, 85 per cent reduction by 1997 and complete phasing out by the year 2000.
	Halons	50 per cent reduction by 1995 and complete phasing out by the year 2000.
	Carbon tetra-chloride	85 per cent reduction by 1995 and phasing out by the year 2000.
	Methyl-chloroform	30 per cent reduction by 1995, 70 per cent reduction by the year 2000, and complete phasing out by 2005.
Genèva(1991)	NMVOC	30 per cent reduction by 1999 with 1989 as base year. Applies to all mainland Norway and Norway's economic zone south of latitude 62° North.
National goals		
	Sulphur	50 per cent reduction by 1993 with 1980 as base year.
	NO_x	30 per cent reduction by 1998 with 1986 as base year.
	CO_2	Stabilization at the 1989 level by the year 2000.
	CFCs and halons	50 per cent reduction in 1991 with 1986 as base year. Complete phasing out in 1995.

Box 3.2. International agreements signed by Norway.

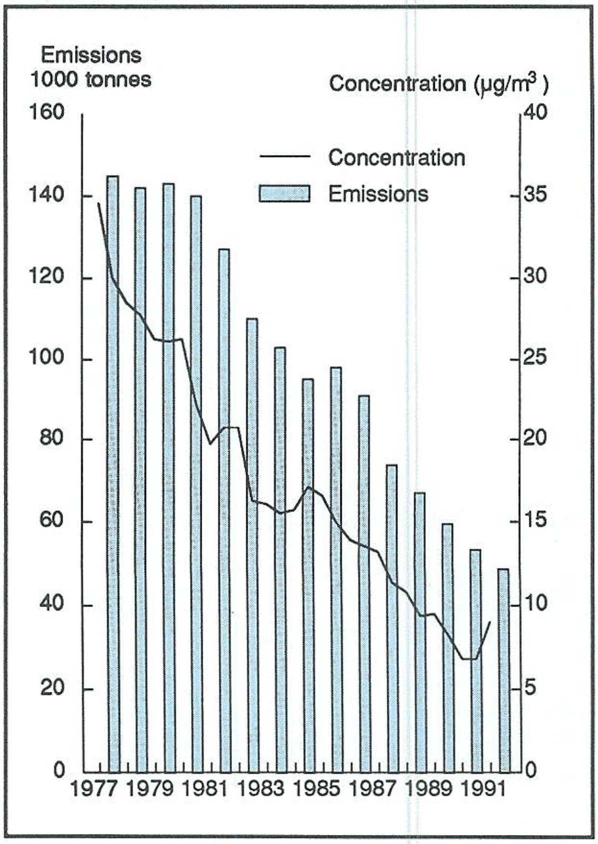
3.3. Trends in regional concentrations of pollutants

The Norwegian Institute for Air Research (NILU) has made regular measurements of sulphur dioxide, soot and lead in air at different places in Norway since 1977. The measurements have been carried out at the request of the State Pollution Control Authority as part of the national pollution monitoring programme. Concentrations of NO_2 have been measured since 1986. Since April 1990, 24 hour average concentrations of these pollutants have been registered at 37 stations in 29 towns and urban districts. The concentrations of the various components are measured at different times of the year.

The measurements show that the concentration of all the components varies significantly over the year, with higher levels in winter and lower levels in summer. This variation is due to higher consumption of fuels (oil, kerosene and wood) for heating in winter, and therefore increased emissions, plus the fact that the pollution is not spread to the same extent in winter as in summer. Figures 3.12, 3.13 and 3.14 show seasonal variations and changes in average concentrations of sulphur dioxide, soot and lead in some larger Norwegian towns (Fredrikstad, Oslo, Drammen, Kristiansand, Stavanger, Bergen, Trondheim and Tromsø). The figures also show changes in national emissions of these components. In general, variations in air quality for these towns correlate with national emissions of the corresponding component.

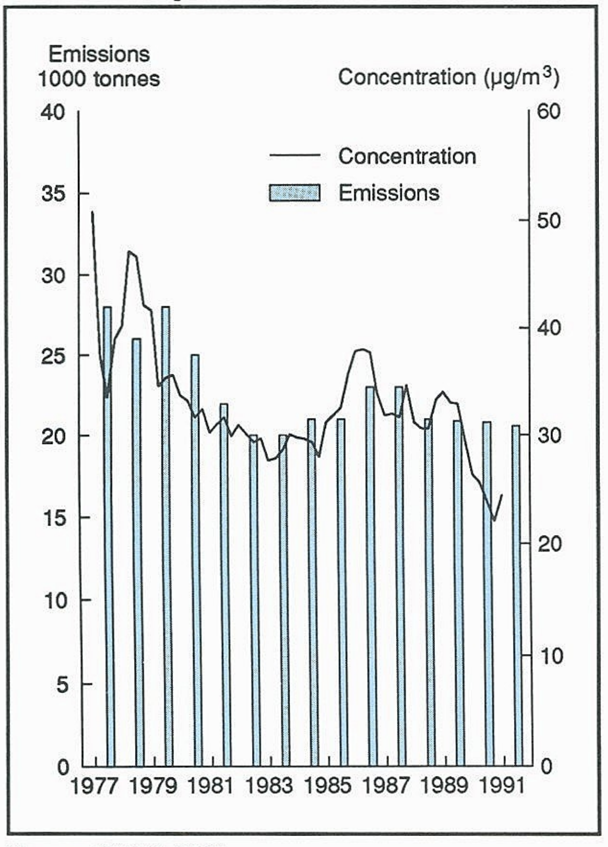
Figure 3.12 shows a marked decline in the average concentration of *sulphur dioxide* in the larger towns since the measurements started. There has been no average change, however, from the winter season 1989/90 to the winter season 1990/91. In Eastern Norway the winter season 1990/91 was colder than the previous winter, which caused a slight increase in the values measured at the stations concerned. Values for towns in other parts of the country have declined. However, the average values indicate sporadic periods of poor air quality. In the case of some components, such as SO_2 and NO_2, greatest harm occurs during these episodes with high concentrations. The measurements show only few such episodes for SO_2 during the period concerned. Values exceeding the 24 hour average critical level (100 $\mu g/m^3$) were registered at seven stations, and values exceeding the upper 24 hour critical level (150 $\mu g/m^3$) at one station. Episodes with high concentrations of sulphur dioxide occur most frequently in places with large emissions from local industrial enterprises. The highest values for SO_2 are now measured at stations in Sarpsborg, Halden, Årdalstangen and Øvre Årdal. No excess values were registered in the largest towns during the period in question. Øvre Årdal was the only place with values exceeding the lower half-yearly critical level, 40 $\mu g/m^3$. Excess values were also registered in Sør-Varanger, outside the national monitoring programme. The high values here are due to SO_2 emissions from Russian nickel works in Nikel and Zapoljarnij.

Figure 3.12. Average concentrations of SO_2 in air in some larger Norwegian towns. $\mu g\ SO_2/m^3$ air. National emissions of SO_2. 1 000 tonnes. 1977-1991



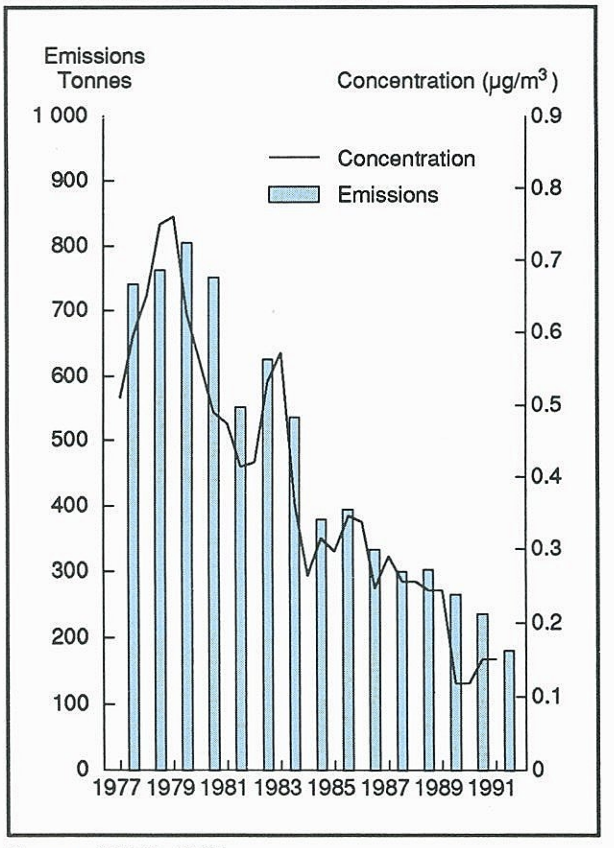
Source: NILU, CBS.

Figure 3.13. Average concentrations of soot in air in some larger Norwegian towns. µg soot/m³ air. National emissions of particulates. 1 000 tonnes. 1977-1991



Source: NILU, CBS.

Figure 3.14. Average concentrations of lead in some larger Norwegian towns. µg Pb/m³ air. National emissions of lead. Tonnes. 1977-1991



Source: NILU, CBS.

Soot concentrations showed a tendency to decline at the beginning of the period, increased during the mid-1980s, and have declined in recent years, see figure 3.13. The 24 hour average critical level (100 µg/m³) was exceeded in 1990/91 in several places with a high level of road traffic. Generally higher concentrations were measured during the first quarter of 1991 compared with the same period in 1990. This is due to a colder winter, implying poorer spread of the soot. Today, road traffic is probably the most important source of soot in the larger towns. At the start of the measuring period the greater part of the soot originated from combustion of oil for heating.

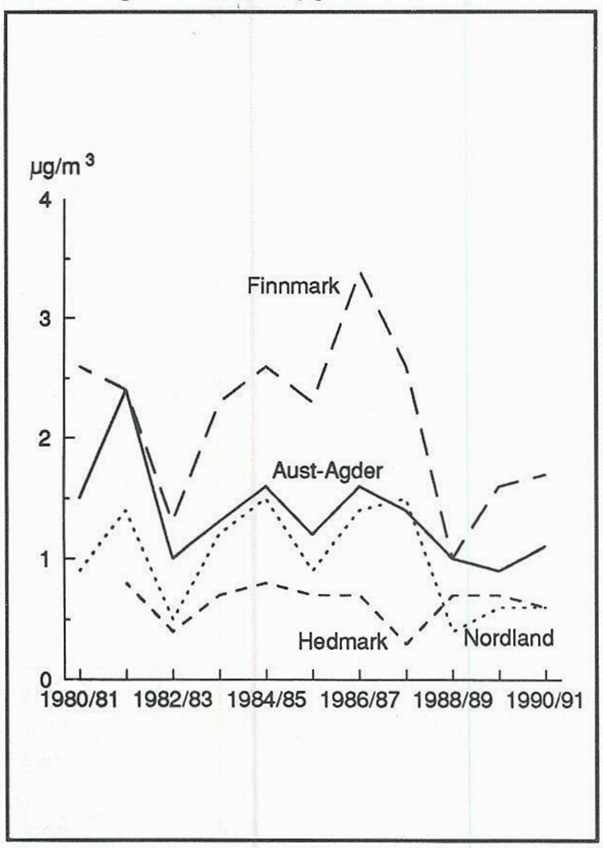
A distinct decline has been observed in concentrations of *lead* following the gradual changeover to non-leaded gasoline. A period of marked reductions in lead concentrations in urban air early in the 1980s has been followed by smaller reductions in recent years, see figure 3.14. No lead concentrations exceeding WHO's critical level for lead concentrations (0.5-1 µg/m³) were measured at any station during the winter 1990/91.

Measurements of *NO_2 concentrations* did not start until autumn 1986. Values exceeding the 24 hour average critical level (100 µg/m³) were measured at 9 of 13 measuring stations during winter 1990/91. The highest values were measured in Bergen and Trondheim. The critical level for the half-yearly mean concentration (75 µg/m³) was not exceeded, but 73 µg/m³ was measured in Drammen. The average value for all stations (50 µg/m³) was higher during winter 1990/91 than during the 1989/90 season (43 µg/m³), but was at the same level as measured in earlier years. Road traffic is considered to be the most important source of high concentrations of NO_2 in air.

Air quality at Norwegian background stations

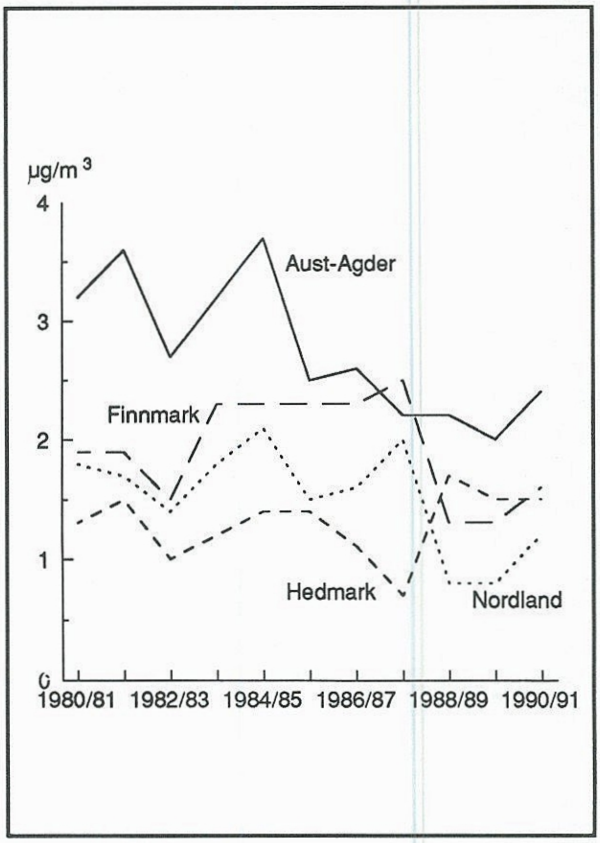
Transboundary pollution is measured in air and precipitation at 7 background stations. These stations are influenced only slightly by local sources of emissions. Much of the pollution comes from other countries, see figures 3.10 and 3.11. Figures 3.15 and 3.16 show changes in annual mean of half-yearly average concentrations of sulphur dioxide and particulate sulphate at certain stations. As a whole, the measurements show a declining tendency, but have varied only slightly in recent years. The figures also show that the sulphur load at the background stations varies between regions. The highest average concentrations were registered at Jergul in Finnmark, Skreådalen in Vest-Agder and Birkenes in Aust-Agder.

Figure 3.15. Annual average concentrations of SO_2 at some background stations. µg/m^3 air. 1980-1991



Source: NILU, SFT.

Figure 3.16. Annual average concentrations of particulate sulphate at some background stations. µg/m^3 air. 1980-1991



Source: NILU, SFT.

3.4. Benefits of measures related to climate

The committee appointed to consider environmental taxes has recently made its recommendations concerning the use of economic instruments as part of the environmental policy (Committee on Environmental Taxes, 1992, see also Committee on Environmental Taxes, 1991). As background data for the recommendations, different model-based scenarios were developed for the Norwegian economy up to the turn of the century. The calculations were carried out using the MODAG model (Cappelen, 1991) and included, in addition to a *reference scenario*, that is to say, a path of economic growth based on the assumption that no taxes are imposed on emissions of, for instance, greenhouse gases, alternative scenarios where such taxes are imposed. In one alternative the rate of the so-called carbon tax is determined by requiring that Norwegian CO_2-emissions be stabilized at the 1989 level in a world where other countries do not introduce special measures to reduce emissions of greenhouse gases (*the stabilization scenario*). The other alternative assumes that Norway enters into an agreement with the most important industrialized countries to introduce measures to reduce the growth in CO_2-emissions (*the agreement scenario*). CBS has made some preliminary calculations of the beneficial effects connected to these measures to reduce CO_2-emissions. These calculations are briefly described in this section. Similar calculations were also carried out in connection with the work of the Interministerial Committee on Climate (Ministry of Environment, 1991), and were described in *Natural Resources and the Environment 1990* (CBS, 1991). See also Moum (1992).

Some effects of changes in climate, and costs of reducing emissions of greenhouse gases

Emissions of greenhouse gases such as CO_2, CH_4, N_2O and CFC affect the global climate by altering the radiation balance of the earth. How the changes in climate will occur, and how they will affect living conditions on the earth, are matters of great uncertainty. Normally it is assumed that a doubling of the CO_2-equivalent concentration (it is usual to express the total effect of greenhouse gases in the atmosphere in terms of *equivalent CO_2-units*, that is to say, the amount of CO_2 required to achieve the equivalent greenhouse effect) in the atmosphere relative to the equivalent in pre-industrial times, would cause an increase in temperature of from 2-5 degrees centigrade. The economic consequences of such changes are difficult to predict, but some attempts have been made to do so.

Nordhaus (1991) reports, for example, estimated damage due to emissions of greenhouse gases which cause a rise in global mean temperature of 3 degrees centigrade. The estimate, which includes only economic damage that could be quantified, and does not include damage connected to possible loss of genetic material and aesthetic values, gives damage amounting to USD 6.60 per tonne CO_2-equivalent emissions. This must be said to be a very low estimate of the damage caused by emissions of greenhouse gases. Nordhaus also presents other estimates of a more ad hoc nature. One estimate is USD 26.80 per tonne CO_2-equivalents, while a high estimate is USD 238 per tonne CO_2-equivalents.

Nordhaus refers in the same article to the estimated costs of reducing global emissions of greenhouse gases. At a theoretical optimum, where marginal damage of emissions is made equal to marginal cost, Nordhaus concludes that, with the low estimate of the damage, no attempt should be made to reduce green-house gases other than CFC. In the middle alternative, emissions of greenhouse gases should be reduced to 11 per cent below today's level, while with the high damage alternative, emissions should be reduced by about a third.

The costs of reducing emissions of CO_2, measured in terms of reductions of GDP on the basis of a proposed reference path with no climate-related measures, have been analyzed in various international studies. Figure 3.17 summarizes the results of these studies. They are not necessarily comparable, however, since they are based on different assumptions.

None of these calculations takes into account the fact that a reduction in the use of fossil fuels will also reduce not only emissions of greenhouse gases but also emissions of other pollutants, and that a higher price of fossil fuel will lead to other gains than those connected to climate change. It is these "additional gains" that are discussed in the rest of this section.

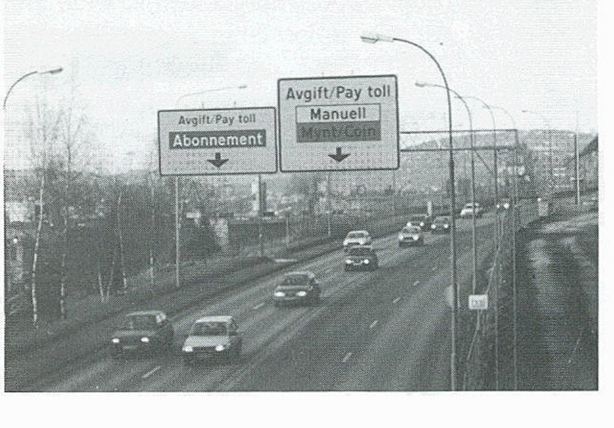
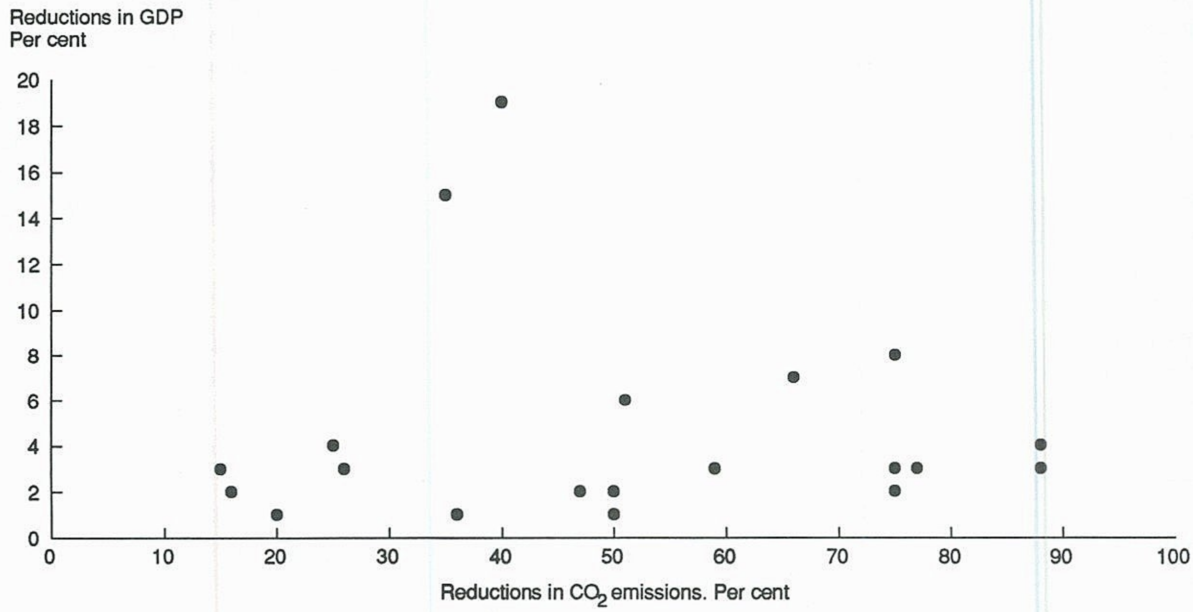


Figure 3.17. Effects on CO_2-emissions and GDP of carbon taxes in international studies



Source: Hoeller et al. (1991).

Benefit of reduced air pollution and road traffic

Two kinds of "additional gains" are estimated here by ex post calculations to the economic model scenarios described in the report from the Committee on Environmental Taxes (1991). The one kind refers to reduced emissions to air of sulphur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and particulates, and the resulting reduction in damage to forest, watercourses, certain types of real capital, and health, as a result of reducing the level of pollution. The other type of gains refer to certain external effects of road traffic such as congestion (queues), traffic accidents, wear and tear on roads, and noise from traffic. Brendemoen et al. (1992) have described the assumptions for these calculations in detail, as well as the data on which they are based. Different methods have been used to place a value on the cost elements. The valuation is based partly on prices observed on the market, e.g. when pricing the costs of corrosion, partly by using studies of "willingness to pay", as when assessing the effects of acidification, and partly by subjective valuation of environmental damage by expert groups (e.g. damage to health). The fact that different methods have been used which cannot be easily compared makes the results uncertain, and implies they should be interpreted with caution. It has nevertheless been decided to present the calculations, since very little other information is available on the beneficial effects of environmental measures.

Results of the calculations

The scenarios

The effects on the Norwegian economy of increased use of environmental taxes can be calculated as the difference between the development as shown in the reference path, where no specific measures are implemented, and in paths with alternative systems of environmental taxes. The detailed assumptions for the reference path and for the two alternatives forming the basis of the present calculations are described in the report from the Committee on Environmental Taxes (1991). The present report discusses only features of particular importance for calculating cost savings due to reduced use of fossil fuels, and therefore of emissions.

The reference path

The reference path reflects an economic development marked by moderate growth and more efficient use of resources in the Norwegian economy up to the year 2000. The only environmental requirements included in the reference scenario are the ones already adopted. Most of these are already in force, and include an environmental tax on gasoline, which was enforced in 1991, and exhaust emission criteria for private cars and light commercial vehicles. Exhaust emission criteria for heavy commercial vehicles are also included in the emission calculations based on the reference scenario.

The calculations assume an increase in energy efficiency of between 1 and 1.5 per cent per year over the period 1990-2000 for dwellings and buildings used for vocational purposes. For industrial processes, energy efficiency is assumed to increase by between 0.5 and 1 per cent per year. It is assumed that the fundamental criteria for allocation of power to energy-intensive industry will remain the same, while power for regular consumption will be supplied at a price approximately equivalent to long-term marginal cost. It is further assumed that the demand for power in the year 2000 will be covered by hydroelectricity alone.

Table 3.9. Consumption of electricity and petroleum products. Reference path

	1988	2000	Growth rate 1988-2000 (Per cent)
Electricity, TWh			
Net domestic consumption	92.8	105.0	1.0
Energy-intensive industry	30.4	31.0	0.2
Regular consumption	62.3	74.0	1.4
Petroleum products, 1000 tonnes			
Transport oils (except for gasoline) and heating oils	4963	5869	1.4
Manufacturing industries and public sectors	4390	5257	1.5
Households	573	612	0.6
Gasoline	1899	2254	1.4
Manufacturing industries and public sectors	654	867	2.4
Households	1245	1386	0.9

Table 3.10. Forecasts of emissions to air. Reference path

	Level 1988 (1 000 tonnes)	Level 2000 (1 000 tonnes)	Growth rate 1988-2000 (per cent)	Goal	Year of fulfilment
SO_2	74	77	0.3	71[1]	1993
NO_x	228	212	-0.6	155[2]	1998
CO	635	514	-1.7	Not decided	
Particulates	25	23	-0.7	Not decided	
CO_2	35[3]	41[3]	1.4	35[3,4]	2000

[1] 30 per cent reduction in relation to the 1980 level.
[2] 30 per cent reduction in relation to the 1986 level.
[3] Million tonnes
[4] Preliminary goal: Stabilization at the 1989 level.

In the reference scenario, consumption of oil and gasoline increases on average by about 1.4 per cent per year up to the year 2000. The increase in the consumption of petroleum products is much lower in private households than in the manufacturing and public sectors, see table 3.9.

Table 3.10 shows estimated changes in emissions to air as reflected in the reference path, as well as the goals for emission levels and the year for fulfilment of these goals. The table only shows emissions of components included in the calculations of damage, plus emissions of CO_2.

The measures already adopted imply that the increase in emissions will be considerably lower than the increase in use of fossil fuels. In the case of certain components a reduction of total emissions will be achieved by the year 2000.

The stabilization scenario

The stabilization scenario is based on the Norwegian goal to stabilize CO_2-emissions at the 1989 level by the year 2000, and it is assumed that this goal will be achieved by imposing a CO_2-tax on fossil fuels. The necessary tax level is about 900 NOK (1990 kroner) per tonne CO_2. It is also assumed that the goal for CO_2-emissions will be achieved cost-effectively, so that all polluters will pay the same price for the carbon content in their emissions. In the case of gasoline this price would be about NOK 1.75 higher per litre in the year 2000 relative to the price in the reference scenario. Similarly, the price of diesel and heating oil would increase by about NOK 2.30 per litre (1990 kroner). This scenario assumes that no comparable measures are introduced abroad. Therefore other assumptions concerning petroleum prices and the international economy are the same as in the reference scenario. The trend shown in the stabilization scenario is unlikely to occur in reality, but it illustrates the type of effects that might be experienced by unilateral Norwegian measures to reduce emissions of greenhouse gases. Table 3.11 shows the expected effect of these changes on consumption of energy.

Since, in this scenario, it is assumed that no measures to reduce use of fossil fuels and CO_2-emissions are introduced in other countries, the competitive situation of export industries, and energy-intensive industry in particular, is dramatically worsened. For example, the gross product in the metals sector, where CO_2-emissions are relatively high due to the coal in the anode material used during electrolysis, is estimated to decrease by as much as 40 per cent. This is one of the major causes of changes in electricity consumption.

Table 3.11. Consumption of electricity and petroleum products. Stabilization scenario. Year 2000

	Level Year 2000	Growth rates 1988-2000 (per cent)	Changes from the reference path (per cent)
Electricity, TWh			
Net domestic consumption	92.7	0.0	-11.7
Energy-intensive industry	17.2	-4.6	-44.5
Regular consumption	75.5	1.6	2.0
Petroleum products, 1000 tonnes			
Transport oils (except for gasoline) and heating oils	4986	0.0	-15.0
Manufacturing industries and public sectors	4518	0.2	-14.1
Households	468	-1.7	-23.5
Gasoline	2014	0.5	-10.6
Manufacturing industries and public sectors	844	2.1	-2.7
Households	1170	-0.5	-15.6

In this scenario, the weakening of the metals sector, among others, implies a deterioration of foreign trade. This means that Norway's net claims abroad, measured as a percentage of GDP, are reduced by more than one percentage point relative to the situation in the year 2000 in the reference scenario.

In the stabilization scenario, the environmental tax will lead to a 15 per cent reduction in use of transport oils (except gasoline) and heating oils in the year 2000 relative to the reference path. Consumption by private households consists almost entirely of oil for heating. In the calculations, this consumption is reduced by about 25 per cent. As far as use of gasoline is concerned, the effect of the tax is obviously greater for private households than for manufacturing industries and the public sectors. In this scenario, consumption of gasoline by private households will, in fact, be less than it was in 1988. Table 3.12 shows changes in emissions to air in the year 2000, relative to the reference path.

In the stabilization scenario, SO_2-emissions in year 2000 are well under the emission goal for 1993. NO_x-emissions are also clearly lower than in the reference path, but are nevertheless 20 per cent higher than the goal for 1998.

Table 3.12. Forecasts of emissions to air. Stabilization scenario. Year 2000

	Level (1000 tonnes)	Growth rates 1988-2000 (per cent)	Changes from the reference path (per cent)
SO_2	61	-1.6	-20.8
NO_x	189	-1.6	-10.8
CO	390	-4.0	-24.1
Particulates	22	-1.1	-4.3
CO_2	35[1]	-0.0	-13.6

[1] Million tonnes.

The agreement scenario

The agreement scenario assumes that an international agreement is signed to impose a tax on carbon emissions amounting to NOK 650 per tonne CO_2. Since Norway has already imposed a tax on carbon (from 1991), the agreement will not lead to such a large increase in prices for Norwegian consumers. Relative to the price estimates in the reference path, the price of gasoline will be about NOK 0.75 higher per litre in the year 2000, and the price of diesel will be about NOK 1.40 higher (in 1990 kroner). The agreement is assumed to enter into force in 1995.

An international agreement will probably reduce the demand for crude oil on the world market. It is therefore assumed that the price paid to the producer for crude oil will fall by 15 per cent relative to the reference path. Thus Norway's gross real disposable income is reduced by about 2 per cent.

An international CO_2-tax will improve the competitive situation for energy-intensive industry based on hydroelectricity, since foreign manufacturers have to pay a higher price for their electricity, which is based largely on combustion of fossil fuel. The sector will nevertheless be affected through its use of coal.

Although total exports are somewhat lower in the year 2000 relative to the reference path, imports are reduced even more. Therefore, the effect on foreign trade as a whole is positive.

In other manufacturing industries and mining, electricity consumption will decrease slightly. This is because the effect of lower income and demand for goods is stronger than the effect of a lower price for electricity. In the service sectors there is a slightly stronger effect in the opposite direction. Therefore, in this scenario, total electricity consumption in industry and the public sector increases by 3 TWh, see table 3.13.

The use of heating oils and transport oils other than gasoline is reduced by about 8 per cent in the year 2000 relative to the reference path. This reduction is about half the comparable reduction in the stabilization scenario. The reduction is relatively evenly distributed between private households, which use most heating oil, and industry, which uses most transport oil. The calculations show a reduction of slightly more than 3 per cent in consumption of gasoline in the year 2000. The reduction is greatest for private households, with a decrease of almost 5 per cent relative to the reference path. In the case of industry and the public sector the reduction is very small. Table 3.14 shows the effects on emissions to air.

Table 3.13. Consumption of electricity and petroleum products. Agreement scenario. Year 2000

	Level Year 2000	Growth rates 1988-2000 (per cent)	Changes from reference path (per cent)
Electricity, TWh			
Net domestic consumption	105.2	1.1	0.2
Energy-intensive industry	29.8	-0.2	-3.9
Regular consumption	75.4	1.6	1.9
Petroleum products, 1000 tonnes			
Transport oils (except for gasoline) and heating oils	5411	0.7	-7.8
Manufacturing industries and public sectors	4854	0.8	-7.7
Households	557	-0.2	-9.0
Gasoline	2180	1.2	-3.3
Manufacturing industries and public sectors	865	2.4	-0.2
Households	1315	0.5	-4.1

Table 3.14. Forecasts of emissions to air. Agreement scenario. Year 2000

	Level (1000 tonnes)	Growth rates 1988-2000 (per cent)	Changes from the reference path (per cent)
SO_2	74	0.0	-3.9
NO_x	203	-1.0	-4.2
CO	409	-3.6	-20.4
Particulates	23	-0.7	0.0
CO_2	39[1]	0.9	-4.0

[1] Million tonnes.

The calculations indicate that, in the agreement scenario, Norway will fulfil her commitments concerning reduced SO_2-emissions in 1993 without introducing new measures, while in the year 2000 the emissions will be slightly higher than the goal of 71 000 tonnes of SO_2. The goal for NO_x is not realized in this scenario. The deviation is more than 30 per cent. It is therefore a clear need to introduce further measures to reduce NO_x-emissions, also in the event of an international agreement.

Figure 3.18. Cost-reductions in the stabilization scenario relative to the reference path in the year 2000. NOK Million (1990-kroner)

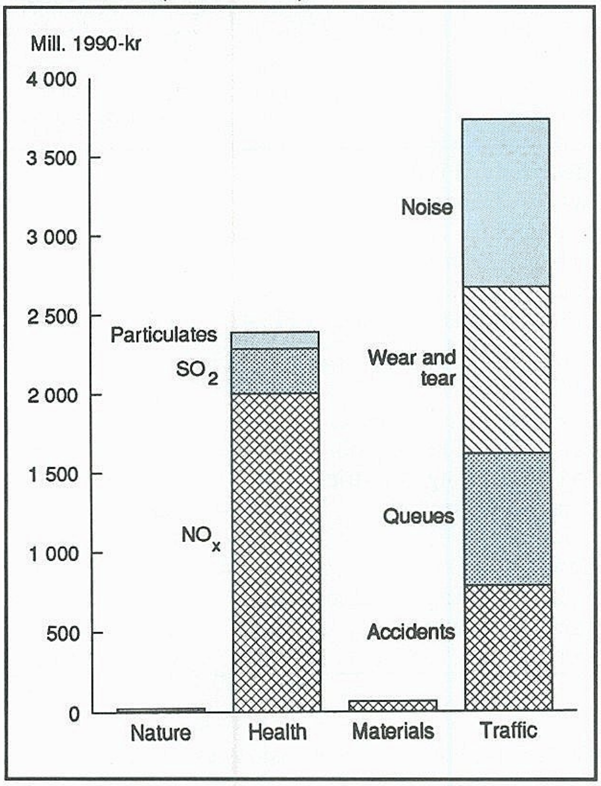
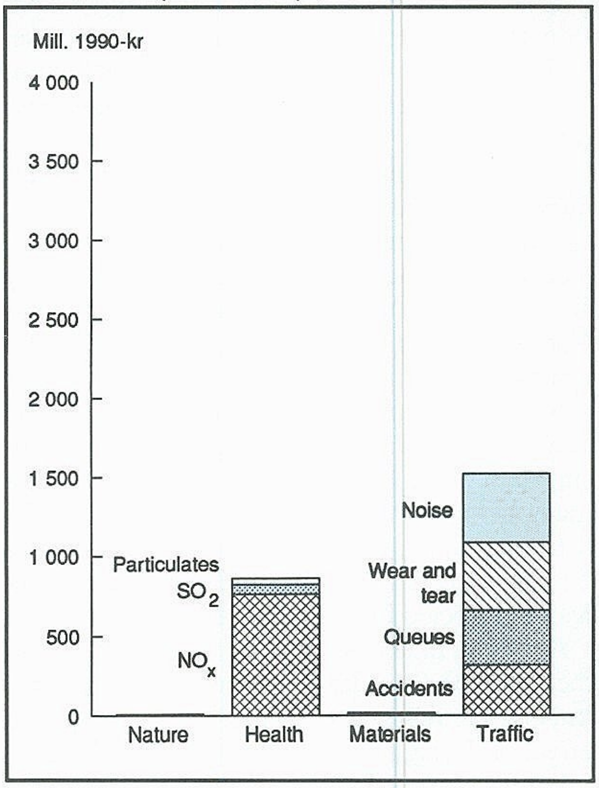


Figure 3.19. Cost-reductions in the agreement scenario relative to the reference path in the year 2000. NOK Million (1990-kroner)



Reduction in costs related to local air pollution and traffic in the year 2000 relative to the reference path

Figures 3.18 and 3.19 show estimates of cost-reductions in the year 2000 in the stabilization and agreement scenarios respectively, relative to the reference path.

The calculations, based on estimates of marginal damage caused by emissions of the different components (see Brendemoen et al., 1992), indicate that a unilateral environmental tax in Norway, as assumed in the stabilization scenario, would reduce costs related to pollution and traffic by more than NOK 6 billion (1990 kroner). The benefit from reduced emissions and less traffic more than outweighs the reduction in private consumption caused by the environmental tax, which is estimated to slightly more than NOK 1.6 billion (1990 kroner). Reduction in the gross domestic product (GDP) is estimated to be somewhat less than NOK 13 billion (1990 kroner). The reduction in the GDP is accompanied by a lower level of foreign trade and reduced investments.

An international agreement (the agreement scenario) will result in a loss of consumption of about NOK 2.6 billion (1990 kroner) in the year 2000. The reduction in GDP is estimated to NOK 3.1 billion. Both the lower consumption and the decrease in GDP are balanced to a large degree by a reduction in the load of pollution and traffic, an estimated cost-saving of approximately NOK 2.4 billion (1990 kroner) in the year 2000.

The reductions in emissions will have little effect on forests and watercourses. This is because the major cause of acidification in Norway is transboundary pollution. The calculations of cost-reductions do not take into account the fact that an international tax on CO_2-emissions will lead to reductions in emissions in other countries of components that cause damage in Norway due to acidification of the natural environment.

Reductions in NO_x-emissions have a strong positive effect on health. Emissions of NO_x originate mainly from transport, and large shares of the emissions are concentrated in towns and urban districts. Therefore, NO_x-emissions, and changes in these, affect a relatively large number of people. The health impacts of other components are relatively insignificant due to low concentrations to start with, and because a smaller number of people are affected.

It must be said that reduced traffic gives large benefits in the form of savings in costs; more than NOK 1.5 billion (1990 kroner) in the agreement scenario and more than NOK 3.7 billion in the stabilization scenario.

There are various elements of uncertainty connected to the calculations. The uncertainty of the data used as a basis for estimating the benefit of the environmental measures is discussed in more detail below. The following are just some comments on the principles applied.

The estimates of the proportion of the emissions that causes damage is assumed to remain constant throughout the period of calculation. In reality, this will depend on the geographical location of the emissions in relation to settlement. For example, a specific reduction of NO_x-emissions from the fishing fleet will have a minimal effect on well-being compared with a reduction in emissions from cars in Oslo. In the same way, a 50 per cent reduction of traffic in Oslo will lead to considerable benefits in the form of less disturbance from noise and less congestion, while such advantages will not be obtained from the same reduction in places with little traffic. The geographical distribution of the transport effort is also assumed to be constant. If the trend in the pattern of settlement continues as before, a steadily larger number of people will become exposed to harmful emissions and other negative effects of road traffic. This tends to suggest that the benefit of a tax on gasoline may be higher than indicated by the calculations. Furthermore, various other positive impacts on the environment are not included in the calculations (for example, reduced damage to concrete, cultural monuments, rubber and plastic products, etc.).

Uncertainties connected to the basic data

An attempt has been made to take some of the uncertainty in the data forming the basis of the benefit estimates into account by estimating reasonable intervals for the parameters included in the calculations, see Brendemoen et al. (1992). For example, the interval for the coefficient connecting wear and tear of roads to consumption of gasoline and autodiesel is fixed from nil to twice the point estimate used above. The effect of the uncertainty of the values of this and other parameters can be investigated by specifying reasonable probability distributions for the different parameters and undertaking so-called Monte Carlo simulations. By repeatedly sampling values of the parameters from the distributions, and calculating cost reductions on the basis of the sampled parameter values, it is possible to obtain a picture of the probability distribution of the cost reductions.

A conservative goal for the uncertainty interval of the cost reduction caused by uncertainty in the damage model (parameter values) may be respectively the lowest 10% and the highest 90% quantile among the simulated distributions. This gives cost reductions of between NOK 1.0 billion and 3.8 billion (1990 kroner) for the agreement scenario and cost reductions of between NOK 2.5 billion and 9.0 billion (1990 kroner) for the stabilization scenario, see table 3.15 in "Summary and conclusions".

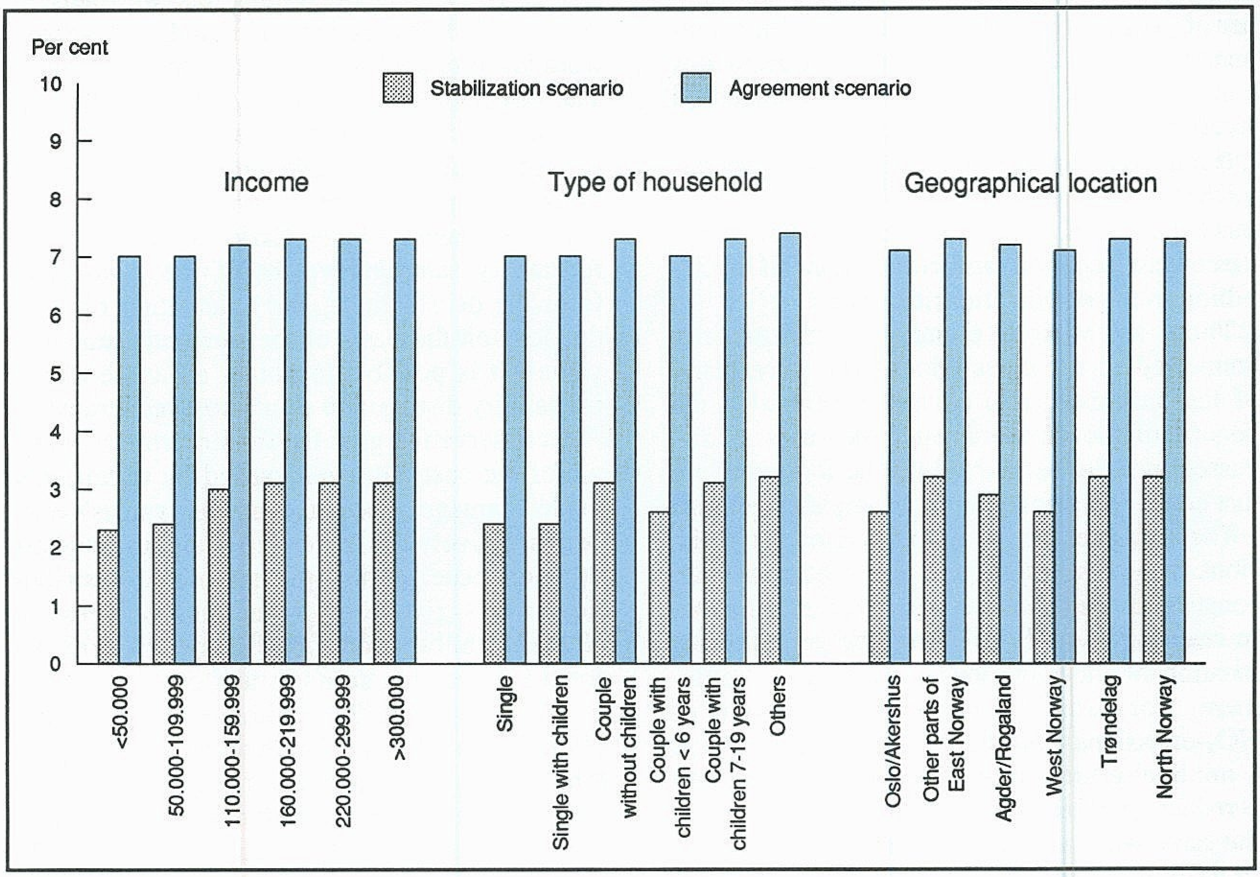
In addition to the uncertainty connected to the calculation of cost reductions there is obviously also some uncertainty connected to the projections of the underlying economic growth and the associated emission levels. No attempt has been made to quantify this uncertainty.

Distributional effects of environmental taxes

The distributional effects of environmental taxes depend on a number of conditions, such as how changes in prices affect the individual household, how improvements in the environment are distributed between different groups of the population, and how the income from the environmental taxes is distributed in society.

The following discussion is limited to considering the effects on total consumption expenditure of changes in prices due to the tax on CO_2. An environmental tax on fossil fuels will lead to an increase in the price of most consumer goods. Oil products are an important input factor in the manufacture of a large number of goods and services. Therefore, higher prices of oil products will obviously lead to an increase in costs for both Norwegian and foreign

Figure 3.20. Compensating variation for different groups of households after introduction of a tax on CO_2. Year 2000. Percentage of income



manufacturers, a price increase which is to some extent passed on to the consumers. The price increase may be high, depending on how much of the production costs of the particular goods or services refers to oil products, and to what extent the price increase can be passed on to the consumer.

The distributional effects are calculated on the basis of a number of simplified assumptions and consumption data for about 1500 households, taken from the Consumer Survey 1986-1988. The calculations assume that the welfare of the household is determined by their consumption of ordinary goods and services through a so-called Cobb-Douglas utility function. The distributional effects of the environmental taxes are estimated by calculating the percentage increase in total potential consumption demanded by each group of households in order to maintain the same level of utility in a situation with price increases due to environmental taxes as experienced in a situation without environmental taxes, the so-called compensating variation, see figure 3.20.

Given a unilateral environmental tax in Norway (the stabilization scenario), an average household whose total consumption potential is increased by 3 per cent will be equally well off relative to the situation depicted in the reference path. In the agreement scenario, the increase in prices is greater (because all import prices increase) and a household must be compensated by an increase in consumption potential of 7.2 per cent.

Figure 3.20 shows that the percentage compensation demanded in the event of introduction of environmental taxes, in order to maintain the level of utility experienced without such taxes, increases slightly with increasing income. This is because the share of income spent on gasoline increases with income, and an increase in the price of gasoline will thus give the largest increase in total cost of living among persons with highest income. Thus an increase in the price of gasoline alone has a levelling effect on income. An increase in the price of electricity and fuel counteracts this levelling effect, since the share of the budget spent on electricity and fuel decreases with increasing income. Since, relatively speaking, the price of gasoline increases most in relation to other prices in the scenario with unilateral environmental taxes (the stabilization alternative), the levelling effect is greatest in this alternative. The persons who are most affected in this scenario must be compensated by about 0.8 per cent more than those who are least affected, while in the agreement scenario the difference is only 0.3 per cent.

We find the same deviation between those who are most and those who are least affected when the households are grouped by type. In this case too, the change favours the groups one usually wants to favour (single parents and couples with small children). One reason is that these types of households do little private driving, but equally important is the change in price of housing. Both alternative scenarios lead to a fall in the real interest rate, and therefore in the real price of housing. In the case of single parents and couples with small children housing accounts for a large share of consumption expenditure, so an environmental tax does not lead to such a great increase in the cost of living as for other types of households.

If the households are grouped geographically, the distribution of loss of material welfare due to an environmental tax becomes even more equally distributed. This is because the households distribute their expenditure on the different goods and services in more or less the same way, independent of where they live.

All in all, the calculations indicate that the loss of material welfare as a result of an environmental tax will be distributed relatively evenly between the different groups of households, as defined above. This conclusion holds good whether the households are grouped by income, type, or geographical location.

It must be emphasized that the conclusion could be quite different if the calculations were based on different assumptions. It is reasonable to suppose, for example, that households in different places in the country have different possibilities as regards use of gasoline and oil. In this connection, households in Oslo, for example, are in a much more favourable position than households in outlying districts as regards access to public transport. Such factors have not been taken into account in the calculations. The result will also be affected by the distribution of non-economic, positive welfare factors due to less pollution of the environment, but it is impossible to include these factors in the system of calculation described above.

Summary and conclusions

This section studies some of the possible gains connected to reduced damage to forests and watercourses, harm to health, and corrosion of certain types of materials, after introduction of environmental taxes. We also consider the usually neglected costs connected to various aspects of road traffic such as congestion, accidents etc. The estimates of possible gains are difficult to calculate and must be regarded as uncertain. An indication of the importance of this uncertainty is presented by simulating the probability distribution of cost reductions under different assumptions of the probability distribution of some of the parameters included in the calculations. Table 3.15 presents the main results and compares these with the calculated decrease in GDP and private consumption in the two alternative scenarios included in the calculations. The changes are relative to the figures for the year 2000 in the reference path, and are expressed in billion NOK.

Table 3.15. Changes in relation to the reference path in year 2000. In billion 1990 kroner

	Agreement scenario	Stabilization scenario
Estimated lower limit of cost reduction	1.0	2.5
Point estimate of cost reduction	2.4	6.2
Estimated upper limit of cost reduction	3.8	9.0
Reduction in GDP	3.1	13.0
Reduction in private consumption	2.6	1.6

3.5. The effect of methane on global climate

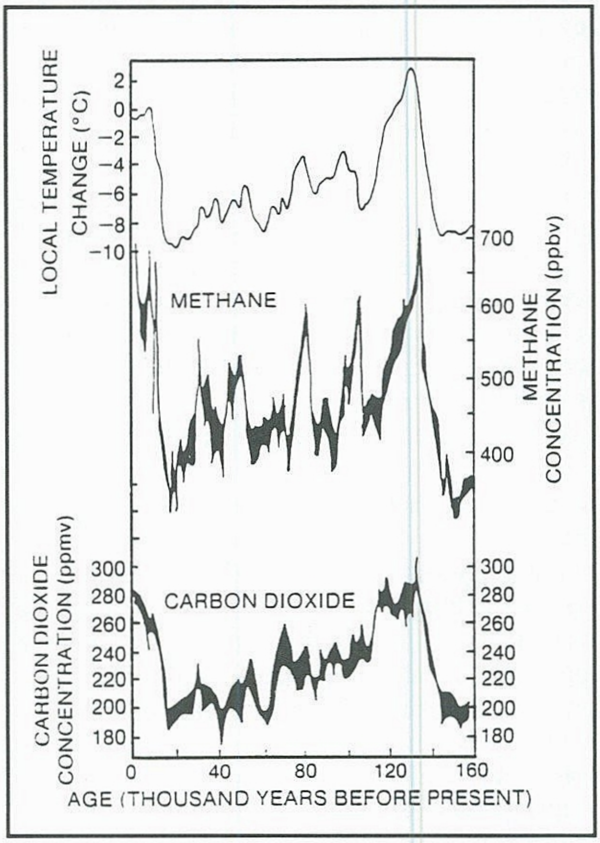
Introduction

During recent years, methane (CH_4) has been the object of increasing research due to the fact that the gas absorbs terrestial infrared radiation and thus contributes to the greenhouse effect. Today, the global mean concentration in the atmosphere is 1.72 ppm (1720 ppb, see explanation in box 3.3). This is far less than the concentration of CO_2 (approx. 335 ppm), but, per molecule, methane is about 26 times more effective than CO_2 as greenhouse gas. Methane has its maximum absorption at 7.66 µm. This is in the spectral region where the earth emits most of its radiative energy. Methane is also chemically active in the atmosphere and affects the concentrations of several other important components, e.g. the OH-radical and ozone (O_3). This implies that methane not only affects climate directly, but also *indirectly.*

Trends in concentration of atmospheric methane

The global mean concentration of methane is now increasing by 12-14 ppb per year, or 0.7-0.8 per cent per year. Analyses of air enclosed in ice cores indicate that, 200 to 2000 years ago, the concentration was stable around 0.8 ppm before starting to rise to today's level of more than twice this figure. Ice core samples have also been used to estimate changes in concentrations as far back as 160 000 years ago. Figure 3.21 shows variations in concentrations of methane and CO_2, and changes in temperature in the Antarctic. The figure shows that, for both gases, changes in concentrations co-vary with changes in climate, but obviously do not indicate the causal relationships. Methane concentration fluctuated between approx. 350 ppb in cold periods and almost 700 ppb in warm periods. Figure 3.21 does not show the trend in recent centuries, but this is shown in figure 3.22. The most rapid change during climate transitions was 0.2-0.3 ppb/yr., while the change was 1.5 ppb/yr. from year 1700 to year 1900. This is much lower than the present increase of 12-14 ppb/yr. Thus, in addition to the fact that the present concentration of

Figure 3.21. Variations in atmospheric concentration of CO_2 and CH_4, and temperature in the Antarctic the last 160 000 years.



Source: IPCC, 1990.

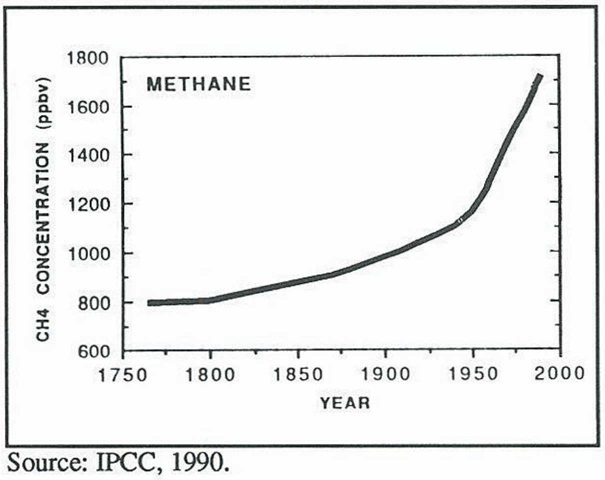
methane is the highest experienced during the last 160 000 years, it also seems that the increase is taking place at a much higher speed than ever before.

What is the cause of this strong increase? It has taken place simultaneously with the rapid increase in the world's population and industrialization. The increase in concentration can be put down either to increased emissions or to reduced degradation or to a combination of these factors. It may be useful, before discussing this subject further, to consider sources of methane, as well as processes of methane loss (sinks).

Sources

Large quantities of methane are emitted from *natural wetlands.* The gas is produced by biological processes under anaerobic conditions in a complex interaction between a number of

Figure 3.22. Development of methane concentration since the 18th century



Source: IPCC, 1990.

specialized bacteria which degrade biological material. These emissions can be affected by human activity. For example, it has been calculated that emissions from wetlands in Sweden have been reduced by about 13 per cent through draining the wetlands. *Rice fields* are an important anthropogenic source of methane, but the contribution is very uncertain, and there is an urgent need for more knowledge about the global strength of this source. As much as 60 per cent of the world's rice fields are located in India and China, but few data are available from these areas. The methane produced under anaerobic conditions is transported to the atmosphere via diffusion, bubbles, or through the vascular system of plants. The size of the flux depends on a number of conditions connected to cultivation, such as type of fertilizer and fertilization practice, type of plant, type of soil, pH, temperature etc. Much of the methane produced is oxidized before it reaches the atmosphere.

Methane is also produced through *enteric fermentation* in animals. The emissions depend on the quantity and type of feed, and there are large variations between animal species.

Methane is the main component of natural gas (around 90 per cent or more). Therefore, emissions and leakages during *production of oil and natural gas, and distribution and use of natural gas* may be another important source of methane. The contributions are uncertain, however, and there may be large regional differences. Methane is also found in pockets of gas in *coal mines*, and may be released during extraction and transport of coal.

Anaerobic degradation in *landfills* (waste deposit sites) probably leads to considerable emissions on a global scale, but a number of conditions regulating the emissions are still not yet clarified (quantities and types of waste, depositing practices, oxidation, etc.). Recent studies also indicate that large quantities are released from waste water and animal waste treatment facilities. *Burning of biomass* in connection with deforestation, agricultural practices and domestic waste treatment in tropical and sub-tropical areas are assumed to be a source that has become more important during the last century. It has been long discussed whether *termites* may be a large global source of methane. Field and laboratory studies have reached global estimates ranging from 2 to as much as 150 Tg CH_4/yr., but the emissions are probably closer to the lower limit.

Methane can also be stored in *chlatrates*, where methane molecules are trapped in a lattice of water. Such chlatrates are found under the continental shelf and in areas with permafrost. Changes in temperature and/or pressure can destabilize and liberate methane, but it is very uncertain whether this source is of any significance at present. Such changes may have been important during earlier climate transitions, and may have an intensifying effect in the future. It is assumed that the *oceans and freshwater* are sources of only moderate emissions of methane, but little data are available as yet, and the processes are not completely elucidated. Earlier measurements, made when the methane concentration in the atmosphere was 20 per cent less than it is today, showed that the open sea was slightly super-saturated with methane in relation to the partial pressure in the atmosphere.

Sinks

The most important sink for atmospheric methane is reaction with the extremely reactive hydroxyl radical, OH, but methane also reacts with excited oxygen atoms and chlorine radicals. The last two reactions take place mainly in the stratosphere. Higher up in the atmosphere, methane can also be broken down by short-wave radiation.

Measurements show that methane is not only released from different types of soil, but can also be taken up in the soil by different types of bacteria that live on methane. It is estimated that this uptake may be as much as 60 Tg/yr., but the data are very uncertain.

Figure 3.23 shows variations in methane concentrations in recent years at different latitudes. The figure reflects how the strength of the sources and sinks referred to above varies over the year and from north to south. The concentrations are highest in the northern hemisphere, since this part of the world has the largest emissions. OH-concentrations are probably higher in the southern hemisphere, which would lead to lower concentrations of methane there.

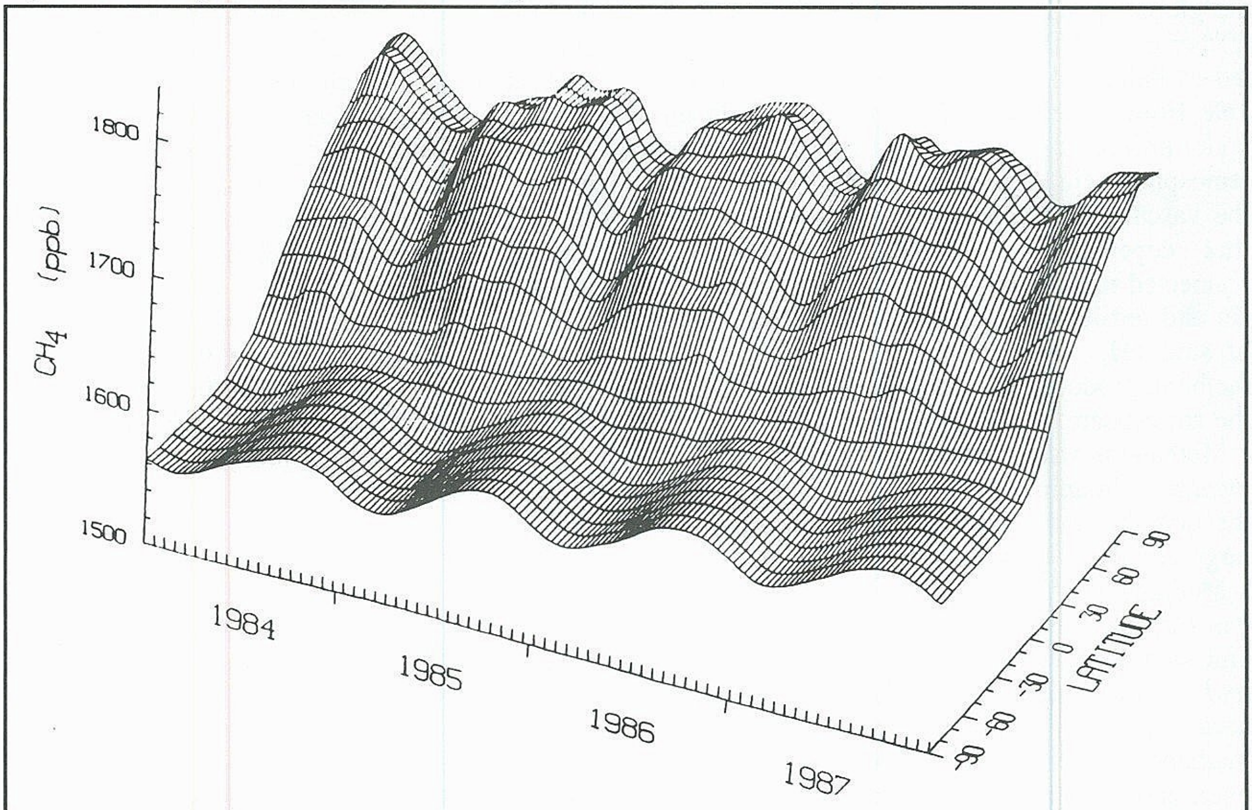
Isotope requirements

The occurrence of the different carbon and hydrogen isotopes in methane can be used to improve quantification of the sources of methane. Some sources are poor in ^{13}C while other are richer. $^{13}CH_4$ reacts slightly more slowly than $^{12}CH_4$ does with OH. If we take this into account, and we know the concentrations of $^{13}CH_4$ in the atmosphere and in the different sources of emissions, then we have a criterion which the distribution on sources must fulfil. As yet, the data are few and uncertain, but in the future this may be a useful method for deciding the contribution from the different sources. Since ^{14}C is unstable, and is degraded with a half life of 5720 years, the occurrence of $^{14}CH_4$ can be used to determine how much of the emissions are "old" or from fossil sources, and how much are of recent origin. If the hydrogen isotopes are also taken into account, such methods can be a very useful means of improving our understanding of the global budget for methane.

The CH_4-budget as we understand it today

When calculating total global emissions of methane, we can start with the amount that is degraded through reaction with OH and during the other processes of chemical loss. The global emissions are calculated by taking into ac-

Figure 3.23. The global distribution, seasonality and trend of methane. 1984-1987



Source: Fung et al., 1991.

count the increases in atmospheric concentrations. The rate-coefficient for reaction of methane with OH is known. As yet, however, no reliable measurement data are available for OH. The OH-concentration can be estimated by models of atmospheric chemistry, or indirectly by using available data on other substances that react with OH.

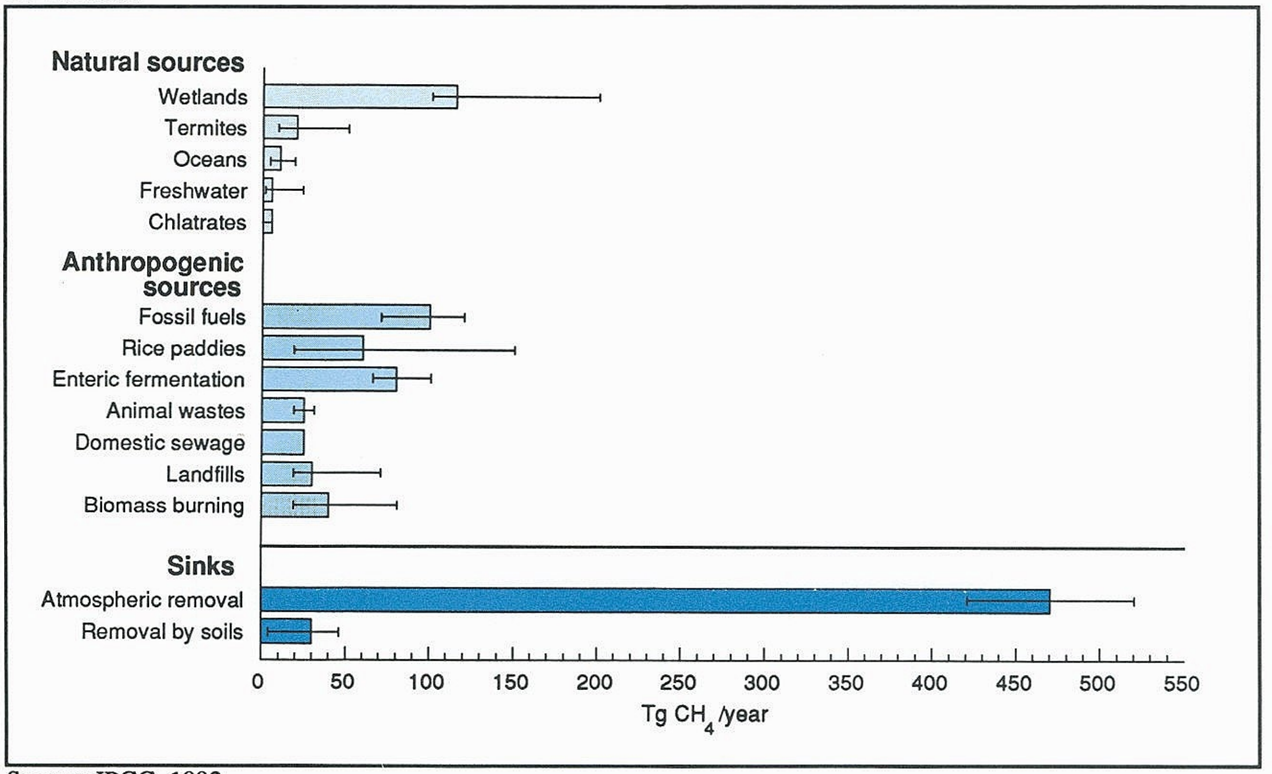
In addition to estimating how much methane is lost from the atmosphere, the calculations of emissions from different sources must take into account the fact that the measurements show that approx. 20 per cent of the total emissions must contain no ^{14}C in order to agree with the observations. In the case of some sources, e.g. wetlands, direct measurements have also been obtained in some areas. By collating all this information it is possible to arrive at the budget shown in figure 3.24. The estimates of the contributions from the different sources are very uncertain.

Direct and indirect effects

The reaction between methane and OH is the start of a long chain of degradation which can proceed in different directions and produce different effects on the chemistry of the atmosphere. For example, let us consider the effect on OH and ozone (O_3) in the troposphere (roughly the lowest 15 km of the atmosphere). OH is the most important oxidizing agent, and is therefore decisive if the cycles of many substances are to remain in balance, so that the gases do not accumulate in the atmosphere. O_3 is an important greenhouse gas, and may also damage plants, materials and human health. However, hydrocarbons other than methane are more important in the development of ozone episodes in the lower 1-2 km of the atmosphere.

Nitrogen oxide (NO) plays a key role in the degradation of methane. In simple terms, it can be said that when the NO-concentrations exceed a certain value, ozone and OH-radicals are *produced.* If the NO-concentration is below this value, these components are *consumed.* Methane, by changing the OH-level as a result of these reactions, will affect its own degradation as well as the degradation of other gases. Carbon monoxide (CO) is responsible for about 60

Figure 3.24. Sources and sinks for methane. The columns show the most probable value. Upper and lower limits are indicated



Source: IPCC, 1992.

per cent of the OH-loss, and will therefore also affect methane and other components. Certain model studies indicate that OH-concentrations have been reduced, mainly due to increased emissions of CO. If this is so, it will have contributed to the increase in methane. However, when NO_x-emissions are taken into account, the model studies show no reduction in OH.

The stratosphere (roughly 15-50 km above the earth) contains very low concentrations of water vapour; about half is produced by degradation of methane. H_2O produces OH and other radicals which take part in the catalytic degradation of ozone in the stratosphere, and may also contribute to increased occurrence of stratospheric clouds in the Antarctic, which cause a strong increase in depletion of ozone. This represents an effect in addition to a possible decrease of temperature in the stratosphere due to depletion of the ozone layer or increased CO_2 in the stratosphere. Increased water vapour content in the stratosphere will also contribute to enhanced greenhouse effect. Climate and ozone problems are thus closely connected.

Increased concentration of methane also causes *increased* production of O_3 in the *lower* part of the stratosphere. Moreover, methane affects the chlorine chemistry in the stratosphere. Through production of HCl, increased concentrations of methane will remove more chlorine, and thus reduce ozone depletion.

Model calculations show that methane accounts for about 17 per cent of the change in radiation balance from 1765 to today. This contribution is even greater if the effect of increased H_2O in the stratosphere due to increase in methane is included. Roughly speaking, the effect of methane would then be about 1/3 of the effect of CO_2.

By causing changes in the radiation balance, methane (and the other greenhouse gases) may initiate important geophysical feedbacks (changes in the albedo of the earth, effects on formation of clouds, atmospheric content of water vapour). Since water vapour is the source of OH, this will in turn affect the atmospheric chemistry.

Microorganisms play a very important role for global emissions of methane. In many cases production occurs at sub-optimal temperatures. Therefore, emissions from several sources, can be expected to increase with a rise in temperature. The production is also dependent on other climate parameters. For example, changed wind conditions can cause a change from anaerobic to aerobic conditions, leading to uptake of methane instead of release, while flooding can cause a strong increase in emissions. Furthermore, an increase in temperature leading to thawing of permafrost liberates degradable biological material which will be partly transformed into methane, or trapped methane may be released directly. As mentioned above, methane in chlatrates may also be released due to changes in temperature and pressure.

Conclusions

The main reasons for the increased concentrations of methane are probably increased production and use of fossil fuels, domestic animals (ruminants), rice cultivation and burning of biomass. The natural sources may also have been disturbed by human activity.

It is also possible that a reduced level of OH may have contributed to the increased methane concentrations, and that uptake in soil has been a more important sink for methane in earlier times. It has been shown that addition of nitrogen to the soil (in the form of fertilizers or in precipitation) reduces uptake of methane from the atmosphere.

Approx. 70 per cent of the total methane emissions are due to human activity. Since methane has a relatively short lifetime in the atmosphere (about 10 years), the effect of reductions in emissions will be more rapid than in the case of other greenhouse gases. In order to stabilize the concentration in the atmosphere, total emissions must be reduced by about 10 per cent. This is far less than for the other important greenhouse gases. It is difficult, however, to achieve a reduction by effective measures without more detailed knowledge of the relative importance of the different sources. This implies that further research is needed on sources of methane, sinks and atmospheric chemistry.

This section is based on an article in KJEMI no. 9, 1991, by Jan Fuglestvedt, CBS, and Hans Martin Seip, Department of Chemistry, University of Oslo.

Albedo: Reflectivity. The albedo of the earth refers to the ratio between total incident solar radiation and the amount reflected (by the earth's surface, clouds and gases in the atmosphere) expressed as a decimal or a percentage.

Anaerobic conditions: When virtually no free oxygen molecules are present.

Diffusion: Movement of molecules or atoms from a region of higher concentration to a region of lower concentration until the concentrations become the same.

Excited atom: An atom that has absorbed energy, so that it is richer in energy than it was to start with. Such atoms are often very reactive.

Isotope: Variants of the same chemical element but with different atomic weights.

Chlatrates: Consist of gas molecules trapped in a lattice of crystals, e.g. of water molecules.

Partial pressure: In a mixture of several gases, partial pressure is the pressure one of the gases would exert if it were present alone (at the same temperature and in the same volume).

Radical: Atom or group of atoms with one or more unpaired electrons. They are therefore very reactive.

1 ppb: 1 molecule per 10^9 molecules of air.

1 ppm: 1 molecule per 10^6 molecules of air.

1 Tg = 10^{12}g = 10^6 tonnes

Box 3.3. Definitions and units.

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4. FISH

A positive trend has been observed in the stock of North-East Arctic cod, which was estimated to 1.2 million tonnes in 1991. The catch quota for 1992 is 300 000 tonnes, of which Norwegian fishermen are allowed to catch 125 000 tonnes. They are also permitted to catch 40 000 tonnes of Norwegian coastal cod. The spawning stock of Norwegian spring-spawning herring was estimated to be about 1.6 million tonnes at the beginning of 1991. The 1983 year class accounts for more than 80 per cent of this stock. There has been a marked increase in the stock of Barents Sea capelin since 1990, and fishing of this species was allowed in 1991 for the first time since 1986.

The total catch of fish in Norwegian fisheries was about 1.9 million tonnes in 1991. This is 380 000 tonnes more than in 1990. Including crustaceans, molluscs and seaweed the total catch in 1991 was 2.1 million tonnes, with a first-hand value of NOK 5.6 billion.

The export value of fish products (including reared salmon) increased by 12 per cent in 1991 to almost NOK 15 billion. Export of salmon accounted for about NOK 4.5 billion. For the first time ever, there was a decrease in the export value and the export volume of reared salmon, even though salmon production in 1991 reached a record high level of between 150 000 and 160 000 tonnes.

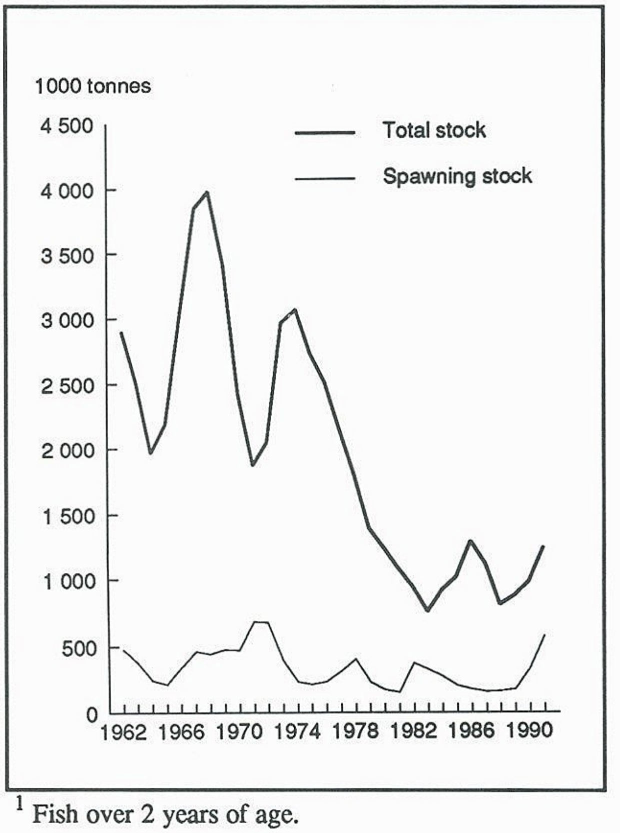
4.1. Stock development

This section reviews the development of some important fish stocks, based mainly on reports from the International Council for the Exploration of the Sea (ICES).

North-East Arctic Cod

The size of the stock of North-East Arctic cod was estimated to 1 240 000 tonnes at the beginning of 1991, see figure 4.1. The estimate of the spawning stock is 570 000 tonnes. The accounted stock of North-East Arctic cod includes fish that are more than 2 years old at the turn of the year. Figure 4.2 shows recruitment to the stock, measured in terms of the strength of the year classes when they enter the accounted stock as three-year-olds. All the year classes from the 1980s, except for the strong year class in 1983 and the more "normal" year classes in 1981 and 1982, were weak. Spawning seems to have been good, however, in both 1990 and 1991. Cod usually mature when 7 or 8 years old.

Figure 4.1. Total stock[1] and spawning stock of North-East Arctic cod. 1962-1991. 1 000 tonnes.



[1] Fish over 2 years of age.

Figure 4.2. Recruitment of North-East Arctic cod. 1962-1988. Millions of three-year old individuals

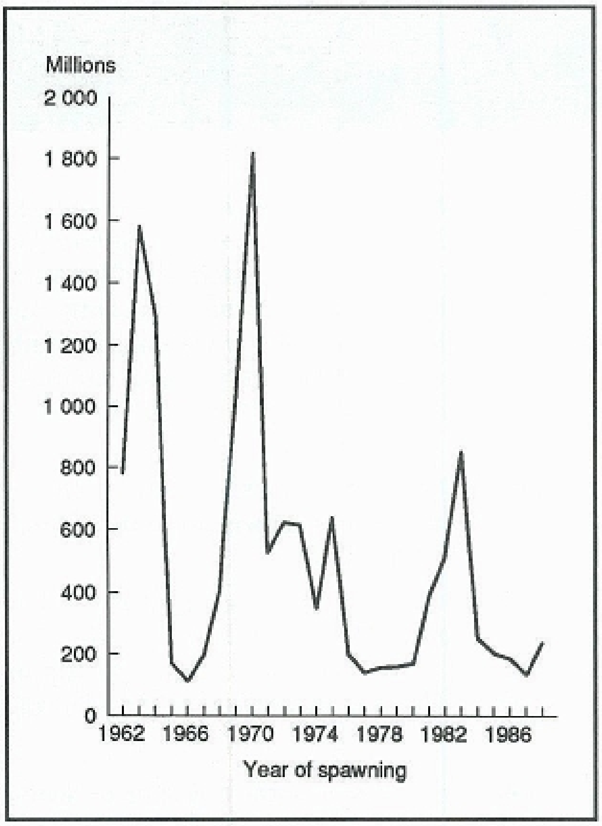
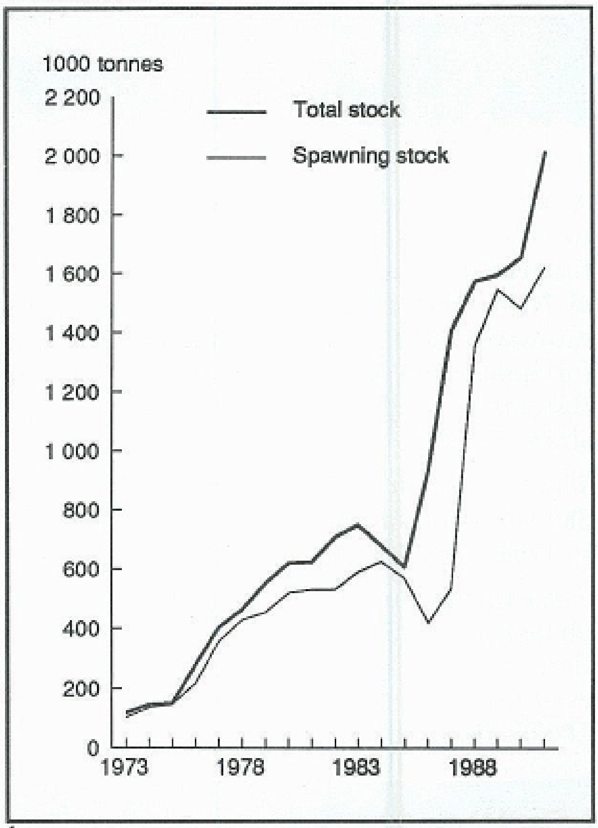


Table 4.1. Stock development[1]. North-East Arctic cod. 1975-1991. 1 000 tonnes.

Year	Initial estimate (1)	1991-estimate (2)	Re-evaluation (3) = (2) - (1)
1975	3 600	2 730	-870
1976	4 110	2 510	-1 600
1977	2 500	2 150	-350
1978	1 920	1 790	-130
1979	1 690	1 390	-300
1980	1 500	1 240	-260
1981	1 560	1 090	-460
1982	1 410	940	-470
1983	960	750	-260
1984	730	910	180
1985	1 020	1 010	-10
1986	1 880	1 290	-590
1987	1 500	1 120	-380
1988	900	810	-90
1989	680	870	190
1990	830	980	150
1991	1 240	1 240	.

[1] Initial stock size estimate and estimate in 1991.

Figure 4.3. Total stock[1] and spawning stock of Norwegian spring-spawning herring. 1973-1991. 1 000 tonnes.



[1] Fish over 2 years of age.

Based on the most recent estimates of the stock, marine researchers carry out recursive calculations for the development of the stock, using data on the catch and on natural mortality. In this way the estimates of the stock size in previous years are re-evaluated. Table 4.1 shows the size of the stock of North-East Arctic cod as estimated for the first time each year and as estimated in 1991. In 1991 the 1987 stock was estimated to have been 1 120 000 tonnes; 380 000 tonnes less than the original estimate.

Norwegian spring-spawning herring

The stock of Norwegian spring-spawning herring was estimated to be 1.7 million tonnes in 1990, see figure 4.3. A prognosis from ICES estimated the total stock of Norwegian spring-spawning herring to be 2.0 million tonnes as per 1 January 1991.

The stock was fished down from a level of between 7 and 10 million tonnes in the 1950s, and right down at the end of the 1960s. No spawning stock was registered at the beginning of the 1970s, but a reasonably good year class in 1969 produced about 80 000 tonnes of mature herring, most of which spawned in 1973. Recruitment was fairly good from some of the year classes from 1973 onwards, and a particularly rich year class was registered in 1983, see figure 4.4. This year class has now been recruited to the spawning stock. The estimated spawning stock of about 1.6 million tonnes in 1991 is about three times as large as the spawning stock in 1987. The year classes since 1983 are expected to make a poor contribution to the spawning stock, which is expected to decrease in the short term, even if no fishing takes place. Preliminary investigations indicate, however, that the 1991 year class will be a very good one. The development of the stock is very uncertain, and is strongly dependent on what happens to the 1983 and 1991 year classes in the next few years. The year class from 1983 accounts for about 80 per cent of both the number and the biomass of herring that are three years old or more. Norwegian spring-spawning herring mature between 3 and 6 years of age.

In 1991 the catch quota for herring was 85 000 tonnes. The recommended maximum quota for 1992 is 78 000 tonnes. By comparison, during the period 1964-1967, total annual catches of Norwegian spring-spawning herring varied from 1.3 to 2 million tonnes.

Barents Sea capelin

Figure 4.5 gives estimated size of the capelin stock (fish that are two years old or more) in the Barents Sea based on acoustic measurements in autumn. During the period 1986-1989 the stock was very small, but since 1989 has

Figure 4.4. Recruitment of Norwegian spring-spawning herring. 1973-1988. Millions of three-year old individuals

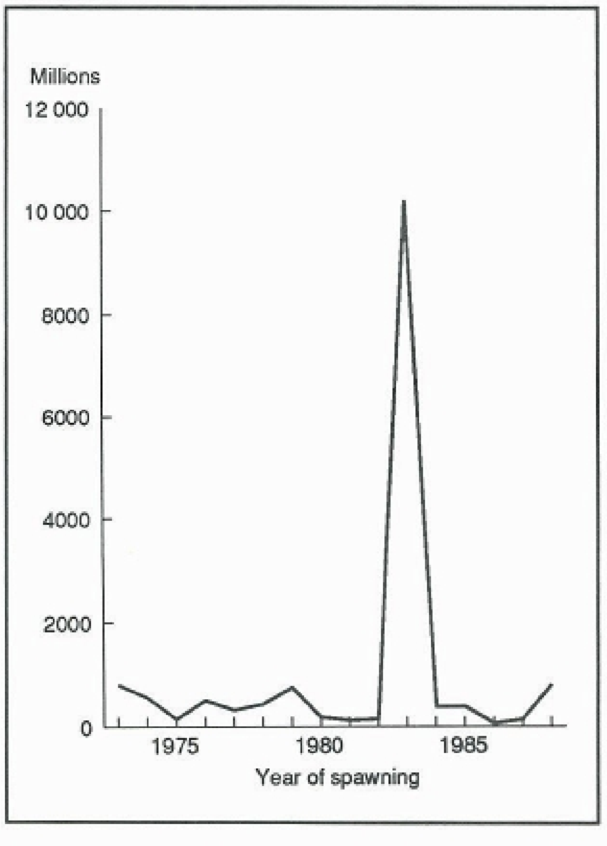
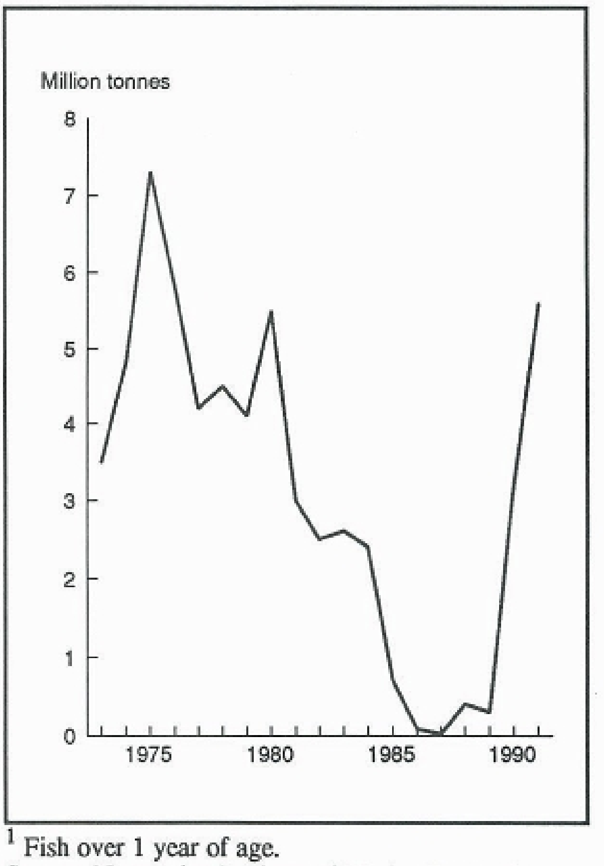


Figure 4.5. Size of the capelin stock[1] in the Barents Sea in autumn. 1973-1991. Million tonnes.



[1] Fish over 1 year of age.
Source: Norwegian Institute of Marine Research.

increased strongly. In autumn 1991 it was estimated to be 5.6 million tonnes.

The positive development of the capelin stock implied that fishing of the species was permitted in 1991 for the first time since 1986.

Other important fish stocks

Table 4.2 shows the development of several stocks of importance to Norwegian fisheries.

There was a drastic decrease for a time in the stock of North-East Arctic haddock. In 1984 the stock reached a bottom level of 60 000 tonnes, about 5 per cent of its size in 1973. This down period was followed by a period of rapid growth, reaching a figure of 340 000 tonnes in 1986. Since then the size of the stock has fluctuated somewhat. The estimate for 1991 is 250 000 tonnes, and it is recommended that care is taken not to overtax the haddock stock.

The estimated size of the stock of North-East Arctic saithe is about 430 000 tonnes for 1991. The stocks of haddock and saithe in the North Sea are decreasing, and the spawning stocks of these two species reached a historic minimum in 1990.

4.2. Quotas and catches

Table 4.3 shows quotas and catches of North-East Arctic cod, North-East Arctic haddock, North-East Arctic saithe and Barents Sea capelin.

Preliminary figures for North-East Arctic cod fished in 1990 indicate a catch of 250 000 tonnes, plus 26 000 tonnes of Norwegian coastal cod. For 1992 the total quota of North-East Arctic cod is fixed at 300 000 tonnes (including Murman cod). To this is added 40 000 tonnes of Norwegian coastal cod. After transfer of part of the earlier Soviet Union's quota to Norway, Norwegian fishermen are allowed to fish 125 000 tonnes North-East Arctic cod in 1992, plus 40 000 tonnes Norwegian coastal cod. Figure 4.6 shows the relationship between quota and catch of North-East Arctic cod since 1978.

After 1984, there was a slight increase in the stock of haddock, and the quotas were fixed at about 250 000 tonnes for both 1987 and 1988. In both these years, however, the catch was much lower than the quota; 151 000 tonnes in 1987 and 92 000 tonnes in 1988. Nor did the catch reach the permitted quota of 83 000 tonnes in 1989. In 1990 and 1991, the quotas of

Table 4.2. Stock development[1]. 1976-1991. 1 000 tonnes.

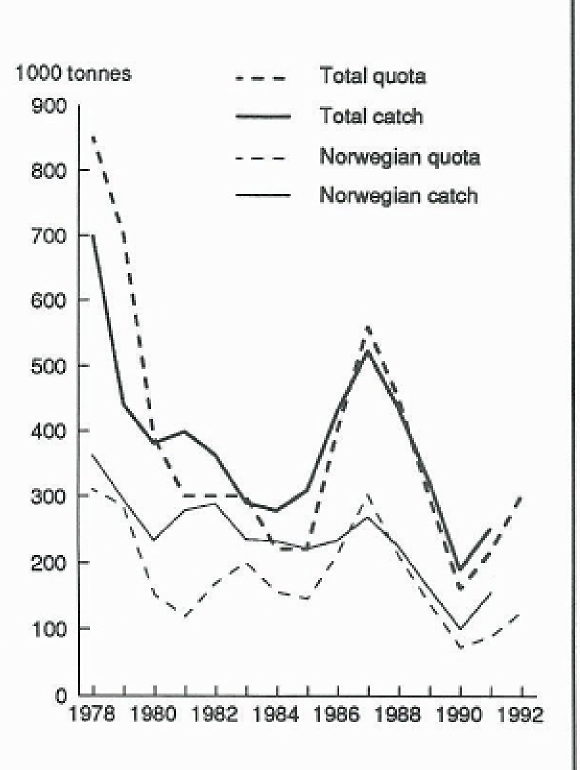
Year	North-East Arctic cod	North-East Arctic haddock	North-East Arctic saithe	Barents Sea capelin[2]	Norwegian spring-spawning herring	North Sea cod	North Sea saithe
1976	2 510	470	620	3 800	290	240	630
1977	2 150	310	490	2 700	400	240	430
1978	1 790	280	470	2 000	460	200	360
1979	1 390	280	440	1 600	550	290	340
1980	1 240	240	570	3 600	620	270	320
1981	1 090	190	560	1 200	620	280	410
1982	940	120	520	1 200	710	310	430
1983	750	70	540	700	750	200	380
1984	910	60	460	1 000	680	200	390
1985	1 010	160	450	300	600	170	390
1986	1 290	340	420	40	930	180	380
1987	1 120	300	450	1	1 410	120	300
1988	810	220	460	4	1 560	170	240
1989	870	210	500	30	1 600	130	180
1990	980	220	460	400	1 660	100	200
1991	1 240	250	430	600	2 010	130	220

[1] Fish over 2 years of age. [2] Stock in autumn according to acoustic measurements.

Table 4.3. Quotas and catches by stock. 1978-1992. 1 000 tonnes.

	North-East Arctic cod		North-East Arctic haddock		North-East Arctic saithe		Barents Sea capelin	
	Quota	Catch	Quota	Catch	Quota	Catch	Quota	Catch
1978	850	699	150	95	160	154	.	1 894
1979	700	441	206	104	153	164	1 800	1 783
1980	390	381	75	88	122	145	1 600	1 649
1981	300	399	110	77	123	175	1 900	1 987
1982	300	364	110	47	130	168	1 700	1 759
1983	300	290	77	22	130	157	2 300	2 375
1984	220	278	40	17	103	159	1 500	1 481
1985	220	308	50	41	85	107	1 100	868
1986	400	430	100	97	75	70	120	123
1987	560	523	250	151	90	92	-	-
1988	451	435	240	92	100	115	-	-
1989	300	323	83	55	120	122	-	-
1990	160	189	25	25	103	105	-	-
1991*	215	250	28	28	90	100	1 100	..
1992*	300	.	55	.	115	.	834	.

Figure 4.6. Quotas and catch. North-East Arctic cod. 1978-1992. 1 000 tonnes.



[1] Norwegian coastal cod not included.
[2] Included transfers from the USSR quota.
[3] Murman cod included.

less than 30 000 tonnes were fished. The prospects for the stock of haddock have improved slightly, and the quota for 1992 has been fixed at 55 000 tonnes.

As mentioned above, there has been a strong increase since 1989 in the stock of capelin. In 1991, fishing of this species was permitted and a total quota of 850 000 tonnes was agreed for the winter fishing and 250 000 tonnes for the autumn fishing. The Norwegian catch was 564 000 tonnes (of a total Norwegian quota of 590 000 after transfers of fishing rights). A total quota of 834 000 tonnes has been agreed for the winter fishing in 1992, of which Norway is allowed to catch 500 000 tonnes. The possibility of autumn fishing will be considered at a later date.

Catches in 1991

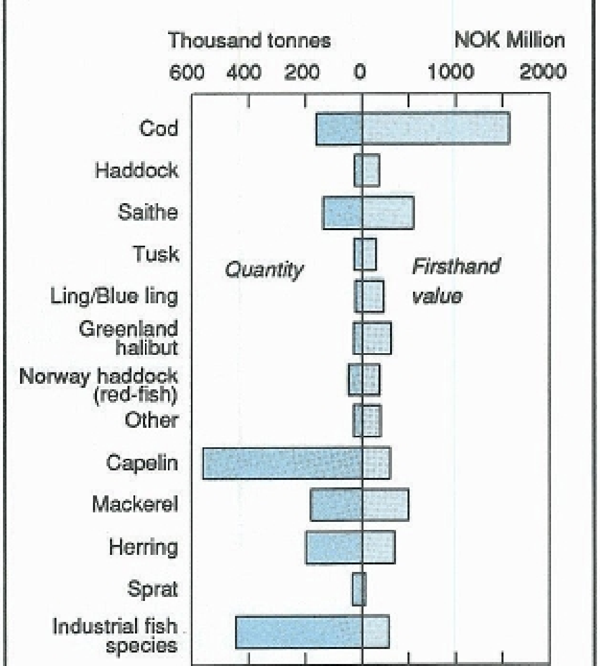
Table 4.4 shows Norwegian catches in the years 1986-1991. Figure 4.7 shows the first-hand value and amounts of the catch in 1991. The total amount fished in 1991 was 1.9 million tonnes. This is 380 000 tonnes more than in 1990. The increase was mainly due to the re-opening of capelin fishing in the Barents

Table 4.4. Norwegian catch by group of fish species. 1986-1991. 1 000 tonnes.

	1986	1987	1988	1989	1990*	1991*
Total	1 790	1 804	1 686	1 725	1 521	1 899
Cod	270	305	252	186	124	162
Haddock	58	75	63	39	22	24
Saithe	131	152	148	144	112	137
Tusk	33	30	23	32	28	26
Ling/blue ling	28	25	24	29	24	23
Greenland halibut	8	7	9	11	22	29
Norway haddock (red-fish)	24	18	25	27	41	47
Others and unspecified	24	34	29	29	39	30
Capelin	273	142	73	108	92	564
Mackerel	157	159	162	143	150	179
Herring	331	347	339	275	207	198
Sprat	5	10	12	5	6	34
Other industrial fish species[1]	450	500	526	696	654	446

[1] Includes lesser silver smelt/grater silver smelt, Norway pout, sandeel, blue whiting, horse mackerel.

Figure 4.7. Norwegian catch by group of fish species. 1991. 1 000 tonnes and NOK million.



Sea, and that the capelin catch increased six-fold to more than 560 000 tonnes. Catches of cod, saithe, Greenland halibut and mackerel all in-creased by 20 to 30 per cent. The catch of industrial fish species decreased by 32 per cent, or just over 200 000 tonnes.

The first-hand value of the fish species included in table 4.4 increased by 23 per cent to NOK 4.9 billion. The total first-hand value of the fisheries in 1991 (including crustaceans, molluscs and seaweed) increased to NOK 5.6 billion. The total catch was about 2.1 million tonnes; a catch of 360 000 tonnes more than in 1990.

4.3. Transfer of fishing rights

In 1977, Norway established a 200 mile economic zone after many years of over-exploitation of fish resources. There is a general ban on foreign fishing within the 200 mile zone, but the Government may permit regulated and limited foreign fishing in accordance with bilateral agreements.

The most important fisheries agreements entered into by Norway are with the EC on fishing in the North Sea and with the earlier Soviet Union on fishing in the Barents Sea. (In future, Russia will be the other party to the agreement on the Barents Sea). The purpose is to ensure a reasonable balance between the fishing carried out by the two parties to the agreement and to establish rules for cooperation concerning effective management of common stocks.

Exclusive stocks, that is to say, stocks which occur only in the zone of one particular country, are owned and managed by this country alone.

In the Barents Sea, cod, haddock and capelin are regarded as common stocks. Cod and haddock are divided equally between Norway and the earlier Soviet Union, while 60 per cent of the capelin belongs to Norway and 40 per cent to the earlier Soviet Union.

As far as the North Sea is concerned, the parties have agreed on a zone division for cod, haddock, saithe, whiting, plaice and North Sea herring, see table 4.5, but have not yet reached agreement on the division of North Sea mackerel.

Table 4.5. Division of stocks in the North Sea. Per cent

Stock	Norway	EC
Cod	17	83
Haddock	23	77
Saithe	52	48
Whiting	10	90
Plaice	7	93
North Sea herring[1]	25-32	75-68

[1] Depends on the size of the spawning stock. In 1991 the distribution was 29 per cent to Norway and 71 per cent to the EC.

No special regulatory measures have been agreed for other common stocks in the North Sea. Neither a distribution ratio nor a TAC (Total Allowable Catch) has been fixed for these stocks, since they are not thought to be threatened by the present level of fishing.

The annual fishery negotiations with the EC, the earlier Soviet Union, the Faero Islands and other countries have two objectives. The first is to fix a TAC, based on recommendations from the International Council for Exploration of the Sea (ICES). The second is to divide and transfer fishing rights, so that each of the parties will be able to fish to an extent best suited to its own particular needs. The TAC is divided in accordance with the agreed zone distribution, and these zone quotas then form the basis for the exchange of fishing rights referred to below as transfers.

Table 4.6 shows the extent and balance of the exchange agreements between Norway and other countries in 1991. By fixing weight values, the transfers are translated from tonnes of each fish species to equivalent quantities of cod, or cod equivalents.

Table 4.6. Transfer of fishing rights between Norway and other countries. 1991. 1 000 tonnes cod equivalents

	Transfer to Norway (1)	Transfer from Norway (2)	Balance in favour of Norway (3)=(1)-(2)
Total	119.7	140.9	-21.2
EC	74.0	74.4	-0.4
Soviet Union .	28.6	50.9	-22.3
Faroe Islands .	12.3	9.5[1]	2.8
Others	4.8	6.0	-1.2

[1] Quotas in the Svalbard zone not included.

The table shows that, in 1991, the balance sheet of transfers between Norway and the Soviet Union was in Norway's disfavour. The balance with the EC was slightly in the EC's favour. The Soviet Union's gain was less in 1991 than in 1990. The reason is a reduction in transfers from Norway of Norway haddock (red fish) and blue whiting. The fishery agreement with the earlier Soviet Union also covers sealing, with a Norwegian quota in the White Sea and a Soviet quota in the Jan Mayen area. These quotas are not included in the transfer balance sheet.

Figure 4.8. Net transfers from Norway to foreign countries. 1981-1991. 1 000 tonnes cod equivalents

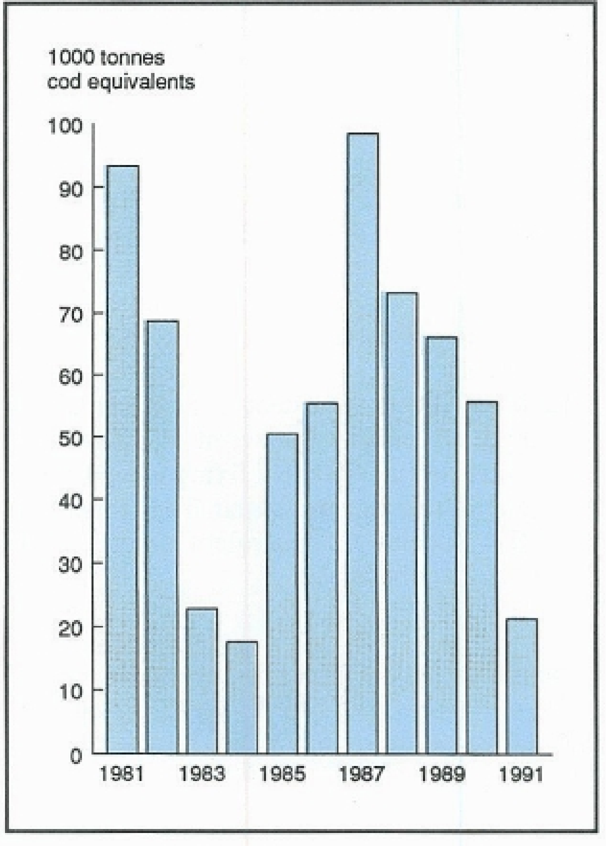


Figure 4.8 shows changes in Norway's balance of transfers with other countries during the period 1981 to 1991.

In the agreement with the Faero Islands it is decided that also the quota assigned to the Faero Islands by the Soviet authorities can be fished in the Norwegian zone. It has also been agreed that the Faroese can fish in the fishery protection zone around Svalbard. These agreements are not regarded formally as transfers from Norway, and are therefore not included in table 4.6.

Quotas to other countries include Swedish fishing in the Norwegian part of the North Sea and Skagerak, and Polish quotas, mainly from Norwegian stocks of Norway haddock (red fish) and blue whiting in the Barents Sea and around Jan Mayen. "Other transfers" in table 4.6 also includes transfers to Norway from Canada.

In connection with the draft EEA agreement, new rules have been proposed for distribution of quotas of North-East Arctic cod to the EC. Previously, as part of the balanced exchange of fishing rights, the EC has received a cod quota of between 2 and 5 per cent of the total quota (TAC). In 1991 the EC's share was 2.14 per cent. For the years 1993 to 1997 this share will be fixed at 2.9 per cent. During this period Norway is required to place an additional quota at the disposition of the EC outside the balance framework, that is to say, without Norway receiving a quota of other fish species as compensation. This extra quota will increase from 6 000 tonnes in 1993 to 11 000 tonnes in 1997, on the condition that the TAC increases from 300 000 tonnes to 700 000 tonnes during the same period. This means that the EC's total quota will be 4.9 per cent in 1993 and 4.5 per cent in 1997. After 1997 the total quota will be fixed as the average for the years 1993-1997. The whole quota will then be incorporated into the balanced exchange of fishing rights.

4.4. Aquaculture

There has been a marked increase in production of reared fish since this activity was started at the beginning of the 1970s. Figure 4.9 shows the development of the production of reared fish since 1980. According to the official statistics, 146 000 tonnes of reared salmon was slaughtered in 1990, as against 111 000 tonnes the year before. Trout production amounted to 3 800 tonnes. According to preliminary figures calculated for the Norwegian Fish Farmers' Association, salmon production increased in 1991 to between 150 000 and 160 000 tonnes, while trout production was between 5 000 and 6 000 tonnes. Both in 1990 and in 1991, production was higher than sales, leading to an accumulation of large stocks of frozen salmon. Prognoses indicate a production of about 120 000 tonnes of salmon in 1992, and of about the same amount of trout as in 1991.

Salmon and trout were slaughtered at a total of 739 stations in 1990, see table 4.7. Hordaland was the county with the largest number of production stations and the largest amount of slaughtered fish.

Investments in fish farming amounted to NOK 326 million in 1990. Of this amount, NOK 69 million were invested in hatcheries and units for rearing fingerlings, and NOK 257 million in units for rearing fish for food. A total of 4 500 persons were employed in the fish farming industry in 1990, distributed between 1 000 persons in hatcheries and fingerling rearing units and 3 500 persons at stations for rearing fish for food.

Table 4.7. Rearing of fish for food, by county. 1990

County	Number of stations	Slaughtered quantity Tonnes
Total	739	149 786
Rogaland	55	11 647
Hordaland	134	30 483
Sogn og Fjordane .	74	17 101
Møre og Romsdal .	107	24 361
Sør-Trøndelag	72	12 242
Nord-Trøndelag ...	53	9 422
Nordland	132	28 783
Troms	60	9 382
Finnmark	32	4 518
Others	20	1 849

Figure 4.9. Rearing of fish. Slaughtered quantities of salmon and rainbow trout. 1981-1991. 1 000 tonnes.

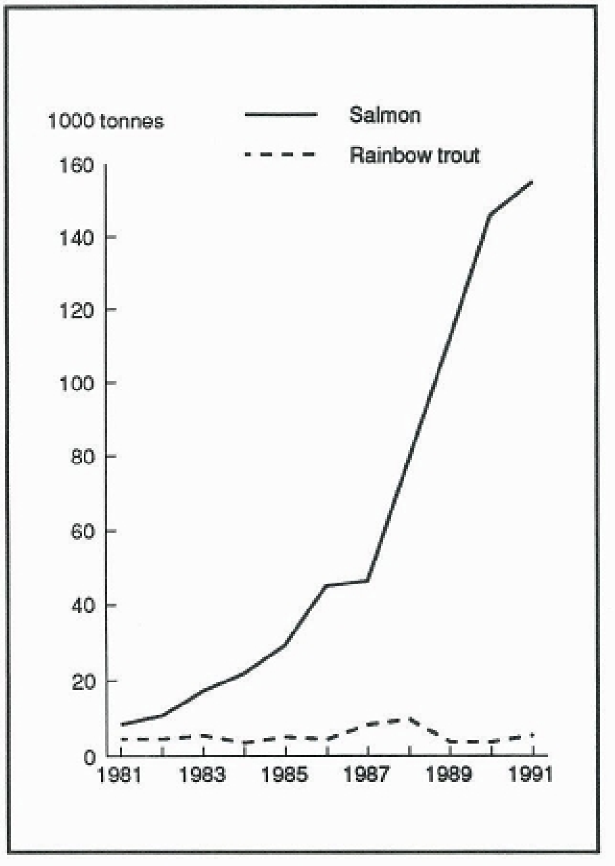


Table 4.8. Use of antibiotics in fish farming. 1981-1991. Kg of active agent.

Year	Total	Oxytetra-cycline chloride	Nifura-zolidone	Oxolinic acid	Trimetoprim + sulfadiazine (Tribrissen)	Sulfa-merazine	Flumequine
1981	3 640	3 000	-	-	540	100	-
1982	6 650	4 390	1 600	-	590	70	-
1983	10 130	6 060	3 060	-	910	100	-
1984	17 770	8 260	5 500	-	4 000	10	-
1985	18 700	12 020	4 000	-	2 600	80	-
1986	18 030	15 410	1 610	-	1 000	10	-
1987	48 570	27 130	15 840	3 700	1 900	-	-
1988	32 470	18 220	4 190	9 390	670	-	-
1989	19 350	5 014	1 345	12 630	32	-	329
1990	37 432	6 257	118	27 659	1 439	-	1 959
1991	26 798	5 751	131	11 400	5 679	-	3 837

Source: Norwegian Medicinal Depot.

The increased production has been accompanied by a strong increase in the use of medicines in the fish farming industry. The substances used belong to three main groups: antibacterial agents, anti-parasitic agents and sedatives. Table 4.8 shows changes in the use of antibacterial agents. Total consumption reached a peak in 1987 and has since fluctuated from year to year. In 1991 total consumption of antibacterial agents amounted to 27 000 kg, almost 30 per cent less than in 1990. Consumption of antiparasitic agents was 6 000 kg and of sedatives 800 kg.

Treatment of nets with antifouling agents containing heavy metals is also an environmental problem.

4.5. Export of fish products

Table 4.9 shows the exported quantities of the most important fish products during the period 1981-1991, including exports of reared fish. Figure 4.10 shows the export value of some fish products. Total exports increased in 1991 by 12 per cent in terms of value and by 28 per cent in terms of volume. Only the export value of fresh fish, fillets and canned fish remained unchanged or was slightly reduced. Export of whole frozen fish accounted for almost fifty per cent of the increase in exports, and now accounts for almost the same share of exports as fresh fish. The largest increase refers to sales of frozen mackerel. The rest of the increase in exports is distributed between smoked and salted fish, dried fish and fish meal. As far as dried fish is concerned, the higher export value is a result of better prices, but in the case of smoked and salted fish is due to a much larger export volume.

In 1991, the export value of reared fish decreased for the first time after an annual growth of almost 40 per cent throughout the 1980s. The exports consist mainly of salmon. Most of the trout is consumed in Norway. Table 4.10 shows that 127 000 tonnes of reared salmon was exported in 1991 (just over 80 per cent of the reared quantity), to a value of NOK 4.5 billion. This represents 31 per cent of the total export value of fish and fish products in 1991. The export value of both fresh and frozen salmon was slightly less than in 1990.

The total export value of fish products increased to NOK 14.6 billion in 1991, see table 4.11. This equals about 13.3 per cent of the total traditional export of commodities (export of commodities excluding crude oil, natural gas, ships and oil platforms etc.).

Table 4.9. Export of fish products. 1981-1991. 1 000 tonnes.

Year	Fresh	Frozen	Fillets	Salted or smoked	Dried	Canned	Meal	Oil
1981	24.6	58.7	74.0	13.6	86.2	15.0	266.5	107.3
1982	46.2	100.2	76.3	14.9	68.8	11.2	228.6	101.1
1983	91.5	62.6	91.6	24.9	59.4	22.4	283.9	128.0
1984	72.9	78.7	98.5	24.6	69.5	22.7	248.9	76.9
1985	74.5	79.5	95.9	20.3	64.6	23.4	173.9	114.3
1986	139.4	98.8	95.2	22.7	62.9	24.4	92.6	38.8
1987	189.6	114.2	105.0	38.0	40.6	24.3	88.3	71.3
1988	212.5	126.7	105.1	36.9	47.0	22.9	68.9	45.6
1989	215.1	159.8	95.2	46.2	48.0	23.2	45.4	39.1
1990	238.8	263.4	71.0	34.6	50.6	23.9	45.3	42.7
1991*	250.0	366.7	62.6	48.8	50.2	23.0	110.8	58.8

Table 4.10. Export of reared salmon. 1981-1991

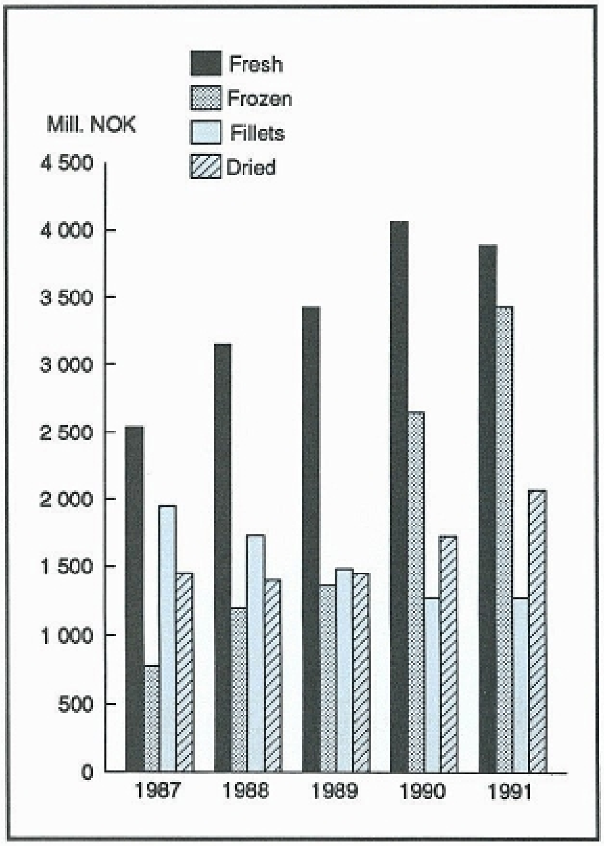
Year	Total		Fresh		Frozen	
	Quantity 1000 tonnes	Value Mill.NOK	Quantity 1000 tonnes	Value Mill.NOK	Quantity 1000 tonnes	Value Mill.NOK
1981	7.4	292.9	5.5	211.4	1.9	81.5
1982	9.2	395.3	7.9	330.8	1.3	64.5
1983	15.4	709.1	13.0	582.6	2.4	126.5
1984	19.7	944.9	17.3	819.1	2.4	125.8
1985	24.0	1 308.3	21.4	1 160.6	2.6	147.8
1986	38.9	1 663.7	34.4	1 458.6	4.5	205.1
1987	43.2	2 174.4	39.2	1 967.3	4.0	207.1
1988	66.0	3 079.7	56.0	2 594.9	10.0	484.8
1989	95.5	3 486.1	81.1	2 954.6	14.4	531.5
1990	130.7	4 834.9	92.8	3 423.8	37.9	1 411.1
1991*	126.9	4 453.3	91.6	3 152.8	35.4	1 300.5

Table 4.11. Export value of fish products[1] in million NOK and as percentage of other traditional exports. 1981-1991.

Year	Fish and fish products	Fish and fish products as percentage of total Norwegian exports of commodities	Fish and fish products as percentage of Norwegian exports of commodities, except crude oil, natural gas, ships and oil platforms
	Mill. NOK	Per cent	
1981	5 955	5.7	11.6
1982	5 931	5.2	11.4
1983	7 368	5.6	12.4
1984	7 675	5.0	11.1
1985	8 172	4.8	11.0
1986	8 749	6.5	12.6
1987	9 992	6.9	12.4
1988	10 693	7.3	11.6
1989	10 999	5.8	10.2
1990	13 002	6.1	11.6
1991*	14 599	6.6	13.3

[1] The table includes a few more products than included in table 4.9.

Figure 4.10. Exports of fresh fish, frozen fish, fillets and dried fish. 1987-1991. Million NOK



5. FORESTS

Norway has approximately 70 000 km^2 of productive forest area. This constitutes about 23 per cent of Norway's total land area. The ownership structure is dominated by relatively small privately owned forest plots. In Norway, the amount of roundwood cut each year is less than current growth. Measurements of forest health status in Norway in 1991 show a slight reduction in crown density for spruce, while the status of pine has remained unchanged. Most European countries report deterioration of forest health status in 1990. The situation is particularly serious in Eastern Europe, but a marked decline in forest health has been registered in several Western European countries as well.

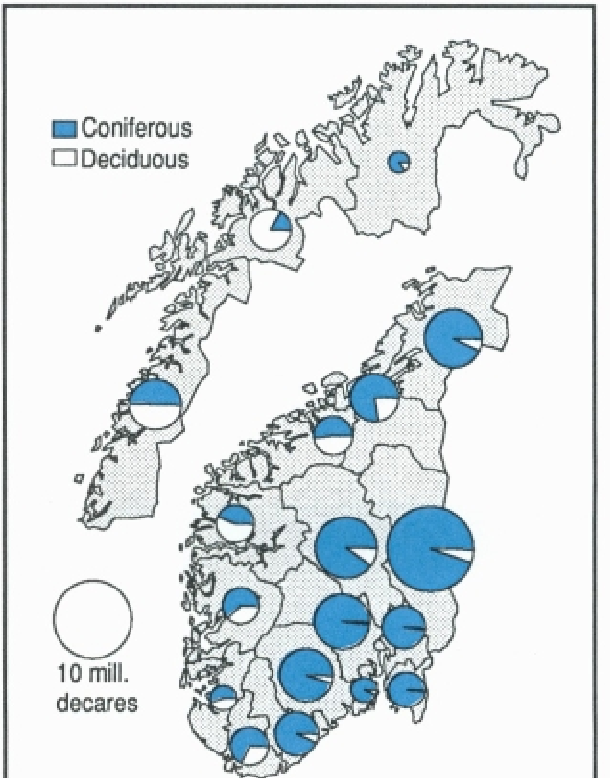
5.1. Forest in Norway

According to the Census of Agriculture and Forestry, 1989, (CBS, 1992), Norway has 70.4 mill. decares of productive forest. This is an increase of 5.7 mill. decares compared with the area stated in the corresponding census in 1979. This increase can probably be put down to better registration of forest areas, and changed evaluations of what constitutes productive forest. The percentage increase in productive forest area was highest in the counties along the coast from Vest-Agder to Møre og Romsdal. The total forest area is divided between 56.8 mill. decares of *coniferous forest*, and 13.5 mill. decares of *deciduous forest*. Figure 5.1 shows that the greater part of the coniferous forest is located in the counties of Eastern Norway and in Sør- and Nord-Trøndelag. The proportion of deciduous forest is highest in the counties of western Norway, and in Nordland and Troms.

The Census of Agriculture and Forestry, 1989, reported a total of 125 000 properties with at least 25 decares of productive forest. 78.5 per cent of the productive forest was owned by individuals, and 8.9 per cent by the State. More than half of the forest properties were operated in combination with agriculture.

During the period 1981 to 1987 the Norwegian Institute of Land Inventory (Norsk institutt for jord- og skogkartlegging - NIJOS) evaluated forest and outfield areas over the whole country, except in the counties of Finnmark and Sogn og Fjordane, and certain municipalities in outlying areas of western Norway, Trøndelag, Nordland and Troms. The evaluations covered about 90 per cent of all productive forest below the coniferous forest limit.

Figure 5.1. County-wise distribution of productive coniferous and deciduous forest. 1989



Source: CBS, Census of Agriculture and Forestry, 1989.

The registered cubic mass in evaluated areas amounted to a total of 495.5 mill. m^3, not including bark. Of this amount, 469.8 mill. m^3 stood in areas of productive forest. The cubic mass of the productive forest area consisted of 51.8 per cent spruce, 30.8 per cent pine and 17.4 per cent deciduous forest. Annual growth in the areas of productive forest was estimated to be 15.5 mill. m^3, not including bark.

There has been a slight increase in roundwood cutting in recent years. During the 1989/90 season, 11.0 mill. m^3 of roundwood was cut for sale and industrial production. According to the Census of Agriculture and Forestry, 1989, a further 0.7 mill. m^3 was cut for use on the owner's property, and for fuel. There is also a natural reduction of forest due to age, climatic conditions, attack by insects and fungi, and natural thinning. Nevertheless, there are grounds to assume that, for many years, there has been an accumulation of cubic mass in productive forest areas in Norway.

The storms at the turn of the year 1991/1992 caused extensive destruction of trees in Sogn og Fjordane, Møre og Romsdal and Sør- and Nord-Trøndelag. Preliminary reports from the forestry administration in each county show that about 1.2 mill. m^3 of roundwood was damaged. This constitutes about 80 per cent of the annual amount of roundwood cut for sale in these counties in recent years.

5.2. Forest health status

Forest health status in Norway

The programme to monitor forest damage was started in 1985. This programme, which forms part of the International Assessment and Monitoring of the Effects of Air Pollution on Forest in the FAO/ECE region, is coordinated by the Norwegian Institute of Forest Research (Norsk institutt for skogforskning - NISK). The programme has a two-fold objective: Firstly to closely follow the health status of forest and study changes in status over time, and secondly to analyze the effects of air pollution on these changes.

The monitoring programme consists of four main parts:

1. *Nation-wide yearly recordings*, which provide data for annual national reports on forest health. The recordings are made by the Norwegian Institute of Land Inventory (NIJOS), and are obtained from permanent plots in a 9x9 km grid (see fig. 5.2). In 1991 the recordings referred to 4 200 spruce and 3 000 pine distributed between 700 plots. About half of the plots were established in 1988, the rest in 1989.

2. *Recordings from permanent plots in each county*, which provide information on local trends in forest health status. County-wise recordings were started in 1988 and refer to 770 plots with a total of 47 000 trees distributed between 189 forestry administrative districts, from Alta in the north to Lindesnes in the south. The recordings are made by the forest administration in each county, and are coordinated and analyzed by NISK. The results of these recordings are not representative for the country as a whole nor for all forest in the county concerned, since all the plots are chosen subjectively and do not represent equally large forest areas. The material consists of a large number of trees and the recordings provide a valuable indication of changes over time.

3. *Detailed monitoring of forest ecological parameters*, carried out in permanent plots in each county. The recordings are made by NISK, and include analyses of soil, water and vegetation. The Norwegian Institute for Air Research (NILU) is responsible for measuring air and precipitation quality in the permanent plots.

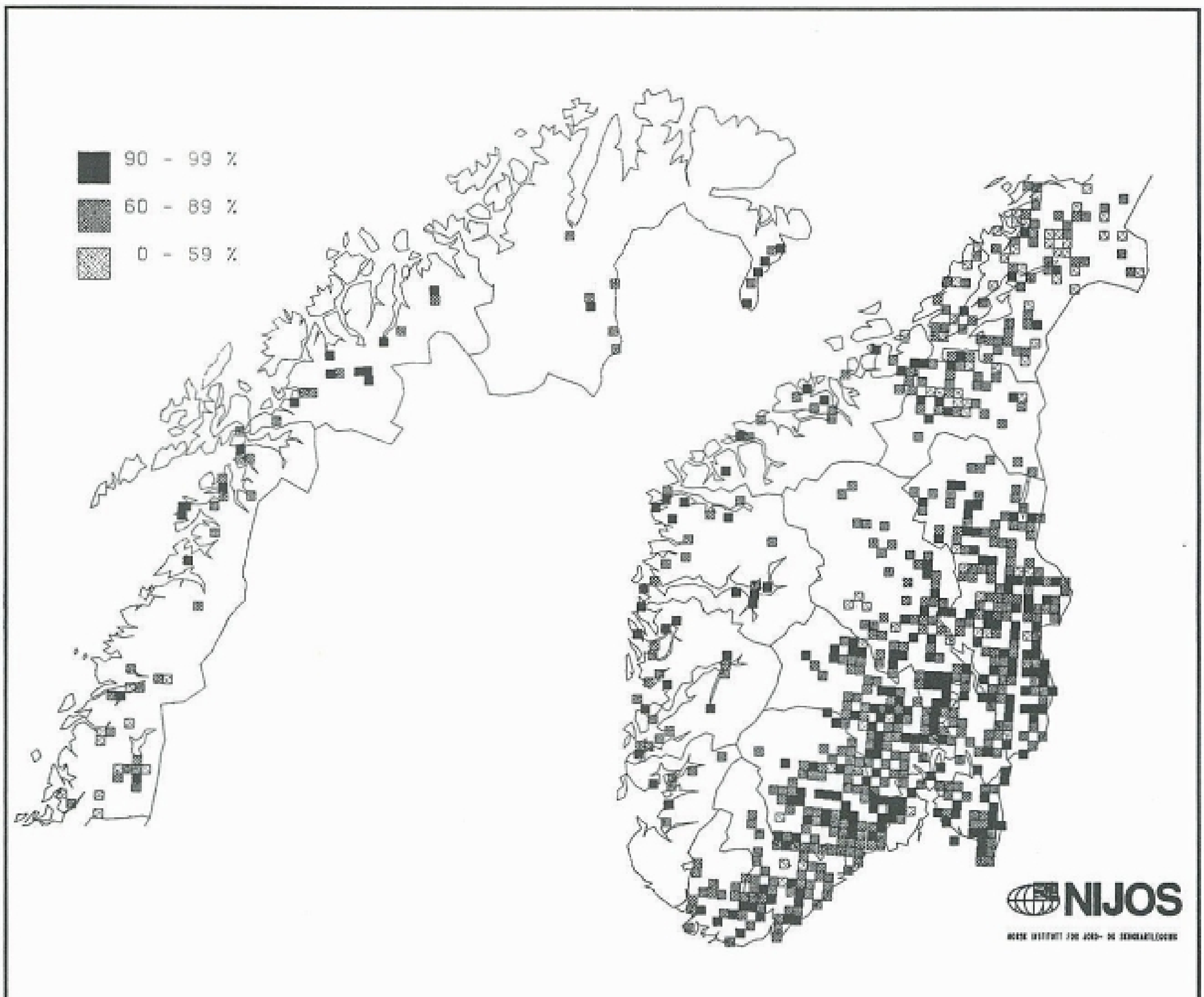
4. *Inspection* by NISK staff, when reports of damage to forest are received.

So far, crown density and crown colour are the most important criteria used to describe forest health. Crown density is obtained by evaluating the remaining foliage in the upper half of the crown for spruce, in the upper two thirds of the crown for pine and in the whole crown for birch. The scale ranges from 0 (no foliage) to 99 (full crown density). The national recordings (NIJOS, 1992) show that crown density for spruce decreased from 84.6 per cent in 1990 to 82.5 per cent in 1991. For pine, the crown density was 86.1 per cent in 1991, with no change from the previous year. Comparisons of changes in crown density during the whole period from 1988 to 1991 show no change for spruce, and a slight improvement for pine.

The crown density of birch in coniferous forest was measured for the first time in 1990, when birch was found in the permanently established plots. For the material as a whole, crown density of birch in coniferous forest averaged 79.7 per cent in 1990 and 79.3 per cent in 1991.

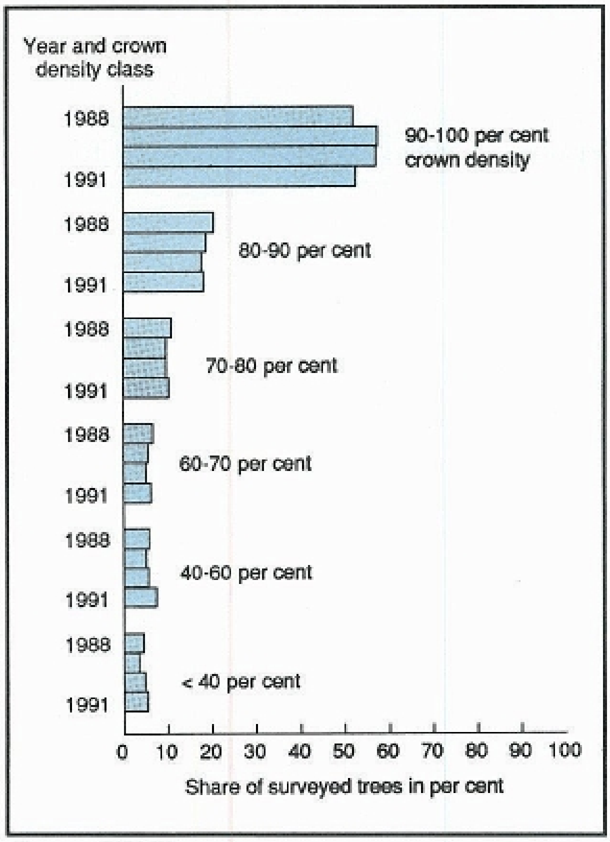
The county-wise recordings (NISK, 1991a) of crown density in 1991 show large regional variations. Crown density was lowest for surveyed plots of spruce in Eastern Norway and Trøndelag, and of pine in Finnmark.

Figure 5.2. Average crown density in the permanently established plots. Spruce. Per cent. 1991



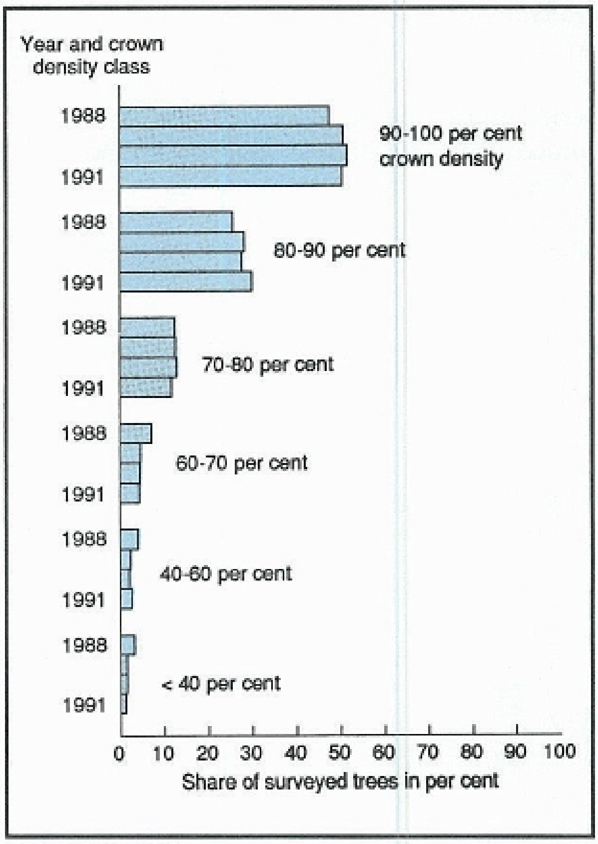
Source: NIJOS.

Figure 5.3. The surveyed trees by crown density class. Spruce. 1988-1991



Source: NIJOS.

Figure 5.4. The surveyed trees by crown density class. Pine. 1988-1991



Source: NIJOS.

The crown density of the trees is observed and grouped into 10-per cent classes from 0 to 90 per cent of full crown density. Figure 5.3 shows that, for spruce, the percentage of trees in crown density class 90-100 per cent decreased from 57.1 per cent in 1990 to 52.6 in 1991, while the proportion of trees in the other density classes increased. Figure 5.4 shows that, for pine, the percentage of trees in the different crown density classes remained almost unchanged from 1990 to 1991.

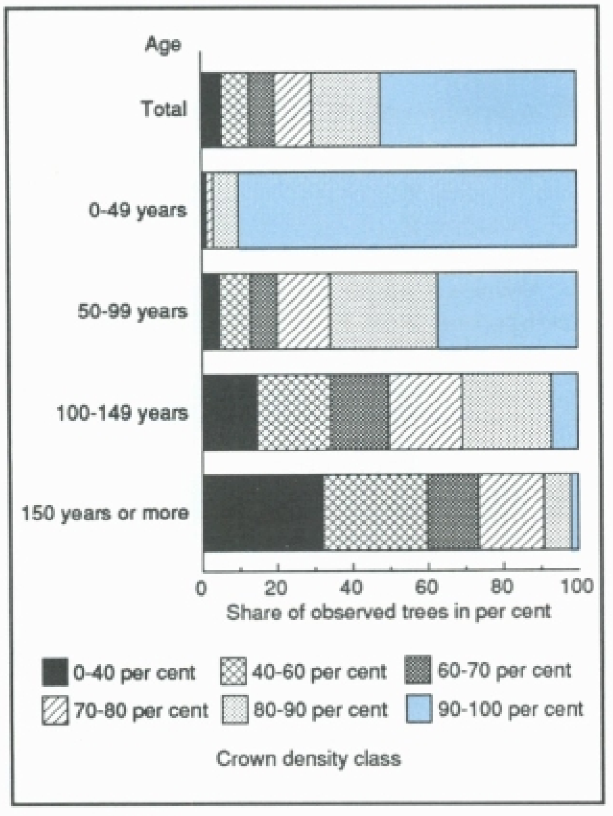
Figures 5.5 and 5.6 show a clear tendency for crown density to decrease with age in both spruce and pine species. This is partly a natural process, but there are also grounds to assume that increasing age and reduced intensity of growth may make the trees more susceptible to external "stress". It is therefore of particular interest to note that, for spruce, a decrease in crown density from 1990 to 1991 was found for all age classes, but in pine, such a decrease was found among the oldest trees only.

Since 1990, crown colour has been divided into five classes, from class 1, i.e. normal green colour (0 per cent discolouration) to class 5, i.e. strong yellow (60 per cent discolouration). In 1991, 89.4 per cent of the surveyed spruce and 95.3 of the surveyed pine trees were grouped into crown colour class 1-2 (normal green to green flecked with yellow). The nation-wide recordings show a slight increase in the percentage of discoloured trees in the case of spruce. For pine, the percentage of normally green trees was higher in 1991 than in 1990.

The county-wise recordings (NISK, 1991a) show regional differences, with more discolouration in 1991 than in 1990 in survey plots of spruce in the southern parts of South-Eastern Norway, and to some extent in North Norway.

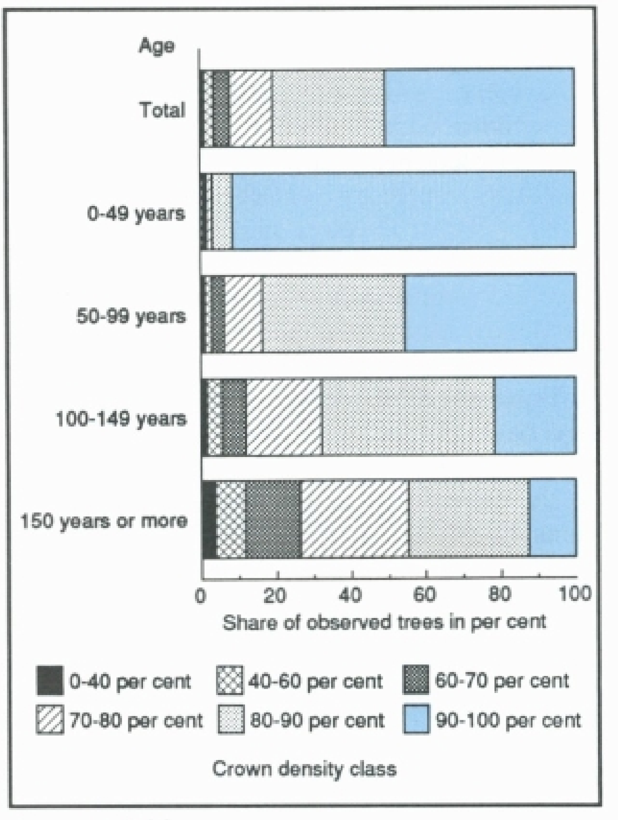
The report on the nutrient content of forest soil in coastal districts of southern Norway (NISK, 1991b), describes a survey of soil data collected from 300 permanent plots in the NIJOS grid of nationally representative plots.

Figure 5.5. Distribution of surveyed trees between crown density classes by age of tree. Spruce. 1991



Source: NIJOS.

Figure 5.6. Distribution of surveyed trees between crown density classes by age of tree. Pine. 1991



Source: NIJOS.

The analysis of soil chemistry data was limited to podsol type soil. The results of the survey show a pattern with low pH, and a high content of sulphur, zinc and nitrogen in the two Agder counties and coastal districts of Telemark. A higher pH, and a lower content of sulphur, zinc and nitrogen was found in Buskerud and higher parts of Telemark. Parts of both Agder and Telemark are particularly vulnerable to acidification, due to acid bedrock, a thin and discontinuous cover of top soil, and high annual levels of precipitation. By the end of 1991, soil analyses had been carried out for all the permanent plots in NIJOS's national grid.

A number of hypotheses have been suggested concerning the effect of air pollution on forest. The most discussed hypothesis assumes that the main agents of forest damage are sulphur dioxide (SO_2) and nitrogen oxides (NO_x). It is assumed that damage may be caused to foliage, either by acid depositions or by high concentrations of SO_2, NO_x and ozone in the air. It is also assumed that SO_2 and NO_x may be an indirect cause of forest damage by affecting the soil through acidification, by increasing aluminium concentration, etc. It is therefore important for the future forest health status in Norway to increase the efforts to reduce air pollution both locally and at the global level.

Forest health status in Europe

Since 1985, the Economic Commission for Europe (ECE) and the United Nations Environment Programme (UNEP) has supported an international cooperative programme to record and monitor the effects of air pollution on forest. In 1991, forest surveys were conducted in a total of 27 European countries or regions, including Estonia, Lithuania, Latvia, the Ukraine and parts of White Russia. The total area of forest in Europe amounts to about 1.8 mill. km^2, of which 70 per cent is included in a grid of permanent plots for systematic monitoring.

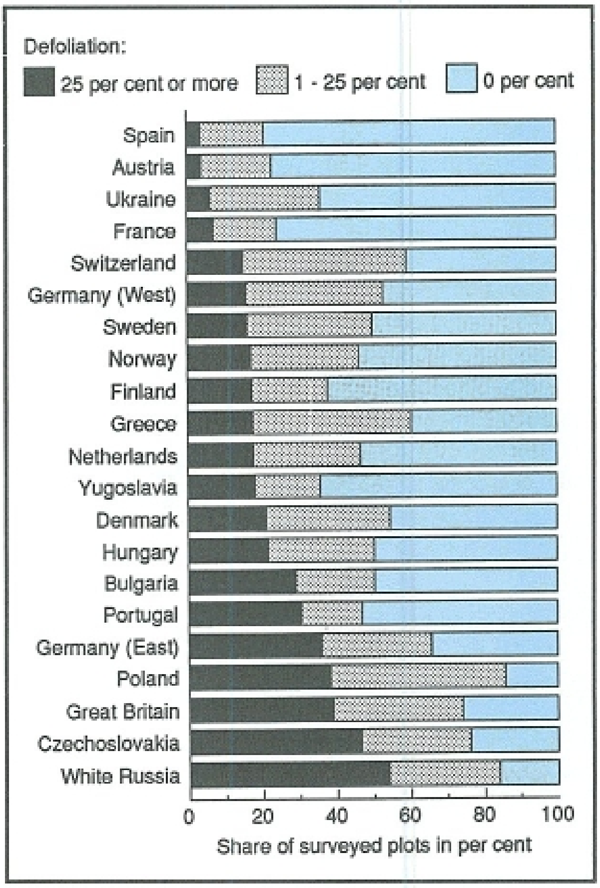
Recordings were made in 27 000 plots, with about 380 000 surveyed trees from 25 coniferous and 34 deciduous species. The economically most important trees in Europe are species of pine, spruce, silver fir, beech and oak. Most of the countries use the same ECE-based principles for recording and classifying forest damage. The results are published annually in the report "*Forest Damage and Air Pollution*" in the series GEMS (Global Environment Monitoring System), which compares the results from most European countries.

Experience from the records of forest damage in Europe (GEMS, 1990) shows that a defoliation of up to 20-25 per cent does not necessarily imply reduced health status, but may be due to the natural adjustment of the trees to variations in climate and supply of nutrients, and can be regarded as normal. Forest damage, in terms of an abnormally large amount of defoliation, occurs in most countries of Europe, but there are large regional differences. Within each country, the extent of damage varies with height above sea level, the age of the forest, and the mix of trees. Due to the subjective nature of the method of recording, caution should be exercised when comparing forest status in the different countries.

The 1991 report from the Ministry of Agriculture in Germany (Bundesministerium für Ernährung, Landwirtschaft und Forsten, 1991) includes results of measurements of forest damage in most European countries. Fig. 5.7 shows forest damage in a selection of European countries. The extent of forest damage is particularly serious in the countries of eastern Europe. More than 25 per cent defoliation was found in more than 30 per cent of the surveyed plots in Lithuania, Poland and White Russia in 1990. Serious forest damage is also reported from certain West European countries such as Great Britain and Denmark.

In Eastern Europe, damage to forest increased from 1989 to 1990. In Western Europe the extent of damage seems to have stabilized at a relatively high level in recent years. Widespread forest death was found in high-lying plots in Bulgaria, Poland and Czechoslovakia and in the eastern states of Germany. Particularly serious damage to deciduous forest in 1990 is reported from Czechoslovakia, White Russia and eastern parts of Germany. In older populations of oak, more than 50 per cent of the surveyed trees showed at least 25 per cent defoliation. The state of beech in these countries also gives grounds for concern.

Figure 5.7. Percentage of plots by occurrence of defoliated trees. All kinds of trees. European countries. 1990



Source: Bundesministerium für Ernährung, Landwirtschaft und Forsten, 1991.

The tendency towards different regional changes in the extent of forest damage has continued in 1990, a fact which supports the theory that the forest damage is due to a number of complex factors. Moreover, opinions differ as to the importance of air pollution for the health status of forest (GEMS, 1990). In some countries, air pollution is considered to be the most important factor for deterioration of forest health status, while other countries consider air pollution to be one of several factors in this connection.

References:

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NISK (1991b): *Overvåkningsprogram for skogskader, skogjordas næringsinnhold i kystnære strøk i Sør-Norge (Monitoring Programme for Forest Damage, nutrient content of forest soil in coastal areas of Southern Norway).* In Norwegian

6. AGRICULTURE. LAND USE AND POLLUTION

The total area of agricultural land in Norway increased by rather more than 4 per cent from 1979 to 1989. Fully cultivated land increased by about 11 per cent, while surface cultivated land decreased by 30 per cent. This may have led to increased runoff of nutrients from agricultural land. This possible increase is counteracted, however, by decreased use of manure and less extreme use of commercial fertilizers.

In 1988, 74 per cent of the manure was spread during the growing season, and in 1989 nitrogen fertilization was spread in several doses on 7 per cent of the grain land. Both these measures imply that a larger share of the nutrients in the fertilizer is absorbed by the plants.

Erosion can be reduced by less soil preparation or by postponing ploughing from autumn to the following spring. In 1989/90, 82 per cent of the area used for grain was ploughed in autumn. The percentage was lowest in Rogaland, with 10 per cent, while as much as 91 per cent of the grain land in Østfold was ploughed in autumn. The runoff caused by autumn ploughing can normally be counteracted by autumn sowing. In 1989, 3 per cent of the grain land was sown in autumn.

6.1. Land use and land resources

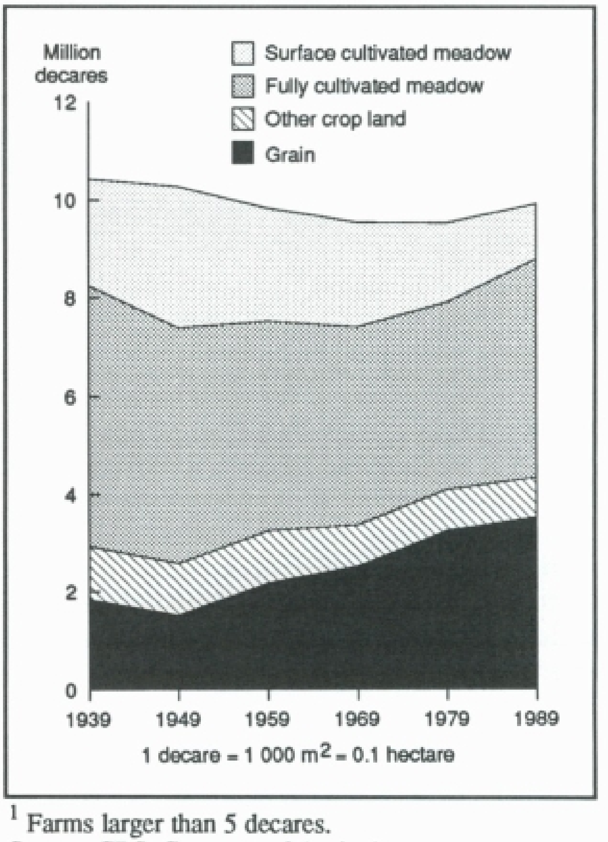
Agricultural land in Norway on farms larger than 5 decares covered about 9 900 km^2 in 1989. This is about 3.2 per cent of the total land area. The comparable figure for 1979 was 9 500 km^2 and in 1939 as high as 10 500 km^2. Figure 6.1 shows how the areas of grain land, other crop land, fully cultivated meadow and surface cultivated meadow (extensive cultivation) have changed since 1939.

The greater part of the agricultural area consists of grain land and fully cultivated meadow (80 per cent in 1989). During the last ten years, the areas of both grain land and fully cultivated meadow have increased, while the area of land used for other crops, and especially the area of surface cultivated meadow, have decreased. During the period 1949 to 1989 there has been a doubling in the area used for grain, but a decrease in the area devoted to the other three groups of crops.

Figure 6.2 shows the distribution of crop land and meadow by county in 1989.

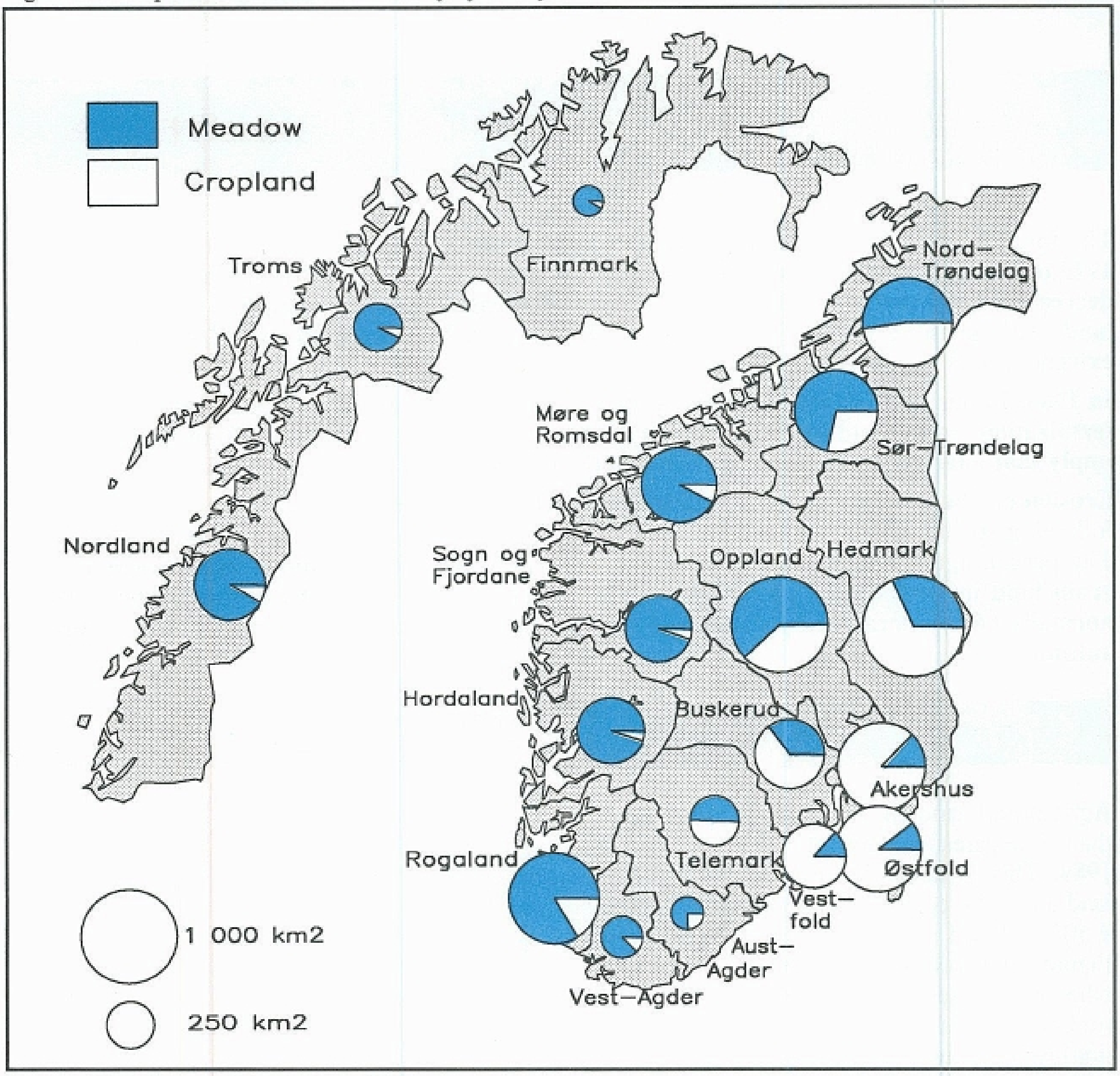
The greater part of the crop land is used for cultivation of grain. Most of this production

Figure 6.1. Agricultural area[1] by type of crop. 1939-1989. Million decares



[1] Farms larger than 5 decares.
Source: CBS, Censuses of Agriculture.

Figure 6.2. Crop land and meadow in Norway by county. 1989



Source: CBS, Census of Agriculture 1989.

takes place in Eastern Norway, where the climate is best, and the terrain and the configuration of holdings has allowed mechanization.

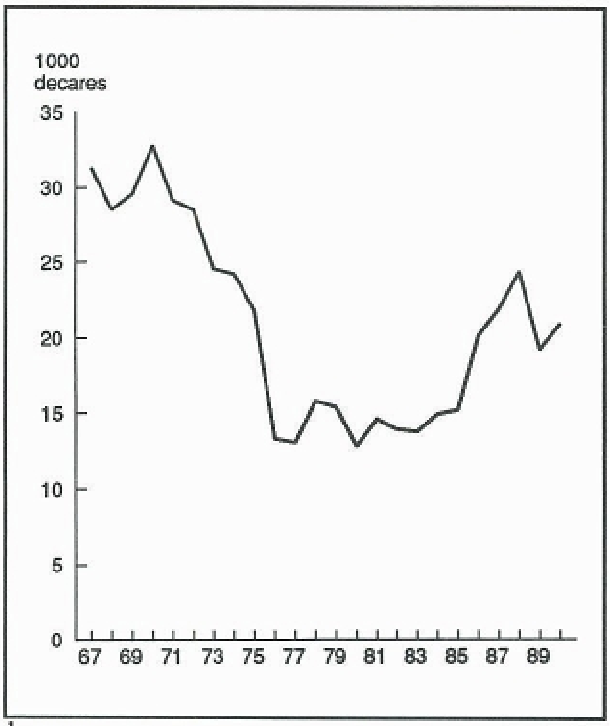
Unlike in many other countries, the area of agricultural land in Norway is small in relation to the population and the total area of land. The cold climate limits the cultivation of many kinds of crops. Only about 10 per cent of the agricultural land is suitable for cereal production (Norwegian Institute of Land Inventory, NIJOS, 1989).

The pressure to use cultivated and cultivable land (cultivable land is arable land that is not cultivated) for purposes other than agriculture has increased with increasing urbanization and growth of other industries. Figure 6.3 shows the number of decares of cultivated and cultivable land that has been transferred to other purposes (roads, buildings etc.) since 1967.

The annual transfers of agricultural land to other purposes decreased during the 1970s, but tended to increase again towards the end of the 1980s. Almost 500 km^2 of cultivated and cultivable land has been transferred to other purposes since 1967. This amounts to about 5 per cent of the present agricultural area. Most of this has been lost for later agricultural production. The greater part of this transferred land is located in areas with other pressing needs for land - around towns and urban settlements. Often these places have the best climate and the best agricultural land.

If all suitable land resources were to be taken into use it would be possible to increase the area of cultivated land from about 10 million decares to 17-18 million decares (NIJOS, 1989). This would increase the cultivated area per capita from about 2.3 to 4.1 decares. The remaining cultivable land is of poorer quality, however, because much of the best land has already been taken into use or has been built on.

Figure 6.3. Cultivated and cultivable[1] land transferred to non-agricultural uses. 1967-1990. 1 000 decares



[1] These statistics did not include cultivable land (arable land that is not cultivated) until 1976. The figures for the years before 1976 are estimated on the basis of the relation between loss of cultivated and cultivable land in later years.

Source: Ministry of Agriculture.

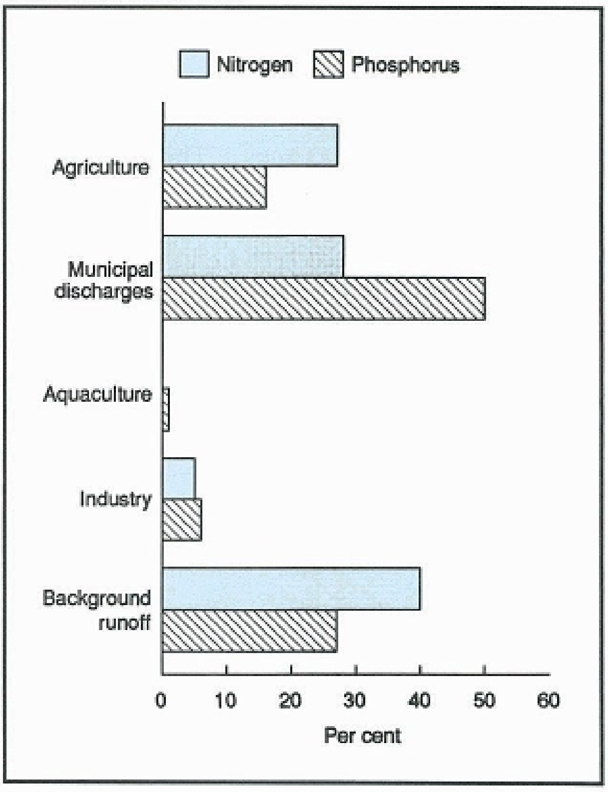
6.2. Pollution from agriculture

The following groups of substances leak out of the agricultural production system and may pollute the environment: *nitrogen (N)* and *phosphorus (P)*, *organic material*, *soil particles* and *micropollutants* (e.g. heavy metals and pesticide residues). In this report, the information on pollution from agriculture is limited to discharges of the nutrients N and P. These nutrients cause algal blooming which in turn may cause deficiency of oxygen in the water masses. Sometimes the algae produce toxic substances (see also chapter 7).

Agriculture's share of total discharges to the North Sea.

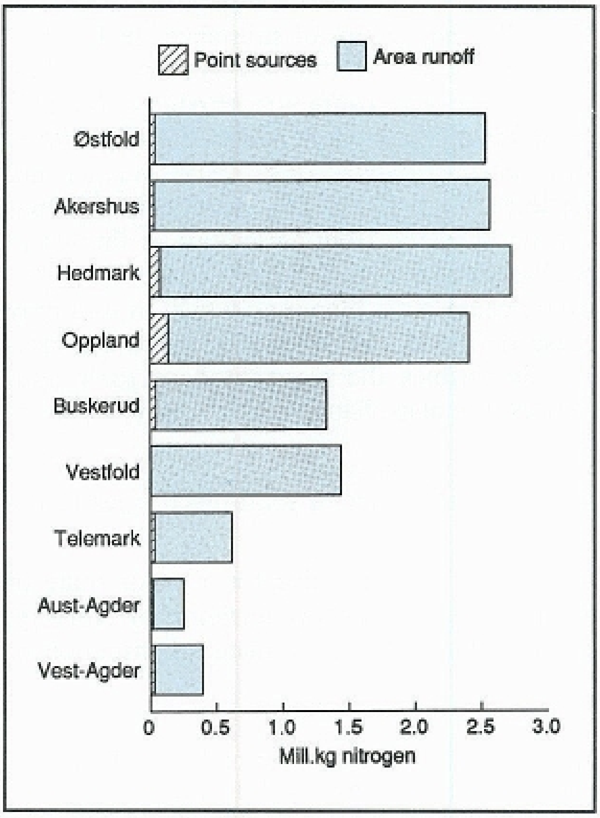
Agriculture is responsible for a major share of the total discharges of nutrients in Norway. Figure 6.4 shows the estimated distribution of

Figure 6.4. Relative distribution of discharges of N and P to the area of the coast Østfold-Lindesnes, by source. 1990. Per cent



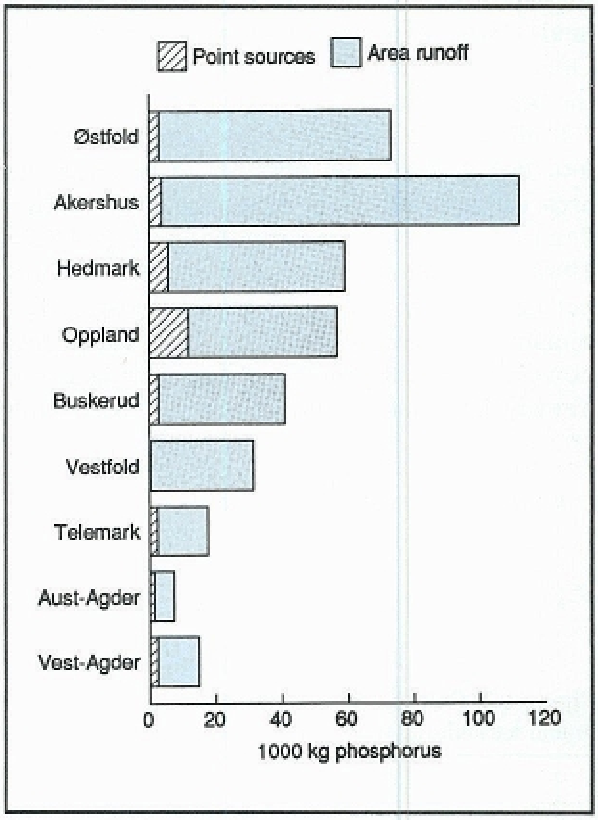
Source: SFT (1991).

Figure 6.5. Nitrogen discharges from agriculture. Point sources and area runoff in the counties covered by the North Sea Declaration. 1985. Million kg



Source: Jordforsk, 1991.

Figure 6.6. Phosphorus discharges from agriculture. Point discharges and area runoff in the counties covered by the North Sea Declaration. 1985. 1 000 kg



Source: Jordforsk, 1991.

total discharges of nitrogen and phosphorus from different sources to the stretch of coast from Østfold to Lindesnes. This is the area covered by the "*North Sea Declaration*" concerning protection of the North Sea, agreed at the meeting of Ministers in London on 24 and 25 November 1987, where the countries bordering the North Sea decided upon a 50 per cent reduction in discharges of nutrients from 1985 to 1995.

The total discharges are estimated to amount to 1 400 tonnes P and 40 000 tonnes N (SFT, 1991). About 27 per cent of the nitrogen discharges and about 16 per cent of the phosphorus discharges come from agriculture. "Background runoff", that is to say, runoff from forest and uncultivated land accounts for 40 per cent of the nitrogen discharges and 27 per cent of the phosphorus discharges. A large share of the background runoff of nitrogen is deposited with precipitation and originates from human activity. Municipal discharges (waste water from households etc.) and runoff from agriculture are responsible for the greater part of the remaining discharges. Discharges from aquaculture are slight, because most of the fish farms are located from Rogaland and further north, i.e. not in the counties covered by the North Sea Declaration.

Sources of discharges

There are two main sources of discharges of nutrients from agriculture; point discharges and diffuse discharges (area runoff). Point discharges are mainly effluents from manure and silage stores. Area runoff includes nutrients lost from crop land and meadows. Point discharges are reduced by sealing the stores. Area runoff is more complicated to control, because these leakages are closely connected to management practices, variations in climate and type of soil.

Figures 6.5 and 6.6 show estimated discharges of nitrogen and phosphorus in the counties covered by the North Sea Declaration (referred to below as the "*algal counties*"), distributed between point discharges and area runoff.

The calculations show that the loss of nutrients from area runoff is far greater than from point sources (Centre for Soil and Environmental Research - Jordforsk, 1991). An average of 90 per cent of the discharges are area runoff. A larger proportion of the nitrogen discharges than the phosphorus discharges are due to area runoff.

Point discharges are connected to livestock production. In Oppland, with a relatively large number of livestock, point sources account for a larger share of the discharges than in Østfold and Vestfold, where the livestock density is low. A high level of phosphorus losses in Akershus is due to extensive erosion.

Agricultural activities affecting pollution

To follow the trend in pollution from agriculture it is necessary to start with changes in farming practices and land use. The *measured* values in the recipients will be affected by inputs from several sources, and these inputs will vary greatly from year to year depending on variations in the weather and in snow-melting. The farming practices that have the greatest impact on runoff are fertilization and soil preparation. Data on soil preparation are available from CBS's sample censuses for agriculture in 1990 and 1991. As far as fertilization is concerned, information on commercial nitrogen fertilizers on grain land and meadows is available in the Censuses of Agriculture in 1979 and 1989, and the sample census in 1990. Data on commercial phosphorus fertilizers, and on use of manure, are available in the censuses from 1989 onwards.

Other relevant statistics are reported figures for domestic animals and areas of agricultural land. These figures are available from 1983 onwards in applications for production subsidies.

The available statistics which throw some light on the contribution made by agriculture to pollution are presented in the following pages.

Land use

Runoff of nutrients per unit of land is greater from fully cultivated land than from forest and mountain areas. Agricultural land can be divided into two main categories: crop land (which is usually ploughed once a year), and meadow (land with grass crops which is only ploughed at intervals of several years). Loss of soil (erosion) is much greater from crop land than from meadows and, in general, loss of nutrients is also greater from crop land.

Therefore, provided that other conditions remain unchanged, a change in the area of agricultural land or a substantial change in the ratio between meadow and crop land indicates a change in discharges of nutrients. There was an increase from 1979 to 1989 in the areas of both fully cultivated meadow (16 per cent) and of crop land (6 per cent), and this may have contributed to greater runoff.

Soil preparation

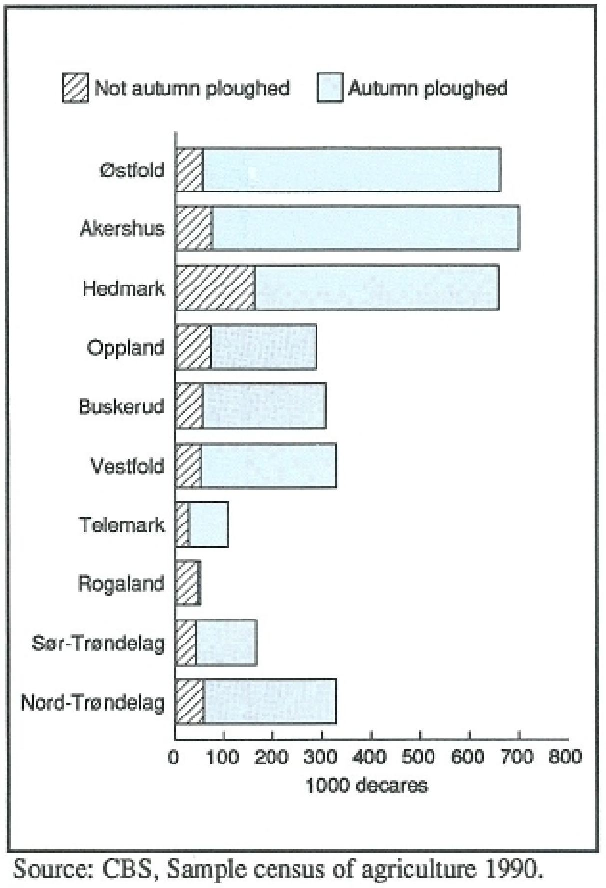
The traditional method of preparing land for grain production is to plough the land in autumn and to do the levelling and harrowing in spring. This means that the land has no cover of vegetation throughout the autumn and winter and is thus exposed to erosion from water and wind. Erosion of the soil from crop land is the most important source of runoff of phosphorus, and the loss of soil in itself will also reduce the production capacity of the land in the long term.

Erosion is less if soil preparation is reduced, particularly in autumn, or is postponed until the spring. Harrowing in autumn, with no autumn ploughing, reduces erosion by an average of 30-40 per cent, while if all soil preparation is postponed until the spring, erosion is reduced by an average of about 60 per cent (Jordforsk, 1990). In absolute figures, the reduction is greatest on land that is steep or consists of highly erodible soils (e.g. silt). As yet, the information on soil preparation has not been specifically geocoded.

Figure 6.7 shows the area used for grain production distributed between autumn-ploughed fields and fields that are not ploughed in autumn (harrowed and/or ploughed in spring).

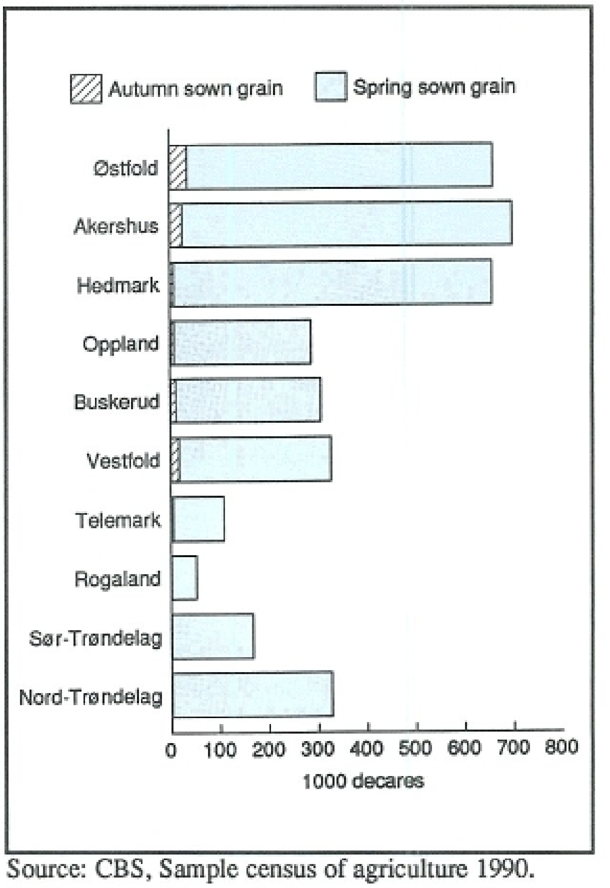
Rogaland is the county with the clearly lowest proportion of autumn-ploughed land, just under 10 per cent. In Hedmark, Oppland, Telemark and Sør-Trøndelag, about 75 per cent of the grain area is ploughed in autumn. In Akers-

Figure 6.7. Grain area distributed between autumn ploughed/not autumn ploughed fields in counties with large areas of grain production. Autumn 1989/spring 1990. 1 000 decares



Source: CBS, Sample census of agriculture 1990.

Figure 6.8. Grain land distributed between autumn sown and spring sown grain. Selected counties. Autumn 1989/spring 1990. 1 000 decares



Source: CBS, Sample census of agriculture 1990.

hus and Østfold, the counties with the largest share of land with high erosion hazard, respectively 89 and 92 per cent of the grain land is ploughed in autumn.

Autumn grain

Autumn grain is relevant in the areas most suitable for grain production. The vegetation cover that is established in autumn reduces erosion by an average of 30-40 per cent in relation to what happens with spring grain with ploughing in early autumn. Nitrogen runoff may also be reduced substantially as a result of plant growth. Figure 6.8 shows the grain area with autumn sowing in 1989.

In the country as a whole, about 3.0 per cent of the area was sown in autumn, but the figure was 3.5 per cent for the "algal counties".

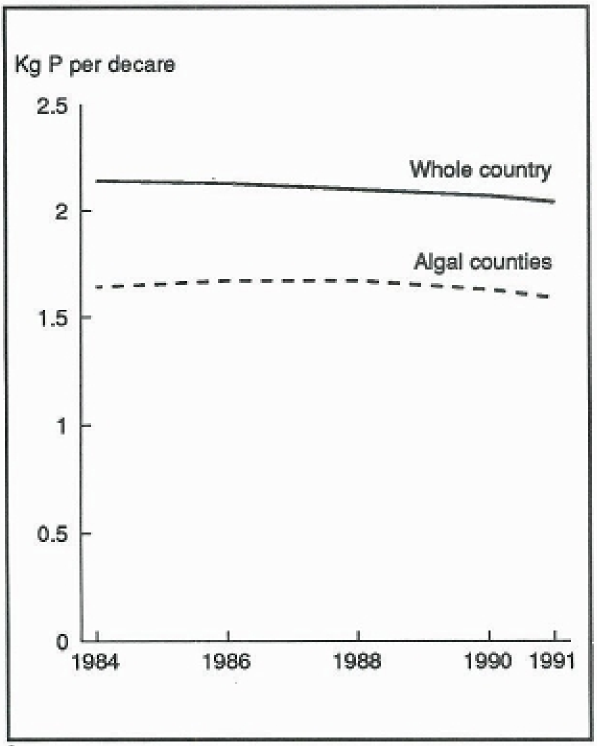
Østfold and Vestfold are the counties where autumn sowing is most common, and account for almost 5 per cent of area devoted to grain. These are also the two counties with the best climate for grain production.

Use of manure

How and when the manure is spread is of major importance for the nutrient losses. The lesser the plants absorb of the nutrients contained in the manure, the greater the share that disappears into the air (evaporation of ammonia and denitrification) or is carried away with the water running off the land that has been spread with manure. The degree of absorption of nutrients depends on three conditions:

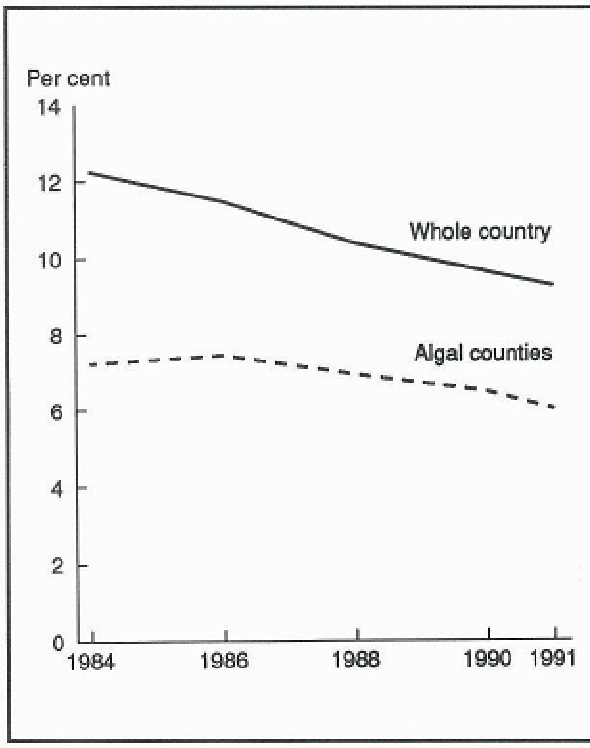
1. The amount of manure spread per unit of land
2. The time the manure is spread in relation to plant growth.
3. The time when the manure is earthed in after spreading.

Figure 6.9. Average quantity of manure used per decare fully cultivated land[1]. The whole country and the "algal counties". 1984-1991*. Kg P/decare



[1] Area of land on farms with no animals not included.
Source: CBS, applications for production subsidies 1984-1991.

Figure 6.10. Surplus manure in relation to the requirement for 4 decares of fully cultivated and per animal manure unit. 1984-1991*. Per cent of all manure



Source: CBS, applications for production subsidies 1984-1991.

There is no systematic information available on item 3.

Figures 6.9 and 6.10 indicate the amount of manure spread per unit of area.

Figure 6.9 shows only small changes in the amount of phosphorus from manure per decare of fully cultivated land on farms rearing animals during the period 1984-1991.

One way of expressing local surplus (concentration) of manure is to calculate how large a proportion of all manure would be in excess if no farm had less than 4 decares of fully cultivated land per animal manure unit. (According to the directives from the Ministry of Agriculture (1989) the number of animals can be expressed in so-called "animal manure units"). This proportion is shown in figure 6.10. According to the Ministry of Environment's regulations concerning animal manure (Ministry of Environment, 1989), by 1995 every farm shall have at least 4 decares of spreading area per animal manure unit.

The figure shows a clear reduction in the amount of "surplus" manure during the period 1984 to 1991.

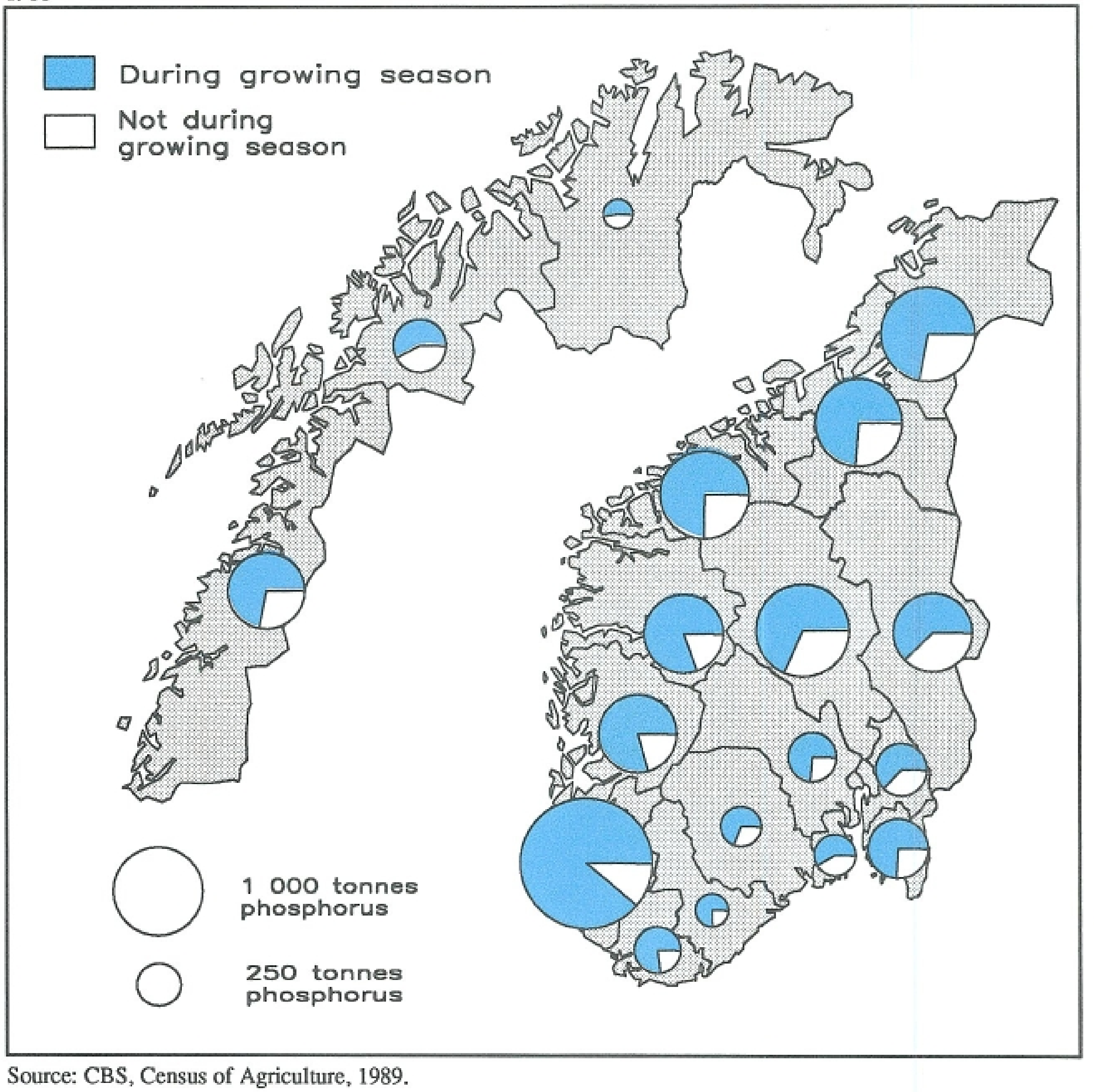
The share of all farms which rear animals and have less than 4 decares of spreading area per animal manure unit has decreased from 19 to 18 per cent. At the same time, the number of farms that rear animals has decreased from 72 000 to 60 000, while the number of animal manure units (amount of manure) has decreased by about 6 per cent.

All in all, the above calculations indicate that the problems due to high concentrations of manure are becoming less serious, which also means less runoff.

It is important to recognize that the concentration of manure is also influenced by a number of conditions other than those referred to above. Firstly, it is assumed that the quantity of manure produced per animal has not changed during the period. Secondly, some of the animals (sheep, goats, young cattle) graze in outfield areas for part of the year. This reduces the amount of manure spread on fully cultivated land. Thirdly, farmers can extend their spreading area, for example, by using surface cultivated land or hiring agricultural land from other farms. Based on information from the Census of Agriculture in 1989, 2.5 per cent of the manure was spread on areas other than the farmer's own cultivated land in 1988.

If the nutrients in the manure are to be used effectively, the manure must be spread in the growing season. According to both the Census of Agriculture in 1989 and the sample census of agriculture in 1990, in both 1988 and 1989 about 74 per cent of the manure was spread during the growing season. There was no or only little change in any of the counties from 1988 to 1989. Figure 6.11 shows the amount of manure spread in 1988, by county and time of spreading.

Figure 6.11. Phosphorus in manure by time of spreading, i.e. during and outside the growing season. Counties. 1988



Source: CBS, Census of Agriculture, 1989.

In Rogaland, the county with clearly the highest animal density and quantities of animal manure, as much as 88 per cent of the manure is spread during the growing season. In the counties covered by the North Sea Declaration, only about 66 per cent is spread during the growing season, but here the quantity of manure is not as great in relation to the spreading area.

Relation between storage capacity and spreading during the growing season

According to the Ministry of Environment's regulations on animal manure (Ministry of Environment, 1989), it is not permitted to spread manure on snow or frozen ground. It is permitted to spread the manure in autumn after the growing season provided that the manure is earthed in immediately. This is a favourable time for many farmers from the point of view of work.

In order to be able to spread the manure in conformity with the regulations it is necessary to have a storage capacity to cover at least 8 months' indoor feeding if the animals remain indoors all year round. Analyses based on the Census of Agriculture 1989 show that about 80 per cent of all the manure is produced on farms with sufficient storage capacity to spread the manure in compliance with the regulations.

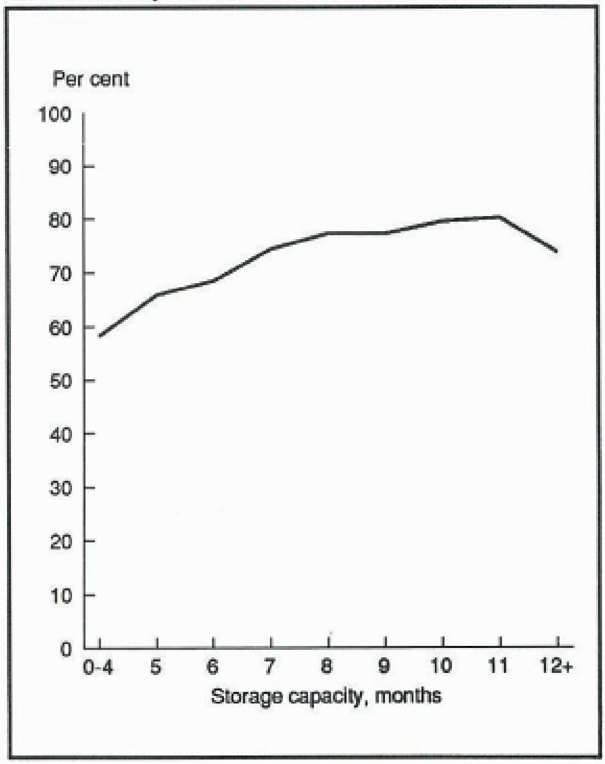
Figure 6.12 shows the relation between capacity for storing manure and spreading practice.

The figure shows that the proportion spread during the growing season varied between 60 and 80 per cent, depending on storage capacity. The fact that farmers with very little storage capacity could state that more than 60 per cent of the manure was spread during the growing season is not adequately explained. Farmers with little storage capacity did not spread more of the manure on land outside their own farm.

In order to be able to spread all the manure during the *growing season* it is necessary to have 10-11 months storage capacity. It is seen from figure 6.12, however, that farmers with a storage capacity of 12 months or more *do not* spread a larger proportion of the manure during the growing season than farmers with a storage capacity of 8-10 months.

Since 1989, about NOK 300 million has been allocated for technical environmental measures

Figure 6.12. Percentage of manure spread during the growing season by the farms' storage capacity for manure measured in terms of months of indoor feeding. Whole country. 1988



Source: CBS, Census of Agriculture 1989.

(Ministry of Agriculture, 1990-92). About half of this money has been spent on increasing the capacity of the manure stores. The purpose of increasing the storage capacity is to be able to spread the manure at the most favourable time, and the subsidies are awarded for environmental reasons. In the sample census of agriculture 1992 it is planned to study whether these investments in manure stores have led to a change in spreading practice.

For an evaluation of the cost-efficiency of various measures in the agricultural sector, see CBS (1991).

Spreading of commercial fertilizers

During the last 10 years, sales of nitrogen in commercial fertilizers have remained stable around 110 000 tonnes per year. Sales of phosphorus have clearly declined, and amounted to 15 200 tonnes in 1990/91 as against as much as 29 000 tonnes in 1979/80. Figure 6.13 shows sales of N and P in commercial fertilizers since 1978.

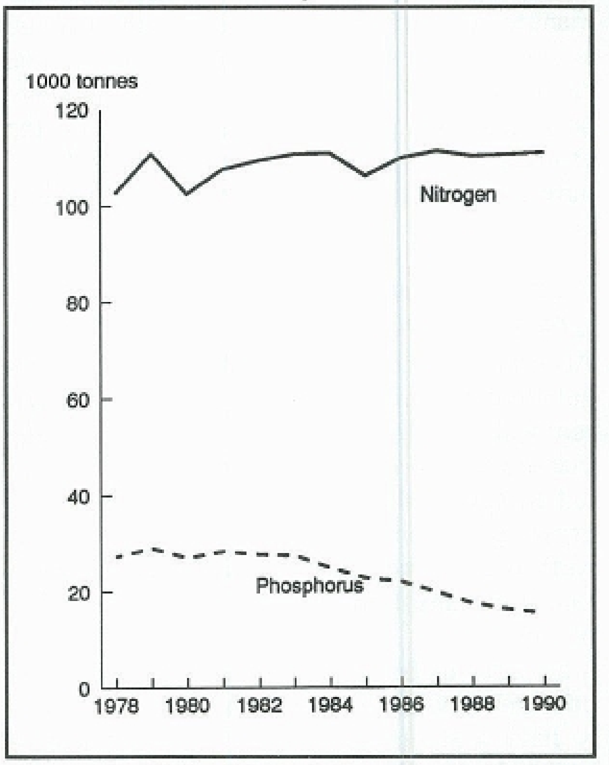
In the Censuses of Agriculture for 1979 and 1989 and the sample censuses in 1990 and 1991 (the results from the 1991 census are not yet available) the farmers reported how much nitrogen from commercial fertilizers they had spread on grain land and on fully cultivated meadow. Similar statistics are available for phosphorus, except for 1979. Table 6.1 shows average N and P fertilization of grain land and meadow in southern Norway and in the "algal counties", based on these reports.

Only small changes have occurred in the amount of commercial fertilizers spread during the period covered by the statistics. The clearest tendency is reduced P-fertilization to meadow, with a decrease of 0.1 kg/decare from 1988 to 1989. The data for 1989 are based on a 20 per cent sample, while the figures for 1978 and 1988 are based on a total registration.

If the nitrogen fertilizer is spread in several doses, it is possible to obtain better adjustment of the fertilization to the needs of the plants. This means that the plants absorb a larger share of the nutrients in the fertilizer, which is both economic for the farmer and causes less loss of surplus nutrients in the runoff. Figure 6.14 shows how much of the grain land was fertilized in several doses in 1989.

About 7 per cent of the grain land is fertilized in several doses. Vestfold is the county with the largest share, almost 11 per cent.

Figure 6.13. Sales of nitrogen and phosphorus in commercial fertilizers in Norway. 1978-1990. 1 000 tonnes



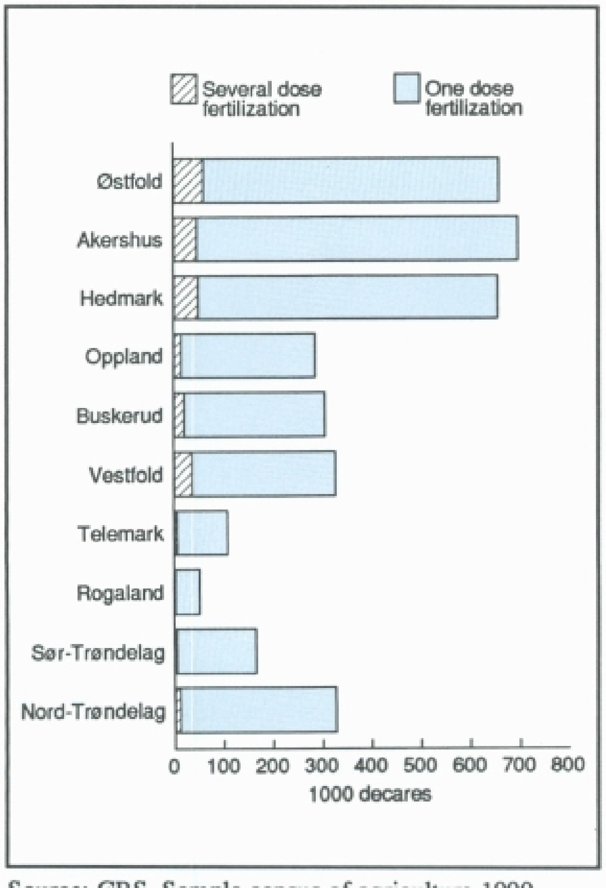
Source: The National Association of Purchasing Pools.

Table 6.1. Average spread of commercial fertilizers to grain and fully cultivated meadow in Southern Norway and in the "algal counties". 1978, 1988 and 1989. Kg N and P per decare

	Nitrogen			Phosphorus		
	1978	1988	1989	1978	1988	1989
Grain						
Southern Norway	10.6	10.6	10.6	..	2.2	2.2
Algal counties	11.0	11.0	11.0	..	2.2	2.2
Fully cultivated meadow						
Southern Norway	14.3	14.4	14.1	..	2.5	2.4
Algal counties	12.7	12.9	12.8	..	2.6	2.5

Source: CBS, Censuses of Agriculture 1979 and 1989. Sample census of agriculture 1990.

Figure 6.14. Grain land distributed between several-dose fertilizing and one-dose fertilizing. Selected counties. 1989. 1 000 decares



Source: CBS, Sample census of agriculture 1990.

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7. WASTE WATER TREATMENT PLANTS

As a basis for monitoring an important water pollution problem, the Central Bureau of Statistics and the State Pollution Control Authority have jointly initiated annual registration of data from all waste water treatment plants in Norway. At the end of 1990 a total number 1387 such plants were registered in Norway, with a total hydraulic capacity of about 3.9 million p.u. (population units) and a total hydraulic load of about 2.9 million p.u. Similar surveys, though of smaller scope, were carried out for the years 1978, 1982, 1983 and 1988.

7.1. Background

In 1991, the Central Bureau of Statistics (CBS) and the State Pollution Control Authority (Statens forurensningstilsyn - SFT) established a data base on all the waste water treatment plants in Norway in order to make it easier to:

- check that requirements were complied with
- check that the large investments in the sewerage sector were giving the intended environmental gains
- check that national goals are being realized and that the international agreements entered into will be fullfilled
- identify problem areas to provide a basis for considering where to take action
- prepare official statistics from the sewerage sector.

In principle, the waste water drainage system can be divided into two parts; the *pipeline network*, including pump stations and spillways, and the actual *waste water treatment plants*, with outlets.

The pipeline network in Norway varies considerably in age. The oldest parts consist of wooden pipes that were laid in the early part of this century. Concrete pipes were commonly used during the intermediate period but most of the pipes laid in recent years are made of PVC. The total length of the pipes is about 30 000 km.

The pipeline network can also be divided by function. In a *separate system* the pipes for storm water and ordinary waste water are separate, while in a *combined system* the storm water and ordinary waste water are carried in the same pipe.

Leakages in the network are a major problem. Surface water penetrates into the pipes, and waste water leaks out. Large quantities of waste water never reach the treatment plants. In periods with heavy precipitation the waste water is diluted, so that the concentration of nutrients and organic material at the inlet is very low. Combined with large quantities of water, this can cause operating problems at the treatment plants.

7.2. Method

CBS and SFT have jointly developed an electronic registration form with computer controls (SSBAVLØP) for collection of information on the country's waste water treatment plants. All the county environmental agencies have installed the system and are using it, and are responsible for updating it each year. The data are sent to CBS on disc. The system was taken into use in 1991, so that the data set for 1990 is the first collected by this method. Several of the counties have expressed uncertainty about the data submitted for 1990, and CBS regards 1991 as a "try-out" year for the system. Greatest uncertainty has been expressed by the counties not involved in the North Sea Agreement.

The registration covers data on time of establishment, geographical location, ownership, capacity, load, chemicals, purification principles, analysis results, sludge treatment methods, sludge disposal (including various forms of use), and recipients.

7.3. Results

Definitions

Mechanical plants include sludge separators, screens, strainers, sand traps and sedimentation plants, and remove most of the largest particles from the water, either by sedimentation or by means of screens and strainers.

So-called *"high-grade" waste water treatment plants* include plants with biological and/or chemical phases.

Biological plants include activated sludge plants, trickling filters and biological discs. In biological plants, readily degradable organic material is removed by means of microorganisms.

Chemical plants include primary precipitation plants and secondary precipitation plants. In these plants, chemicals are added during the purification process in order to remove phosphorus from the waste water. The chemicals used are mainly aluminium sulphate, ferric chloride or calcium. In secondary precipitation plants, the chemical precipitation is preceded by sedimentation.

Chemical/biological plants combine a biological and a chemical stage, and include pre-precipitation, post-precipitation and simultaneous precipitation plants. In the pre-precipitation plants the chemicals are added before the biological stage, and in post-precipitation plants they are added afterwards. In simultaneous precipitation plants the chemical precipitation occurs simultaneously with the biological degradation.

Unconventional plants include sand filter plants, infiltration ditches, biological dams, biological dams with precipitation, and precipitation dams.

The group "other/unknown" includes plants where the purification principles are not known, or special adjustments make it unnatural to place the plant in one of the groups defined above.

Population equivalents (p.e.) means waste water from industry, institutions, service activities etc. converted into an equivalent number of persons producing a specific volume of waste water.

Population units (p.u.) is the number of permanent residents plus the number of population equivalents in an area.

Capacity and load

A total of 1387 waste water treatment plants were registered in 1990, with a total hydraulic capacity of 3.9 million p.u. and a hydraulic load of about 2.9 million p.u. The registration only included plants with a reported capacity of more than 50 p.u.

In the previous survey of waste water treatment plants in 1988, 700 such plants were registered, with a total capacity of 2.9 million p.u. and a load of 2.3 million p.u. However, the figures for 1988 and earlier are not directly comparable with the figures for 1990, since the classification of waste water treatment plants has been changed somewhat. Infiltration ditches, sludge separators and screens were not included in the total figures for 1988. In 1988 these types of plant were presented separately and comprised 590 plants with a total capacity of 439 000 p.u. and a load of 330 000 p.u.

Table 7.1 shows that the total number of plants has increased from 1290 in 1988 to 1387 in 1990. During the same period the capacity increased by 15.2 per cent and the load by 9.7 per cent. The number of *biological plants* was reduced by 16 per cent during the period. The total capacity of these plants decreased by 17.2 per cent during the period, and the load by 13 per cent. The number of *chemical plants* increased by 13.4 per cent. The total capacity of these plants increased by 17.9 per cent and the load by 20.4 per cent. The number of *chemical/biological plants* decreased by 4.4 per cent during the period, accompanied by a decrease in capacity of 1.6 per cent and a reduction of 20.6 per cent in the load. The largest percentage increase in the number of plants (16.7 per cent) refers to *mechanical/unconventional*

Table 7.1. Waste water treatment plants. Number, capacity and load, by purification principle. 1988 and 1990.

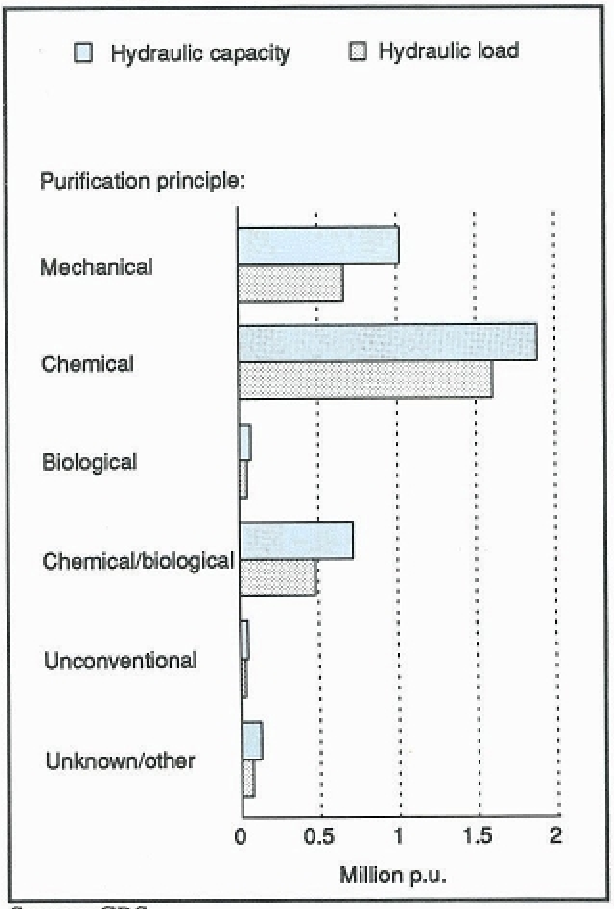
Year	Number	Capacity	Load
		1 000 p.u.	
Total			
1988	1 290	3 365	2 649
1990	1 387	3 877	2 907
Biological			
1988	156	87	54
1990	131	72	47
Chemical			
1988	149	1 604	1 333
1990	169	1 891	1 605
Biological/chemical			
1988	296	732	606
1990	283	720	481
Mechanical/ unconventional [1]/ other [2]			
1988	689	942	656
1990	804	1 194	774

[1] For 1990, *unconventional plants* includes trickling filters and biological dams with precipitation. In the statistics for 1988 these types of plants were categorized as either biological or biological/chemical plants, but in the above table they are categorized as unconventional plants.
[2] *Other* includes plants that have not reported what type of purification technology is used, and plants with special adjustments.

plants. This was accompanied by a 26.8 per cent increase in capacity and an increase of 18 per cent in the load.

The marked decrease in the number of biological and chemical/biological plants is not a real one. The reason is that some plants reported special adjustments, and were therefore transferred to the group "other purification principles". For various reasons, some of the mechanical plants reported earlier to SFT as part of the total capacity of a county (*"Kommunale utslipp i Norge. Status 1.1. 1991" - Municipal discharges in Norway. Status 1.1. 1991, Report no. 91:08 from SFT*) have not been reported in SSBAVLØP. This applies in particular to the stretch of the coast from Vest-Agder northwards.

Figure 7.1. Waste water treatment plants. Capacity and load, by purification principle. Millions p.u. 1990



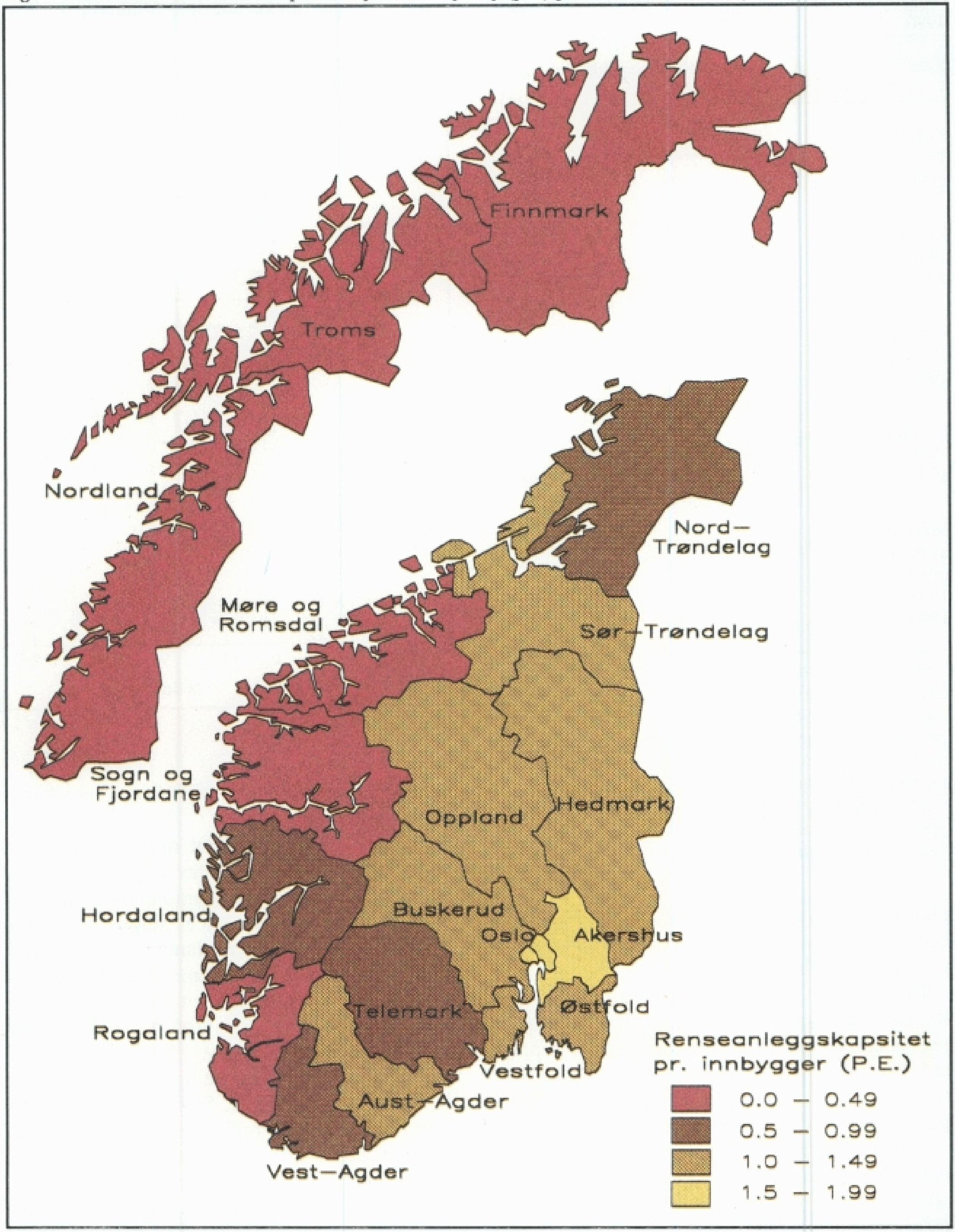
Source: CBS.

In 1990, the greater part of the capacity of waste water treatment plants referred to *plants based on chemical precipitation*, either alone or combined with a biological stage (see figure 7.1). A total of 452 such plants were registered. These have a combined capacity of 2.6 million p.u. (67 per cent of the total capacity) and a combined load of 2.1 million p.u. (72 per cent of the total load).

Mechanical plants make up the largest group in terms of number, i.e. 519 plants, and represent a capacity of 1 million p.u. (26 per cent of the total capacity). The load on these plants is 0.7 million p.u. (24 per cent of the total load).

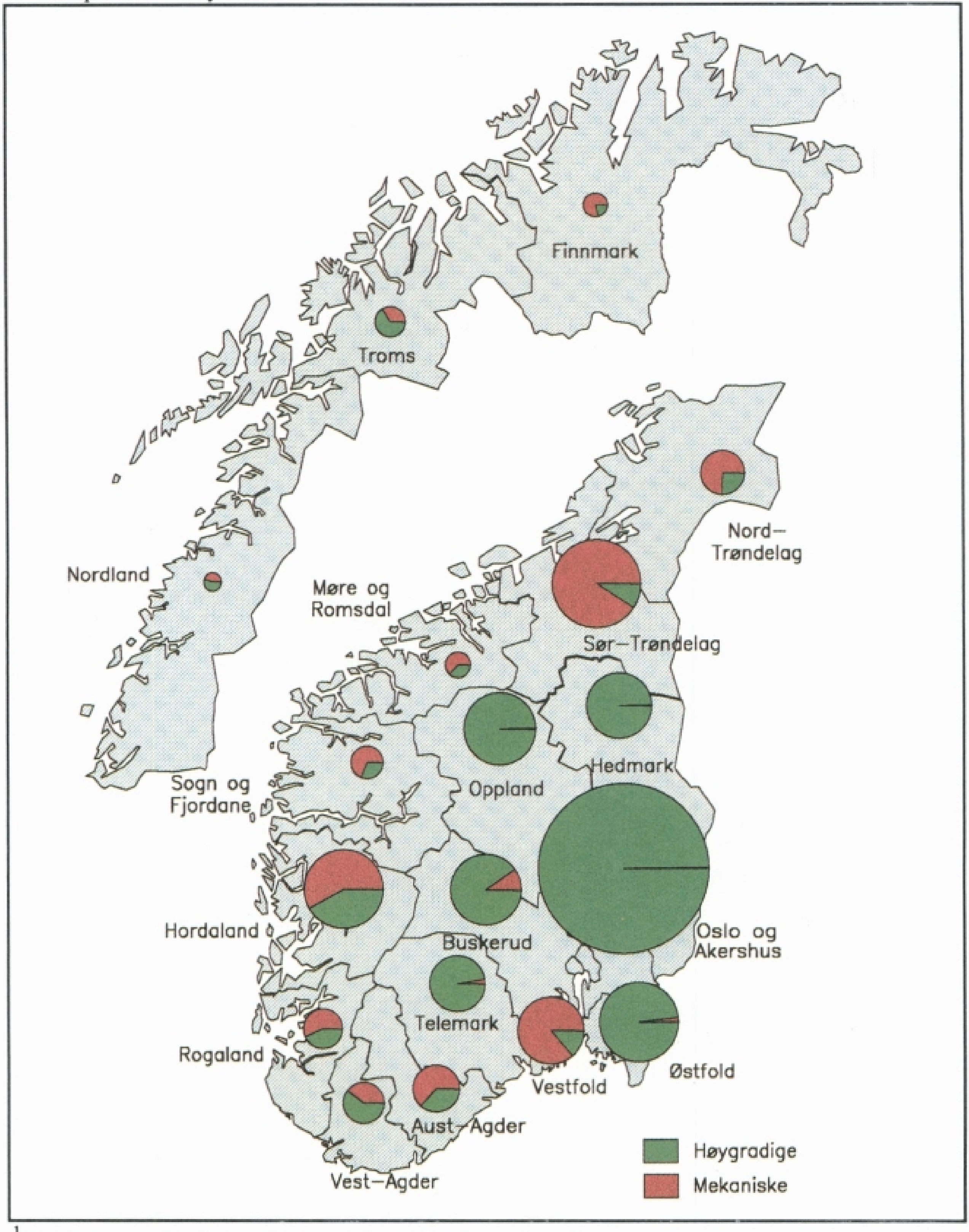
The *biological plants* have a combined capacity of just over 70 000 p.u. (2 per cent of the total capacity), and the load on these plants is about 45 000 p.u. (1.5 per cent of total load).

Figure 7.2. Waste water treatment plants. Hydraulic capacity (p.u.) per inhabitant [1]. County. 1990



[1] The figure includes plants with a reported capacity of more than 50 p.u.
Source: CBS.

Figure 7.3. Waste water treatment plants. Hydraulic capacity (p.u.) distributed between mechanical and "high-grade" treatment plants [1]. County. 1990



[1] The figure includes plants with a reported capacity of more than 50 p.u.

Source: CBS.

The remaining plants have a capacity of 0.2 million p.u. (4.5 per cent of total capacity) and a load of 0.1 million p.u. (2 per cent of the total load).

The capacity of the waste water treatment plants is highest in Eastern Norway (figure 7.2). For example, the plants in Oslo/Akershus have a capacity of more than 1.5 p.u. per inhabitant.

Figure 7.3 shows that in Eastern Norway most of the waste water is treated in so-called "high-grade" plants (biological, chemical or chemical/biological), while in Western Norway and further north most of the water is treated in mechanical plants. No purely mechanical plants with a capacity of more than 50 p.u. are registered as operative in Oslo, Akershus, Oppland or Hedmark.

Ownership

Most of the plants are municipally owned, either by one municipality or several municipalities jointly.

Most of the large intermunicipal treatment plants are located in Østfold and Akershus (see figure 7.4). Vestfjorden Avløpselskap (VEAS), in Akershus, serves large parts of Oslo and parts of Akershus. This is a chemical plant and alone has a capacity of 0.7 million p.u.

The waste water treatment plants in West Norway, Trøndelag and North Norway are owned almost without exception by the municipalities.

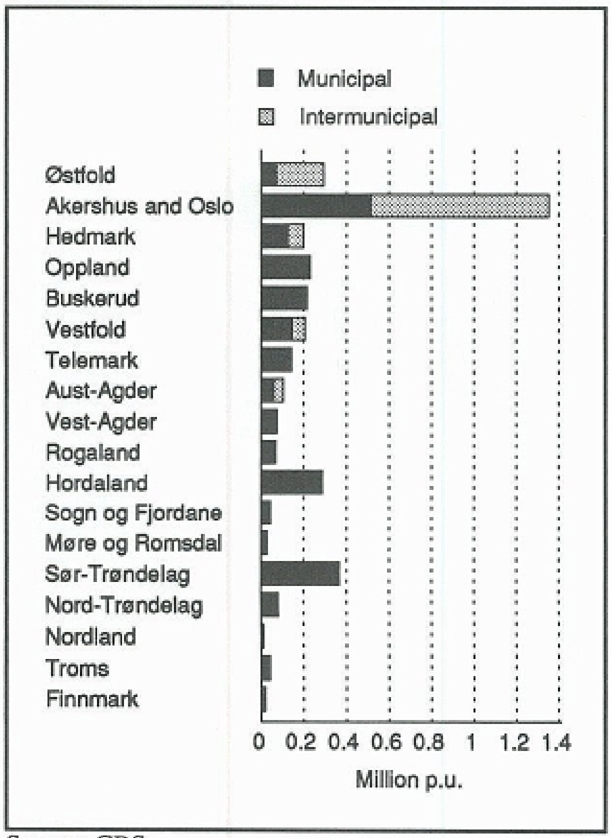
Chemicals

Use of chemicals is registered in most of the plants with a chemical stage (see figure 7.5).

The chemicals most commonly used to precipitate phosphorus are aluminium sulphate, ferric chloride and calcium.

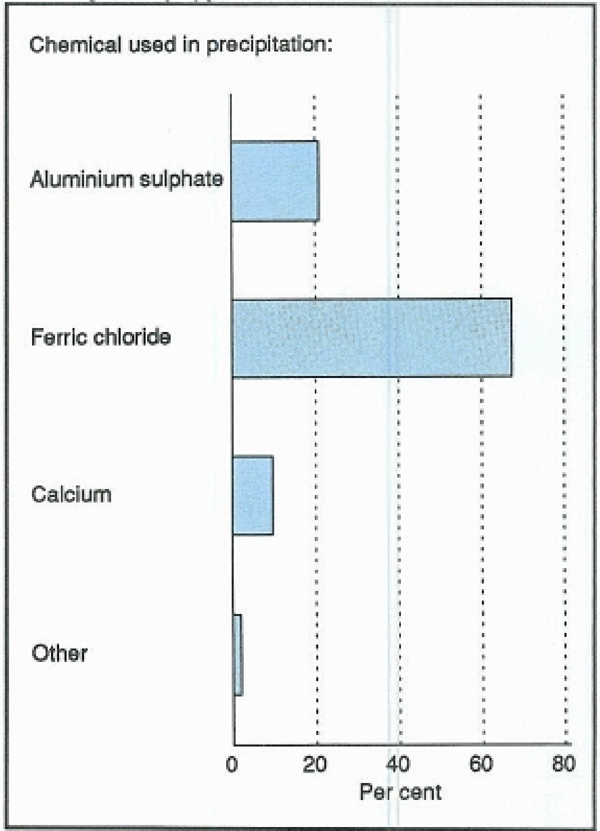
A few of the plants use prepolymerized aluminium in the precipitation process. Ferric chloride accounts for between 60 and 70 per cent of the chemicals consumption, and alu-

Figure 7.4. Waste water treatment plants. Capacity by ownership. Millions p.u. County. 1990



Source: CBS.

Figure 7.5. Waste water treatment plants. Chemicals consumption by type of chemical. Per cent. 1990.



Source: CBS.

minium sulphate for just over 20 per cent. The two largest plants in Norway, together accounting for 25 per cent of the total capacity, use mainly ferric chloride in the precipitation process.

Purification efficiency

The main function of the municipal waste water treatment plants is to remove nutrients and organic material. Input of nitrogen (N), phosphorus (P) and organic material from municipal waste water contributes to pollution of lakes, rivers and fjords. In general, it can be said that phosphorus is the nutrient that determines the extent of algal growth in fresh water. It is assumed on the other hand that, in marine recipients, nitrogen is more important.

Algae use the nutrients and sunlight in order to grow (increase the biomass), producing oxygen in the process. This oxygen production takes place in the upper water layers where sunlight is able to penetrate. An increased supply of nutrients leads to increased growth. This process is called *eutrophication* and is important for the composition of the flora and fauna, water quality and conditions on the bottom of the lake, fjord, etc.

When they die, the organisms that live in the water masses sink to the bottom. Here they undergo a process of decomposition with consumption of oxygen (aerobic decomposition). Organic material also enters the water from the waste water treatment plants. If the amount of sedimented organic material is large enough, the bottom may become devoid of oxygen. The decomposition of the organic material will then continue without oxygen (anaerobic decomposition), during which process a number of gases are generated, including hydrogen sulphide (H_2S), which is extremely toxic.

The different types of waste water treatment plants achieve different degrees of purification (see table 7.2). According to the results of the analyses, chemical plants remove 93 per cent of the phosphorus in the waste water, and chemical/biological plants remove 92 per cent. As far as phosphorus is concerned, mechanical plants have a purification efficiency of just less than 20 per cent, and the biological plants a purification efficiency of 50 per cent.

The average amount of water entering the plants is 441 litres per person per day. The average concentration of phosphorus entering the waste water treatment plants is about 3.3 mg P/litre.

The lowest discharge values are obtained for plants with a chemical stage in the purification process. At *chemical plants* the average discharge concentration of phosphorus is 0.24 mg P/litre, and at the *biological/chemical plants* the discharge concentration is 0.33 mg P/litre. These two types of plants are much more efficient in this respect than the *mechanical plants*

Table 7.2. Waste water treatment plants. Average purification efficiency for phosphorus, by purification principle.

	No.	Capacity p.u.	Load p.u.	Concentration at inlet mg P/l	Discharge concentration mg P/l	Purification efficiency per cent
Total	504	3 037 972	2 437 046	3.30	0.64	80.6
Mechanical	29	441 254	369 522	2.42	1.95	19.5
Chemical	149	1 837 683	1 573 808	3.36	0.24	93.0
Biological	51	29 955	19 915	4.77	2.38	50.1
Chemical/biological	233	653 740	430 559	4.05	0.33	91.8
Unconventional	10	13 155	8 010	4.23	0.49	88.5
Other	32	62 185	35 232	7.04	0.77	89.0

or the *biological plants*, where the average concentration is 1.95 mg P/litre and 2.38 mg P/litre respectively.

The reason why the discharge concentration is lower for the mechanical than for the biological plants is that the concentration at the inlet is almost twice as high at the biological plants. This is because there are less restrictions at the mechanical plants to prevent the entry of extraneous water (surface water).

Municipal waste water also contains various hazardous substances, such as heavy metals. There are presently no statistics available, however, on the content of these substances.

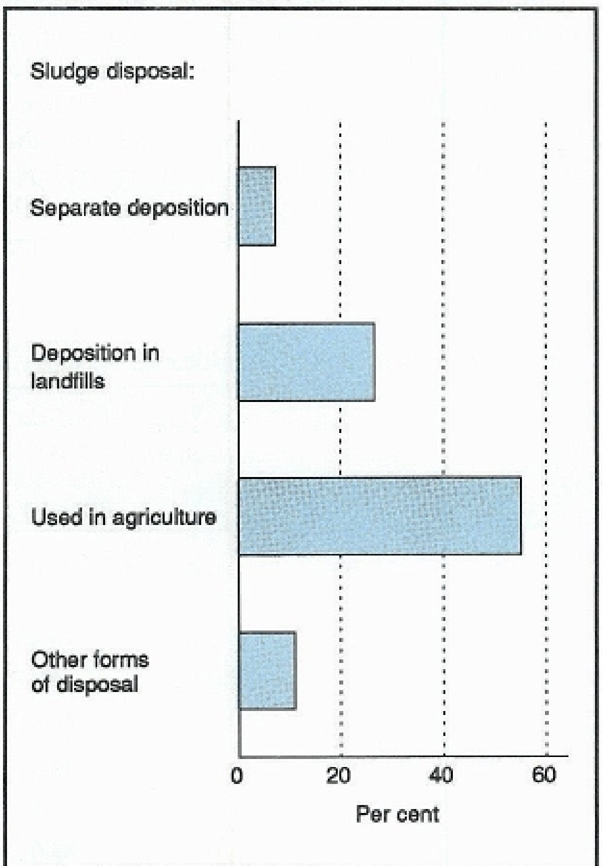
Sludge disposal

Figure 7.6 shows how the sludge from the waste water treatment plants is disposed of. The two main recipients of sludge are agriculture and landfills. These receive more than 75 per cent of the produced sludge. The category "other forms of disposal" includes sludge used as top cover on landfills, sludge transferred to other treatment facilities etc.

Recipients

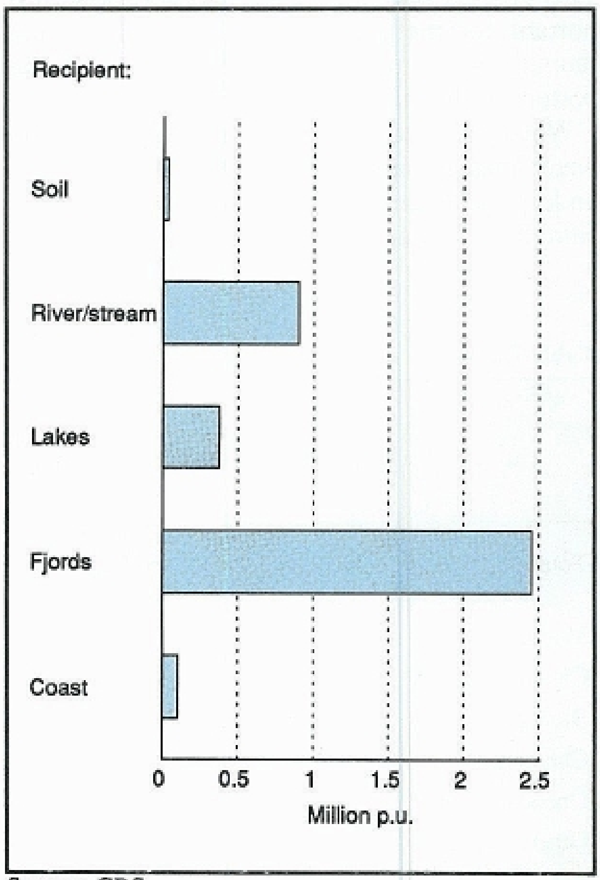
Figure 7.7 shows that waste water treatment plants with a combined capacity of 2.5 million p.u. discharge into fjords, while plants with a combined capacity of 1.3 million p.u. discharge into rivers, streams and lakes. Plants with a chemical stage (chemical and chemical/biological plants) account for 84 per cent of the capacity connected to freshwater recipients, and 62 per cent of the capacity connected to saltwater recipients. If plants discharging into the inner Oslo fjord are excluded, chemical plants account for only 34 per cent of the capacity connected to saltwater recipients.

Figure 7.6. Waste water treatment plants. Disposal of sludge, by area of application. Per cent. 1990



Source: CBS

Figure 7.7. Waste water treatment plants. Capacity, by recipient. Mill. p.u. 1990



Source: CBS

8. WASTE

Norway still lacks nation-wide, regular statistics on waste and recycling of waste. The development of such has therefore become an important task for CBS, in cooperation with the State Pollution Control Authority (SFT) and international agencies.

In recent years there has been a marked improvement in the data base for hazardous waste. At the request of SFT, the Norwegian Geological Survey has carried out nation-wide mapping of deposits of hazardous waste and contaminated ground, during which almost 2500 sites have been registered. 90 per cent of these sites lie less than 1000 m from residential areas. About 200 000 tonnes of hazardous waste is generated in Norway each year. About 90 000 tonnes of this waste is disposed of by industry itself. In 1991, another 66 000 tonnes were delivered to the Norwegian system for management of hazardous waste. More than 60 per cent of this waste was oily waste.

According to the Population and Housing Census, 1990, 37 per cent of Norway's households sorted their waste in one way or another in autumn 1990. There were large regional differences, however, and the percentage that sorted waste varied from 19 to 60 per cent in the different counties. The most common practice was to sort out batteries.

Waste from households and industry is a major pollution problem. The problem is connected to both present and previous disposal of waste. Many landfills that are no longer used, particularly landfills with industrial waste, may contain hazardous substances that leak out into the environment. Sites are also being discovered where dangerous substances have been deposited illegally.

According to the Pollution Control Act, residues/waste can be divided into the following main types:

* *Consumer waste:* Ordinary waste, including larger objects such as furnishings etc. from households, small shops etc. and offices. The same applies to waste of a similar nature and quantity from other activity.

* *Production waste:* Waste from industrial activities and service activities which in type and quantity is significantly different from consumer waste.

* *Special waste:* Waste which cannot appropriately be treated together with consumer waste because of its size, or because it may lead to serious pollution or risk of injury to persons or animals (hazardous waste). In practice, special waste that is not hazardous waste - i.e. is too large to deal with together with consumer waste - is calculated into the other two categories.

Table 8.1 shows the amounts of the different types of waste generated in Norway yearly at the end of the 1980s.

At the start of the 1990s, recycling of waste became the focus of increasing attention both in Norway (Norwegian Official Report, 1990:28) and internationally (OECD, 1991).

Table 8.1. Annual quantities of waste in Norway. End of 1980s

Type of waste	Quantity of waste 1000 tonnes per year
Municipal waste[1]	2 000
Production waste[2]	12 000
Car wrecks, large household appliances	70
Sewage sludge	100
Hazardous waste	200

[1] Includes some production waste

[2] Uncertain estimate. Includes waste from building and construction activity, and from mining.

Source: SFT, 1989.

This has led to a greater need to obtain an overall picture of the problem, and a need for more data, for example, in the form of regular statistics. Several limited registrations of waste and waste management have been carried out in Norway, but these are to some extent out of date, are not sufficiently representative, or vary in coverage.

In the opinion of the State Pollution Control Authority (Statens forurensningstilsyn - SFT), reliable statistics are essential for the development of a system of waste management that conforms with the country's environmental and economic objectives. This is stated specifically in the report "*Avfallsstatistikk i Norge - forslag til framtidig system*" (Waste Statistics in Norway - proposal for a future system) (SFT document 91:01). CBS has been given the prime responsibility for this work, and also participates in a joint EC/EFTA project to develop waste statistics. International cooperation is important in order to achieve the best possible comparability of the statistics from different countries (see inter alia EUROSTAT, 1991).

With regard to *hazardous waste*, during the last couple of years SFT has undertaken registrations of old waste disposal sites and A/S Norsk Spesialavfallselskap - NORSAS (Norwegian Hazardous Waste Corporation Ltd.), a company established specifically to administer the hazardous waste treatment in Norway, has registered the quantities of such waste delivered for disposal. Sections 8.1 and 8.2 present some of the main results from these registrations.

The last section (8.3) describes sorting of waste in private households.

8.1. Hazardous waste in waste disposal sites and contaminated ground

It is the goal of the Ministry of Environment and SFT to clean up the worst cases of contaminated ground by the year 2000. In 1987, SFT started a nation-wide registration of contaminated ground and waste disposal sites with hazardous waste, in order to establish the extent of the problem. The Norwegian Geological Survey (Norges geologiske undersøkelser - NGU) has carried out the actual registration, and has developed a data base in which all the sites are plotted. The methodology and the results as per 8 April 1991 have been published in two reports from SFT (1991 a and b).

The registered sites have been ranked into five categories depending on information on quantity and type of hazardous waste, conflict with the surrounding environment and the need for follow-up investigations or measures:

Category 1: Sites requiring immediate investigations or measures

Category 2*: The case is being considered by SFT

Category 2: Need for investigation

Category 3: Need for investigation in the event of change of land use or recipient

Category 4: No investigations needed.

Hazardous waste was found or suspected to exist at 1742 (Groups 1-3) of 2452 registered sites. 40 per cent of these sites are municipal landfills, 24 per cent are industrial waste disposal sites and 18 per cent are defined as contaminated ground (see table 8.2).

Table 8.2. Waste disposal sites and contaminated ground containing hazardous waste, by category[1] and site[2]. 1991

Type of site		Category				
	Total	1	2*	2	3	4
TOTAL	2452	61	42	439	1200	710
Waste disposal sites						
Municipal landfills	1032	12	1	149	533	337
Industrial waste disposal sites	492	20	11	124	205	132
Other waste disposal sites	482	6	6	48	181	241
Contaminated ground						
Industrial ground	273	8	19	55	191	-
Other contaminated ground	70	3	1	19	47	-
Waste disposal sites with contaminated ground	103	12	4	44	43	-

[1] See text for a definition of the categories.
[2] In addition, 40 unranked sites in Finnmark.
Source: SFT, 1991a.

Table 8.3. Waste disposal sites and contaminated ground with hazardous waste. County. 1991

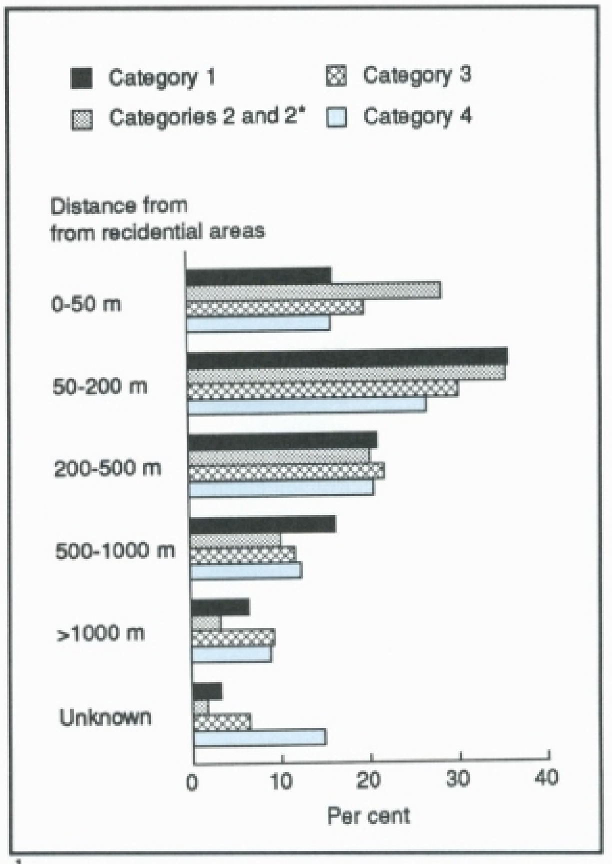
	Number of sites	Number in categories 1 and 2*
Whole country	2 452	108
01 Østfold	103	10
02 Akershus	228	13
03 Oslo	96	7
04 Hedmark	89	5
05 Oppland	112	6
06 Buskerud	182	2
07 Vestfold	180	2
08 Telemark	102	18
09 Aust-Agder	107	4
10 Vest-Agder	113	10
11 Rogaland	142	4
12 Hordaland	149	2
14 Sogn og Fjordane ..	111	4
15 Møre og Romsdal .	99	2
16 Sør-Trøndelag	135	3
17 Nord-Trøndelag ...	153	1
18 Nordland	179	10
19 Troms	104	-
20 Finnmark[1]	68	-

[1] 40 unranked sites in addition.
Source: SFT, 1991a.

Table 8.3 shows that the counties Akershus, Telemark, Vest-Agder and Nordland contain a larger percentage of sites in Groups 1 and 2* than the other counties. About 90 per cent of the sites are located less than 1000 m from residential areas, and the large majority are located less than 200 m from such areas, see figure 8.1.

Industry and other commercial activity are directly responsible for most of the cases where hazardous waste or contaminated ground is suspected. The percentage of industry-related sites is highest in categories 1 and 2*, with a predominance of chemical industry (26 per cent of all registered sites) and metals manufacturing (22 per cent of all registered sites). Municipal landfills containing hazardous waste account for 50 per cent of all the waste disposal sites in categories 1-3, but for only 18 per cent of all the sites placed in categories 1 and 2*. The types of hazardous waste found in municipal landfills can often be traced to small and medium-sized industrial enterprises, since many of the large industrial enterprises have established their own disposal sites.

Figure 8.1. Waste disposal sites and contaminated ground with hazardous waste. Sites in the different groups[1], by distance from nearest residential area. 1991. Per cent



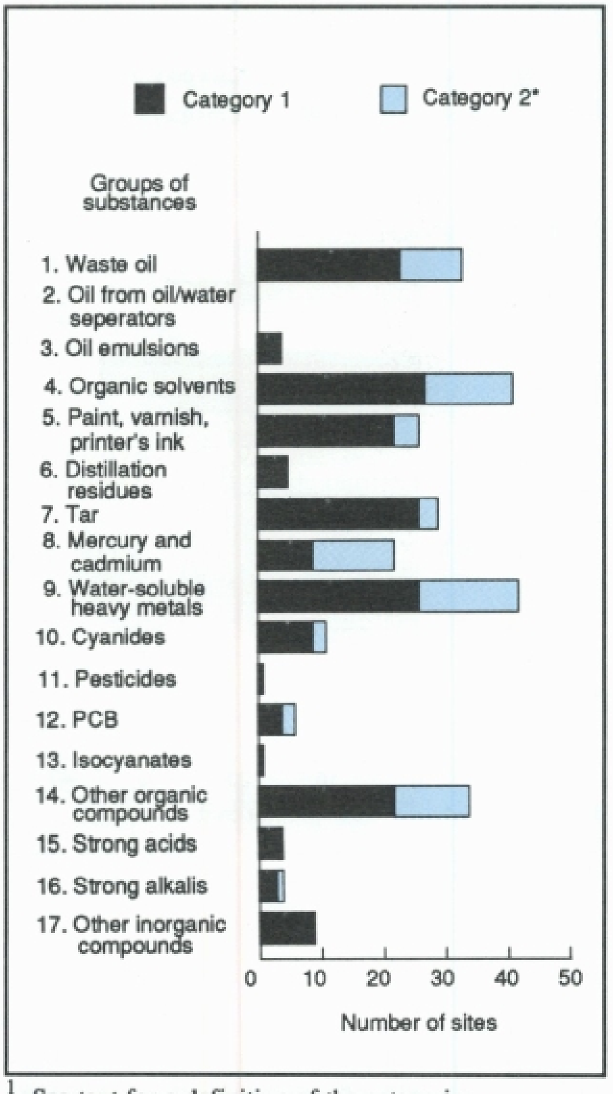
[1] See text, for definition of categories.
Source: SFT, 1991a.

The most frequently recorded types of hazardous waste are *organic solvents and water-soluble heavy metals*, see figure 8.2. Waste oil and other oily residues, paint, glue and varnish, tarry substances and other organic substances are also common. Deposits of tars and other organic substances usually originate from the smelting industry.

In the case of 75 per cent of the sites placed in categories 1, 2* and 2, the grounds for the ranking are risk of water pollution, or that the pollution makes the area unsuitable for purposes of recreation. The sites are often located along watercourses or on the edge of fjords, see figure 8.3.

Figure 8.4 shows how the sites are distributed between types of area, based on the dominating

Figure 8.2. Waste disposal sites and contaminated ground with hazardous waste. Occurrence of different groups of hazardous waste at the sites in category 1 and category 2*[1]. 1991.



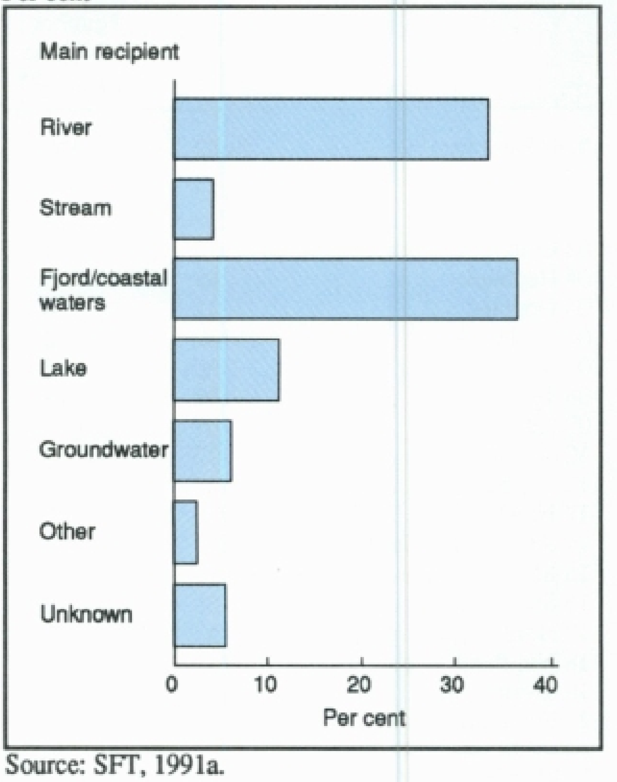
[1] See text for a definition of the categories.

Source: SFT, 1991a.

activity. About half of the waste disposal sites are located in built-up areas, industrial areas or agricultural areas, or are in conflict with recreational interests.

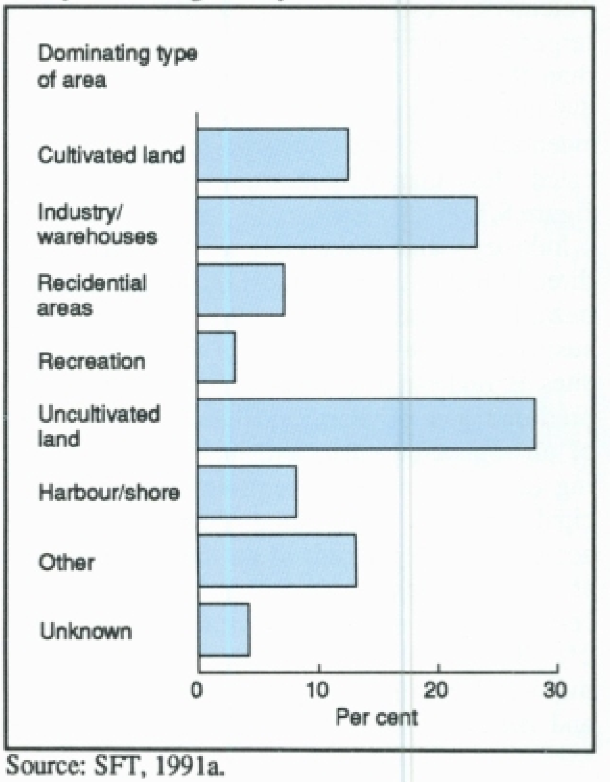
It is very likely that many sites have not yet been discovered. This is because lack of capacity has made it necessary to give higher priority to some branches of industry than others. Various registrations will have to be carried out in connection with defence installations and activities, shipyards, road building and mining. The coverage is considered to be particularly

Figure 8.3. Waste disposal sites and contaminated ground with hazardous waste, by main recipient. 1991. Per cent



Source: SFT, 1991a.

Figure 8.4. Waste disposal sites and contaminated ground with hazardous waste, by type of area categorized by dominating activity. 1991. Per cent



Source: SFT, 1991a.

good for municipal landfills but, seen in relation to the actual extent of the problem, is probably not as good for contaminated ground.

In Proposition No. 111 (1988-89) to the Storting (Norwegian National Assembly) on the further efforts to deal with hazardous waste, it is decided that a national plan of action should be prepared for implementation of measures/clean-up of landfills and industrial ground polluted by hazardous waste. The data obtained from the registrations will provide an important basis for this plan of action.

8.2. Delivery of hazardous waste

Uncontrolled dumping of hazardous waste has caused serious damage to the environment in many countries and has resulted in coercive measures to force the involved companies to clean up the pollution, payment of large sums in compensation, winding up of enterprises and several bankruptcies (Ministry of Environment, 1985).

The Pollution Control Act provides the legal foundation for controlled management and disposal of hazardous waste. The regulations concerning hazardous waste, laid down pursuant to the Act, apply to the following groups of substances (if the quantity in brackets is exceeded, the generator of the waste has an obligation to deliver it to an approved collecting site):

1. Waste oil (200 kg)
2. Oily waste from oil-water separators, and oily waste water (200 kg)
3. Oil emulsions (1000 kg)
4. Organic solvents (20 kg)
5. Waste paint, glue, varnish and printer's ink (200 kg)
6. Distillation residues (200 kg)
7. Tars (200 kg)
8. Waste containing mercury or cadmium as a chemical compound or in metallic form (1 kg)
9. Waste containing water-soluble chemical compounds of lead, copper, zinc, chromium, nickel arsenic, selenium or barium (10 kg)
10. Waste containing cyanide (1 kg)
11. Discarded pesticides (5 kg)

The following groups of hazardous wastes have been defined in addition to the groups regulated by the regulations:

12. Wastes containing PCB
13. Isocyanates
14. Other organic waste
15. Strong acids
16. Strong alkalis
17. Other inorganic wastes

According to calculations carried out at the end of the 1980s, roughly 200 000 tonnes of hazardous wastes are generated each year (SFT, 1989). Although the quantity of hazardous waste is fairly small compared with the quantity of municipal waste (about 10 per cent), it represents a major risk to the environment owing to sometimes high concentrations of micropollutants. About 90 000 tonnes of hazardous waste are treated by the companies where the waste is generated, either by recycling or by deposition in the company's own approved system. The remaining 110 000 tonnes is delivered for external treatment, in more or less controlled form. Table 8.4 shows how this 110 000 tonnes of externally treated waste is distributed between the different main groups of waste. It is estimated that households are responsible for less than 5 per cent of this quantity (SFT, 1989).

Table 8.4. Hazardous waste for external treatment. End of 1980s

Main groups	Groups of substances[1]	Quantity 1000 tonnes per year
Total		110
Waste oil	1	40
Other organic waste (combustible)	2-7, 11-14	40
Inorganic waste (non-combustible) ...	8-10, 15-17	25
Mixed organic/ inorganic waste		5

[1] See text for explanation.
Source: SFT, 1989.

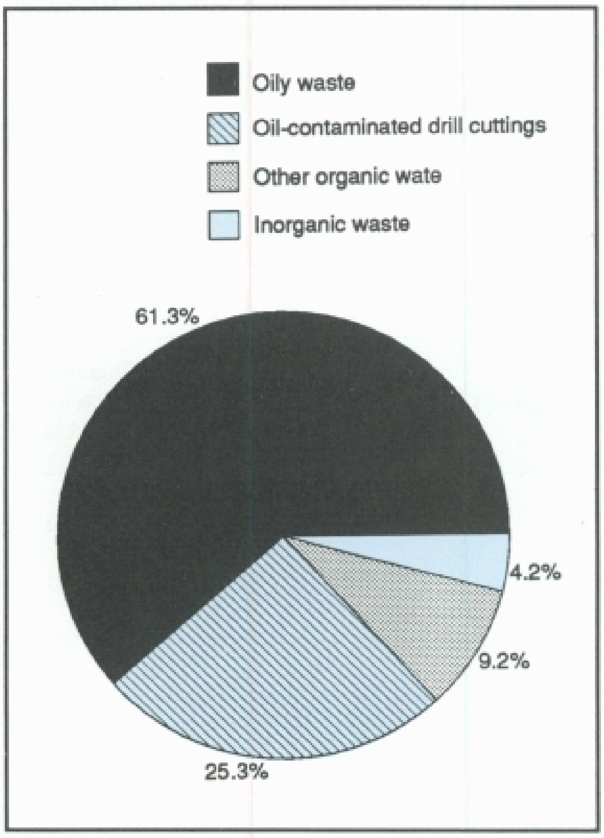
Table 8.5 shows that, in the last 5 years, the quantity of hazardous waste delivered to approved collection facilities has increased. The quantity of waste oil remains fairly constant. This waste accounted for 45 per cent of the waste delivered to approved collection facilities in 1991.

Table 8.5. Delivered hazardous waste to approved collection facilities. 1987-1991. 1 000 tonnes

Type of waste	1987	1988	1989	1990	1991
Total	52	54	58	60	66
Waste oil	30	31	..	31	30
Other wastes	22	23	..	29	36

Source 1987-89: SFT. Source 1990-1991: NORSAS, 1992.

Figure 8.5. Delivered hazardous waste, by main groups of waste. 1991. Per cent



Source: NORSAS, 1992.

Table 8.6. Hazardous waste delivered to the system for management of hazardous waste. 1991

Groups of substances	Quantity tonnes
Total	65 681
1 Waste oil	29 901
2.1 Oily waste from oil-water separators	8 256
2.2 Oil-contaminated drill cuttings[1]	16 590
3 Oil emulsions	2 095
4.1 Halogenous organic solvents	228
4.2 Non-halogenous organic solvents	2 150
5 Paint, glue, varnish and printer's ink	2 333
6/7 Distillation residues and tar	314
8/9 Waste/batteries containing heavy metals	1 099
10 Waste containing cyanide	20
11 Discarded pesticides	16
12 Waste containing PCB	16
13 Isocyanates	5
14 Other organic waste	987
15 Strong acids	588
16 Strong alkalis	288
17 Other inorganic waste	762
18 Aerosols	7
19 Laboratory waste	22
20 Unknown	1

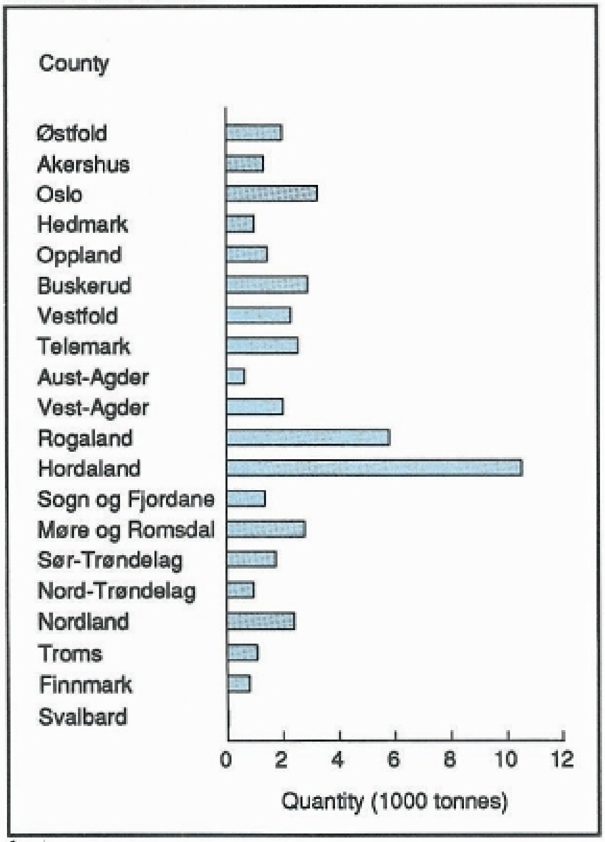
[1] Applies to Vest-Agder (4), Rogaland (6849), Hordaland (9227) and Sogn og Fjordane (510).
Source: NORSAS, 1992.

A/S Norsk spesialavfallselskap (NORSAS) was established in 1988 and is responsible for coordinating all streams of waste that are subject to regulation and cannot be handled internally by the companies themselves. NORSAS has developed a data base (NorBas) to record data on waste delivered to the system for management of hazardous waste in Norway. The records are based on declaration forms, and are updated monthly. NORSAS' Annual Report includes statistics right down to municipal level.

In terms of quantity, oily waste and waste from oil drilling operations (oil-contaminated drill cuttings) account for a very large part of the delivered hazardous waste, see table 8.6 and figure 8.5. Even if waste from oil drilling is excluded, Hordaland and Rogaland are the counties that deliver the largest amounts of hazardous waste, see figure 8.6.

In 1990, 90 per cent of the hazardous waste could be distributed according to which types

Figure 8.6. Delivered hazardous waste [1] by county. 1991. 1 000 tonnes



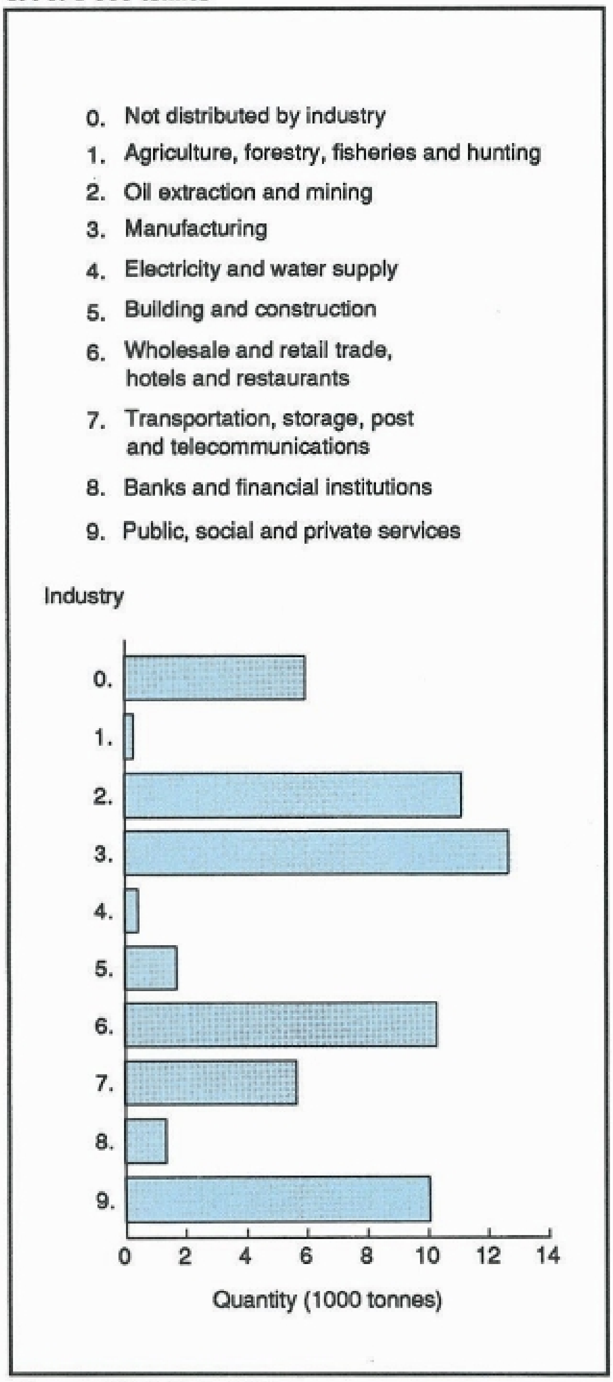
[1] Waste from oil drilling not included.
Source: NORSAS, 1992.

Table 8.7. Exports of hazardous waste. 1986-1990. Tonnes

	Total exports	Of which waste oil
1986	1 700	-
1987	18 000	12 000
1988	4 000	-
1989	8 000	4 800
1990	21 800	12 500

Source: SFT.

Figure 8.7. Delivered hazardous waste, by industry. 1990. 1 000 tonnes



Source: NORSAS, 1992.

of industries or commercial enterprises delivered the waste. Oil extraction and mining accounted for the largest total deliveries, and the figures were also high for manufacturing, wholesale and retail trade/operation of hotels and restaurants, and public/private services. If oil extraction and mining are excluded, the average amount of waste delivered per company varied from 2 kg in the primary industries to 11 kg in manufacturing industry.

The most important arrangements for dealing with hazardous waste are *collection* (mostly private transport companies with a licence), *reception* (local and regional reception facilities) and *treatment.* More than 70 per cent of the delivered waste is delivered to waste collecting companies. Most of the remainder is delivered directly to approved reception facilities or treatment plants. Most of the waste oil is treated in Norway, while the rest of the waste is stored for shorter or longer periods before being treated.

Some hazardous waste is directly exported for treatment in other countries after a permit has been obtained from SFT. Table 8.7 shows legal exports of hazardous waste during the period 1987-1990.

NORSAS has started the work of building *a central storage facility* for hazardous waste at Hjerkinn. The facility is intended to be ready for operation sometime in 1992. A waste management company, "Norsk avfallshåndtering A/S" (NOAH), was established towards the end of 1991. The majority of the shares are owned by the State, and the rest by Norsk Hydro, Statoil and 7 other companies. The Storting has decided that NOAH itself will decide the site of *a central facility for treatment of hazardous waste.*

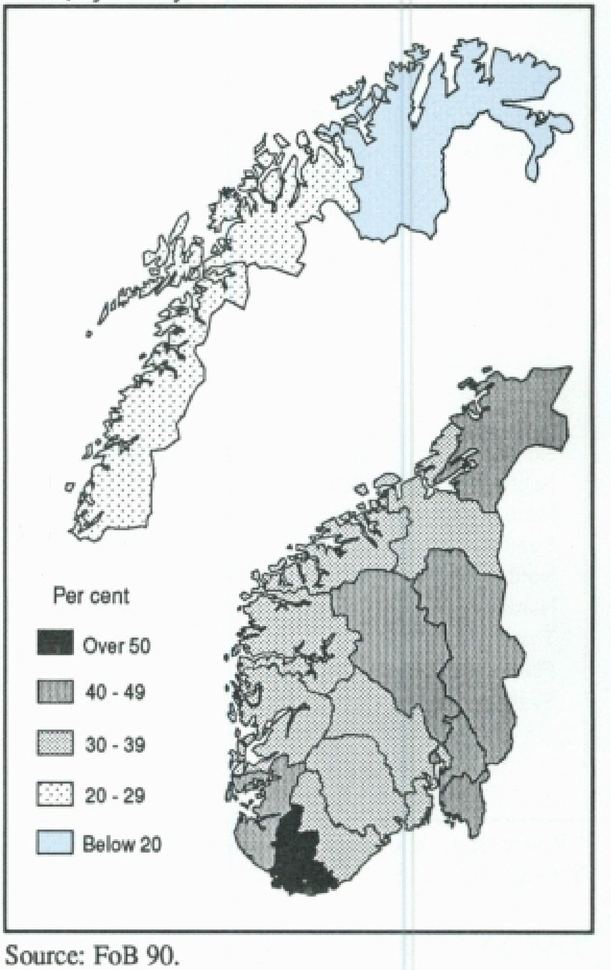
8.3. Sorting waste by source in private households

In the Population and Housing Census 1990 ("Folke- og boligtelling 1990 - FoB 90"), the various households were asked whether they usually sorted their waste. The respondents were just asked to tick off the kinds of waste that were delivered/collected after sorting.

Preliminary figures from the census show that 37 per cent of Norwegian households sorted out one or several types of waste in autumn 1990, but there were *large variations between regions,* see figure 8.8. In North Norway only 1/4 of the households sort their waste, while Vest-Agder headed the list, with 60 per cent of the households sorting waste. In Oslo the percentage was 33 per cent, as against 40 per cent for the rest of Eastern Norway.

Sorting out batteries was the most common practice, see figure 8.9, followed by sorting out of paper and glass. In this connection Vest-Agder and Rogaland stand out, since sorting out of paper was more common than sorting out of batteries. Only 7 per cent of the households sorted out paint, varnish, oil etc.

Figure 8.8. Percentage of private households that sort waste, by county. November 1990

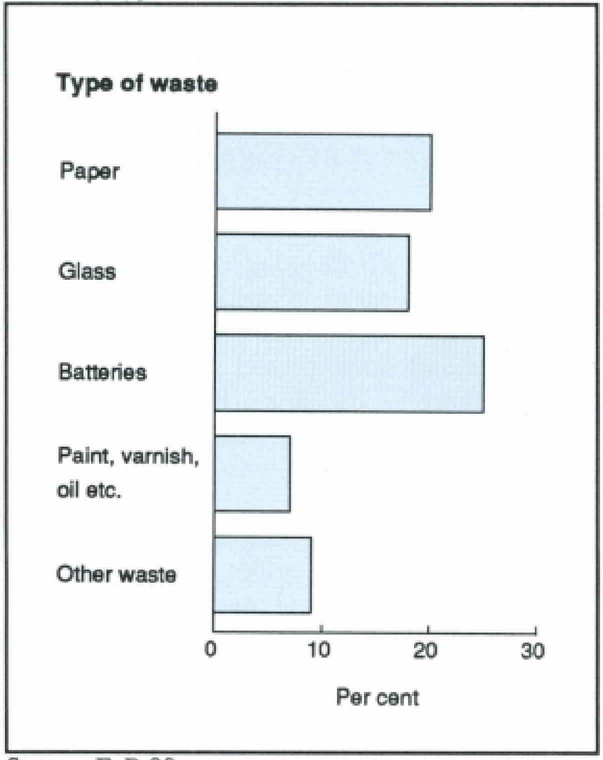


Source: FoB 90.

The proportion of households that sort their waste varies considerably with *type of household* (see figure 8.10), and *type of building* (see figure 8.11). The percentage was much higher among multi-member households, and particularly among households with children, than in single-member households. The percentage decreased from 40 per cent among households living in detached houses to 30 per cent in households living in blocks of flats.

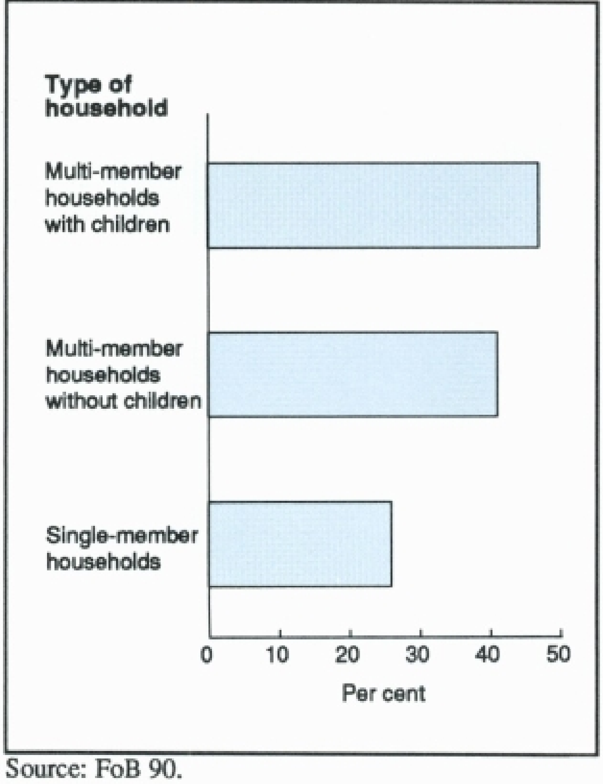
In autumn 1990 the Storting decided that all the municipalities in the country had to prepare plans for sorting of waste by source by 1 January 1992. It will be assessed whether the information collected through the planning work can form a basis for nation-wide statistics on waste and recycling of waste (Ministry of Environment, 1991).

Figure 8.9. Percentage of private households that sort waste, by type of waste. November 1990



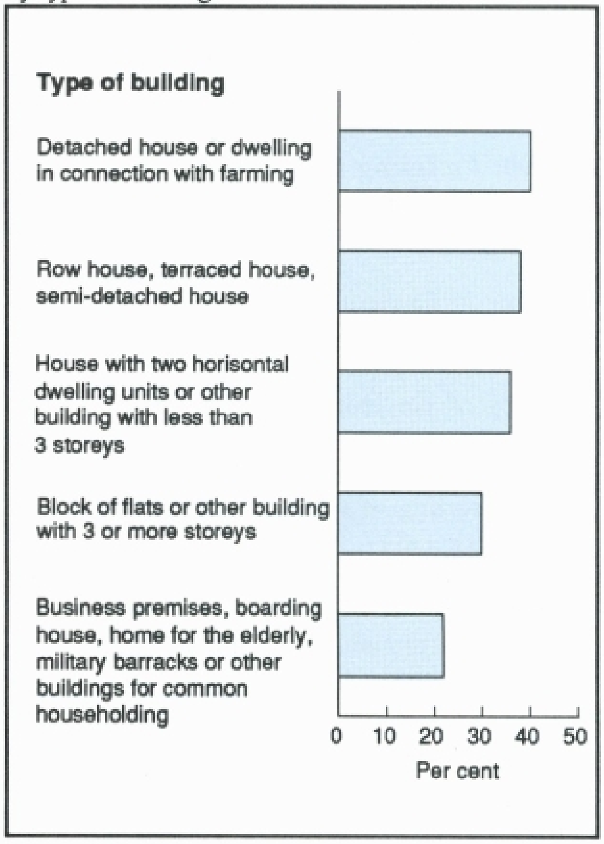
Source: FoB 90.

Figure 8.10. Percentage of households that sort waste, by type of household. November 1990

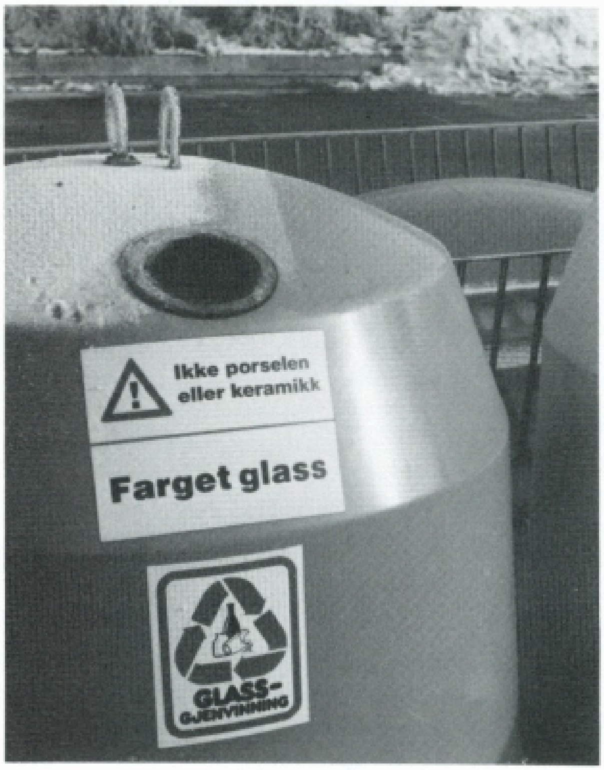


Source: FoB 90.

Figure 8.11. Percentage of households that sort waste, by type of building. November 1990



Source: FoB 90.



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9. ENVIRONMENTAL INDICATORS

Increasingly more environmental statistics are being published both in Norway and in other countries. Nevertheless, there is probably great variation in just how much of this information reaches a widespread public. The subject is not only very comprehensive; it is often necessary to have prior knowledge in order to understand what the figures imply. This means that the information that does reach the public about changes in the state of the environment may often be haphazard and incomplete.

The Central Bureau of Statistics (CBS) is in the process of developing a set of environmental indicators. These indicators are intended to provide a simple picture of the status of the environment. This chapter describes the main features of the work done so far. A final presentation of the set of indicators will be prepared in the course of 1992.

In recent years, several groups of persons have suggested that, when calculating the domestic product, it would be desirable to adjust the figure to include deterioration of the environment. No indicators of this type will be included in the set of indicators now being prepared. However, a domestic product adjusted for environmental deterioration is discussed in section 9.5.

9.1. What are environmental indicators?

An indicator is a figure used to give a picture of changes in a specifically defined condition. The indicator is not intended to provide detailed and exact information; as the name implies, it is rather a question of *indicating* - that is to say, pointing out - the broad outlines of the development.

In an economic context it is usual to refer to quantities such as GDP, consumption, rate of inflation and rate of unemployment. These quantities can be regarded as indicators of economic change, even if there are many important aspects of the economy about which they are *unable* to provide any information. Similarly, a set of environmental indicators should be able to provide a picture of important aspects of changes in the environment.

However, the need for an overall picture may easily conflict with the wish to supply as correct information as possible. In the case of many environmental conditions, it is these very details, finely tuned biological and chemical interactions and local conditions that are important. It is necessary to weigh the need for detail against the need for overview. It should be remembered, however, that a set of indicators is not intended to provide complete information on all important aspects of the problem.

Target group

The set of environmental indicators being developed at CBS is intended primarily for *the general public*, that is to say, people who are not experts on environmental matters, but are interested in these issues. Therefore the indicators will be presented in a form that is easy to understand and interpret. Sometimes this may imply a lower level of accuracy than required for scientific analyses. Experts will in any case be able to obtain information from the extensive amount of data available in the field.

Making the general public the main target group implies that the set of indicators is not primarily designed as a tool that can be used by the authorities to follow up their environmental policy. Such a follow-up often requires more detailed information. However, some of the indicators do, in fact, concern areas with specifically defined national objectives.

A reference group for environmental indicators has been appointed under the Ministry of Environment. This group is to propose a set of indicators to describe the status of the environment in Norway. CBS is represented in this group, and the Bureau's work in connection with environmental indicators can be regarded as a contribution to the work of the national reference group. Many of the indicators proposed by CBS will be included in the set of indicators defined by the reference group.

What kind of indicators?

In principle, there is an important difference between indicators which take into account various elements of economic valuation, and indicators that do not. The most important example of the first type is "green GDP", a concept which several persons have suggested should be incorporated into the national accounts. The idea is that the domestic product (gross or net) should be adjusted for the value of the deterioration of the natural environment that has occurred during the period. Important aspects of such an adjustment of the domestic product are discussed in more detail in section 9.5.

CBS has chosen to develop indicators based on physical units of measurement. Thus, the indicators do not include a valuation of environmental "goods" in terms of money.

Every environmental problem has several causes, but our knowledge about these causes is often limited. This makes it necessary to decide whether to try to provide indicators of the *cause* of a problem (stress indicators) or of the *effect* (response indicators). Often the chain of cause-effect will be a long one, so that many indicators can be regarded as both stress and response indicators.

If the indicators are intended to be used as a tool in promoting the authorities' environmental policy it is important to concentrate on causes, since this is where measures can be introduced. However, as mentioned above, the target group in this case is the general public, and not primarily the authorities. CBS has therefore chosen to develop a set of indicators which provide a picture of important aspects of the state of the environment (response indicators), independent of the causes of the various problems. These response indicators will be supplemented, however, by a set of stress indicators.

At the moment, only indicators of the state of the environment are being developed. Later, indicators will be developed to show the stock of natural resources. The boundary between these two types of indicators is diffuse, however. For example, fish stocks are regarded as a natural resource, while biological diversity is treated as an environmental condition.

9.2. Why are we interested in the environment?

If the set of indicators is to be accepted and used by the target group it must be able to describe those aspects of the state of the environment that this group considers important. At the same time, the number of indicators should be limited, to avoid losing the overall picture. The first step in selecting what is most important is to ask the question: What factors in the environment are people really concerned about?

1. Physical health

Pollution of air and contamination of food and drinking water may have negative impacts on physical health. Mental health is also affected by the environment, but it is more natural to include this aspect in the items below.

2. Economic damage

This item is connected to some extent with item no. 1, because poor health among the labour force reduces productivity. In addition, air pollution can cause corrosion of buildings and other capital equipment, and damage valuable economic resources such as fish and forests. Use of poor quality air and water as input factors in production will also lead to economic loss.

3. Recreation, aesthetics and culture

The elements mentioned under this heading refer to conditions that are not really the same, but it is difficult to make clear distinctions between them. For example, it can be difficult to separate the value of a walk in the forest in terms of recreation from the aesthetic value of the fact that the forest is a beautiful place. This heading will include conditions such as access to areas for walks, protection of particularly beautiful landscape areas and preservation of the cultural heritage.

4. Uncertainty and long-term perspectives
We know what we have today, but not what we will have in the future. Uncertainty and lack of knowledge of the consequences of disturbance of the ecosystem may be an argument for environmental conservatism; that the natural environment should be changed as little as possible.

5. Ethical and religious values
On the basis of a religious philosophy of life, whether Christian or otherwise, nature has been created by God. To judge intervention in nature on the basis of cost-benefit alone is to set oneself up as master of this creation, and, from a religious standpoint, human beings do not have the moral right to do this.

Similar standpoints may also be expressed by persons without a religious ideology; human beings should find their place in nature and respect it, and not believe that they are the masters of nature.

Consequences for the set of indicators

The items listed above provide different motives for being interested in the environment. Selecting what is the "most important", and thus what aspects the indicators should shed light on, will obviously be a subjective evaluation. The points of view forming the basis of the Bureau's set of indicators can be summed up briefly as follows:

Item 1, the importance of the environment for physical health, should be elucidated in the set of indicators. On the other hand, little emphasis has been placed on item 2, because this is not considered to be a principal element of people's concern about the environment. (This aspect will be evaluated later, however, in connection with the set of indicators for natural resources). Items 3-5 are considered important. However, these elements, and particularly those mentioned under point 5, do not refer mainly to specific effects of intervention in nature. They should rather be regarded as concerning the "overall status" of nature. It is difficult to visualize a single indicator that can shed light on this condition, but a *set* of indicators may be of interest in this respect if the picture provided of the state of the natural environment is fairly holistic, or complete.

This can perhaps be illustrated by an example: When parents take their child to a mother and child clinic their primary interest is not whether the child has the "right" weight, measurements etc. They want to know if the child is healthy and contented. Collectively, the results of the examination at the clinic are indicators of the state of health of the child. The parents know that there is no single indicator which answers what they really want to know, but the results do at least give an indication of whether anything is wrong. In the same way, a set of environmental indicators can be interpreted as an attempt to provide some important data on the "state of health" of the environment. In other words, it may be more important for the set of indicators to cover a fairly *wide range* of topics, than to include certain specific indicators.

9.3. Classification of the environmental indicators

Possible systems of classification

At present, data on environmental conditions are classified in several different ways. The systems of classification already in use provide a natural basis for systematizing environmental indicators. Several different systems of classification have been considered. The most important are listed below.

A. Classification by economic sector: The problems are classified according to which economic sector is assumed to have caused them (e.g. industry, agriculture, transport).

B. Classification by polluting substance (e.g. CO2, sulphur compounds, lead).

C. Classification by recipient (air, water, soil).

D. Classification by type of area where the damage occurs (e.g. urban areas, rural areas, wilderness, coastal areas).

E. Classification by effect on welfare: Items 1-5 in section 9.2 would be possible headings for this kind of classification.

These different classification systems have different points of focus with regard to the cause-effect chain. The first points are "cause-oriented", while the last are more "effect-oriented". Since our purpose is to concentrate on the effects it might well be thought natural to go as far down the list as possible, i.e. to classify the indicators by effect on welfare (E). However, as mentioned above, it is the complete picture, rather than specific data, that is relevant for some of the items referred to in section 9.2. Therefore the list of effects on welfare provide a good starting point for evaluating what type of information should be included in the complete picture that is presented, but is not very useful as a stringent system of classification for the different indicators.

A list of important environmental issues

Irrespective of which of the above proposals is chosen, problems will arise when classifying one or more important environmental conditions. For example, is acidification a problem connected to air, water or soil? None of the systems outlined above seem to make an adequate distinction in this respect. It was found, however, that, whatever system was used, *the list of environmental conditions for which indicators are desired is the same*; it is only the headings that differ.

The classification systems used for environmental data have been developed to handle relatively large quantities of data. In the opinion of CBS, an important point is that a set of indicators should consist of a very limited number of indicators. For this reason it seems more fruitful to concentrate on *issues* rather than on trying to *define boundaries between groups of data.*

Most of the proposals presented internationally refer to systems of classification of type A - D. This is perhaps connected to the fact that they contain a much larger number of indicators.

Consequently, the "classification system" for CBS's set of indicators will consist, in fact, of a number of important environmental issues and the environmental impacts connected to these (see box 9.1).

Environmental effect	Response indicator	Stress indicator
1. Climatic change	Global mean temperature	Norwegian emissions of greenhouse gases
2. Depletion of the ozone layer	Thickness of ozone layer	Import and concentration of CFC/halons
3. Health	Air pollution above threshold limits	Norwegian emissions of SO_2, NO_x, CO, particulates, lead and VOC
4. Noise	Noise above threshold limits	
5. Eutrophication	Lakes classified as polluted	Discharges of phosphorus and nitrogen to primary recipients
6. Forest damage	Crown density in forest	Import of sulphur and nitrogen oxides
7. Damage to fish	Lakes with extinct fish populations	
8. Contamination - sea	Mercury in cod muscle	Discharges of hazardous substances
9. Contamination - land	Eggshell thickness in birds of prey	
10. Recreation	No. of persons living more than 500 m from an area for recreation	
11. Wilderness	Areas more than 5 km from a road	
12. Biological diversity	Area of land with rare biotopes	

Box 9.1. Outline of CBS's set of environmental indicators.

9.4. The set of indicators

Box 9.1 presents a list of the environmental conditions forming the basis for CBS's set of indicators. The list has been prepared with a view to providing the best possible information on the points mentioned in section 9.2 (with the exception of economic damage), while at the same time keeping the indicators down in number. Because the work is not yet complete, various changes may be made to the list later.

All the indicators are closely connected to environmental *effects*, fairly independent of cause. However, as a rule, it will be possible to extend the cause-effect chain at both ends, so that most conditions can be regarded as both a cause and an effect of something else.

As mentioned above, an additional set of stress indicators will be prepared to supplement the list of environmental indicators. Box 9.1 also shows which stress indicators will be included.

Examples

A complete set of indicators will be published in the course of 1992. The following are just some examples of response indicators. Some of the indicators are also found together with more detailed information in other parts of the report. This applies in particular to stress indicators (Chapter 3 contains figures for emissions to air of all important components).

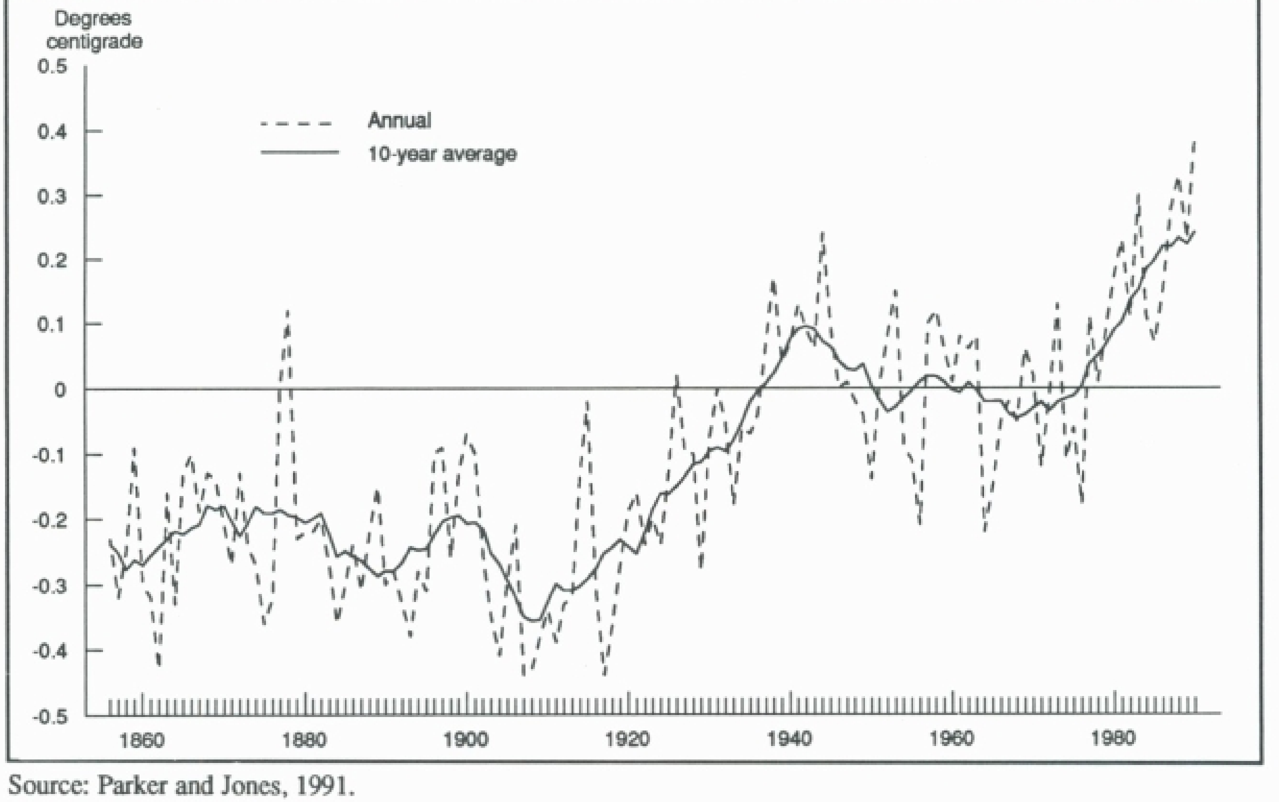
Changes in climate

Figure 9.1 shows changes in global mean temperature during the period 1856 - 1990. The figure also includes a 10-year running mean which makes it easier to identify possible trends. The global mean temperature shows a tendency to increase from beginning of the century up to 1940, and during the last ten years. Eight of the 10 warmest years during the period have occurred since 1980.

Crown density in forest

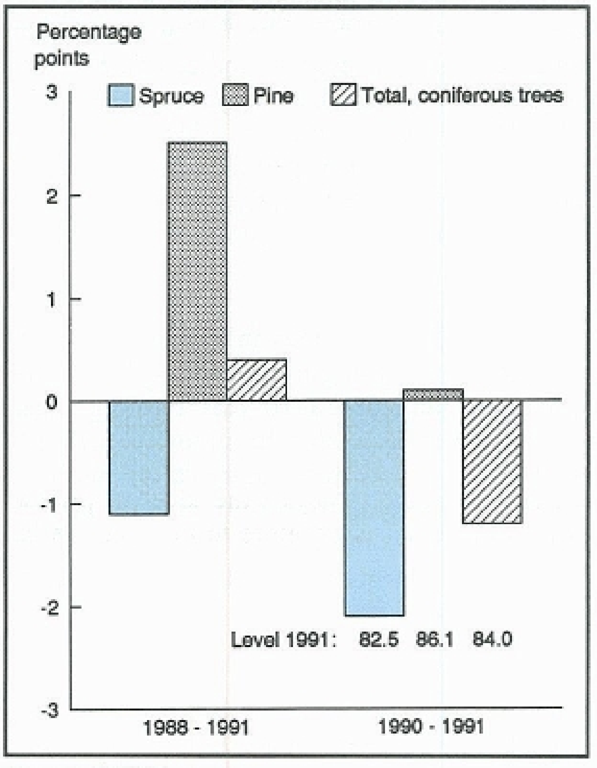
Forest status is dealt with in chapter 5, which presents figures for changes in average crown

Figure 9.1. Global mean temperature. 1856-1990. Deviations from the reference period 1951-1980 in degrees centigrade.



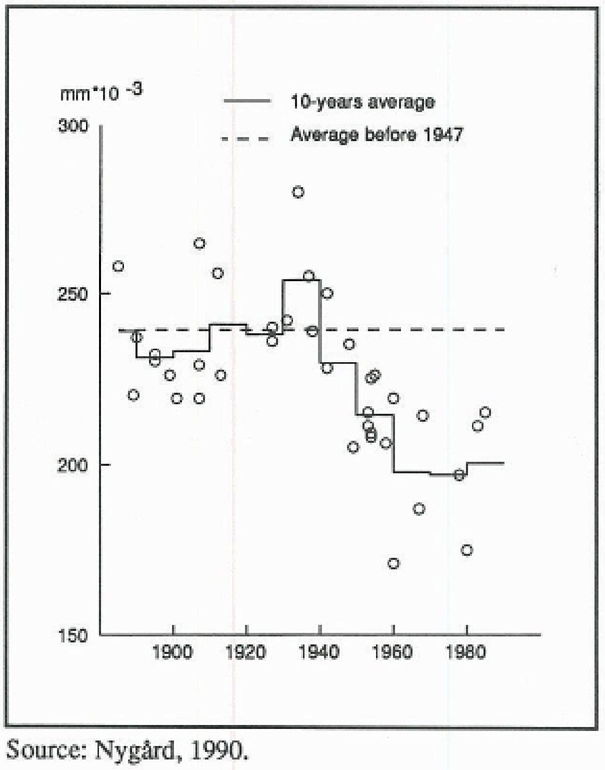
Source: Parker and Jones, 1991.

Figure 9.2. Changes in crown density of conifers in Norway. 1988-1991. Percentage points.



Source: NIJOS.

Figure 9.3. Eggshell thickness of Merlin. 1885-1985. µm



Source: Nygård, 1990.

density of spruce and pine in Norway. The crown density for conifers is calculated in terms of a weighted sum of these figures. Figure 9.2 shows average changes in crown density from the time the recordings started in 1988 up to 1991, and from 1990 to 1991.

The figure shows small changes during this (relatively) short period, considered as a whole. As pointed out in chapter 5, section 5.2, no significant changes have been found for spruce. For pine, there was a slight improvement in crown density during the period. For conifers as a whole the changes are small. A significant decrease in crown density occurred for spruce from 1990 to 1991.

Contamination of the natural environment

Eggshell thickness of birds of prey can be used as an indicator of environmental pollution. Figure 9.3 shows the thickness of the shells of eggs of the Merlin (*Falco columbarius*) during the period since 1880. A significant decrease in thickness of around 15 per cent was recorded when DDT was used in post-war years. Such a large decrease in thickness is close to the limit of how thin a shell can become without it breaking when the parent sits on the eggs. The data are taken from Nygård (1990).

9.5. "Green GDP"

In recent years, certain politicians and economists have argued that the net or gross domestic product (NDP or GDP) should be adjusted by the value of the environmental damage that has occurred during the year. This kind of "green GDP" is actually not a typical environmental indicator. Its primary purpose is to give some indication of economic development, but *also* to take into account changes in the environment.

GDP is a measure of economic activity, not a measure of welfare. One reason why many people argue for a "green GDP" is that GDP, nevertheless, is commonly interpreted to be a measure of welfare. In many countries it seems as if the objective of the policies is to maximize GDP without, for example, taking the environment into account. The purpose of establishing a "green GDP" thus seems to be that of achieving a greater degree of integration between the economic and environmental policies.

In 1990, the Statistical Office of the United Nations (UNSO) presented a proposal for how such an environment-adjusted gross domestic product can be prepared (UNSO, 1990). A Swedish expert group has concluded that further research should be done on a "green GDP" for Sweden. (Commission for Environmental Accounting, 1991). Several individual researchers or groups of researchers in other countries have started to work on a domestic product adjusted for depreciation of the environment (Tropical Science Center/WRI, 1991, Hueting et al., 1991).

Market price and value

All quantities in the national accounts are measured in terms of money, not in physical units. It is easy to forget this, and to conceive that, in some way or other, the national accounts measure *physical quantities*. If this were the case, data from physical resource accounts could be transferred relatively directly to the national accounts. However, the concept of value is of major importance when resources with different physical units of measurement are to be weighed together in terms of a single quantity, as in the national accounts.

When preparing the national accounts, all goods and services are valued on the basis of market price. (The exception is production in public administration, which is valued on the basis of the market price of the input factors, not the market price of the final product). Most environmental "goods" do not have a market price. This implies that, if the domestic product is to be adjusted for deterioration of the environment, the natural environment, or at least the annual changes in the natural environment, must in some way or another be valued in terms of money. This setting of values must be carried out by a different method than used in the national accounts otherwise.

Many people will react against even trying to set such values. From an economist's point of view too, the term "value" is fairly ambiguous and diffuse in this connection.

In the case of goods that are sold in markets with free competition it can be maintained that, under certain circumstances, the supplier and the consumer "agree on" the value of a unit of the good. The reason is that all adjust to the price they observe on the market: If a consumer thinks that a packet of sugar is of less use to him than other goods of the same value, he will reduce his consumption of sugar and buy more of the other goods instead. A rational consumer will make such changes right up to the time when he considers that the "benefit" of the last packet of sugar he buys more or less balances the value. In the same way, the manufacturer of the sugar is able to adjust the level of production so that it costs no more to produce the last packet of sugar than what he is paid for it on the market. Therefore, to some extent it is correct to say that the market price reflects the value of the good, both to the producer and the consumer.

Environmental goods are normally not sold on markets, partly because the right of ownership of such goods is difficult to define. Therefore it is impossible to observe any value for these goods directly. However, this is not only a *problem of information*: The lack of a market also implies that there is no mechanism which complies economic actors to use larger or smaller quantities of "natural goods" so that they end up at a point where the marginal, relative value is equal for all actors and in different situations. Therefore, the "value" of these goods, even at the margin, is not an unambiguous term.

Different approaches give different answers

In UNSO (1990) changes in environmental goods are valued on the basis of *what it would have cost to avoid the damage to the environment*. Thus a "green GDP" can be calculated by deducting this value from the net domestic product (see box 9.2). This can be interpreted as a measurement of how large the economic activity could have been if no damage had been caused to the natural environment during the course of the year. The method does not, however, give any reliable answer to this question (see the section below on accounts and hypothetical quantities).

Whatever the case, it is important to be aware that the "value of the year's environmental damage" obtained by this method of setting values does *not* provide general information on other aspects of the damage to the environment. This is because the word "value" is so ambiguous when used about a good that is not sold on a market. The method described above *only* answers the question of how much one believes it would have cost to avoid the damage. The result says nothing about how serious the damage actually was to the ecosystem, what it will cost to repair the damage once it has happened, or how the damage has affected the welfare of the country's inhabitants. Such questions must be answered by other methods and will generally give other answers.

	GROSS DOMESTIC PRODUCT
-	CAPITAL DEPRECIATION
=	NET DOMESTIC PRODUCT
-	NATURAL CAPITAL DEPRECIATION
=	"GREEN DOMESTIC PRODUCT"

Box 9.2. UNSO's proposal for a "green domestic product"

An example

The greater the environmental problems, the more pronounced becomes the problem of different marginal values. This can be clarified by an example. Let us visualize that an enterprise in a developing country discharges a toxic substance into a river. This leads to death of fish and other damage, and makes the water unsuitable as drinking water for the population living below the site of the discharge. The discharge could have been cleaned at fairly low cost before it reached the river but, in spite of this, the enterprise neglected to undertake this cleaning.

What is the value of this damage to the environment? On the basis of UNSO's method (see above) the value is small, because it would have been cheap to clean the discharge. If the value is measured instead in terms of what it would cost to repair the damage once it had occurred, the value obtained will probably be very high (if the damage is irreversible, the value is in fact infinitely high).

A third method is to ask the population what they would have been prepared to pay to avoid the discharge. Since the enterprise is located in a developing country, it must be assumed that the people are poor. In this case they will state a low figure, quite simply because they have nothing to pay with. The value is thus low. The question could have been put differently, however: "What compensation in terms of money, must you receive so that your situation is just as good as it was before?" This time, if the people conceived the river water as totally irreplaceable, the figure could be very high; this is because this time the answer to the question is not connected to the amount of money at their disposal.

As we see, it is possible to obtain almost any value one wants, just by varying the method of setting the value. In our case this is not due to errors of measurement, but because we evaluated different questions. Thus there is no "right" value of environmental goods. The value will depend on the connection, or to put it another way: What aspect of the matter one wishes to study.

This implies that an "environment-adjusted domestic product" can also have almost any value, depending on how one defines "the value of environmental goods". A "green GDP" prepared, for example, on the basis of how large the economic activity could have been without damaging nature and the environment will *not* be able to also provide information about the extent of the damage to nature and the environment that has actually taken place.

Accounting and hypothetical quantities

The domestic product is an accounting quantity; it shows only what has happened in the year that has passed, not what could have happened or should have happened. On the other hand, "necessary use of resources to avoid environmental damage" is a hypothetical quantity. A combination of these two kinds of quantities leads to an inconsistency which could easily make the results misleading.

In many countries, widespread destruction of the environment occurs every year, and extensive resources would be required to avoid or repair all this damage. It is hardly realistic to assume that all of it could be covered by unused capital and labour. In other words, relatively large resources must be transferred from other productive activity. The question then becomes, how will this affect the rest of the economy? Some branches will have to reduce their activity, others will have to extend it. This will imply changes in relative prices, the distribution of resources between industries, and the distribution of income. The economy will also be affected by better quality input factors (cleaner air and water, healthier workers, less corrosion).

These changes will, in the first place, lead to changes in the price of the input factors needed to avoid damage to the environment. Therefore, ideally speaking, "the value of the environmental damage" should be calculated again. It is of greater importance, however, that the actual net domestic product that is to be adjusted (see box 9.2) will also change.

Conclusion: "Green GDP"

As we have seen, a "green environment-adjusted domestic product" is often defined as net domestic product minus the value of depreciation of natural resources capital. However, this definition can be interpreted in many different ways.

An important reason why many people want an environment-adjusted domestic product is that GDP is often interpreted as something it is actually not intended to be, namely a measurement of welfare. "Green GDP" is based on GDP, but introduces a very ambiguous term; the value of depreciation of natural resources capital. It is thus an open question whether it will be easier to avoid misunderstandings and wrong interpretations of "green GDP" than of the present GDP. Such misunderstandings may well tend to give the impression that environmental problems are *less serious* than they actually are, or vice versa. Therefore, even on the basis of a wish for greater focus on environmental problems, an adjustment of the domestic product to take into account depreciation in the value of the environment may be an unfortunate strategy.

Even after having defined what is meant by the value of the environment it will still be difficult to interpret what an environment-adjusted domestic product really indicates. The reason is the introduction, on a large scale, of "intended" use of resources, without evaluating where these resources are to be taken from, and how this will effect the rest of the economy.

In preparing an environment-adjusted domestic product as an aid to an integration of economic and environmental policies, the persons preparing the statistics have to make a long series of subjective assessments of values. This implies that the statistics may contain a number of political evaluations, which will not necessarily be obvious to those who are to use the data. Thus it is possible that conditions which require a balance of different considerations may become more obscure instead of being clarified.

On the basis of the above considerations, CBS has chosen not to recommend the preparation of an environment-adjusted domestic product. Analyses of the connection between the economy and the environment, and the preparations of tools of management to promote stronger integration of the environmental and economic policies, are important matters which will be awarded further attention. However, the framework for this work will probably be more closely connected to economic models than to the preparation of environment-adjusted data for the national accounts.

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Utkommet i serien Rapporter fra Statistisk sentralbyrå etter 1. januar 1991 (RAPP)

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ISSN 0332-8422

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ISSN 0332-8422