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CENTRAL BUREAU OF STATISTICS OF NORWAY

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NATURAL RESOURCES AND THE ENVIRONMENT 1990

ENERGY, AIR, FISH, FORESTS, AGRICULTURE, ATTITUDES TO ENVIRONMENTAL ISSUES

RESOURCE ACCOUNTS AND ANALYSES

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ANDRE EMNEORD
Forurensninger
Naturmiljø
Miljøøkonomi
Utslipp

PREFACE

The Central Bureau of Statistics (CBS) elaborates statistics on the state of the environment and accounts for selected natural resources. CBS also develops methods and models to analyze the interrelationships between socio-economic development, resource use and environmental conditions. The publication *Natural Resources and the Environment* presents an annual survey of this work. This report is a complete translation of the publication for 1990.

Natural Resources and the Environment 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 and forest damage. The final chapter of the present report describes the results of an interview survey on attitudes to environmental issues.

The Central Bureau of Statistics wishes to thank the institutions that have helped to collect the data for *Natural Resources and the Environment 1990.*

Senior Executive Officer Frode Brunvoll and Executive Officer Anne Strandli edited the report, which was translated into English by Mary Bjærum.

Central Bureau of Statistics, Oslo 14 June 1991.

Svein Longva

Lorents Lorentsen

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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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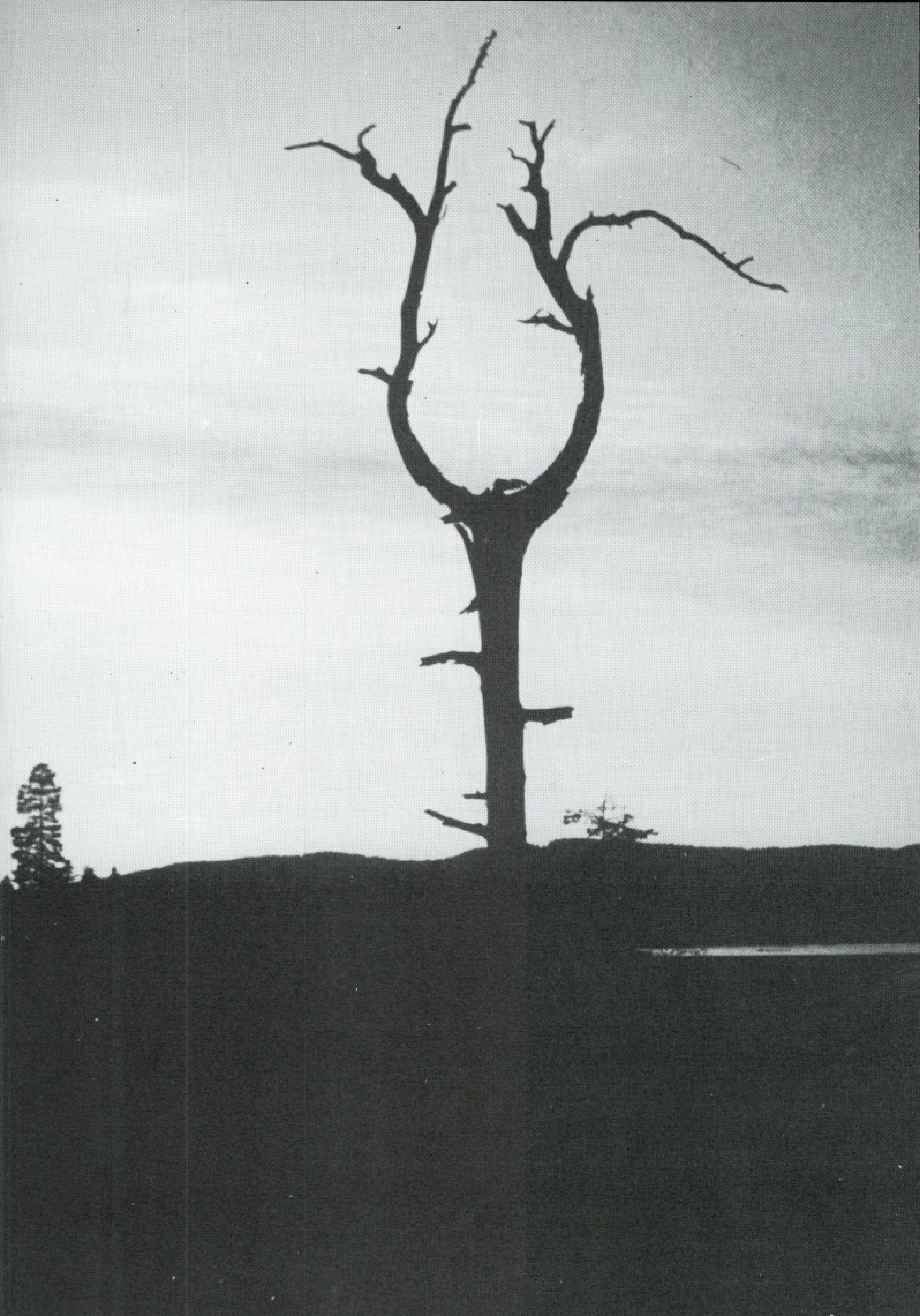


1. INTRODUCTION AND SUMMARY

OECD presented its report "The State of the Environment" in January 1991. The report describes changes in environmental conditions in OECD countries over two decades, and also illustrates the totally dominating role of the industrialized countries in the world economy.

The OECD countries represent only 16 per cent of the world's population and 24 per cent of its land area, but their market economies account for about 72 per cent of the world gross product, about 76 per cent of all world trade, 78 per cent of all road vehicles and 50 per cent of global energy use. The OECD countries also generate 45 per cent of CO_2 emissions, 73 per cent of exports of chemical products and 73 per cent of imports of forest products. Moreover, the OECD countries provide 95 per cent of all bilateral assistance. This means that the OECD countries make a substantial contribution to many of the environmental problems, and considering their strong position in the world economy should also help to solve them.

In certain areas, Norway does not rank very favourably in the OECD comparison between countries. However, some of the criticism that has been voiced since the report was published is misleading. This is because the indicators in the OECD Report do not always provide an adequate basis for comparison between countries. The fact that Norway spends a smaller share of its GDP on environmental measures compared with other OECD countries tells just as much about choice of instruments as about the priority awarded protection of the environment. The fact that a smaller share of the Norwegian population is served by sewage treatment plants than in Denmark, for example, says more about population density and geography than about the damaging impacts of Norwegian discharges compared with Danish ones. In other areas, however, the criticism may be more warranted, for example, in connection with waste disposal and certain emissions to air.

The OECD report also establishes that some of the most serious international environmental problems can only be solved through international agreements. The agreements on reductions of emissions should be designed to ensure that the largest reductions take place where it is cheapest to achieve them, ideally down to a level where the costs of further reductions in emissions are the same in all countries. This would ensure cost efficient reductions of emissions. An agreement on greenhouse gases must also include rules for sharing the burden of such reductions.

An interesting question is how far each country should go unilaterally in contributing to solve international environmental problems in areas where no international agreements exist as yet, or where such agreements are deficient. The greenhouse effect is an example of a global environmental problem where the contribution from a specific country may be relatively moderate. For example, Norway generates only 0.2 per cent of the world's total emissions of CO_2. Therefore, to solve the greenhouse problem it is essential to coordinate measures in many countries. However, reductions in the consumption of fossil fuels to limit CO_2 emissions will also lead to a reduction in certain forms of local pollution such as SO_2, NO_x and particulates. This may be an argument for taking steps at the national level while awaiting international agreements.

Estimates have been made of what it would cost Norway to stabilize her emissions of CO_2 by the turn of the century (Calculations for the Committee on Climate Change, and the SIMEN project - a study of industry, energy and environment towards 2000). The overall effects on the Norwegian economy seem to be moderate measured in terms of changes in macro-economic indicators such as GDP and total private consumption. The calculations indicate reductions of about 1-2 per cent in these indicators in the year 2000 compared with a reference path without the goal to stabilize emissions.

A common feature of the SIMEN project and similar analyses is that they focus only on the socioeconomic cost of measures to reduce emissions of greenhouse gases. Measures to limit the use of fossil fuels would be socially beneficial in terms of reduced local environmental damage and a more appropriate distribution of transport services between the different forms of transport, in addition to the expected benefits due to decreased emissions of greenhouse gases. If these additional benefits are taken into account, the cost of introducing moderate measures to counteract emissions of greenhouse gases is greatly modified.

The Central Bureau of Statistics has made some preliminary calculations of the marginal cost to society of emissions which cause local damage. Relevant types of damage are negative health effects, damage to certain types of materials, and acidification of lakes and soil from acid rain. The calculations also include estimates of changes in external costs connected to road traffic, such as wear of roads, accidents, cost of queuing and disamenity from noise.

According to these calculations, the total changes in emission levels of SO_2, NO_x, CO and particulates in the 1980s imply annual external costs that are about NOK 10 billion higher now than in the early 1980s. About half of these costs refer to the negative health effects caused by emissions of NO_x. Most of the remaining costs refer to external costs connected to increased road traffic. Similarly, calculations based on results of the SIMEN project show that the benefits may to a large degree compensate for loss in production and consumption due to stabilization of CO_2 emissions.

The calculations do not cover all the known damaging effects of emissions from fossil fuels. For example, the cost of negative health effects from ozone are not included, nor possible costs connected to the greenhouse effect.

It must be emphasized that calculations of damage to the natural environment, health and capital equipment due to a deteriorated state of the environment are so far very uncertain. One of the most important contributions of social science in the years to come will be to integrate more well-founded damage functions into economic models and analyses. Only then will it be possible to make a proper assessment of the benefits and costs to society of an improved environment, instead of focusing entirely, as now, on what environmental policies cost in terms of increased use of resources or reduced consumption.

SUMMARY

Chapter 2 describes Norwegian energy reserves, domestic energy extraction and use, and changes in energy prices over the last ten years. It also includes an overview of the international oil market and a brief description of trends in energy consumption in Europe.

During the period 1976-1988, total energy consumption in Norway, not counting the energy sector and ocean transportation, increased on average by 1.8 per cent per year. From 1988 to 1989, consumption decreased by 3.5 per cent. According to preliminary figures, total domestic energy consumption was 743 PJ in 1990; an increase of 1.2 per cent compared with 1989.

Hydropower production was record high in 1990, reaching about 122 TWh. 16 TWh was exported, while water equivalent to 7.5 TWh bypassed the production system. Oil and gas production increased in 1990 to 111 million tonnes of oil equivalents; an increase of 7 per cent compared with 1989. Combined with the rise in prices, this led to a strong increase in revenues from petroleum activities.

The new Energy Act and the Petroleum Fund Act are both intended to improve the management of Norwegian energy resources. The main purpose of the Energy Act is to improve the efficiency of the energy market. The potential to achieve this goal is obstructed, however, because the Act does not apply to contracts with energy-intensive industries. The purpose of the petroleum fund is partly to improve monitoring of oil revenue spending, and partly to function as a "buffer" in the event of an unexpected fall in prices. In practice, the fund does not place any real restraints on the annual spending of revenues from petroleum activities.

The chapter also discusses use of resources and costs in the energy sector and trends in stationary energy consumption in households and the production sectors. A steadily larger share of the total energy consumption is based on electricity. This trend was also observed after the fall in oil prices in 1986. Possible explanations may be increased use of electricity-specific equipment and the relatively lower costs of electrical heating equipment, as well as expected high prices for oil products.

Chapter 3 presents inventories of Norwegian emissions of several polluting compounds, and comments on changes in emission levels over time. Seen in a perspective of almost 20 years the emission situation can be characterized briefly as follows: In the 1970s, the level of emissions of most compounds changed in step with changes in oil consumption. That is to say, there was a slight decrease in emissions in the early 1970s due to the rise in oil prices at that time. Emissions then increased until 1980 when a new rise in the price of oil put a stop to the rising trend. In the 1980s, on the other hand, two groups of emissions followed different paths. The first 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 the higher consumption of transport fuels. In recent years, however, the increase in emissions has been much diminished as a result of mild winters and a slower rate of economic growth. As for the second group, consisting of SO_2 and Pb, emissions have been substantially reduced; 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 composition of heating oils and gasoline have obviously led to a significant decline in air pollution from sulphur and lead.

The fact that a reduction in emissions has 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.

As illustrated in the chapter, total emissions in the long term may be strongly influenced by measures to reduce emissions of greenhouse gases. In addition to estimating the costs of such measures to society, an attempt is made to present calculations of some of the beneficial effects of reduced use of fossil fuels and the associated decrease in emissions. The results indicate that a large share of the social costs connected to higher prices for fossil fuel will be compensated by reduced negative effects on health from air pollution and better efficiency of road traffic.

The chapter concludes by considering how environmental status in Norway will be affected by different forms of association with the EEC.

Chapter 4 presents resource accounts for fish, including information on changes in fish stocks, quotas and the size of the catch in 1990, as well as figures for exports of fish products and reared salmon. In 1990 the spawning stock of Norwegian spring spawning herring was estimated to be about 1.6 million tonnes, but is totally dominated by one specific year class. Even if not exploited, the spawning stock is expected to decrease in the next few years due to poor recruitment. There was a strong increase in 1990 in the stock of Barents Sea capelin, and fishing of this species will be allowed in 1991 for the first time since 1986. The cod stock is still assessed as very low. The total catch in Norwegian fisheries decreased by about 200 thousand tonnes from 1989 to 1990, but the first hand value remained the same. The export value of fish products increased by about 18 per cent from 1989 to about NOK 13 billion. The exported quantity of reared salmon increased by 37 per cent from 1989, and the export value by 39 per cent.

Chapter 5 describes the status of Norwegian forest, and presents more or less corresponding calculations for Germany (West) and Europe. The forest status has changed only slightly in Norway from 1989 to 1990. For spruce, the average defoliation increased from 14.9 per cent in 1989 to 15.4 per cent in 1990. For pine the average defoliation was 14.3 per cent in 1989 and 14.0 in 1990.

Chapter 6 assesses the contribution made by agriculture to nutrient discharges (nitrogen and phosphorus) to the parts of the North Sea covered by the North Sea Declaration. It is estimated that agriculture is responsible for 48 per cent of the anthropogenic discharges of nitrogen, and 27 per cent of such discharges of phosphorus. An assessment is made of changes in discharges over the last ten years, based on available statistics on land use and farming practices. For example, the Agricultural Censuses of 1979 and 1989 are used as a basis for comparing use of fertilizers in the different years. According to the available statistics, no changes seem to have taken place in the agricultural sector leading to marked reductions in discharges during this period. The chapter also includes an evaluation of the cost-efficiency of relevant measures to reduce discharges from agriculture. The most cost-efficient way to reduce discharges seems to be reduced use of fertilizers, but above all a fertilizer practice more suited to the plants' need of nutrients. The chapter concludes with a description of a project conducted jointly by CBS and the Centre for Soil and Environmental Research, aiming at quantifying changes in loss of nitrogen, phosphorus and soil from agricultural land.

Chapter 7 presents the results of an interview study on attitudes to environmental problems. 49 per cent of the population believe that protection of the environment and economic growth can be combined, while 48 per cent think that the environment should receive priority, even if this means a slower rate of economic growth. Only one per cent think that priority should be given to economic growth even if this has a negative effect on the environment. The local environmental problem that gives greatest cause for complaint is pollution of rivers, lakes and fjords. 15 per cent report serious cause to complain about this problem, while only 5 per cent report serious cause to complain about noise and 6 per cent about air pollution. The Norwegian population is obviously more concerned about international environmental problems than about national problems. 39 per cent stated that they were very concerned about national air pollution problems, whereas 65 per cent said they were very concerned about possible climate change due to emissions of greenhouse gases. 31 per cent thought that the authorities are not concerned with environmental protection. 65 per cent of those who thought that the authorities are concerned about the environment also thought that they are not doing an effective job. Only 17 per cent of the interviewees thought that the authorities are concerned with protection of the environment and are doing an effective job.

2. ENERGY

Hydropower production was record high in 1990 for the third consecutive year. Production of electricity reached about 122 TWh, an increase of 2.4 TWh compared with 1989. There was an increase of just over 1 TWh in both domestic consumption and export. Slightly more than 16 TWh electricity was exported in 1990. Like in 1989, water equivalent to 7.5 TWh bypassed available production capacity because of the rather inflexible system of electricity prices in Norway. The main reason for the large domestic surplus of electricity is good inflow of water to the reservoirs. In a normal year the production would have been as much as 14 TWh lower than in 1990.

In 1990, the self-imposed ceiling on oil production was removed. Oil production increased only slightly, however, from 1989 to 1990. This is because oil production was low during the first half of the year due to lack of reservoir capacity. Towards the end of the year, oil production reached 1.8 million barrels a day, which is close to production capacity. The price of crude oil (Brent Blend) varied considerably during the year, from the lowest level of somewhat less than 15 dollars per barrel at the start of the third quarter, to a peak level of more than 40 dollars per barrel at the end of September.

The new Energy Act and the Petroleum Fund Act are both intended to improve the management of Norwegian energy resources. The main purpose of the Energy Act is to improve the efficiency in the energy market. The potential to achieve this goal is obstructed, however, because the Act does not apply to contracts to energy-intensive industries. The purpose of the Petroleum Fund is partly to improve monitoring of oil revenue spending, and partly to function as a "buffer" in the event of an unexpected drop in oil prices. In practice, the Act does not place any real constraints on the annual use of revenues from petroleum activities.

2.1. The Norwegian energy market

Supply

Hydropower reserves

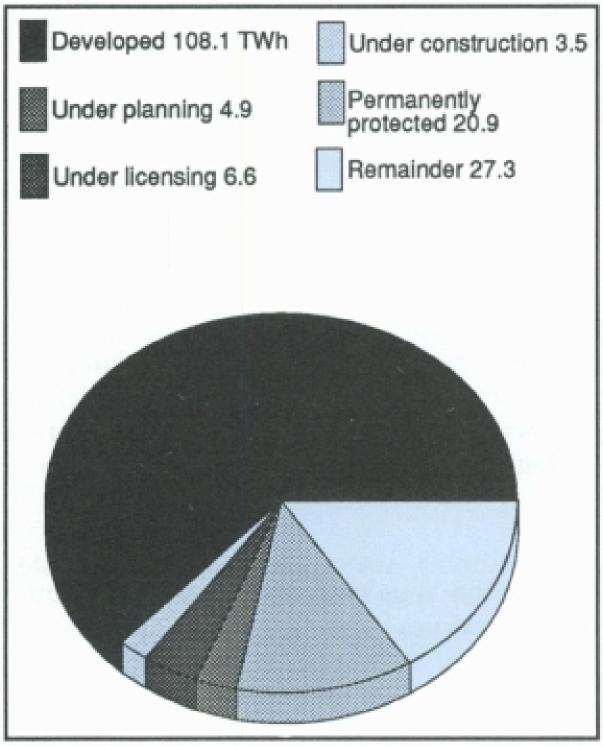
The hydropower reserves can be placed into four categories:

- 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 1991, Norway's total economically exploitable hydropower resources amounted to 171.4 TWh. This figure includes permanently protected watercourses with a power potential of 20.9 TWh. Per 1 January 1991, hydropower resources had been developed with an average power potential (the production capacity of the power plants in a year with normal precipitation) of 108.1 TWh. This is 0.3 TWh higher than at the turn of the year 1989/90. Undeveloped hydropower resources, excluding permanently protected watercourses, amounted to 42.3 TWh per 1 January 1991. Of this amount, about 15 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 79 TWh. Like in the late 1980s, for most of 1990 the reservoirs were filled to a far higher level than the average for the last ten years. In April the reservoirs were filled to more than 50 per cent capacity. The normal is about 30 per cent. At the turn of the year 1990/91 the reservoir holding was 61 TWh, which corresponds to a percentage filled capacity of about 77 per cent. The normal is 67 per cent.

Figure 2.1. Exploitable hydropower 1 January 1991. TWh



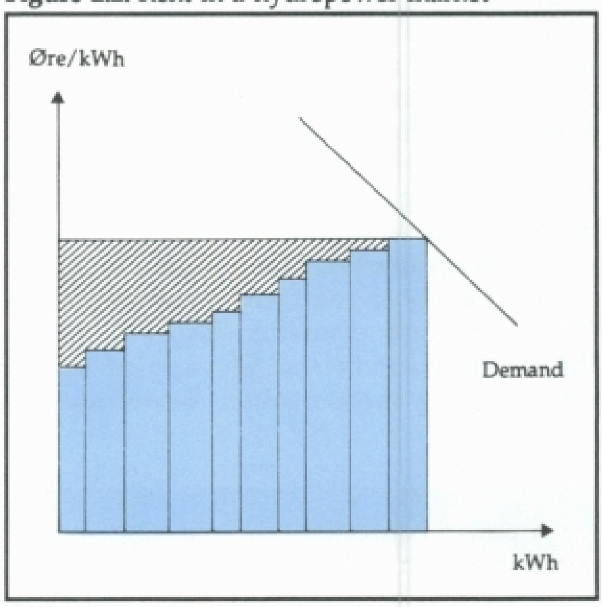
Hydropower production

In 1990 production of electricity reached 121.6 TWh, an increase of 2.4 TWh compared with 1989. This figure includes 0.4 TWh thermal power, the rest is hydropower. Thus a new production record could be noted for the third year running, see table 2.17 (in appendix of tables). Water equivalent to 6 TWh passed outside free production capacity in 1989, and to 7.5 TWh in 1990.

The hydropower rent

The costs of constructing and operating a hydropower plant vary from project to project, depending on size and other naturally-determined conditions. Different hydropower plants can be ranked by increasing costs per kWh. When the market price for electricity increases, plants with low costs will have a surplus return. This surplus return, the hydropower rent, is due to a scarcity of low cost hydropower projects. If the market price of electricity is high and the cost per kWh at the plant is low, the rent will be high.

Figure 2.2. Rent in a hydropower market



The term hydropower rent is illustrated in figure 2.2, depicting different hydropower projects and market price. The height of the columns corresponds to the average cost at the hydropower plant, and the width shows production capacity. The average cost includes both capital costs (normal return on capital and capital depreciation) and operating costs.

The rent corresponds to the shaded area in the figure.

The rent is a theoretical term. Certain conditions must be fulfilled in order to capture the whole of the rent indicated in figure 2.2. the capacity of the electricity supply system must be correctly dimensioned (the price equal to the long-term marginal cost is in equilibrium), and the price adjusted for differences in costs must be the same for all consumers.

In the data forming the basis for these calculations (National Accounts and Electricity Statistics) the electricity sector consists of production, transmission and distribution of electricity. Ideally, transmission and distribution should be excluded when calculating the rent in hydropower production. However, when calculating the rent for the electricity production sector it can be assumed that the costs of transmission and distribution in the electricity sector are covered.

CBS has calculated the long-term marginal costs for the first half of 1990 by inflating the figures from the Norwegian Water Resources and Energy Administration (NVE) per 1 January 1990 with the consumer price index. In 1990, the long-term marginal supply cost for electricity for residential consumption was 39.8 øre/kWh. In energy-intensive industry the average load is higher, transmission costs are lower and there are no distribution costs. The calculated long-term marginal costs for supply of electricity to this kind of industry is 28.2 øre/kWh.

Given these prices of electricity, and sales of firm power equivalent to the average annual production in 1990, the operating surplus potential in the electricity sector, including the tax on electricity, is calculated to NOK 22.1 billion. Assuming a normal return of 7 per cent on a capital of NOK 195 billion, the rent is NOK 8.5 billion. This illustrates the long-term annual potential rent in the electricity sector at present capacity, assuming a high enough demand to keep the market in equilibrium. Provisional estimates for 1990 give an operating surplus of about NOK 15.1 billion for the electricity supply. This implies a return on capital of about 7.7 per cent in the sector this year. This means that the realized rent in the electricity sector in 1990 was NOK 1.5 billion.

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 better production technologies are developed, 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 (1990) estimates a reserve potential of 5 400 million tonnes oil equivalents (mtoe) south of Stad as per 1 January 1989. Of this amount, 4 460 mtoe have been discovered. Development licences amount to 2 990 mtoe, of which just over 25 per cent has been extracted. In addition to the reserves south of Stad, proven resources are estimated to be 480 mtoe on Haltenbanken and 270 mtoe on Tromsøflaket.

Table 2.14 and table 2.15 in the appendix of tables show the changes over time in the estimated reserves for total development licences. In 1990 the oil reserves in these fields increased, partly due to revaluation of the remaining reserves in "old" fields, and partly as a result of new licences. The new fields included Brage, Embla and Statfjord North and East. The growth in reserves exceeded extraction. Reserves of gas, on the other hand, decreased, since the reserves in new fields were not enough to compensate for extraction. The revaluation thus made a negative contribution to the reserves.

At the present rate of extraction the oil reserves in developed fields and in fields to be developed will last just less than 13 years, while the gas reserves will last for 42 years. If the reserves in fields which are not to be developed as yet are added, the oil reserves will last for 18 years and the gas reserves for 126 years, given the present rate of extraction. Since oil and gas production will increase as the fields are taken into operation, the R/P rates (ratio between reserves and production) will be considerably lower in the next few years if no new reserves are added.

Oil and gas extraction in 1990

In 1990, Norwegian oil and gas production amounted to 110.9 million tonnes oil equivalents, 7 per cent more than in 1989. Oil production increased by about 9 per cent from 75 million tonnes in 1989 to 81.9 million tonnes in 1990, see figure 2.3. The main reason for the increased production is the development of the Oseberg field, but production was also started in four smaller fields; i.e. Veslefrikk and Troll West, with start of production in January 1990, Gyda, with start of production in June, and Hod, as yet the smallest field on the Norwegian continental shelf, where production started in October 1990. Of these fields, Gyda reached a plateau production of an estimated 70 000 barrels a day already in November.

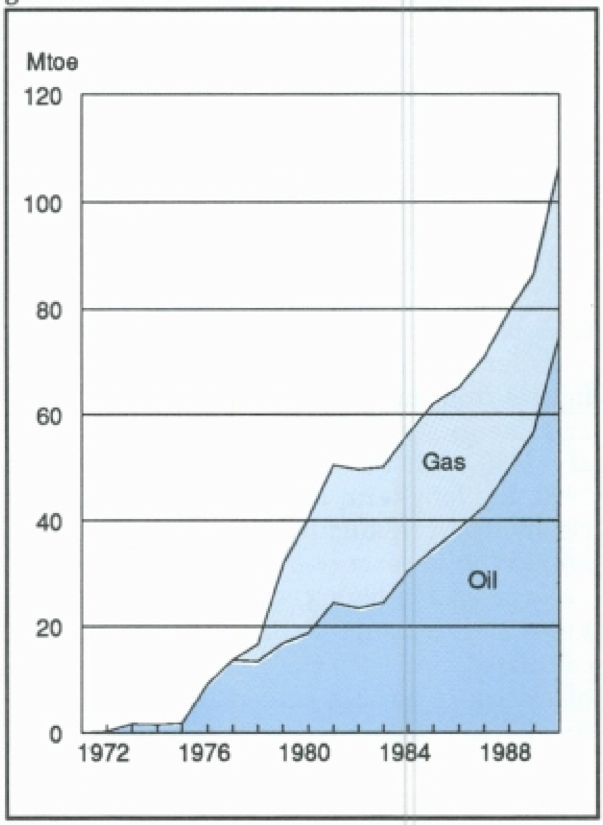
There was little increase in production of natural gas in 1990. The development was marked by the exhaustion of the reserves on the Frigg field. This production was compensated partly by new satellites in the area, by production from small fields and by associated gas production from the large oil fields. This implies less export to Great Britain and more to the continent. Production of gas from associated fields is adjusted to the goal of optimal oil production. No increase in gas production is expected until the Sleipner field reaches operational maturity in the middle of this decade.

The limit on production capacity was reduced to 5 per cent at the start of 1990 and removed completely on 1 July. During the first half of 1990 production was fixed at 1.7 million barrels of crude oil per day, excluding NGL and condensate. Partly due to lack of reservoir capacity on the Gullfaks field, the average annual production did not reach more than 1.6 million barrels per day. In December, production reached 1.8 million barrels per day. A further increase in Norwegian oil production is expected in 1991.

Figure 2.4 shows oil and gas production on the largest fields in 1990.

Production from the Statfjord field has passed its peak, but this field still accounts for the greatest share of Norwegian oil production, almost 35 per cent of total production. After a relatively low level of production in the period July to September, due to industrial action and maintenance stop, production increased again in the fourth quarter. In December this field produced an average of 610 000 barrels per day. The annual average was 560 000 barrels per day.

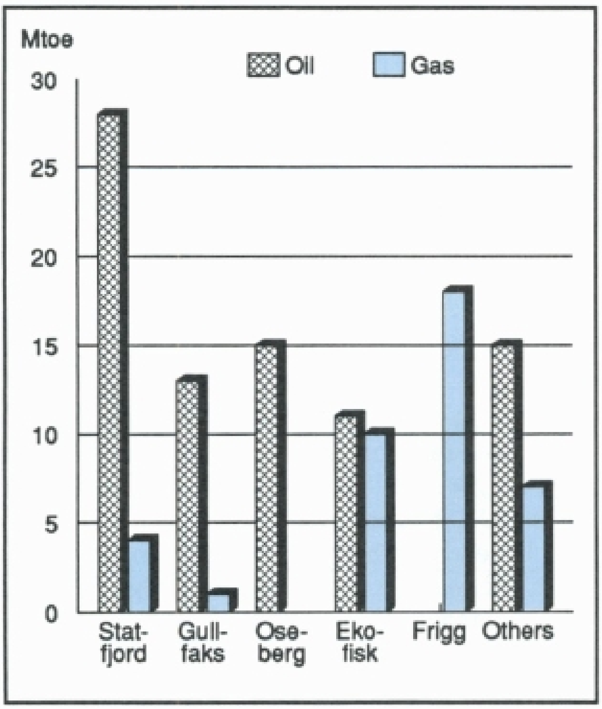
Figure 2.3. Oil and gas production on the Norwegian continental shelf. 1971 - 1990. Mtoe



In 1990 the Oseberg field accounted for 18 per cent of Norwegian oil production, with an average increase in production of 27 per cent despite low production in the summer months, including a stop in production in June in order to keep within the allocated production quota. The average daily production in 1990 was 290 000 barrels per day. By comparison, the estimated capacity of the field in phase 1 was 240 000 barrels per day. The Oseberg C platform will be placed on site during the first half of 1991. Troll-Oseberg gas injection, with the intention of increasing the degree of exploitation on the Oseberg field, will also start to function sometime in 1991.

On the Gullfaks field there was a 4 per cent drop in production from 1989 to 1990. Production was particularly low in July and August, but picked up again later. The Gullfaks C platform was taken into operation at the beginning of the year, but there have been serious reservoir problems. These problems were the reason for the decrease in production on this field. In 1990 the Gullfaks field accounted for just over 16 per cent of Norwegian oil production. The field produced an average of 250 000 barrels per day over the year, and 300 000 barrels per day at the end of the year.

Figure 2.4. Oil and gas production from the largest fields in 1990. Mtoe



On the Ekofisk field, the increase in production as a result of water injection ceased towards the end of 1989. In 1990, production on this field was about the same as in 1989 but 40 per cent higher than in 1987, which was the year with the poorest result prior to starting water injection.

Oil investments in 1990

In the investments survey undertaken by CBS in the 4th quarter of 1990 accrued investment costs for extraction of crude oil and natural gas are estimated to NOK 29.4 billion in 1990, see table 2.1. According to the most recent estimate the accrued investment costs in the extraction sector decreased by 6.7 per cent from 1989 to 1990.

Measured in volume (1988-prices) the accrued investment costs decreased from NOK 32.1 to NOK 25.4 billion from 1989 to 1990, and amounted to 208 per cent of investments in industry and mining in 1989 and 175 per cent in 1990. Oil investments accounted for more than 20 per cent of Norway's total real investments in 1990.

In the most recent survey, accrued investment costs in *field development* were estimated to be NOK 19.6 billion in 1990, giving a decrease in value of 13.7 per cent in relation to 1989. The reason for the decrease is that a number of large fields which weighed heavily for field development reached operational maturity at the end of 1989. Simultaneously with the reduction in investment costs for field development there has been a shift in the composition of the costs towards a large share of commodities and a smaller share of services. This is because, in 1989, several fields were in the final phase of development, where a large share of the costs refers to payment for services. The fields which weighed heaviest for field development in 1990 were Snorre, Sleipner and Draugen. These had entered or entered the construction phase in the course of 1990, and during this phase a large share of the costs refers to goods. According to quarterly figures from the investments survey, the share referring to goods increased during the first three quarters of 1990, at the expense of investments in services.

According to the most recent investments survey, the accrued investment costs for *fields in operation* are estimated to NOK 3.9 billion in 1990, representing a growth of 22 per cent. Since the investment survey in the third quarter some of these costs have been delayed to 1991. The largest share of investment costs for fields in operation refers to costs for production drilling.

Accrued *exploration* costs are estimated to NOK 5 billion in 1990. Exploration costs have remained at this level since the fall in oil prices in 1986. Various short-term indicators show a very high level of exploration activity towards the end of 1990. The number of preliminary appraised wells increased from 28 in 1989 to 36 in 1990. The number of drilled metres increased by 50 per cent and the number of drilling vessel days by 28 per cent during the same period.

Table 2.1. Executed and assumed accrued investment costs in oil extraction and pipeline transport. NOK billion, current prices

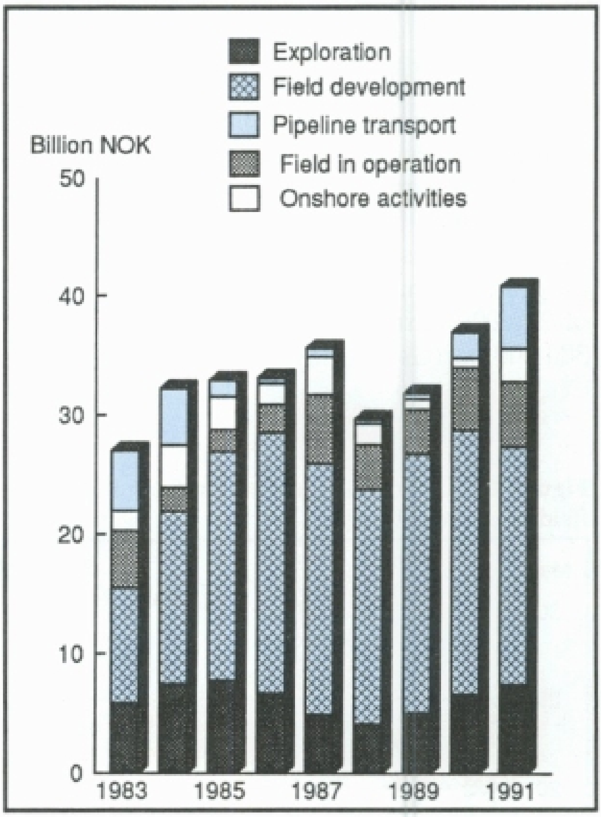
	1989	1990[1)]	1991[1)]
Oil sector as a whole . .	32.0	32.7	40.9
Extraction of oil and gas	31.5	29.4	35.7
Exploration	5.0	5.0	7.5
Field development . .	22.7	19.6	19.9
Goods	9.7	12.4	13.8
Services	11.8	6.2	5.3
Production drilling	1.1	1.1	0.9
Fields in operation . .	3.2	3.9	5.4
Goods	0.3	0.6	0.5
Services	0.5	0.7	0.9
Production drilling	2.4	2.6	4.0
Onshore activity[2)] . .	0.6	0.8	2.8
Pipeline transport . . .	0.5	3.3	5.2

1) Estimated from data from CBS's investments survey collected 4th quarter 1990.
2) Includes office buildings, bases and terminal buildings on land.

There has been a strong increase in investments in *pipeline transport*, from NOK 0.5 billion in 1989 to NOK 3.3 billion in 1990. The high level of activity in 1990 is due to advancement of work on the Zeepipe pipeline, connecting Sleipner to Zeebrügge.

Figure 2.5 shows trends in investment costs during the period 1983-1990.

Figure 2.5. Accrued investment costs in the petroleum sector. 1983 - 1990. NOK billion



Petroleum revenues - the oil rent

There was a marked increase in the value of extracted oil and gas for the second year running, see table 2.2. Value added was about NOK 90.2 billion in 1990. In current kroner this is nearly as high as the peak level in 1985. Both increased production and higher prices have added to the growth.

The excess return from oil and gas production compared with other production is often called the oil rent. This can be calculated as the part of the share of the total income from production of oil and gas achieved after subtracting production costs and a normal return on invested capital. This method of calculation ignores the fact that several of the input factors used in the extraction of oil and gas receive a higher return than in other industry. Therefore, to some degree, it can be said that they receive part of the oil rent.

Table 2.2. Petroleum income and oil rent. 1977-1990

Year	Value added in petro-leum ex-traction	Oil rent	Oil rent as a share of gross domestic product
	NOK billion		Per cent
1977	7.4	2.8	1.5
1978	12.8	7.0	3.3
1979	20.8	13.7	5.7
1980	41.1	31.8	11.2
1981	50.1	36.5	11.1
1982	55.7	37.8	10.4
1983	67.3	48.0	11.9
1984	83.8	59.7	13.2
1985	90.7	63.4	12.6
1986	50.0	17.8	3.5
1987	51.8	13.9	2.5
1988	45.1	2.1	0.4
1989	70.8	21.9	3.5
1990*	90.2	38.2	5.7

Theoretically, the oil rent can be traced back to several causes. A distinction is often made between the classic rent, which arises because the marginal unit of production is more expensive than the average, and the Hotellings rent (or scarcity rent), which occurs because the reserves are limited. Both these can occur in prefect competitive markets. The third cause, the so-called monopoly rent, is a result of imperfect competition. CBS's estimated oil rent does not distinguish between these causes. Nor is it a perfect measure of the total rent, since no attempt is made to calculate alternative prices for the input factors.

Assuming a normal return on capital of 7 per cent, preliminary calculations show that the oil rent amounted to more than NOK 38 billion in 1990. This is almost twice as much as in 1989, but nevertheless clearly lower than in 1985. In 1990 the oil rent was equivalent to 5.7 per cent of the gross domestic product, as against 12.6 per cent in 1985, and the per capita income from the oil rent was thus about NOK 9 000 in 1990. The average return on capital was 24.7, as against 17.3 per cent in 1989. Return on capital reached a peak of 80.2 per cent in 1980, and a low in 1988 of 8.1 per cent. The measures of return, oil rent and return on capital, have not improved to the same degree as the gross product because the capital to be serviced by the total operating surplus becomes steadily bigger as more fields are developed.

Estimated petroleum wealth

"Natural Resources and the Environment, 1989" presented an estimate of the petroleum wealth, defined as the expected value of oil and gas reserves at the start of the year. The calculations have been updated for recent years by the Ministry of Petroleum and Energy, based on assumptions defined by the Ministry of Finance. Table 2.3 shows the estimated petroleum wealth for the years 1988-1991. Changes in the petroleum wealth depend on the value of the extraction, return on capital, and expectations concerning future oil reserves and future oil and gas prices. The "value of the extraction" can be defined has the net flow of cash to society as a result of petroleum activities. The estimates of the wealth assume a discount rent of 7 per cent. A lower discount rent would give a higher figure for the wealth.

Table 2.3. Estimated petroleum wealth. 1988-1991. NOK billion

	Wealth	Expected return on capital	Value of extrac-tion	Re-evalu-ation
1988 ..	413	29	15	155
1989 ..	582	41	38	465
1990 ..	1 050	74	55	-157
1991* ..	912	64	.	.

* Based on calculations per 1 July 1990.

The estimates of the wealth are strongly dependent on assumptions about prices. Changes in assumptions about future prices will be expressed when the reserves are revalued.

The expected return on the petroleum wealth is now much greater than in the years following the fall in prices in 1986. The main reason is a substantial upward adjustment of the price curves. The value of the extraction is still lower than the expected return on the petroleum wealth.

Energy production 1930 - 1990

Table 2.4. Extraction of energy sources in Norway. 1930 - 1990. 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* .	4 900	427	3 171	1 292	10
1990* .	5 037	436	3 463	1 129	9

Table 2.4 shows changes in the 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 the production of energy sources in Norway. After production of crude oil and natural gas started in the mid-1970s, these energy sources have taken over a steadily increasing share of the total energy production. Coal production in Svalbard remained at about the same level from 1950 to 1987, since when it has decreased slightly. There has been a particularly large increase in extraction of crude oil. Production of crude oil increased more than threefold during the ten-year period from 1980 to 1990. There has been a slight increase in extraction of natural gas from 1980 to 1990. Hydropower production was about 45 per cent higher in 1990 than in 1980. 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 4 900 PJ in 1989. The primary supply, that is to say, the gross supply of energy for use in Norway, is 1 073 PJ. This comprises 21.9 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 1990 the production of electricity in Norway amounted to 121.6 TWh, an increase of 2.4 TWh in relation to 1989. In 1990, gross domestic consumption of firm power and surplus power was about 105.6 TWh, of which about 10.3 was lost in the transmission and distribution networks and used in pumping stations. About 30.3 TWh was used in energy-intensive industry, 59.3 TWh in regular consumption and 5.7 TWh was used as surplus power to electric boilers. About 16.3 TWh was exported and about 0.3 TWh was imported. Thus, in relation to a production of 121.6 TWh, there was a large domestic surplus of electricity in 1990, as in 1989.

In 1990, the Norwegian hydropower system had an average annual production capacity of about 107.5 TWh. This means that with the installed capacity in 1990, and given normal precipitation and flow of water, production would have been 14 TWh lower than was actually achieved in that year. The temperature-adjusted net domestic consumption for regular consumption was about 62.5 TWh, i.e. 3.5 TWh higher than the actual consumption. Therefore, with almost full exploitation of capacity in energy-intensive industry and normal loss of electricity, 4.5 TWh would have been available for sale as surplus power or for net export in a normal year. If the temperature-adjusted firm power consumption is compared with the firm power production capacity (104.5 TWh) in the Norwegian electricity market in 1990, there is a reasonable balance between supply and demand at existing prices. The surplus of about 1.5 TWh covers one to two years' gross increase in consumption, given the same rate of increase as in recent years. The main reason for the huge domestic excess of electricity in both 1989 and 1990 is extremely good flow of water to the reservoirs. A second reason is mild winters.

Table 2.5. Observed production and consumption of electricity and estimated firm power production and demand given normal flow of water and normal temperature. 1989 and 1990. TWh

	1989 observed	1989 "normal year"	1990 observed	1990 "normal year"
Overflow ..	6.0	-	7.5	-
Production .	119.2	107.0	121.6	107.5
Export	15.5	-	16.3	-
Import	0.3	-	0.3	-
Domestic consumption ..	104.3	107.0	105.6	107.5
Loss+power to pumping stations ...	10.8	10.7	10.3	10.6
Surplus power	5.0	4.8	5.7	4.4
Energy int. industry ...	30.3	30.0	30.3	30.0
Regular consumption...	58.2	61.5	59.3	62.5

A large share of the electricity produced in Norway is sold through fixed contracts, partly long-term contracts with energy-intensive industry and partly medium-term contracts to regular consumption. Sale of surplus power, that is to say, electricity in excess of firm power, occurs on an electricity spot market. On this market the price of electricity is decided from hour to hour depending on supply and demand. However, only a small percentage of Norwegian consumers have access to this market. The greater part of the surplus power is offered to customers with large electric boilers, usually in the pulp and paper industry and some sectors of energy-intensive industry. The restrictions on the access to demand and purchase of surplus power in Norway are the main reason why large quantities of the surplus electricity were exported at very low prices in 1989 and 1990.

Table 2.6. Average electricity prices in different user groups. Electricity tax incl. Øre/kWh

	1989	1990
Export	5.0	6.0
Import	5.2	6.0
Domestic consumption		
(excl. loss)	24.6	27.9
Surplus power	6.0	6.0
Energy int. industry	11.3	11.7
Regular consumption	36.8	38.3

Estimates of average prices for different consumers of electricity in Norway and abroad show that, both in 1989 and 1990, energy-intensive industry paid a higher price for electricity than Norway obtained on the export market. According to NVE, the marginal cost of delivering electricity to regular consumption is about 50 per cent higher than the cost of delivering to energy-intensive industry. However, on average, the price for regular consumers is three times higher than for energy-intensive industry, see table 2.6. The large differences in prices for the different kinds of deliveries are due to the stringent regulations of both price and quantity in the different sectors of the Norwegian electricity market. More effective use of the electricity requires more flexible prices and a change towards equal electricity prices for all consumers (adjusted for differences in delivery costs).

The water that passed outside the production system in 1989 and 1990 could have been used at low cost. Given reductions in prices, this water could have been used to increase domestic consumption of electricity. However, in the short term, it is unlikely that the Norwegian market could have absorbed much more than the 7.5 TWh that passed outside the power stations in 1990.

At the turn of the year 1990/91 the reservoirs were filled to about 77 per cent capacity. The normal is 67 per cent. This implies that there will very probably be surplus electricity in 1991 too. In spite of this, it has been decided in the State Budget for 1991 to increase the price of electricity from state-owned power stations by 4 per cent. Certain county-owned power stations, however, have promised their customers substantially lower prices in 1991, in an attempt to use more of the electricity. This may mean that Statkraft (the company responsible for selling electricity from state-owned plants) will have difficulty in selling some of its electricity.

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, oil refineries, thermal power stations and district heating plants. So far, Energy Accounts have been prepared for the years 1976 to 1989. Table 2.16 shows the preliminary accounts for 1989, see section 2.8. appendix of tables.

In 1989 the energy used outside the energy sectors was 968 PJ, see table 2.7. This is an increase of 7.1 per cent from 1988 to 1989. The increase occurred mainly in ocean transportation (foreign trading), where there has been a strong increase in the fleet registered in NIS (The Norwegian International Ships Register). Domestic use of energy decreased by 3.5 per cent from 1988 to 1989, falling to the same level as in the mid-1980s. Use of energy in energy-intensive industry decreased by 4.3 per cent from 1988 to 1989. In other manufacturing the decrease was 2.7 per cent. Private households used 3.4 per cent less energy in 1989 than in the year before. The total use of energy in other commercial sectors decreased by 3.5 per cent during the same period.

Table 2.7. Use of energy[1] outside the energy sectors by industry. 1989*. Changes 1976 - 1989[2]

Industry	1989 PJ	Average annual percentage change 1976-88	Average annual percentage change 1988-89
Total	968	-0.3	7.1
Ocean transportation	233	-6.5	62.9
Domestic use	734	1.8	-3.5
Agriculture and fisheries	32	0.5	-
Energy intensive industry	199	2.1	-4.3
Other manufacturing and mining	109	-0.8	-2.7
Other industries . . .	195	2.6	-3.5
Private households	200	2.6	-3.4

1) Includes use of energy sources as raw materials.
2) From 1987 district heating is included in the figures.

Preliminary figures indicate an average decline of 1.2 per cent in energy consumption outside the energy sectors and excluding ocean transportation over the last two years, see table 2.8. Recent years have been very warm, and this explains the lower consumption of energy for heating. The average annual decrease in the use of firm power in regular consumption was 0.7 per cent from 1988 to 1990.

In 1989, consumption of petroleum products in sectors other than the energy sectors and ocean transportation was 547 PJ. This accounts for 56.5 per cent of the total energy consumption in these sectors. Domestic consumption of petroleum products decreased by 5.1 per cent from 1988 to 1989. This decrease can be put down to stationary use of oil, and use of liquified gas. There has been a slight decrease since 1987 in the amount of oil used for transportation, see table 2.18 in the appendix of tables, section 2.8.

Table 2.8. Use of energy outside the energy sectors and ocean transportation (foreign trading), by source of energy. 1990*. Changes 1976-1990

Energy source	1990	Average annual percentage change	
	PJ	1976-88	1988-90
Total	743	1.8	-1.2
Electricity	343	2.9	0.6
Firm power	323	2.8	-
Regular consumption	213	3.9	-0.7
Energy intensive industries	109	1.0	0.9
Surplus power	21	4.9	14.6
Oil total	311	0.5	-3.1
Oil other than transportation	61	-6.0	-11.0
Oil for transportation	198	2.7	-1.0
Liquefied gas.	52	39.0	-
District heating	3	.	-
Solid fuels	86	2.6	-1.1
Coal, coke	52	1.0	-0.9
Fuelwood, paper waste, other solid waste	34	5.4	-

Consumption of electricity and of solid fuels decreased by just over 2 per cent from 1988 to 1989. Electricity accounts for 34.3 per cent and solid fuels for 8.9 per cent of the total consumption of energy outside the energy sectors.

Gross domestic consumption of electricity was 105.6 TWh in 1990. Power to pumping stations accounts for 6 TWh of this amount, and 10 TWh was lost in the transmission and distribution network. Net firm power consumption was distributed as follows: 30 TWh to energy-intensive industry and 59 TWh for other purposes, see table 2.9. About 16.3 TWh was exported: 12.3 TWh to Sweden, 4.0 TWh to Denmark and 0.1 TWh to Finland. Just under 0.3 TWh was imported, mainly from Sweden.

In 1990 the value of the exported electricity was almost NOK 1 billion. The value of the imported electricity was NOK 40 million.

Table 2.9. The electricity balance[1] 1990. Changes 1975-1990

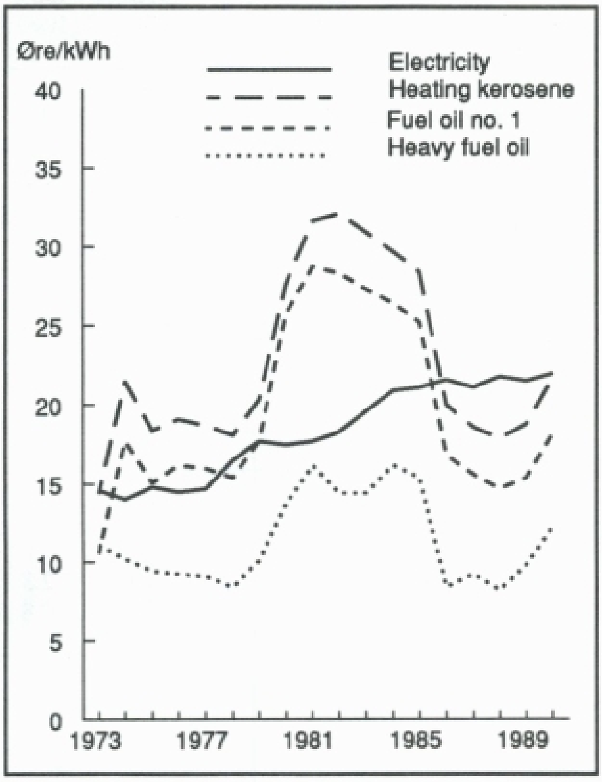
	1990	Average annual percentage change	
	TWh	1975-1989	1989-1990
Production	121.6	3.1	2.0
+ Import	0.3	8.2	-
- Export	16.3	7.3	7.2
= Gross dom. prod.	105.6	2.7	1.2
- Consumption in pumping plants	0.3	10.4	-25.0
- Surplus power	5.7	3.9	3.6
- Losses in exports and surplus power	1.5	4.1	7.1
= Gross firm power consumption	98.2	2.6	1.3
Energy int. ind.	31.2	0.9	2.3
Regular cons.[2]	67.0	3.6	0.8
- Losses in the transmission lines, cons. in the power stations, stat. diff.	8.6	2.4	-2.3
= Net firm power consumption	89.6	2.6	1.7
Energy int. ind.	30.3	0.9	2.4
Regular cons.[2]	59.3	3.7	1.2
Regular cons., temperature adjusted[2]	63.1	3.9	2.1

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.

Energy prices

Figure 2.6 shows the prices of electricity and petroleum products per energy unit (converted to utilized energy), measured in terms of constant 1980-prices. Figure 2.7 shows trends in the price of fuel oils.

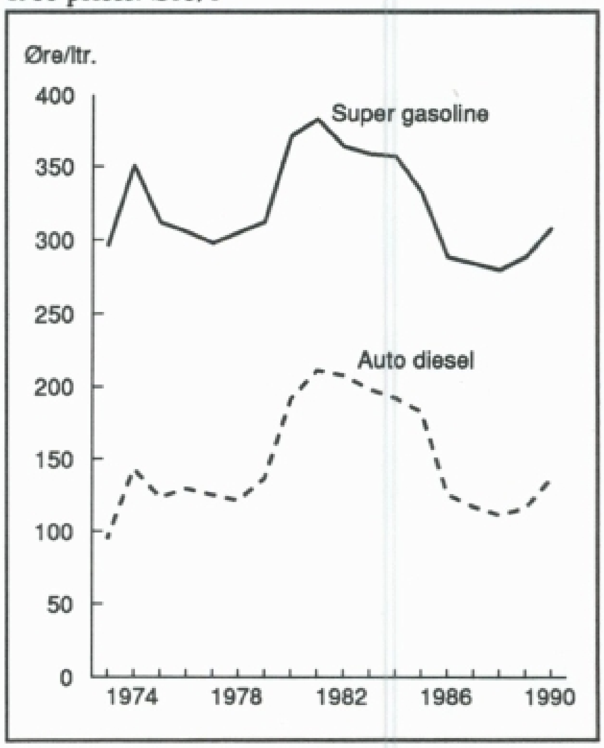
Figure 2.6. Estimated prices of utilized energy. 1973-1990. Constant 1980-prices. Øre/kWh. All taxes included



The average price of electricity rose by just under 7 per cent from 1989 to 1990, or 2.5 per cent in real terms, in spite of a substantial surplus of electricity on the Norwegian market. The average price to private households was 41.4 øre/kWh, although 16.3 TWh was exported at an average price of 6 øre/kWh. In the State Budget for 1991 it was decided to raise the price of electricity by 4 per cent, in spite of the introduction of a new Energy Act which assumes more market-based sales of electricity.

There was a substantial increase in the price of petroleum products throughout 1990. The price of heating kerosene increased by almost 20 per cent, of fuel oils by 23-24 per cent and of heavy oils by as much as 30 per cent. This means that, if the environmental taxes imposed in the State Budget are added, the price of heating kerosene has almost reached the price of electricity, calculated in terms of utilized energy.

Figure 2.7. Prices of fuel oils. 1973-1990. Constant 1980-prices. Øre/l



The price of electricity to private households and agriculture increased by 160 per cent from 1980 to 1990, or 35 per cent in real terms. At the same time, the nominal increase in price was less than 50 per cent for fuel oil 1, and 85 per cent for heavy oil. This means that during the 1980s the real decrease in price was about 5 per cent for heavy oil and about 25 per cent for fuel oil 1.

The price of unleaded gasoline rose by 10.5 per cent from 1989 to 1990, or somewhat over 6 per cent in real terms. The price of the highest grade of leaded gasoline rose by just over 11 per cent. In the State Budget for 1991 it was decided to increase the tax on leaded gasoline by 10 øre more than for unleaded gasoline. The difference in price between these two types of gasoline will then be 55 øre per litre.

The nominal price of high octane gasoline increased by 73 per cent from 1980 to 1990, that is to say, it has decreased by about 10 per cent in real terms. The price of auto diesel has increased by 43 per cent, which means a fall in price of almost 25 per cent in real terms.

2.2. The world market

The oil market

The relatively high level of production of crude oil in 1989 continued in 1990. OPEC's production increased through the first quarter and, by 1 April, had reached 23.8 million barrels per day. Production was maintained close to this level until August.

At the start of 1990 the spot price of Brent Blend was about USD 22.5 per barrel, see figure 2.8. A lower rate of increase in the demand for oil products led to a marked drop in prices during the first half of 1990, and at the beginning of the third quarter the spot price of Brent Blend had fallen to less than USD 15 per barrel. This is more than 3 USD lower than the average price in 1989.

At the OPEC meeting in Geneva in July the member countries agreed to reduce production in order to secure a price of USD 21 per barrel. The Gulf conflict started shortly after the meeting. This led to a large increase in the spot price of crude oil. Towards the end of November, North Sea oil was quoted at USD 40 per barrel, the highest price since the first quarter of 1981. There were large fluctuations in the price of crude oil from October to the end of the year. At the turn of the year 1990-/91 the price of Brent Blend was about USD 27 per barrel.

Figure 2.8. Spot price of Brent Blend. USD per barrel

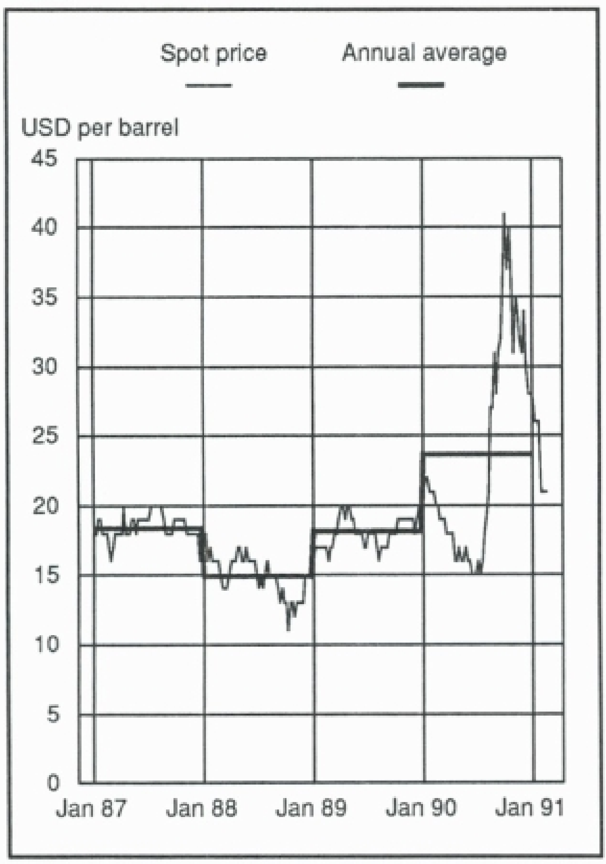
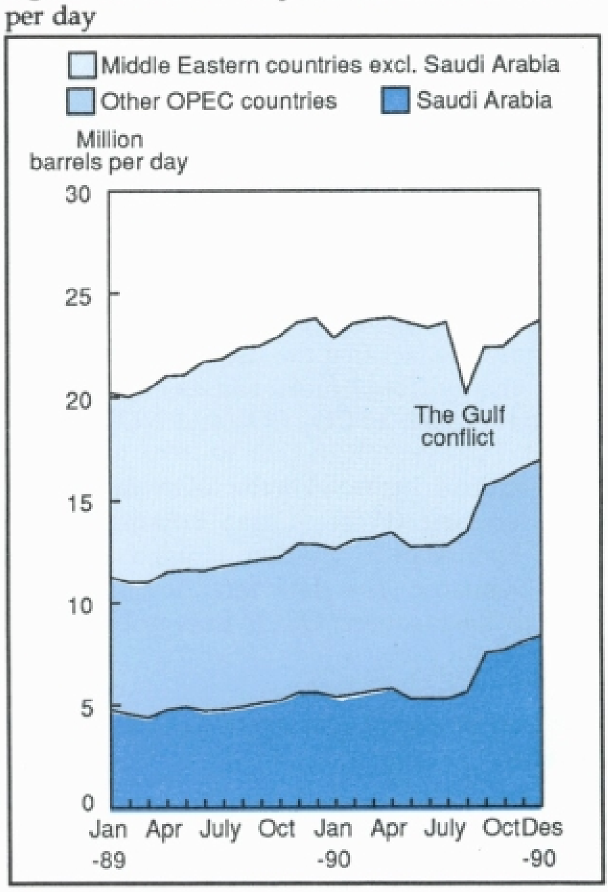


Figure 2.9. OPEC's oil production. Million barrels per day



The embargo on oil from Iraq and Kuwait meant that the supply of oil on the world market was reduced by an average of about 4.5 million barrels per day. The loss of the oil from Iraq and Kuwait was quickly compensated and, in October, the total production from OPEC countries was only one million barrels per day lower than in July. The greatest increases were in Saudi Arabia, Abu Dahbi and Venezuela. In Saudi Arabia production increased by more than 40 per cent in two months. There was a rise in production in other countries too, and at the turn of the year, production from OPEC countries reached the same level as before the embargo on Iraq. Outside OPEC, there was an increase in the supply of oil from the North Sea, USA and Mexico. Other producers than the CPE countries (Centrally Planned Economies) have experienced a net increase in production of just over 1.3 million barrels per day, while the net export from CPE countries has fallen slightly. At the end of 1990 the loss of the oil produced by Iraq and Kuwait was more than compensated by increased production in other countries.

The trend in energy consumption in Europe

Introduction

The trend in energy consumption in Europe has been followed with great interest. The reasons for this interest are firstly the importance of energy for economic growth, and secondly the fact that the use of certain sources of energy (fossil fuels) causes emissions of pollutants such as CO_2, SO_2, and NO_x.

The countries included in the following review are Germany (West), Great Britain, France, Italy, Netherlands, Sweden, Finland, Norway and Denmark. The data refer to the period 1978 to 1988 (source: OECD Energy Balances).

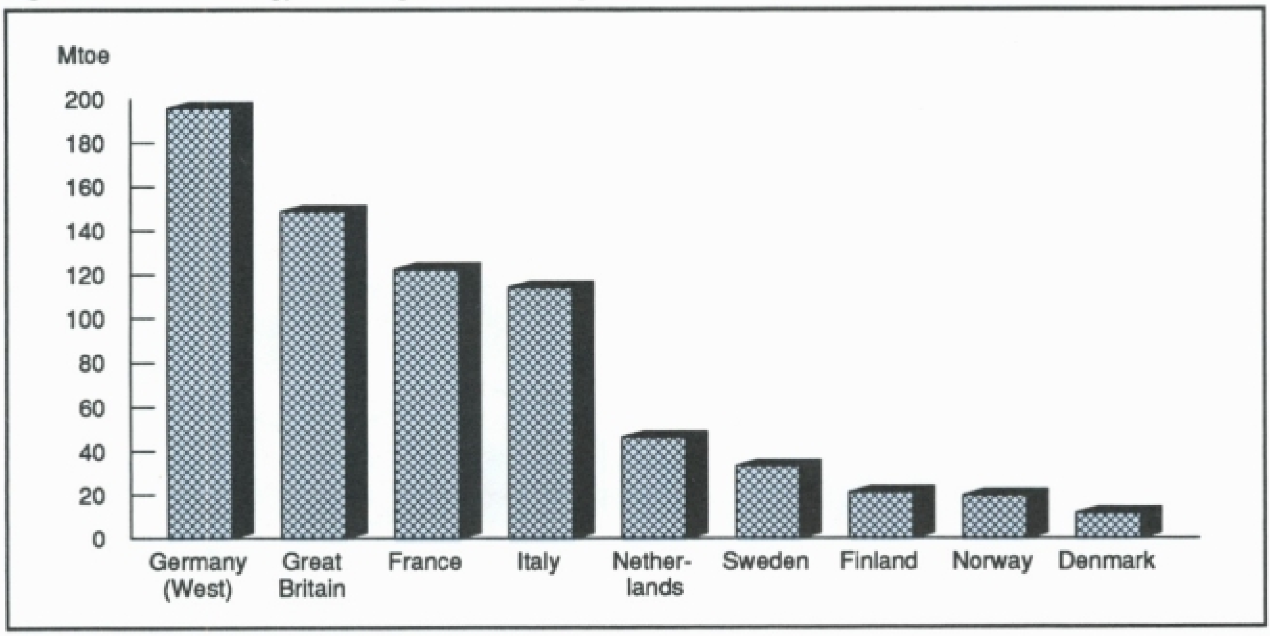
The level of energy consumption in the different countries

Figure 2.10 shows that Germany (West) has the highest consumption of all nine countries, measured in mtoe (million tonnes oil equivalents). Next come Great Britain, France and Italy. Norway and Finland each use about half as much energy as Sweden, while energy consumption is lowest in Denmark, amounting to about half the consumption in Finland and Norway.

The observed differences in the level of total energy consumption are caused mainly by differences in the level of economic activity and population. Germany (West) is the country in the sample with the highest gross domestic product (GDP) and the largest population. Other reasons may be differences in temperature and different industrial structures, which give different energy intensities (energy consumption per produced or consumed unit), see figure 2.11. In this connection it is interesting to study the difference between the total energy consumption in Norway and Denmark, which is far larger than indicated by the difference in GDP. One of the reasons for the large difference in energy consumption between these two countries is the larger amount of energy-intensive industry in Norway than in Denmark. In addition, goods etc. have to be transported over longer distances in Norway, and the average temperature is lower than in Denmark.

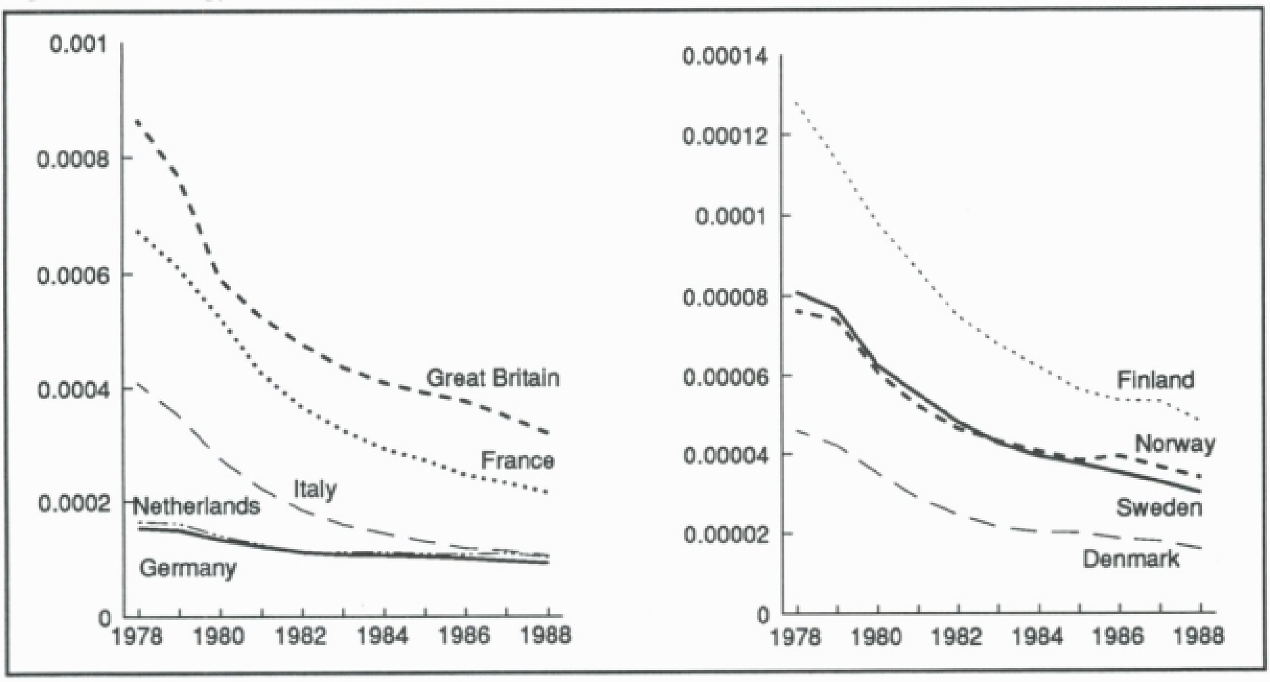
Figure 2.12 shows that oil is the dominating source of energy (measured in mtoe) in all countries except Netherlands and Norway. In Netherlands consumption of natural gas is higher than consumption of oil, while in Norway electricity consumption is the same as consumption of oil. Netherlands is a large producer of natural gas, and Norway has a large electricity production based on hydropower. It is also worth noting that natural gas is the second largest source of energy in Germany (West), Great Britain and Italy. In France, electricity consumption (largely based on nuclear power) is as high as consumption of natural gas.

Figure 2.10. Total energy consumption in 9 European countries. 1988. Mtoe



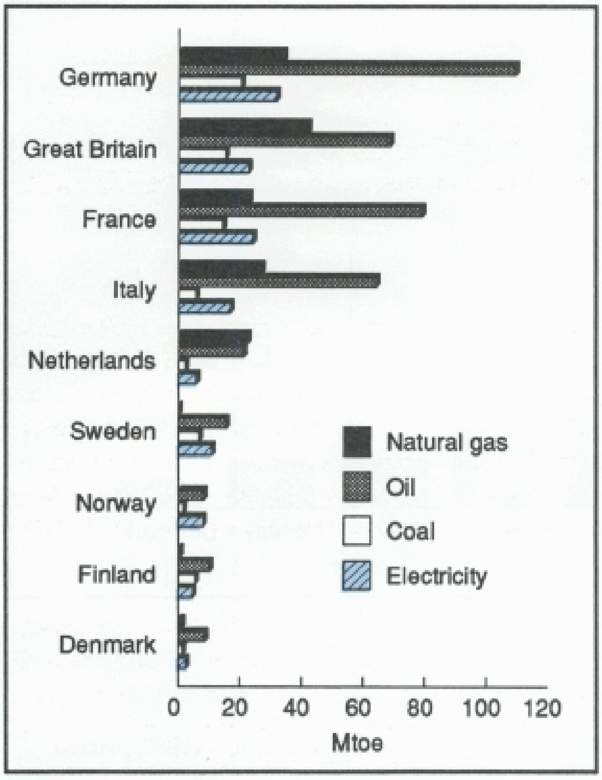
Source: OECD, 1990.

Figure 2.11. Energy intensities in 9 European countries. 1978-1988. Mtoe per NOK million (1980-prices)



Source: OECD, 1990.

Figure 2.12. Energy consumption distributed between energy sources in 9 European countries. 1988. Mtoe



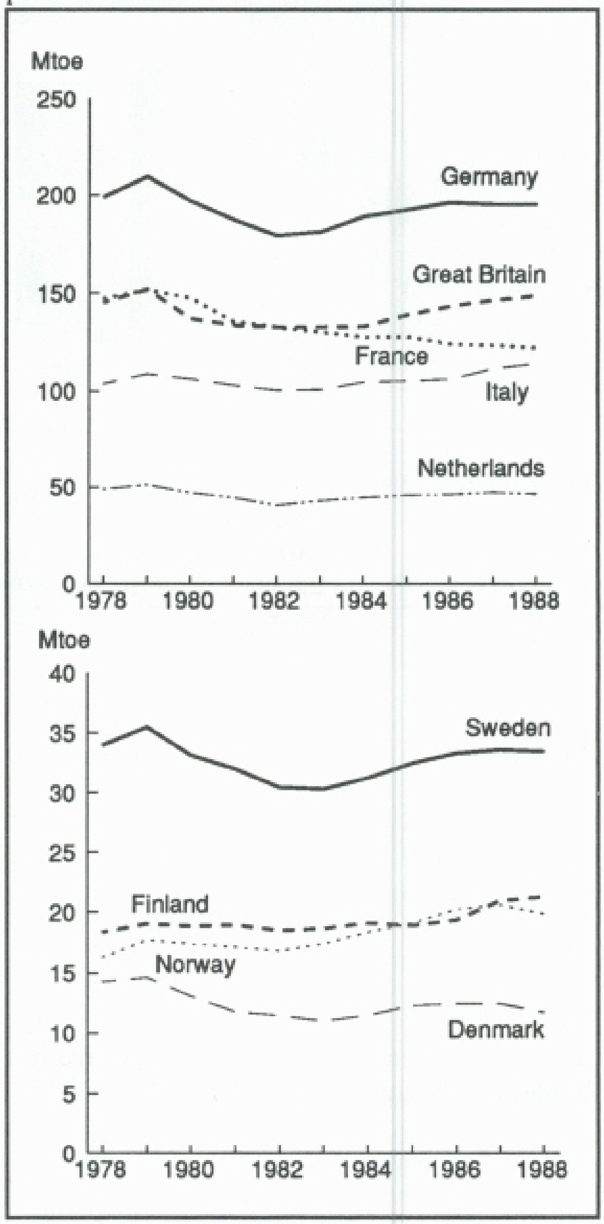
Source: OECD, 1990.

The trend in energy consumption (1978- 1988)

In most countries a decline in energy consumption during the period 1979/80 to 1982 was followed by a slight increase (figure 2.13). This increase was somewhat more obvious in 1986, after which it levelled out. Most countries experienced a slight decline in total energy consumption from 1987 to 1988. This trend is connected partly to changes in the price of oil. 1979/80 saw the second large rise in oil prices (OPEC II). This was followed by a real decrease in prices up to the large price drop in spring 1986. Energy consumption in France and Finland followed other courses than described above. In France the trend was a steady decline in energy consumption from 1979 up to 1988. In Finland the trend was a slight increase in energy consumption over the same period.

To the degree that an increase in energy consumption can be observed it was not as great as the increase in GDP during the same period. This can be put down to technological developments, changes in economic structure, or higher prices. Figure 2.11 shows the observed decreases in energy intensities.

Figure 2.13. Total energy consumption in 9 European countries. 1978 - 1988. Mtoe



Source: OECD, 1990.

Common to all countries is that the consumption of electricity relative to consumption of oil has changed in favour of electricity. This development is particularly noticeable in France, Sweden and Norway. Up to 1982 this can be explained by the fact that oil, relatively speaking, became more expensive than electricity. After this time, however, the relative prices developed in the opposite direction, but this did not prevent a further increase in electricity consumption in relation to oil consumption. Possible explanations are more use of electricity-specific appliances in private households and in production, more use of electricity for heating and a tendency towards lower costs for heating equipment based on electricity than for heating equipment based on oil, and expectations of high and increasing oil prices. Possible explanations of these conditions in Norway's case are discussed in sections 2.5 and 2.6.

Other typical features of the trend in the composition of the energy supply is a slight decline in consumption of coal, and a slight increase in consumption of natural gas. The decline in use of coal is particularly noticeable in Germany (West), Great Britain, France and Italy. In the last two countries and in Denmark there is a clear tendency towards increased use of natural gas.

2.3. Energy policy

The Energy Act

Up to 1 January 1991 the Norwegian energy market has been regulated through a set of Acts; the "Act concerning the Building and Operation of Electrical Installations" (1969) and the "Act relating to Acquisition of Waterfalls, Mines and other Real Property etc." (The Industrial Licences Act of 1917). As from 1 January 1991 these two Acts are replaced by the "Act concerning Production, Conversion, Transmission, Sale and Distribution of Energy etc." (The Energy Act).

In addition to meeting the need to collect all the Acts referring to the energy market in one Act, the purpose of the new Energy Act is to promote the development of more effective use of Norwegian hydropower resources. The need to do this is expressed, inter alia, by the large differences in the price paid for electricity by different consumers, and the lack of ability to use random surplus capacity. Experience from the last two years also shows that, in years with a very good flow of water, regulation of both price and quantity of electricity on the energy market through contracts for firm power leads to very inefficient use of energy resources.

One of the main purposes of the Energy Act is to provide the right conditions to ensure, as far as possible, free sale of energy between the different actors on the energy market. The intention is to level out the price of energy for the different users (giving due consideration to different delivery costs, different safety requirements for the deliveries, etc.) and to achieve a better adjustment of capacity and a better balance between choice of energy sources and investments in energy conservation.

The long-term contracts with energy-intensive industry are excluded from the deregulation authorized by the Energy Act. Since the prices of these contracts are very low in relation to the prices on the rest of the energy market, the beneficial effect of a more liberal sale of electricity is limited. However, a better functioning market will make it possible to estimate the alternative value of the energy used in this industry.

The Act indicates that the future organization of the electricity supply must be based on a clear distinction between the parts that can be organized through a market, and the functions that are by nature monopolies. The intention is to stimulate competition between production enterprises, while distribution and transmission networks are natural monopolies which must be regulated. To achieve efficiency it must be possible for purchasers of large quantities of electricity to participate in an energy market through direct contact with the producers. The Act does not define precisely what is meant by "purchasers of large quantities". The purchasers, or subscribers, will no longer be tied to deliveries from the distribution company responsible for delivering electricity in their particular area.

Today, many of the power companies are vertically integrated, implying that the production units and transmission/distribution units are organized as a single profit-making unit. According to the Energy Act, this means that monopoly and competitive functions are included in the same unit, which is considered very inexpedient. The intention of the Act is to split these functions up into independent profit-making units. The electricity should be paid for among the units at market prices, which would bring to light its alternative value and therefore also any cross-subsidizing. Vertical integration is widespread in Norway, and a very important matter in the implementation of the Act will be to investigate and check these power companies. It is not the intention to coerce vertically integrated companies to split up into separate units.

Up to now, sales/purchases of electricity to/from the export/import market have not been permitted, except in the case of electricity on the exchange market (surplus power). The Energy Act provides for a change in this situation. Statkraft controls about 30 per cent of electricity production and sales of electricity in Norway, and has a monopoly on the export/import market. The Storting is to discuss the organization of Statkraft in spring 1991, and it is assumed that the future organization will comply with the intentions of the Energy Act. An essential point is whether there will then be access to export electricity also through permanent contracts. Closer approximation to the EEC may also lead to extended exchange of electricity across national borders.

The Petroleum Fund

The Petroleum Fund was established on 1 January 1991. The purpose of the fund is to improve the long-term management of the petroleum wealth, and possibly to function as a "buffer" to reduce the undesired effects on the economy of unexpected fluctuations in oil prices.

Incomes to the fund consist of the net cash flow to the State from petroleum activities, defined as revenues from the petroleum activities (taxes on petroleum and dividends) minus the costs to the State in connection with petroleum activity, including accrued investments.

Payments from the fund take place in two stages. The first step is withdrawal of the sum required to bring the State Budget excluding loan transactions into balance, as well as half the funds needed to finance the loan transactions.

As a second step, funds *can* be withdrawn for other purposes. However, these withdrawals must be approved by the Storting, and the purpose of the withdrawal must conform with the guidelines laid down in the Government's Long-Term Programme. Any balance shall be invested in the same way as other State-owned, financial assets.

The arrangement that has been established does not establish a clear connection between the money placed in the fund and the actual value of the oil and gas reserves, the petroleum wealth. This wealth can be defined as the present value of the expected return from petroleum activities in the future. This return includes the whole of the oil rent, while the money "passing through" the Petroleum Fund refers to revenues to the State only. Thus, the size of the Petroleum Fund at any time will also depend on the deficit in the State Budget before calculating in the net flow of cash to the State from the petroleum activities. This means that the Fund is mainly an accounting routine.

Therefore, in periods with large State investments in petroleum activities the income to the fund will be low. Since the fund has been established after the largest investments have been made, the income to the fund may exceed the oil rent, which is a more suitable measure of the income which can be directly traced to the existence of the oil and gas resources (see section 2.1).

2.4. Analysis: Resources allocation and costs in the hydropower sector

The hydropower sector includes units which produce, transmit and distribute electricity to different purchasers. When analyzing costs and use of input factors in the electricity supply system it is interesting to study the development within the different parts of the hydropower sector over time. A priori one would expect to find a more than proportional increase in production relative to use of input factors in the transmission and distribution sectors, but a less than proportional increase in production relative to use of input factors (decreasing scale of return) in the production sector.

Based on the Electricity Statistics, the use of the different input factors can be distributed between production, transmission and distribution of electricity, cf. Johnsen (1990). The production sector comprises power companies producing electricity. The transmission sector delivers transmission services, i.e. the sector transports electricity from the producers to the distribution companies. The distribution companies distribute electricity to the various consumers.

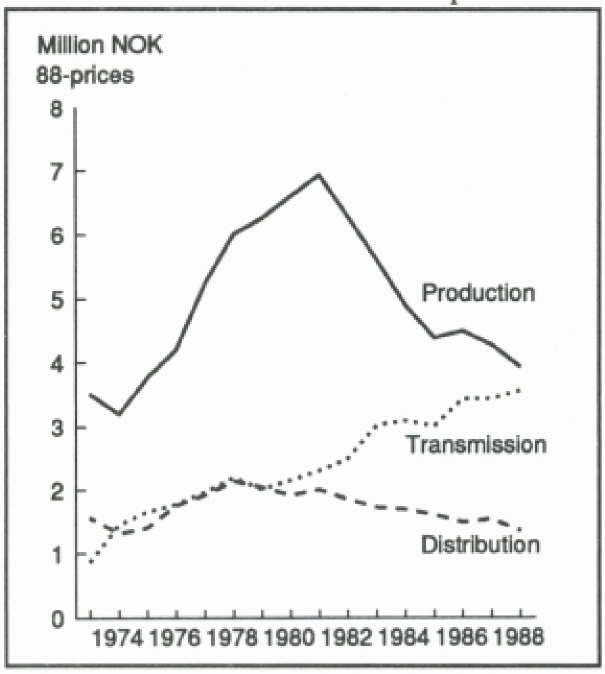
Investments and capital assets

Figure 2.14 shows investments in the hydropower sector in 1973-1988, distributed between the three sub-sectors.

Investments in the *production sector* amounted to around NOK 3.5-4 billion per year during the period 1973-1975. During the period 1976-81 investments increased rapidly, and in 1981 reached almost NOK 7 billion. This period saw several large individual projects, including new developments such as Skjomen, Eidfjord, Leirdøla and Ulla-Førre, which contributed to the high level of investments. Since 1981 investments in the production sector have declined, and in 1988 had returned to a level of somewhat less than NOK 4 billion per year.

Investments in the *transmission sector* have remained at a level of NOK 1.3-2.1 billion per year. There was a tendency for investments in transmission installations to increase during the period 1975 to 1978. This rise took place parallel with large investments in the production sector. Thus the large development of production facilities demanded greater capacity in the transmission sector.

Figure 2.14. Investments in the hydropower sector 1973-88. NOK million. Constant 1988-prices



Investments in the *distribution sector* increased throughout the period 1973-1988. The investments were more than 4 times as high in 1988 as in 1973. In 1988, investments in this sector consisted of more than 40 per cent in plants and more than 40 per cent in machinery. The remainder referred to buildings and vehicles. The strong increase in investments in the distribution sector can be explained by a large rise in electricity consumption by regular consumers. Generally speaking, most of the distribution services are used in regular consumption. Energy-intensive industry is often connected directly to the transmission network and receives electricity with a higher voltage than ordinary consumers. Use of electricity in regular consumption has almost doubled since

1973. Electricity production capacity increased by about 40 per cent during the same period, and a similar increase in capacity was experienced in the transmission sector. Another reason for the high investments in the distribution sector could be the rising real price of electricity, implying a higher return on investments in the cable network to reduce loss of electricity.

Accrued investments over the period 1967 to 1988 are divided between 57 per cent in the production sector, 19 per cent in the transmission sector and 24 per cent in the distribution sector. The National Accounts only contain figures for the hydropower sector as a whole. Calculated distribution factors can be used to distribute the different kinds of capital assets in the National Accounts between the three sub-sectors.

According to the National Accounts, total real capital assets in the hydropower sector amounted to NOK 187 billion in 1988. If this capital is distributed between the three subsectors using the distribution factors referred to above, it is found that total real capital assets were NOK 108 billion in the production sector, NOK 35 billion in the transmission sector and NOK 44 billion in the distribution sector.

Wages costs are highest in the distribution sector, amounting to NOK 2.7 billion (1988 prices) in 1988. These costs were NOK 1.1 billion in the production sector and NOK 0.5 in the transmission sector.

Costs of commodities are also highest in the distribution sector, amounting to NOK 2.6 billion in 1988. These costs were 1.0 billion in the production sector and NOK 0.4 billion in the transmission sector.

In 1988 a total of 7.6 TWh electricity was lost from the transmission and distribution networks. The figure for 1973 was 6.3 TWh. Calculated as a percentage of input electricity, the percentage loss from the distribution network was reduced from 11.3 per cent in 1973 to less than 9 per cent in 1988. Similarly, the percentage loss from the transmission network was reduced during the same period from 3 to less than 2.5 per cent of the input electricity. The percentage loss was reduced as a result of investments and repairs to improve the quality of the transmission and distribution networks. The increase in absolute loss is due to increased sales of electricity and a larger share of the electricity consumption in regular consumption.

Calculation of input coefficients

The development of input coefficients, i.e. capital, labour and commodities, and amount of electricity lost per produced unit, is not sufficient to ensure economies of scale in the different parts of the electricity sector. Changes in the relative prices of capital, labour and materials, and of lost electricity, will distort the figures for the different input factors. These distortions imply input coefficients. The scale functions should be studied as part of models which specify both the distorting effect of changes in prices and scale properties. Preliminary estimates in Johnsen (1991) indicate increasing returns to scale in the transmission and distribution sectors.

Figure 2.15 shows the development in the use of capital and materials and the loss of electricity per produced unit. Labour has been excluded since the figures for this factor are not available for the years before 1983.

In the production sector, average annual production capacity is used as the production measurement. The transmission sector is scaled to transmit an amount of electricity equivalent to the average annual production. The amount of electricity transmitted with average production is used as a production measurement for the transmission sector. Production in the distribution sector is closely connected to electricity consumption in regular consumption. This consumption is affected to a lesser degree by fluctuations in electricity production, but is influenced on the other hand by fluctuations caused by changes in temperature and economic activity. In spite of these fluctuations, the amount of electricity delivered from the distribution network is used as a production measurement in the distribution sector.

In the production sector, there was a slight upward trend in the consumption of real capital per unit of production during the period. This agrees with an order of development where the cheapest (least capital intensive) projects are realized first. Consumption of materials seems to have remained a constant share of production.

In the transmission sector, the use of the different factors remained stable over the period for both capital and materials, as well as for loss of electricity.

In the distribution sector there was a slight increase in consumption of real capital per unit of production during the period. Use of materials (including repairs) also increased over time. Loss of electricity was reduced, however, thus being substituted by capital and materials.

Figure 2.15. Use of input factors per produced unit of electricity 1973-1988. Indices. 1973 = 1

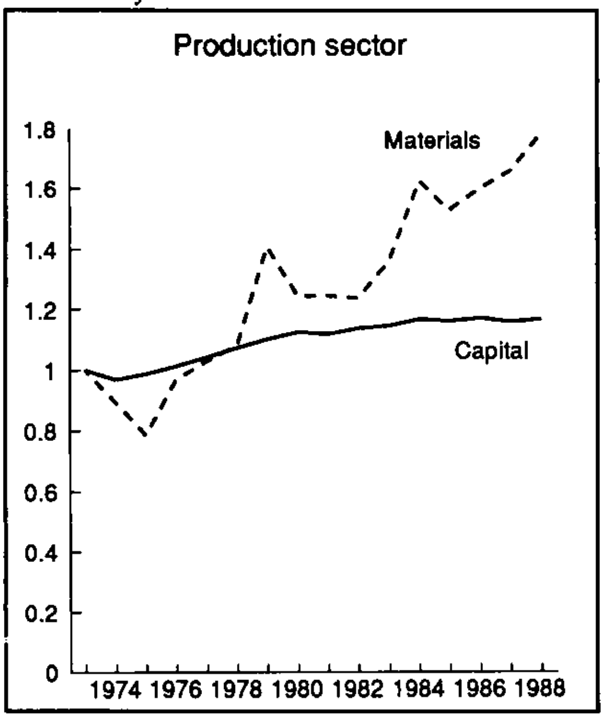
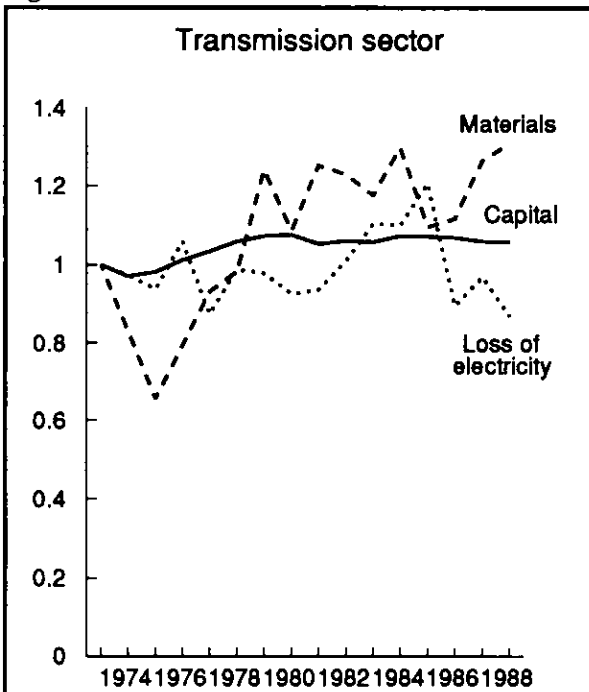
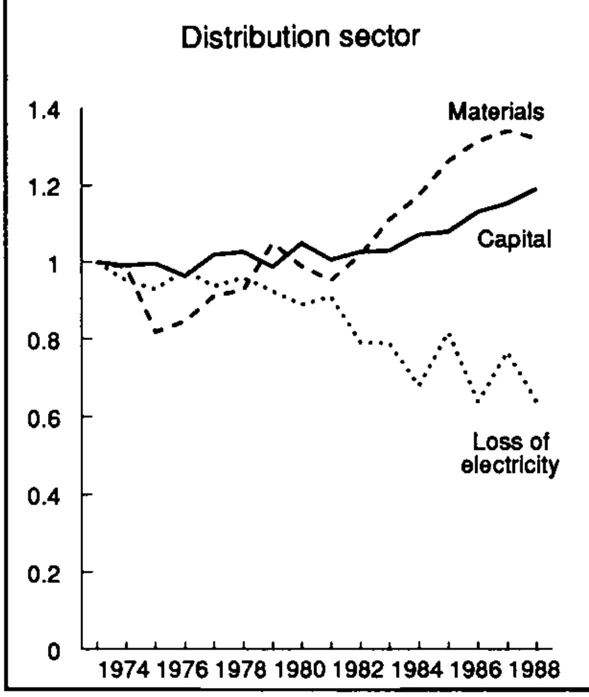


Figure 2.15 cont.





2.5. Analysis: Energy substitution, pollution and economic incentives

Introduction

Emissions to the air of gases such as carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) are linked to combustion of fossil fuels such as oil products, coal and gas. One instrument that can be used to achieve the targets for reduction of emissions is to impose a tax on the use of fossil fuels. In order to study the effects of imposing environmental taxes on fossil fuels it is necessary to develop macroeconomic models which describe the demand for different sources of energy and the potential for substitution, both between each other and in relation to other input factors. The use of different energy goods for stationary purposes in private households and in the Norwegian production sector is discussed below. For a more detailed discussion see Bye and Mysen (1991).

In 1986 emissions of CO_2 from stationary combustion accounted for about 40 per cent of total CO_2 emissions. The greater part of the oil products used for stationary purposes goes to heating. Oil for heating can be substituted by electricity which, when produced from hydropower, is a clean source of energy.

In CBS's macroeconomic models it has so far been assumed, based on estimates of relative demand functions, that there is a relatively large potential for substitution of electricity for oil products and vice versa. Trends in the consumption of electricity and heating oils in the 1980s do not seem to agree very well with the existing model specifications. Throughout the period there was an increase in the use of electricity relative to oil in spite of the fact that, since 1985, oil prices have declined relative to prices of electricity. This made it desirable to study this phenomenon in more detail, and to try other model specifications which would perhaps provide a better explanation of the trend.

The purpose of this analysis is to study the importance of different methods of modelling energy demand through projections of energy consumption and by considering the use of various instruments in the energy and environmental policy.

The trend in stationary energy consumption. 1973- 1988

The relatively large rise in oil prices during the 1970s was followed by a decrease in oil consumption relative to consumption of electricity, both in private households (figure 2.16) and in the production sectors (here represented by the sectors *"production of consumer goods"* (figure 2.17a) and *"production of other private services"* (figure 2.17b), which show a typical trend in electricity and oil consumption in the production sectors). The drop in oil prices in the mid-1980s was not followed, however, by a decrease in consumption of electricity relative to oil, rather the contrary.

The fact that no return to the use of oil products is observed may have been due to a tendency to use more electricity, for various reasons. Electricity is not only used for heating but is also an input factor in the production of services from electricity-specific technical appliances such as washing machines, tumble dryers etc. in private households. The stock of this kind of equipment has more than doubled during the last 15 years (Magnussen (1990)). The production sectors, especially in connection with production of services, have experienced an increase in capital equipment such as computer equipment, air conditioning systems and other equipment based on electricity.

Thus a trend towards increased use of electricity relative to oil can be put down partly to increased use of electricity-specific equipment. Another reason is the trend in the capital cost of installing heating equipment in a dwelling or in production or business premises. In the 1980s the capital costs of installing an oil burner, with associated heating equipment, were much higher than for a heating system using electricity. Furthermore, uncertainty about future prices, as well as greater public awareness of the environment, may have led to a preference for equipment based on electricity.

Figure 2.16. Trend in the relative prices and consumption of electricity and oil. Private households. 1973-1989. 1980 = 1

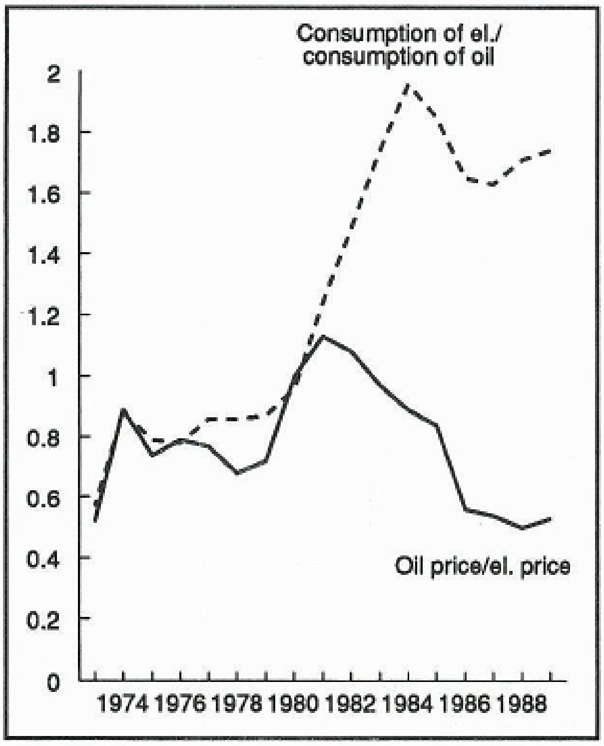


Figure 2.17b. Trend in the relative prices and consumption of electricity and oil. Production of other private services. 1976 - 1988

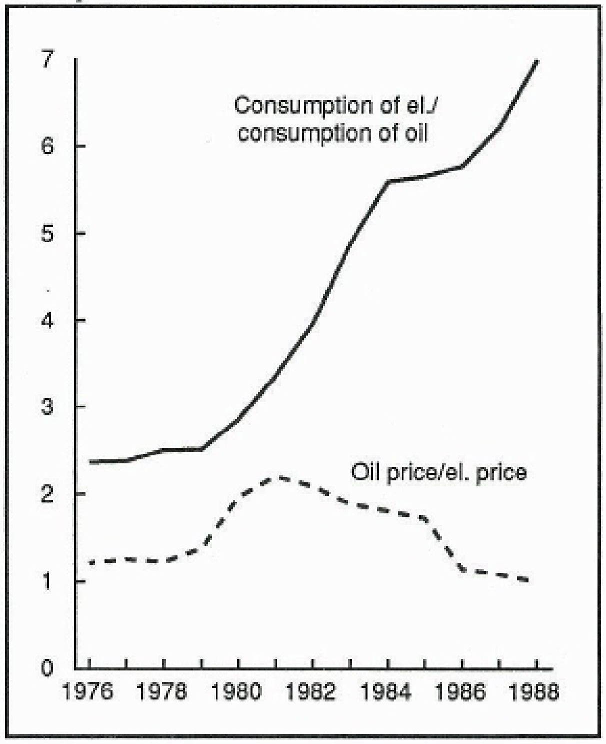
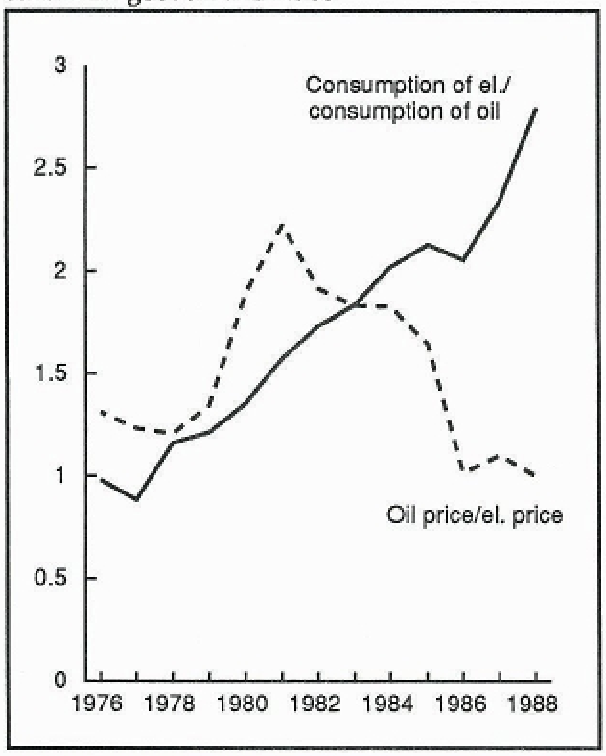


Figure 2.17a. Trend in the relative prices and consumption of electricity and oil. Production of consumer goods. 1976 -1988



Modelling of electricity and oil substitution

In the existing model, substitution elasticities between electricity and oil do not take into account the fact that an increasing share of the electricity is used for electricity-specific capital equipment, and therefore cannot be replaced by oil. Therefore new model functions have been estimated both for the production sectors (Mysen (1991)) and for private households (B. Bye (1991)). Data on consumption of energy with associated prices were obtained from the Norwegian Energy Accounts. For both the production sectors and households, the estimates are based on a functional form allowing for non-neutral technical change (trend).

The new estimates indicate far less potential for electricity and oil substitution after changes in relative prices than previously estimated. In the case of households the elasticity of substitution is reduced from 1.17 to 0.36. Similar reductions are also observed for the production sectors. The trend is estimated to be an increase of slightly less than 10 per cent per year in the use of electricity relative to oil.

A possible reason for the low elasticity of substitution in the "new" model may be that the estimates are based on new and more comprehensive data. Moreover, the "old" model was estimated during a period marked by increasing oil prices relative to the price of electricity. Since there is no explicit factor allowing for trend in the model, a trend towards electricity during this period was expressed by an overestimate of the elasticity of substitution.

Reference path and calculations of effects

A reference path has been simulated and effects calculated using the "old" and "new" models. The purpose of this analysis is to compare the results of the simulations and the effects of imposing taxes on fossil fuels in the two different model specifications. The difference between the two models is illustrated by simulating the "old" and "new" model specifications up to the year 2000.

Two very simplified (partial) models are used for the "new" and the "old" model respectively. The models calculate the use of electricity and oil for stationary combustion, while the production in each sector and thus the total energy consumption is determined exogenously. Similarly, total private consumption and total energy consumption in households are also determined externally to the model.

The reference path assumes a growth in production and consumption of about 2 per cent per year during the period 1990-2000. The price of both oil and electricity is assumed to rise by about 4 per cent per year. The trend for other important variables is about the same as in the calculations for the reference alternative, carried out as part of the SIMEN project (a study of industrial development, energy use and environmental change) (B. Bye et al (1989)).

All the calculations assume that the energy demand functions contain a trend variable which correlates with time. When such a trend is included, oil consumption will gradually become zero. However, there is great uncertainty as to how long the trend observed during the estimation period will last. The trend is bound to slack off as the potential to substitute electricity for oil decreases. All the figures are indexed to 1 in the first year of simulation, 1990.

The reference path

Figures 2.18 and 2.19 show trends in the total consumption of electricity and oil respectively for stationary combustion in the "new" and the "old" model. The "new" model implies higher electricity consumption and lower oil consumption in the year 2000 than expressed in the "old" model. The "old" model implies an increase in electricity consumption of 18 per cent during the period 1990-2000, and the "new" model an increase of 33 per cent. The corresponding figures for oil are an increase of total 36 per cent in the "old" model, and a reduction of 20 per cent from 1990 to the year 2000 in the "new" version of the model. The price trends for both commodities are the same, so that the only factor of importance for electricity and oil substitution in the reference path is the trend towards increased use of electricity.

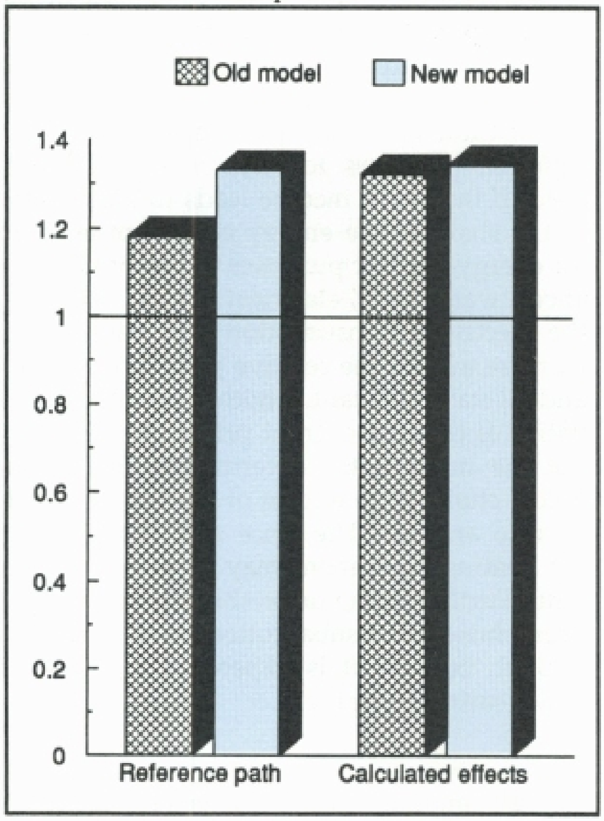
Alternative scenarios

Two scenarios have been calculated to analyze the effects of an increase in the price of oil. The assumed growth in total production, consumption and energy use are the same as for the reference path. In the first scenario the annual rise in the price of oil increases to 10 per cent from 1992. The rise in the electricity price remains unchanged (4 per cent). Therefore, the price of oil increases by 6 per cent relative to the price of electricity. This implies a total increase of about 66 per cent in the price of oil relative to the price of electricity over the period 1990 to 2000.

The substitution effects are much lower in the new model, especially for the production sectors. Therefore, according to this model, increased taxes have much less effect. Consumption of electricity increases by 32 per cent in the "old" model and by 35 per cent in the "new" one, while oil consumption increases by

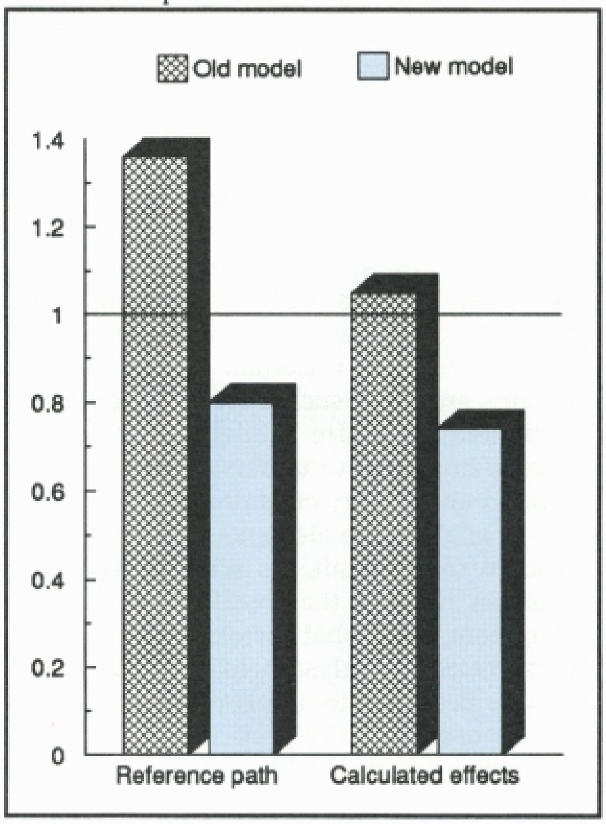
5 per cent in the "old" model but decreases by 26 per cent in the "new" one during the same period. In the year 2000 electricity consumption is 12 per cent higher than the reference path in the "old" model, but in the "new" model the corresponding figure is only just over 1 per cent. According to the "old" model total oil consumption decreases by 23 per cent in relation to the reference path, but according to the "new" model the reduction is only 7 per cent.

Figure 2.18. Total consumption of electricity for stationary purposes in the year 2000. Reference path and calculated effects given a 10 per cent annual increase in the price of oil as from 1992



reference path by the year 2000, as against about 3.5 per cent according to the "new" model. In the "old" model the substitution effects offset the combination of trend and lower substitution effects in the "new" model, and consumption of electricity is therefore higher than shown by the "new" model. It must be emphasized that the use of a simultaneous model might give different conclusions.

Figure 2.19. Total consumption of oil for stationary purposes in the year 2000. Reference path and calculated effects given a 10 per cent annual increase in the price of oil as from 1992



In the second scenario the price of oil is further increased to give an annual rise in price of 20 per cent as from 1992. This corresponds to an increase of 16 per cent relative to the price of electricity. The reduction of oil consumption by the year 2000 is 47 per cent in the "old" model, and 15 per cent in the "new" model in relation to the reference path. According to the "old" model electricity consumption increases by 33 per cent in relation to the

Conclusion

In contrast to the old ones, the new energy functions imply a gradual increase in consumption of electricity relative to consumption of oil. Thus a reference path calculated from a macromodel based on the new functions will imply higher electricity consumption and lower oil consumption than a reference path based on the old energy functions, given the same trend of energy prices, private consumption and production. Therefore the new reference path leads to lower emissions of CO_2, SO_2 and NO_x than the old reference path does.

The "new" model gives a higher electricity consumption and therefore a need for more hydropower development. However, further development of hydropower will cause an increase in the price of electricity, and therefore to some extent offset demand. Reductions in emissions of CO_2 as a result of higher taxes on oil products will depend on whether the increased demand for energy is covered by hydroelectricity or by electricity produced from gas. The choice between developing hydropower or gas power depends on the costs. If the aim is to reduce CO_2 emissions, a CO_2 tax will also have to be imposed on gas power, which will substantially increase the cost of producing electricity from gas.

The "new" model specifications have now been used to some extent in CBS's macroeconomic models. In these specifications the trend factor dominates towards a higher consumption of electricity, given a small change in relative prices. It is very uncertain what this trend contains and how such a trend factor should be treated in future model simulations. In order to improve our understanding of energy demand and energy consumption it is important to analyze the elements contained in the trend in more detail, i.e. what decisions are taken as regards the installation of capital equipment, and what factors influence these decisions. Such analyses will also be important for the potential to improve the system of models used to make projections and to analyze policies in this field.

2.6. Analysis: Energy consumption in private households

In the attempt to explain the trend in energy consumption by private households, an appropriate starting point is to distinguish between alternative services produced by the energy. The demand for gasoline or diesel oil depends on the demand for transport (mobile energy consumption), while the demand for heating oil, kerosene, electricity and solid fuel (wood, coal and coke) depends on various activities in the home (stationary energy consumption).

Electricity is used for many different purposes such as heating, lighting, operation of household appliances etc., while the stationary use of the other sources of energy usually refers to heating. In other words there are several alternatives available for meeting the need for heating.

As outlined in detail in the previous section, the trend in energy consumption by private households no longer reflects changes in the relative prices of oil and electricity. This may have many different explanations. Two possibilities are studied in this section. One possible explanation is a shift in composition of the different purposes for which the energy is used. If increased income leads to an increase in the share of the energy consumption used for energy-specific purposes (household appliances, water beds, electrical cables, etc.), then the electricity consumption will continue to increase even if the relative price of electricity and oil stays constant. Another possible explanation is that the current prices of energy are not the main factor determining the households' choice of one form of heating in preference to another. The price and properties of the heating equipment may be just as important. Furthermore, once the equipment has been chosen, the substitution possibilities are limited, because it is expensive to invest in new heating equipment.

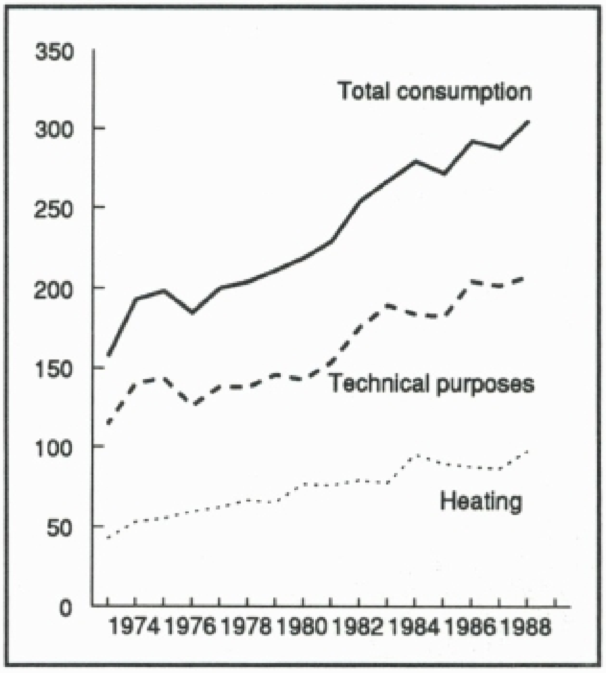
Energy consumption by purpose

CBS has no time series for consumption of electricity for different purposes in private households. Data have been constructed, however, for consumption of electricity for heating and technical purposes respectively by using monthly data on total use of electricity in regular consumption. To estimate how much of the total energy used in regular consumption that refers to technical purposes, monthly data for electricity in regular consumption are used. Then the distribution of the households' annual electricity consumption between heating and technical purposes is estimated. In order to estimate the share of the regular electricity consumption used for technical purposes it is simply assumed that during the four summer months (May, June, July and August) all the electricity is used for purposes other than heating. The average electricity consumption during these four months is said to be equal to the average electricity consumption for technical purposes for all months of the year (B.Bye (1981)).

The calculated share of the electricity consumption used for technical purposes varies from 0.65 to 0.73 during the period 1973-1988. It is highest at both ends of the period, and lowest in 1980. Figure 2.20 shows total consumption of electricity in private households and the distribution between heating and technical purposes. Although the share used for technical purposes is estimated to vary, consumption for both heating and technical purposes increases, due to the relatively strong increase in total energy consumption over the period. The price shock for oil in 1973/74 was followed by a changeover to electricity instead of oil for heating. This could partly explain the calculated reduction in the share of the total electricity consumption used for technical purposes. Possible reasons for the increase in the share used for technical purposes during the 1980s are that the potential for substituting electricity for oil for heating purposes was almost exhausted and/or an even bigger increase in purchase and use of electricity-specific equipment in the 1980s. Since the description of regular consumption is based on monthly data the share may also have been influenced by other factors, e.g. changes in economic activity during the period, the fact that some companies close down during the summer months, and temperature fluctuations during the selected summer months.

The consumption of electricity for technical purposes in private households is calculated simply by using the corresponding share for total regular consumption. Thus the amount consumed for heating is the difference between total electricity consumption and calculated consumption for technical purposes. The calculated consumption for heating was used to estimate substitution between electricity and fuel oils. The result was still an equally strong trend towards the use of electricity for heating during the period, but the substitution elasticity is greater than when the calculations are based on total consumption. Figure 2.20 shows that the increase in the use of electricity for heating in the 1980s was not as strong as the increase in total electricity consumption.

Figure 2.20. Consumption of electricity in private households 1973-1988. 100 GWh



The trend towards increased electricity consumption, even after trying to exclude the electricity used for technical purposes, again indicates a trend towards electrical heating equipment which cannot be explained by changes in the relative prices of electricity and oil. The calculations indicate that increased purchase and use of electricity-specific equipment is not enough in itself to explain the increase in total electricity consumption. There was a simultaneous increase in the changeover from oil to electricity for heating. However, it is important to emphasize the uncertainty of the data used in these calculations.

Choice of heating equipment

The choice of energy source for heating must be considered in relation to the heating system already existing in the household. Changing from one source of heating to another requires quite big investments. The choice can be influenced by current energy prices, but the physical properties of the different heating systems, the costs of investing in equipment, etc. are equally important. Another important factor may be individual preferences (habits). In other words, the choice made by the household is determined by observable variables (price, physical properties) and non-observable variables (personal taste). Therefore, in order to explain the choice made by the household between different sources of energy it is also necessary to consider the factors which determine their choice of heating equipment. The household's choice of heating equipment is decided by:

- the prices of heating equipment at the time the equipment is purchased

- physical properties of the different alternatives

- the household's evaluation of the alternatives

It is difficult to find data on prices of heating equipment at the time the equipment was purchased, and to find variables to express the physical properties of the equipment, such as its ability to distribute heat through the dwelling from a certain amount of energy. A preliminary study of the choice of heating equipment is based on data from a consumer study from 1983 (CBS, 1987) comprising about 1 500 households. In spite of the relative comprehensiveness of the material, several quite strong assumptions are needed before a suitable set of data can be established.

In the first place, wood has not been included as a source of heating. This is partly because the stated use of wood includes only the consumption which the households had paid for, which is assumed to account for only part of the wood actually used. Many households only use wood in an open fire. Therefore, for these households, wood represents only a very small part of the need for heating. In other households, however, this assumption clearly does not hold.

The consumer study does not provide any information on when the heating equipment was bought. It is therefore assumed that the equipment was bought when the dwelling was new. This assumption is clearly unrealistic for old dwellings. Table 2.10 shows the distribution of heating equipment by year of construction of the dwelling.

Table 2.10. Distribution of heating systems by year of construction of the dwelling. Per cent

Year of construction	Electricity	Oil	Kerosene
Before 1950 . . .	75.7	4.8	19.5
1950 - 1959 . . .	70.3	11.5	18.2
1960 - 1969 . . .	68.7	8.7	22.6
1970 - 1979 . . .	78.0	9.5	12.6
1980 - 1983 . . .	95.7	1.1	3.2

It is seen that after 1970 there has been a marked changeover from oil and kerosene to heating by electricity. Since 1980 the heating of almost all new dwellings has been based on electricity. The distribution of equipment in dwellings built before 1950 seems to confirm that, in many old dwellings, the original equipment has been replaced by new. This conclusion is supported to some extent by studying the trend in prices of electrical equipment in the consumer price index. The price of such equipment has fallen steadily throughout the period.

Table 2.11. Average energy content, thermal efficiency coefficients and density, by energy source

Energy source	Theoretical energy content	Unit	Thermal efficiency coefficients Manufacturing, mining	Transportation	Other consumption	Density
Coal	28.1	TJ/ktons	0.80	0.10	0.60	..
Fuelwood[1]	8.4	TJ/kfm^3	0.65	-	0.65	0.5 tons/fm^3
Paper waste (solid)	12.6-15.5	TJ/ktons	..	..	..	..
Wood waste (solid)	15.0-18.5	TJ/ktons	..	..	..	..
Crude oil	42.3	TJ/ktons	..	..	..	0.85 tons/m^3
Natural gas	40.6	TJ/MSm^3	..	..	..	0.77-1.07 kg/Sm^3
Liquefied petroleum gas (LPG)	46.0	TJ/ktons	0.95	-	0.95	0.53 tons/m^3
Gasoline	44.0	TJ/ktons	0.20	0.20	0.20	0.74 tons/m^3
Kerosene	42.7	TJ/ktons	0.80	0.30	0.75	0.79 tons/m^3
Diesel oil, gas oil, fuel oil nos. 1 and 2	42.3	TJ/ktons	0.80	0.30	0.70	0.83 tons/m^3
Heavy fuel oil	41.9	TJ/ktons	0.90	0.30	0.75	0.95 tons/m^3
Electricity	3.6	TJ/GWh	1.00	0.95	1.00	.

1) fm^3 = m^3 solid wood.

2.7. Energy units and conversion factors

Table 2.11 shows average theoretical energy content and thermal efficiency coefficients for a number of selected energy sources in different applications. The theoretical energy content will vary within one and the same energy source. For example, crude oil from the North Sea has a different composition and thermal efficiency coefficient than oil from the Middle East. Therefore the factors presented in Table 2.11 should be regarded as average values. The estimates of thermal efficiency coefficients are very uncertain. Some studies include results which deviate strongly from the thermal efficiency coefficients presented in the table.

There are a large number of measuring units for energy in use. Several contributory factors decide the relationship between them. The conversion factors presented in table 2.12 must be regarded as approximate. This applies to the measuring units for oil (toe and barrels) and to an even greater degree to the measuring units for gas (m^3 and Scuft), and to the conversion factors between these units.

Table 2.12. Energy units[1]

Unit	PJ	TWh	quad (oil)	Mtoe (oil)	M-barrel (gas)	GSm^3 (bcm) (gas)	GScuft
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	1053	292.5	1	24.9	184.1	25.6	877.5
1 Mtoe	42.3	11.8	0.04	1	7.4	1.03	35.3 (oil)
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 million 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 2.13. 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}

2.8. Appendix of tables

Table 2.14. Reserve accounts for crude oil. Developed fields and fields to be developed. 1979-1989. Million tonnes of oil equivalents

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989*	1990*
Reserves per 1/1	570	520	496	509	495	495	650	733	838	871	1028	995
New fields	-	24	80	-	38	147	65	29	60	155	-	105
Reevaluation	-31	-24	-43	11	-7	43	56	118	22	59	41	109
Extraction	-19	-24	-24	-25	-31	-35	-38	-42	-49	-57	-75	-82
Reserves per 31/12	520	496	509	495	495	650	733	838	871	1028	995	1127

Source: Petroleum Directorate, Central Bureau of Statistics.

Table 2.15. Reserve accounts for natural gas. Developed fields and fields to be developed. 1979-1990. Million tonnes of oil equivalents

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989*	1990*
Reserves per 1/1	445	406	385	381	348	332	399	387	1259	1248	1267	1261
New fields	-	32	40	-	15	84	9	893	8	20	-	19
Reevaluation	-17	-27	-18	-8	-6	10	66	6	10	28	23	-18
Extraction	-22	-26	-26	-26	-26	-27	-27	-27	-29	-29	-29	-29
Reserves per 31/12	406	385	381	348	332	399	387	1259	1248	1267	1261	1232

Source: Petroleum Directorate, Central Bureau of Statistics.

Tabell 2.16. Extraction, conversion and use[1] of energy sources. 1989*. PJ

	Total	Coal	Coke	Fuelwood paper waste, other solid waste	Crude oil	Natural gas	Petroleum products[2]	Electricity	District heating
Extraction of energy goods ...	4900	10	-	-	3127	1292	44[2]	427	-
Energy use in extraction sectors ..	-84	-	-	-	-	-72	-5	-6	-
Imports and Norwegian purchases abroad ...	476	18	29	0	42	-	386	1	-
Exports and foreign purchases in Norway	-4214	-7	-2	0	-2755	-1159	-236	-55	-
Stocks (+Decrease, -Increase)	-5	1	1	.	3	.	-10	.	-
Primary supply .	1073	22	27	0	417	61	178	367	-
Petroleum refineries	-33	-	5	-	-419	-	383	-1	-
Other energy sectors, other supply	40	-1	-	34	-	-	2	1	4
Registered losses, statistical errors .	-112	0	-1	-	2	-61	-16	-35	-1
Registered use outside energy sectors	968	21	31	34	-	-	547	332	3
Ocean transp. ...	233	-	-	-	-	-	233	-	-
Domestic use ...	734	21	31	34	-	-	314	332	3
Agriculture and fishery	32	0	-	-	-	-	27	4	0
Energy intensive manufacturing .	199	12	26	0	-	-	50	110	0
Other manufacturing and mining	109	8	4	15	-	-	29	51	0
Other ind.	195	-	-	-	-	-	127	67	1
Private households	200	0	0	19	-	-	80	100	1

1) Including energy goods used as raw materials.
2) Including liquefied gas. Coke includes petrol coke.

Table 2.17. Electricity balance[1]. 1975 - 1990. TWh

	1975	1980	1984	1985	1986	1987	1988	1989*	1990*
Production	77.5	84.1	106.7	103.3	97.3	104.3	110.0	119.2	121.6
+Import	0.1	1.8	0.9	4.1	4.2	3.0	1.7	0.3	0.3
-Export	5.7	2.3	9.1	4.6	2.2	3.3	7.4	15.2	16.3
=Gross dom. consumption ...	71.9	83.6	98.4	102.7	99.3	103.9	104.4	104.3	105.6
-Consumption in pumping plants	0.1	0.5	0.6	0.8	0.9	0.7	1.0	0.4	0.3
-Surplus power	3.2	1.2	4.8	4.8	2.7	4.1	4.5	5.5	5.7
-Losses in exports and surplus power	0.8	0.3	1.3	1.0	0.3	0.5	0.8	1.4	1.5
=Gross firm power consumption	67.7	81.6	91.7	96.2	95.4	98.6	98.1	96.9	98.2
Energy intensive industries ...	27.0	28.7	32.1	30.9	29.2	29.8	30.5	30.5	31.2
Regular consumption[2]	40.7	52.9	59.6	65.3	66.2	68.8	67.6	66.5	67.0
-Losses in the transmission lines, consumption in the power stations, statistical differences[3]	6.3	7.7	8.0	8.7	9.1	9.2	9.2	8.8	8.6
=Net firm power cons.[3]	61.4	73.9	83.7	87.5	86.4	89.3	88.9	88.1	89.6
Energy intensive ind.	26.2	27.9	31.2	30.0	28.4	28.9	29.6	29.6	30.3
Regular consumption[2]	35.2	46.0	52.5	57.5	58.0	60.4	59.3	58.6	59.3
Regular consumption[2], temperature adjusted	36.3	45.1	53.0	55.0	57.1	58.6	60.2	61.8	63.1
Average annual change, per cent		4.4	4.1	3.8	3.8	2.6	2.7	2.7	2.1

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.

Table 2.18. Use of energy sources outside the energy sectors and ocean transport, by energy source. 1976 - 1990. PJ

Energy source	1976	1980	1983	1984	1985	1986	1987	1988	1989*	1990*
Total	617	688	677	722	743	747	772	761	734	743
Electricity	241	269	298	319	329	324	335	339	332	343
Firm power	232	265	283	302	312	315	321	323	315	323
Surplus power	9	4	15	17	17	10	15	16	17	21
Oil total	311	344	293	312	323	336	348	331	314	311
Oil other than transportation	161	141	84	80	84	95	84	77	69	61
Gasoline	13	6	4	5	4	4	0	0	0	0
Kerosene	17	18	8	7	9	10	11	10	8	7
Medium distillates	65	61	41	40	43	43	45	42	38	36
Heavy fuel oil	66	56	31	28	28	37	29	25	23	18
Oil for transportation	147	162	171	181	187	202	208	202	201	198
Gasoline, gasoline type jet fuel, kerosene type jet fuel	69	77	81	84	89	96	102	103	104	103
Medium distillates	75	80	84	89	91	98	99	93	91	91
Heavy fuel oil	3	5	6	8	7	8	7	6	6	4
Liquefied gas	1	40	40	50	52	40	56	52	43	52
District heating	.	.	.	.	.	.	3	3	3	3
Solid fuels	65	74	86	91	91	88	86	88	86	86
Coal, coke	47	49	56	60	57	53	51	53	52	52
Fuelwood, paper waste, other solid waste	18	25	30	31	34	34	35	34	34	34

Table 2.19. Average prices[1] of electricity[2] and selected petroleum products. Delivered energy. 1981-1990

Energy source	1981	1982	1983	1984	1985	1986	1987	1988	1989*	1990*
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
	(17.5)	(20.2)	(23.4)	(26.5)	(28.5)	(31.6)	(34.3)	(37.2)	(38.6)	(41.4)
Heating kerosene .	26.9	30.5	31.8	32.5	32.8	24.8	25.0	25.7	28.3	33.9
Fuel oil no. 1	22.8	25.1	26.2	26.9	27.2	19.4	19.6	19.7	21.6	26.6
Fuel oil no. 2	21.7	23.8	25.0	25.7	25.7	18.1	18.3	18.8	20.7	25.7
Heavy fuel oil ...	13.8	13.7	14.8	17.7	17.8	10.4	12.4	11.7	14.7	19.1
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
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
Auto diesel	240.0	262.7	272.3	280.3	282.0	207.6	210.0	214.0	233.0	285.9

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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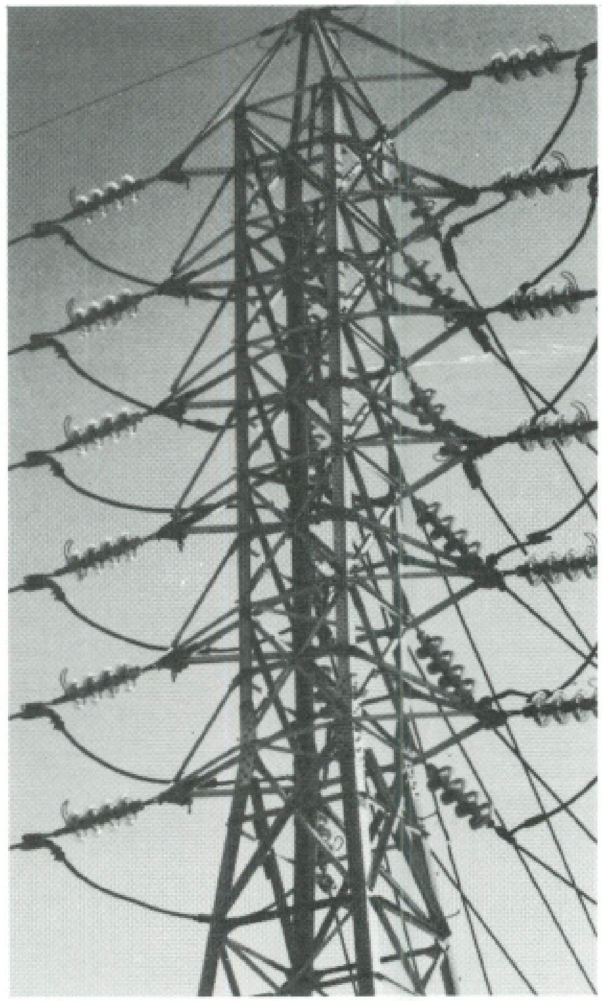


3. AIR

Each year CBS prepares inventories of Norwegian emissions of several polluting compounds. These emissions vary with changes in production and consumption of goods and services. The total level of emissions, however, is determined partly by changes in the amount of energy used per produced unit and emissions per unit of utilized energy. The emissions contribute in their turn to the total concentration of air pollution. The inventories are a necessary part of the monitoring of environmental status, and provide a basis for analyses of future trends in emissions to air and of the effects of various pollution control measures. These measures impose costs on society, but also provide benefits in the form of reduced negative effects on human health, and reduced damage to nature and production equipment.

This chapter discusses some effects of a potential climate policy, given specific assumptions concerning international economic development and the formulation of an international agreement on climate. Estimates are presented of socio-economic costs and some benefits. The chapter concludes by discussing certain factors which may be of importance for Norway's environmental policy should Norway become a member of the EEC.

3.1. Air pollution - some sources and effects

The main sources of emissions to air in Norway are use of coal, coke and oil products for heating and transport, various industrial processes and evaporation. Characteristic of the emissions from *industrial processes* is that they are released from input factors other than energy. The sources of pollution by *evaporation* are solvents and oil products. It is customary to distinguish between emissions caused by combustion of fossil fuels in stationary installations, so-called *stationary fuel emissions*, and *mobile fuel emissions* from motor vehicles, aircraft, boats etc. The distinction between emissions from stationary and mobile sources is important when assessing the potential for substituting different forms of energy.

Air pollution in Norway comes partly from emissions from industry, transportation and heating systems and partly from long-range pollution from other countries (transboundary pollution). Norwegian emissions are the main source of local pollution which impairs health and damages materials, while transboundary pollution from Great Britain and the continent is the main source of acidification of the soil and of freshwater lakes in the southern part of Norway.

The emissions are determined mainly by the level and composition of production and consumption of goods and services. Economic activity requires use of energy, with associated emissions. Emissions can be reduced by cleaning or by modifying the production process. Other efforts to reduce pollution can be directed at the use of polluting production factors and products, for example by specifying quality criteria for oil, or by imposing taxes to reduce the use of especially polluting products.

The harmful effects of air pollution depend on the concentration of the different components and the duration of exposure of humans and the environment. The concentration is determined by the intensity and location of the emissions, weather conditions, spreading conditions etc. In the case of some components the damage does not occur until the concentration has exceeded a certain critical load or threshold level. For other components there are no such critical values. Even very low concentrations may be harmful to health or damage environment. This applies in particular to pollutants with carcinogenic properties. Very often, those who are hardest hit by pollution are groups who are vulnerable already, such as children and elderly, and persons with asthma.

The effects of air pollution are sometimes due to secondary pollutants. These are substances generated, for instance, through oxidation of certain components of the original emissions. Examples of so-called secondary pollutants are sulphate (SO_4), produced by oxidation of sulphur dioxide (SO_2), and ozone (O_3), created in photochemical reactions between nitrogen oxides (NO_x) and hydrocarbons or carbon monoxide (CO) under the influence of solar radiation.

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

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

Compound	Source	Damage	Threshold 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.	Health: 100-150 µg/m³ (day) 40-60 µg/m³ (half year) Vegetation: 30 µg/m³ (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 µg/m³ (hour) 100-150 µg/m³ (day) 75 µg/m³ (half year)
Carbon monoxide	Transportation Burning of wood Combustion of oil Process emissions: - Silicon carbide	*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/m³ (hour) 10 mg/m³ (8-hours)
Volatile organic compounds	Transportation Burning of wood Combustion of oil Solvents Filling stations	*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	

Table 3.1 continued

Compound	Source	Damage	Threshold level
Polycyclic aromatic hydrocarbons	Burning of wood Aluminium plants	*Health:* PAH in air might cause cancer in the respiratory system	
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 reduce 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
Carbon dioxide	Fossil fuels Deforestation/land-use changes, burning of biomass Manufac. of cement	Contributes to increased greenhouse effect	
Methane	Extraction, transportation and combustion of fossil fuels, burning of biomass, wetlands, rice fields, ruminants, etc.	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, land-use changes, burning of biomass, fertilizers, microbiological processes	Contributes to increased greenhouse effect. Reduces the stratospheric ozone layer.	
Chlorofluorocarbons	Refrigeration installations, chemical cleaning, aerosols	Reduces the stratospheric ozone layer. Contributes to the greenhouse effect.	
Halons	Fire extinguishers	Reduces the stratospheric ozone layer	

Source: CBS.

3.2. Emissions to air in Norway

Inventories of emissions to air have been compiled for sulphur dioxide (SO_2), nitrogen oxides (NO_3), carbon monoxide (CO), carbon dioxide (CO_2), volatile organic compounds (VOC) excluding methane, particulates and lead for the years 1973-1988. Inventories have been compiled for methane (CH_4) and nitrous oxide (N_2O) for the years 1987 and 1988. The State Pollution Control Authority (SFT) has estimated preliminary figures for 1989 and 1990. Cruder estimates also exist for some components for the years 1960-72.

Sulphur dioxide	SO_2
Sulphate	SO_4^{2-}
Nitrogen oxides	NO_X (NO and NO_2)
Carbon dioxide	CO_2
Lead	Pb
Ozone	O_3
Methane	CH_4
Nitrous oxide	N_2O
Chlorofluorocarbons	CFC
Volatile organic compounds	VOC

Box 3.1 Some chemical formulas and abbreviations

In general, the inventories for earlier years are less detailed and more uncertain than inventories for later years. Emission inventories for later years are based on detailed surveys of energy consumption (Resource Accounts for Energy, and Manufacturing Statistics from the Central Bureau of Statistics), emission coefficients, and recorded emissions from industrial companies with a discharge permit from SFT. The figures for fuel combustion and the emission coefficients are both associated with a certain degree of uncertainty. In the case of the emission coefficients the uncertainty is greatest for N_2O, VOC and CH_4. The emission coefficients can change as more knowledge is obtained. Least uncertainty is connected to the emission coefficients for CO_2, Pb and SO_2.

Tables 3.2 and 3.3 present some of the emission coefficients used to calculate emissions. The emission coefficients are adjusted from year to year, partly because of changes in the chemical composition of the fuels and changes in combustion technologies, and finally in the light of increased knowledge about other factors which determine the coefficients. In recent years, especially emission coefficients which relate emissions of VOC, CO and particulates to consumption of marine fuels have been adjusted downwards.

Emissions of SO_2 and lead from energy use are determined respectively by the content of sulphur and lead in the energy source. CO_2 emissions from the different energy sources are decided by the carbon content of the fuel and by emissions of other carbon compounds during the combustion process. The emissions of the other components are determined mainly by the combustion conditions. Emissions from industrial processes and evaporation are determined by factors other than use of energy, such as the materials used in production, the level of activity in certain industries such as agriculture, the amount of deposited waste, etc. The emission inventories do not provide direct information on the *concentrations* of pollution which may cause damage to health, the natural environment or materials. For some components, however, a good correlation is found between measured changes in pollution concentrations and changes in the level of emissions (see section 3.3). Therefore the emission inventories give some indication of concentrations and the total pollution load. They thus provide a very useful basis for assessing where to introduce pollution control measures and show the effects of any measures already introduced. The emission inventories also provide the necessary data to make forecasts of emissions to air, and thereby indicate whether or not Norway is fulfilling national objectives and international agreements on reductions of emissions to air, see section 3.5.

Table 3.2. Emission coefficients for NO_x VOC, CO and particulates. 1988

		NO_x	VOC	CO	Particulates
		kg/tonne			
STATIONARY COMBUSTION					
Natural gas	Industry	7.0	1.5	2.0	0.0
Heating	Households	2.5	0.6	6.5	0.3
kerosene	Industry	3.0	0.4	2.0	0.25
Heating oil	Households	2.5	0.6	6.5	0.3
	Industry	3.0	0.4	2.0	0.3
Heavy oil	Households	4.2	0.3	0.4	1.3
	Industry	5.0	0.3	0.2	1.3
Coal	Households	1.4	10.0	100.0	8.5
	Industry	4.5	0.8	3.0	1.4
Wood	Households	0.7	20.0	100.0	10.0
	Industry	0.9	1.3	15.0	2.4
MOBILE SOURCES					
Marine fuels	Ocean transport	70.0	2.5	5.0	1.2
		g/km			
GASOLINE					
Light vehicles	Town driving	1.65	3.7	34.8	0.06
	Highway and country driving	2.2	1.1	7.5	0.06
Heavy vehicles	Town driving	5.2	8.6	85	0.13
	Highway and country driving	7.8	2.9	28	0.13
DIESEL					
Light vehicles	Town driving	1.0	1.0	2.0	0.42
	Highway and country driving	1.5	1.0	2.0	0.42
Heavy vehicles	Town driving	9.3	1.4	2.8	0.84
	Highway and country driving	13.9	1.4	2.8	0.84

Sources: CBS, SFT (State Pollution Control Authority).

Table 3.3. Emission coefficients for SO_2 and CO_2. 1988

Energy source	Kg SO_2/tonne energy source	Tonnes CO_2/tonne of energy source[1)]
Natural gas	-	2.75
LPG (propane)	-	3.00
Kerosene	0.4	3.15
Gasoline	0.7	3.15
Heating oils	4.0	3.15
Diesel	4.0	3.15
Marine fuel	4.0	3.15
Special distillate	9.0	3.15
Heavy oil LS	19.0	3.15
Heavy oil NS	44.0	3.15
Coal, industry	16.0	2.42
Coal, households	20.0	2.42
Wood	0.4	-

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.

Sources: NP, SFT.

Emissions to air by economic sector and source of energy

Table 3.4 shows emissions of SO_2, NO_x, VOC, CO, CO_2, particulates, Pb, CH_4 and N_2O from various economic sectors in 1988. Table 3.5 shows the same emissions by source. Emissions from ocean transportation in Norwegian territorial waters are *not* included in the tables. In 1988 emissions from this type of activity (Norwegian and foreign vessels) amounted to about 10 000 tonnes SO_2, 24 000 tonnes NO_x, 2 000 tonnes CO, 1 million tonnes CO_2, almost 1 000 tonnes VOC, 500 tonnes particulates, just over 300 tonnes CH_4 and only small amounts of lead (Pb) and nitrous oxide (N_2O). As a rule, emissions from air traffic refer to landing and take-off cycles only. In the case of CO_2, CH_4 and N_2O, however, all emissions from domestic air traffic are included. Alternative calculations have been carried out by SINTEF (Foundation for Scientific and Industrial Research, University of Trondheim) and NILU (Norwegian Institute for Air Research) for emissions from ships in Norwegian waters and from aircraft flying in Norwegian air territory. To some extent these calculations cover other activities and other years, and for this reason may deviate from the figures presented here.

Sectors with relatively high emissions of several compounds include private households, domestic transportation (other than private cars) and metal production, see table 3.4. Table 3.5 shows that road traffic and coastal water transport are among the largest sources of most emissions.

Emissions in Norway 1973-1990

The main features of the trend in emissions to air is determined by the basic trend of economic activity and associated use of energy, together with technological developments and special measures to reduce emissions. The historical trend in the use of different sources of energy is described in more detail in chapter 2. This section describes the most important trends in emissions of SO_2, NO_x, CO, VOC, particulates, Pb and CO_2 during the period 1973-1990. Inventories are available for CH_4

and N_2O for the last two years only. The total "greenhouse effect" of Norwegian emissions is discussed at the end of the section. Emissions from ocean transportation (shipping in foreign trade) are not included in the calculations. The figures for 1989 and 1990 are preliminary estimates from SFT, and are not distributed by sector or by source.

There was a marked reduction in **emissions of SO_2** during the period 1973-1990, see figure 3.1. Emissions from stationary combustion decreased from 73 000 tonnes in 1973 to about 20 000 tonnes in 1990, and emissions from industrial processes decreased from 67 000 tonnes to just over 30 000 tonnes during the same period. Reductions in SO_2 emissions are due to several factors:

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

- A 10-year programme to clean up older polluting industry was started in 1974. The programme entails permits for emissions and instructions to install cleaning equipment in a number of undertakings. Cleaning has been directed mainly at emissions of particulates.

- There was a good supply of cheap surplus power in the 1980s. This led to a decrease in use of oil, especially in the pulp and paper processing industry.

- There were several mild winters at the end of the period, leading to less use of energy for heating.

The largest reductions in emissions occurred in the pulp and paper processing sector, from 33 000 tonnes in 1976 to 5 400 tonnes in 1988. This sector consumes the largest amounts of surplus power. Emissions from energy-intensive industry (manufacture of metals and industrial chemicals) remained about the same throughout the period. There was a marked reduction in emissions from petroleum refineries, and emissions from other industry and other commercial activity, not including the transportation sector, were more than halved during the period due to emission-abatement measures such as the requirement for a lower content of sulphur in heavy oils and the changeover from oil to electricity as a source of energy. The main reason for the large reduction in emissions from 1986 to 1987 is the closing down of the smelting works at A/S Sulitjelma mines, which had been responsible for extensive emissions from industrial processes. Emissions from industrial processes were further reduced by 1 000 tonnes from 1987 to 1988, mainly as a result of reduced emissions from the pulp and paper processing sector and from oil refineries. Emissions from stationary combustion were also reduced by almost 4 000 tonnes. Emissions from mobile sources also decreased by almost 3 000 tonnes from 1987 to 1988. Total SO_2 emissions were reduced by 10 per cent from 1987 to 1988 and by a further 10 per cent from 1988 to 1989. Preliminary estimates indicate that the emission level in 1990 will be about the same as in 1989.

In 1988, the most important source of SO_2 emissions was industrial processes, which accounted for 45 per cent of the total emissions. 31 per cent came from stationary combustion and 24 per cent from mobile sources.

The industrial sectors combined accounted for about two thirds of the total SO_2 emissions, 30 per cent of this amount coming from metals production. Other important sectors for SO_2 emissions were domestic transportation, manufacture of chemical and mineral products, pulp and paper product manufacture, and production of industrial chemicals.

Table 3.4. Emissions to air by sector. 1988. In 1 000 tonnes unless otherwise specified

	MSG-sector	SO_2	NO_x	CO	CO_2	VOC[1]	Particu-lates	Pb	CH_4	N_2O
					Mill. tonnes			Tonnes		
	Total	67.1	224.9	634.5	34.5	188.8	20.7	279.9	289.6	12.8
11	Agriculture	0.9	5.5	11.4	0.7	3.6	0.9	2.0	105.4	4.1
12	Forestry	0.1	0.7	3.1	0.1	1.1	0.1	0.8	0.0	0.0
13	Fishery etc.	2.0	32.8	4.1	1.5	1.9	0.6	0.7	0.4	0.1
15	Manuf. of consumer goods	3.5	2.3	1.6	0.7	0.4	0.3	0.8	0.0	0.1
25	Manuf. of production input commodities	6.1	6.7	2.8	2.4	0.7	0.5	1.2	1.6	0.2
34	Manuf. of pulp and paper products	5.4	1.5	0.4	0.4	0.1	0.2	0.1	0.1	0.2
37	Manuf. of industrial chemicals	6.9	5.3	38.3	1.9	0.8	0.1	0.0	0.0	6.1
40	Petroleum refining	3.1	1.7	0.0	1.0	2.8	0.1	0.0	0.0	0.1
43	Manuf. of metals	19.7	5.6	4.0	5.0	1.4	0.2	5.1	0.0	0.1
45	Manuf. of fabricated metal products	0.4	0.8	0.9	0.2	0.1	0.1	0.5	0.0	0.0
50	Shipbuilding and platform construction	0.1	0.2	0.2	0.1	0.0	0.0	0.1	0.0	0.0
55	Construction	0.8	7.8	4.4	0.6	1.1	0.6	1.5	0.1	0.1
63	Financing and insurance	0.0	0.5	3.8	0.1	0.4	0.0	2.6	0.0	0.0
64	Oil and gas extraction	0.4	12.6	3.7	4.7	85.1	0.0	0.0	12.7	0.3
68	Oil well drilling	0.8	6.2	0.4	0.3	1.8	0.1	0.0	1.2	0.0
71	Prod. of electricity[2]	0.5	0.9	0.4	0.2	0.3	0.1	3.5	0.1	0.1
75	Domestic road transport	2.4	27.4	21.2	2.0	5.3	2.2	9.2	0.3	0.2
76	Domestic air transport	0.2	3.6	9.8	1.6	2.1	0.2	0.0	0.1	0.1
77	Coastal water transport	7.6	41.2	3.4	1.9	1.5	0.7	0.5	0.5	0.1
78	Rail transport	0.1	0.5	0.2	0.1	0.1	0.1	0.0	0.0	0.0
79	Post and telecommunications	0.1	2.0	9.4	0.2	1.0	0.1	6.2	0.1	0.0
81	Wholesale and retail trade	1.1	11.9	51.5	1.3	5.8	0.5	34.1	0.4	0.1
83	Housing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	Other private services.	0.5	3.5	22.7	0.6	2.4	0.1	15.2	0.2	0.1
92	Defence	0.4	4.3	2.0	0.6	0.3	0.1	0.6	0.1	0.0
93S	Education and research (state)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
93K	Education and research (municipal)	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
94S	Health and social welfare (state)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
94K	Health and social welfare (municipal)	0.4	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0
95S	Other public services (state)	0.1	0.7	0.5	0.1	0.1	0.0	0.3	0.0	0.0
95K	Other public services (municipal)	0.0	0.1	0.2	0.1	0.0	0.0	0.2	160.0	0.0
P	Private households	3.4	38.4	433.8	6.0	68.4	12.9	194.6	6.3	0.5

1) Not incl. evaporation from storage and handling of gasoline, and from use of solvents. See table 3.5.
2) Incl. emissions from waste incineration plants.
Sources: CBS, SFT.

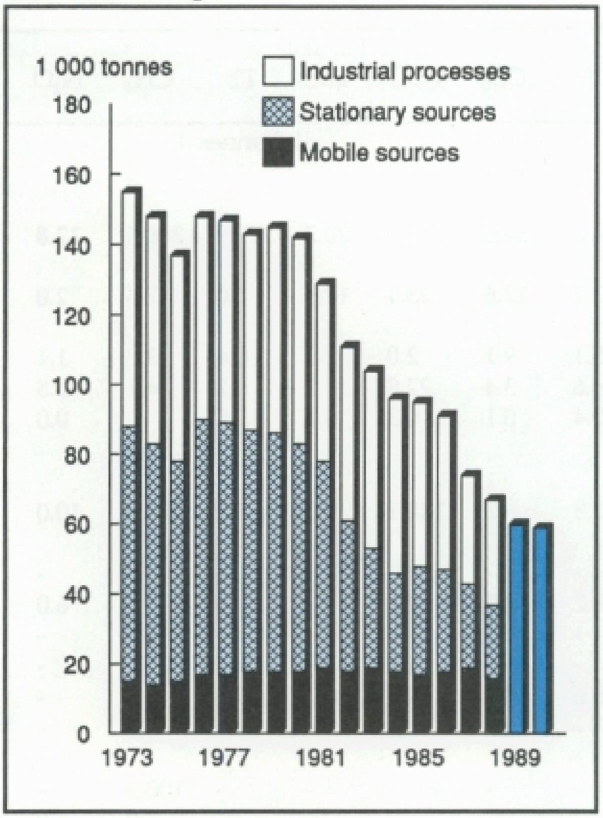
Table 3.5. Emissions to air by source. 1988. In 1 000 tonnes unless otherwise specified

Sources	SO_2	NO_x	CO	CO_2	VOC	Particulates	Pb	CH_4	N_2O
				Mill. tonnes			Tonnes		
TOTAL	67.1	224.9	634.5	34.5	248.0	20.7	279.9	289.6	12.8
STATIONARY COMBUSTION	20.8	26.5	122.2	12.6	25.1	12.6	4.0	7.3	2.0
- Industrial combustion	15.5	22.1	5.1	9.1	2.0	1.0	0.4	3.2	1.1
- Non-industrial combustion	4.9	3.4	116.6	3.4	22.8	11.5	0.2	4.1	0.8
- Incineration of waste	0.5	0.9	0.4	0.1	0.3	0.1	3.5	-	0.0
INDUSTRIAL PROCESSES AND EVAPORATION	30.2	8.6	41.8	6.7	148.1	0.0	5.0	277.6	10.0
- Pulp and paper prod.	2.7	-	-	-	-	-	-	-	-
- Industrial chemicals	6.1	4.4	38.2	1.0	0.8	-	-	-	6.0
- Mineral products	1.5	-	-	1.0	-	-	-	1.5	-
- Petroleum refining	2.5	-	-	-	2.8	-	-	-	-
- Manuf. of metals	17.4	4.1	3.6	4.5	1.3	0.0	5.0	-	-
- Agriculture, liming	-	-	-	0.2	-	-	-	-	-
- Agriculture, domestic animal husbandry	-	-	-	-	-	-	-	100.3	-
- Agriculture, fertilizing	-	-	-	-	-	-	-	5.0	4.0
- Petroleum activities[1]	-	-	-	-	85.1	-	-	10.8	-
- Landfills (waste disposal)	-	-	-	-	-	-	-	160.0	-
- Storage of gasoline	-	-	-	-	3.1	-	-	-	-
- Filling stations	-	-	-	-	5.0	-	-	-	-
- Solvents	-	-	-	-	50.0	-	-	-	-
MOBILE SOURCES	16.1	189.9	470.6	15.2	74.8	8.1	270.9	4.7	0.8
- Automobiles	4.5	84.3	386.8	7.8	44.1	4.3	255.8	3.2	0.3
- Light vehicles	1.7	46.8	352.1	5.3	37.6	2.0	236.2	2.7	0.2
-Gasoline	1.1	44.4	348.7	4.9	35.9	1.3	236.2	2.6	0.1
-Diesel	0.6	2.4	3.4	0.4	1.7	0.7	0.0	0.0	0.1
-Heavy vehicles	2.8	37.5	34.7	2.5	6.5	2.3	19.6	0.5	0.2
-Gasoline	0.1	4.2	27.2	0.4	2.8	0.1	19.6	0.3	0.0
-Diesel	2.7	33.3	7.5	2.1	3.7	2.2	0.1	0.2	0.1
- Motorcycles, mopeds, tractors etc.	1.0	13.3	66.9	1.1	25.4	2.0	14.8	0.2	0.1
- Railways	0.1	0.5	0.2	0.1	0.1	0.1	0.0	0.0	0.0
- Air traffic	0.2	4.0	10.5	1.9	2.2	0.2	0.0	0.1	0.1
- Coastal water transport	8.1	48.8	3.5	2.2	1.7	0.8	0.2	0.6	0.1
- Fishing fleet	2.0	32.8	2.3	1.5	1.2	0.6	0.1	0.4	0.1
- Oil well drilling	0.4	6.2	0.4	0.6	0.2	0.1	0.0	0.2	0.0

1) Including gas terminals.

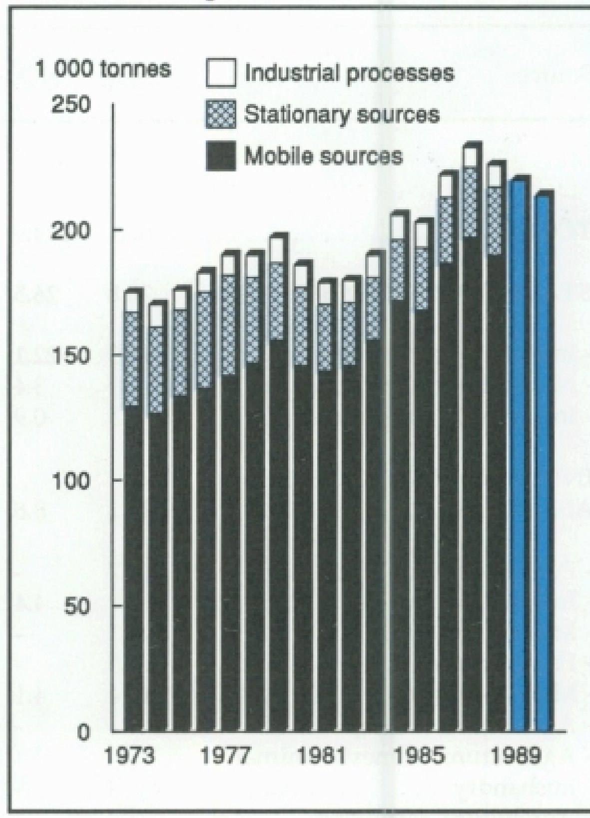
Sources: CBS, SFT.

Figure 3.1. Emissions of SO_2 by source. 1973-1990*. 1 000 tonnes SO_2



Source: CBS, SFT.

Figure 3.2. Emissions of NO_x by source. 1973-1990*. 1 000 tonnes NO_2



Source: CBS, SFT.

There was a substantial increase in **emissions of NO_x** from the beginning of the 1980s up to 1987, followed by a slight decrease, see figure 3.2. The greatest reduction occurred in connection with mobile sources, the main reason being reduced use of diesel and marine fuels. Combustion of these fuels is one of the most important sources of emissions of NO_x. The large increase in emissions in the early 1980s was due to increased emissions from private households. A major part of this increase in the 1980s referred to purchase and use of private cars. At the same time, emissions of NO_x per unit of fuel increased slightly due to higher energy efficiency in new cars. This has been counteracted to some extent by the requirement for catalytic cleaning of exhaust gases in new cars as from 1989. NO_x emissions from stationary combustion decreased during the period due to less use of heating oils, but emissions from industrial processes remained stable.

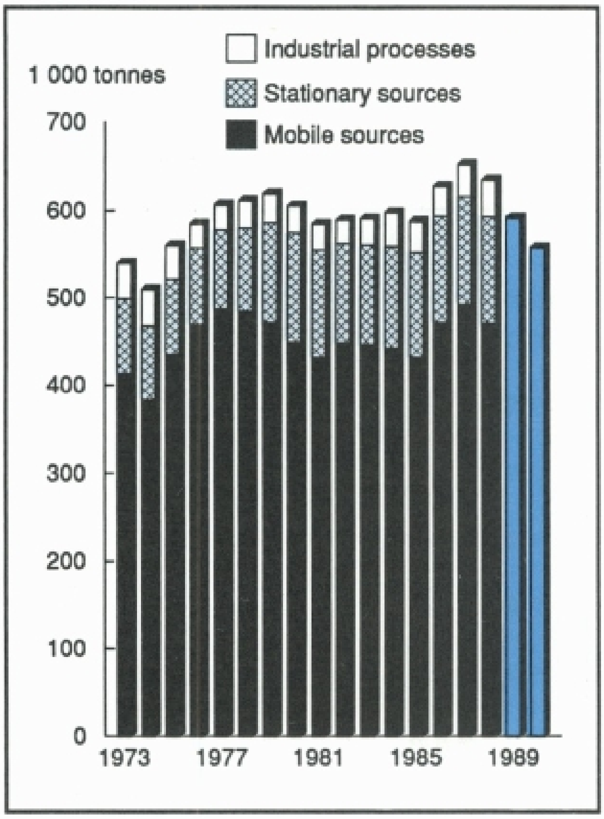
In 1988, as much as 84 per cent of the emissions of nitrogen oxides came from mobile sources. Emissions of NO_x relative to fuel consumption are much larger from diesel-driven vehicles and boats than from vehicles driven by gasoline. Stationary sources accounted for 12 per cent of the emissions of NO_x, and industrial processes for 4 per cent.

Distributed by sector, the largest emissions of NO_x in 1988 came from domestic transportation (other than private cars) (33 per cent), of which coastal water transport alone accounted for 18 per cent. Private households accounted for 17 per cent, and the fishing fleet for 15 per cent of total NO_x emissions in 1988.

Emissions of CO remained relatively stable during the 1980s up to 1985, increased up to 1987, and then decreased towards the end of the period, see figure 3.3. The reason for the increase from 1985 to 1987 was the larger sales of gasoline combined with the fact that almost 70 per cent of the total CO emissions comes from combustion of gasoline. The increase in purchases and use of private cars in the 1980s had a stronger impact than improvements in technical standard. There has been a slight decrease in the sale of transport oils (inclusive gasoline) during the last two years.

Emissions of CO from industrial processes have remained stable throughout the period. Emissions from stationary sources increased slightly during the 1980s due to more use of wood for fuel. However, the estimates for wood consumption are based on uncertain data.

Figure 3.3. Emissions of CO by source. 1973-1990*. 1 000 tonnes

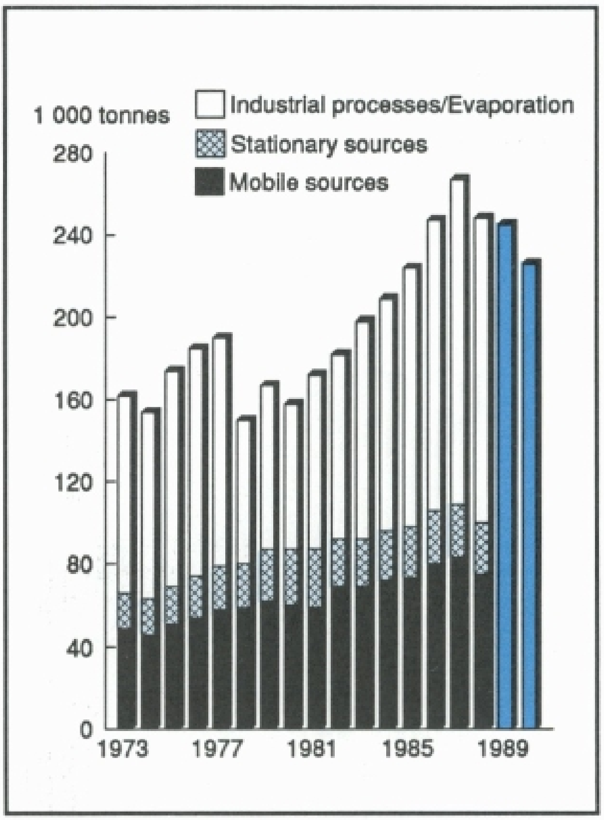


Source: CBS, SFT.

In 1988, as much as 74 per cent of the emissions of carbon monoxide came from mobile sources. Stationary combustion accounted for slightly less than 20 per cent of the total CO emissions, the main source being combustion of wood. Heating based on combustion of wood accounted for about 90 per cent of the stationary emissions of carbon monoxide. Private households are the most important source of emissions, accounting for 68 per cent of total emissions and 95 per cent of stationary emissions of carbon monoxide.

Emissions of VOC 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 gas. The increase in total emissions up to 1987 can be partly put down to landing of gas from new fields and, like the emissions of CO, to a higher level of emissions from mobile sources, see figure 3.4. It was not until recently that one realized the extent of VOC emissions from petroleum activities. In 1988 these emissions amounted to 85 000 tonnes.

Figure 3.4. Emissions of VOC by source. 1973-1990*. 1 000 tonnes



Source: CBS, SFT.

The main sources of emissions of volatile organic compounds (VOCs) are evaporation and industrial processes other than combustion. In 1988 these sources accounted for just over 60 per cent of the total emissions. Incomplete combustion in mobile sources accounted for about 30 per cent of the emissions. The largest sources of evaporation are petroleum activities (34 per cent) and use of solvents (almost 20 per cent). Another important source of VOC emissions is evaporation connected to storage and sales of gasoline. Stationary combustion accounted for 10 per cent of the VOC emissions in 1988. The estimates for VOC emissions are fairly rough and must be regarded as uncertain. Evaporation of solvents has not as yet been distributed by sector.

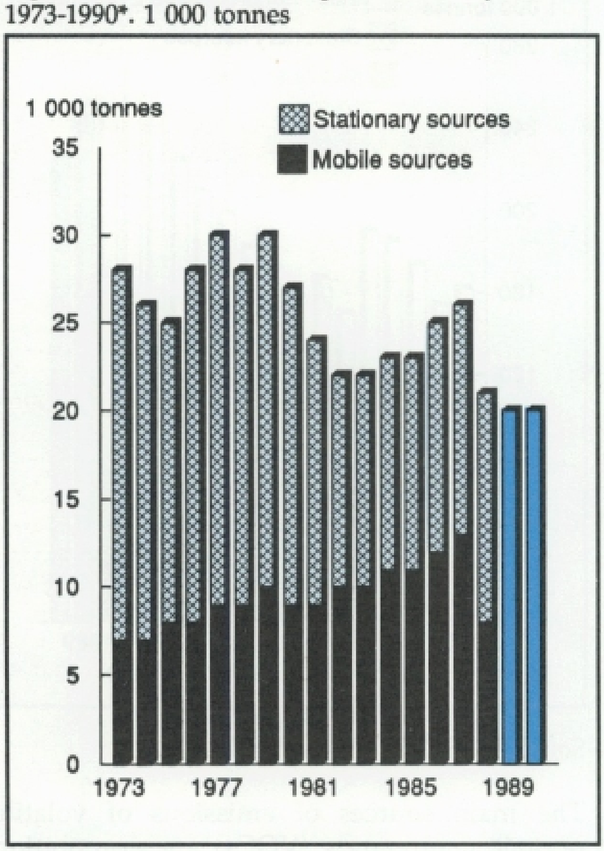
Emissions of particulates decreased from 1973 up to 1983, see figure 3.5. This was mainly due to less extensive stationary combustion of heavy oils. Emissions then increased up to 1987 due to high consumption of wood in private households and a general increase in traffic. Emissions have decreased again in recent years, especially emissions from coastal water transport.

Diesel-driven motor vehicles are the most important mobile source of emissions of particulates.

In 1988, private households accounted for more than 60 per cent of total emissions of particulates, and 19 per cent came from domestic transportation (other than private cars).

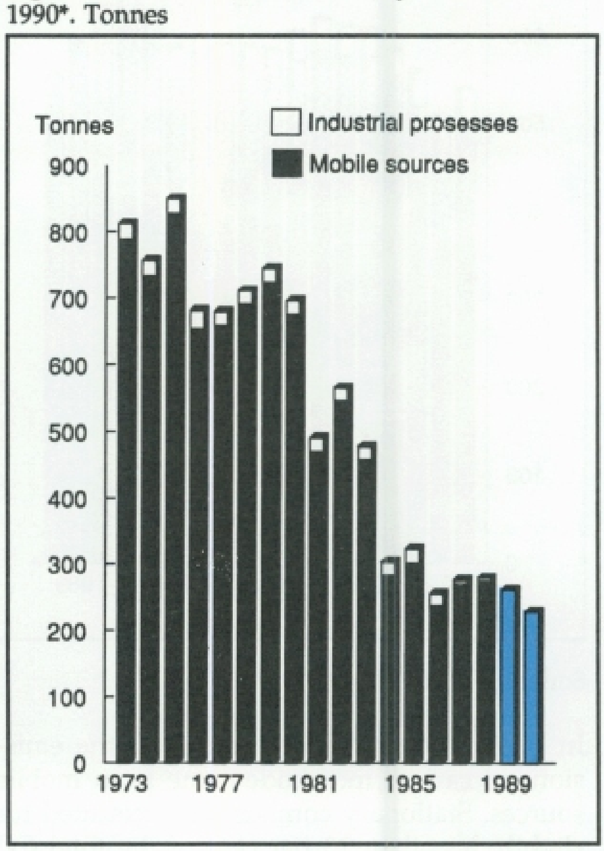
There was a marked reduction in **emissions of lead** up to 1986, see figure 3.6. This was due to reduced content of lead in gasoline (the regulations entered into force in 1980 and 1983) and the introduction of non-leaded gasoline as from 1986. Emissions of lead from industrial processes remained fairly stable up to 1986, after which there was a marked reduction due to the closing down of the smelting works at Sulitjelma and decreased production of iron and steel.

Figure 3.5. Emissions of particulates by source. 1973-1990*. 1 000 tonnes



Source: CBS, SFT.

Figure 3.6. Emissions of lead by source. 1973-1990*. Tonnes



Source: CBS, SFT.

As much as 97 per cent of emissions of lead in 1988 came from mobile sources and are almost entirely due to addition of lead to gasoline. The rest of the emissions originate from industrial processes in the metallurgical industry, and from incineration of waste and combustion of oil.

In 1988 the most important sources of emissions were private households, wholesale and retail trade, domestic transportation (other than private cars) and other private services.

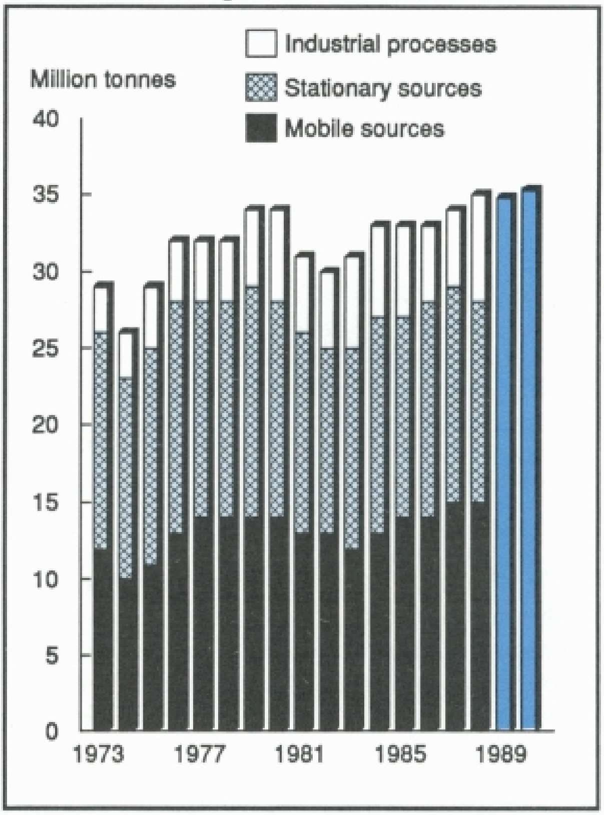
Emissions of CO_2 have fluctuated somewhat during the period. Figure 3.7 shows a marked reduction in emissions from 1973 to 1974, followed by an increase up to 1979/1980. Emissions decreased again up to 1982, after which there has been a slight, but steady increase. The reason for the two distinct reductions in emissions of CO_2 was reduced consumption of oil products due to the rise in oil prices in 1973-74 and 1979-80. The effects of these higher oil prices are particularly marked for CO_2, since these emissions cannot be decreased by cleaning.

Mobile sources accounted for 44 per cent of CO_2 emissions in 1988, and stationary combustion for 37 per cent. 19 per cent came from industrial processes. The largest source of CO_2 emissions was domestic transportation (other than private cars) (17 per cent), fairly equally distributed between land, sea and air transport.

Private households were responsible for 17 per cent of the CO_2 emissions, gas and oil extraction on the continental shelf for 15 per cent, metals production for 14 per cent, and chemicals and minerals production for 5 per cent.

In 1988 **emissions of the two greenhouse gases CH_4 and N_2O** amounted to about 293 000 tonnes and almost 13 000 tonnes respectively. The CH_4 emissions originated from two main sources; domestic animal husbandry, which accounted for 100 000 tonnes or 34 per cent of the emissions, and waste deposit sites (landfills), which accounted for 160 000 tonnes or 55 per cent of the total emissions in 1988. There are also two dominating sources of N_2O emissions; production of nitric acid, which accounted for 6 000 tonnes or 47 per cent in 1988, and use of agricultural fertilizer, which accounted for 4 000 tonnes, or just over 30 per cent of the emissions.

Figure 3.7. Emissions of CO_2 by source. 1973-1990*. Million tonnes CO_2



Source: CBS, SFT.

A total assessment of the greenhouse strength of CO_2, CO, CH_4, N_2O, NO_x and VOC

Certain gases upset the global radiation balance by directly absorbing heat radiated from the earth. Other gases have an indirect impact on this balance through chemical reactions which affect concentration and distribution of substances which absorb the radiated heat. These gases and their behaviour in the atmosphere are discussed in *"Natural Resources and the Environment 1989"*, chapter 6 (CBS, 1990a).

CO_2 is the gas which makes the greatest contribution to the increased greenhouse effect. One way of estimating the relative importance of the different greenhouse gases for climate is to convert the warming effect (greenhouse strength) of these gases into CO_2-equivalents. Such conversions must be based on several assumptions, many of them somewhat uncertain. Therefore calculations of the greenhouse strength of emissions of the different gases will also be subject to a certain degree of uncertainty over and above the uncertainty connected to the physical emission figures.

Table 3.6. Greenhouse strengths of certain gases. Indirect effects are taken into account. CO_2-equivalents per kg emissions

CO_2	1
CO	4
CH_4	14
N_2O	300
NO_x	17
VOC	1.7

Source: SFT.

Table 3.6 shows the greenhouse strengths used in the calculations. Indirect effects of chemical reactions in the atmosphere are taken into account. These greenhouse strengths, or climate factors, will be revised as further knowledge is obtained.

Table 3.7 shows emissions of CO_2, CO, CH_4, N_2O, NO_x and VOC by sector, measured in terms of CO_2-equivalents, and table 3.8 shows emissions distributed by source.

CO_2 is clearly the most important greenhouse gas and alone accounted for about 70 per cent of the increased greenhouse effect from the compounds included in this survey from 1988. The next most important gases in this connection are CH_4, NO_x and N_2O, each of which contributed 8 per cent. About 5 per cent of the effect was due to CO, and VOC accounted for only 1 per cent of the Norwegian anthropogenic contribution to increased greenhouse effect. Note that emissions of CFCs and halons are not included in these calculations.

In 1988, mobile sources accounted for 42 per cent of the total emissions in terms of CO_2 equivalents, with road traffic as the most important source of emissions (22 per cent), see table 3.8. Stationary combustion, and industrial processes and evaporation were each responsible for 29 per cent.

The industrial sectors combined accounted for almost 30 per cent of the emissions. Large quantities of greenhouse gases were emitted from energy-intensive industry in particular. 18 per cent of the emissions came from private households, 15 per cent from domestic transportation (not including private cars), 12 per cent from primary industries, another 12 per cent from private and public services, and 11 per cent from other industries, mainly petroleum activities, see table 3.7.

Table 3.7. Emissions to air by sector. 1988. Million tonnes CO_2-equivalents

Sector		NO_x	CO	CO_2	VOC	CH_4	N_2O
	Total	3.8	2.5	34.5	0.3	4.1	3.8
11	Agriculture	0.1	0.1	0.7	0.0	1.5	1.2
12	Forestry	0.0	0.0	0.1	0.0	0.0	0.0
13	Fishery etc.	0.6	0.0	1.5	0.0	0.0	0.0
15	Manuf. of consumer goods	0.0	0.0	0.7	0.0	0.0	0.0
25	Manuf. of production input commodities and investment goods	0.1	0.0	2.4	0.0	0.0	0.1
34	Manuf. of pulp and paper products	0.0	0.0	0.4	0.0	0.0	0.1
37	Manuf. of industrial chemicals	0.1	0.2	1.9	0.0	0.0	1.8
40	Petroleum refining	0.0	0.0	1.0	0.0	0.0	0.0
43	Manuf. of metals	0.1	0.0	5.0	0.0	0.0	0.0
45	Manuf. of fabricated metal prod.	0.0	0.0	0.2	0.0	0.0	0.0
50	Shipbuilding and platform construction	0.0	0.0	0.1	0.0	0.0	0.0
55	Construction	0.1	0.0	0.6	0.0	0.0	0.0
63	Financing and insurance	0.0	0.0	0.1	0.0	0.0	0.0
64	Oil and gas extraction	0.2	0.0	4.7	0.1	0.2	0.1
68	Oil well drilling	0.1	0.0	0.3	0.0	0.0	0.0
71	Prod. of electricity[1]	0.0	0.0	0.1	0.0	0.0	0.0
75	Domestic road transport	0.5	0.1	2.0	0.0	0.0	0.1
76	Domestic air transport	0.1	0.0	1.6	0.0	0.0	0.0
77	Coastal water transport	0.7	0.0	1.9	0.0	0.0	0.0
78	Rail transport	0.0	0.0	0.1	0.0	0.0	0.0
79	Post and telecommunications	0.0	0.0	0.2	0.0	0.0	0.0
81	Wholesale and retail trade	0.2	0.2	1.3	0.0	0.0	0.0
83	Housing	0.0	0.0	0.0	0.0	0.0	0.0
85	Other private services	0.1	0.1	0.6	0.0	0.0	0.0
92	Defence	0.1	0.0	0.6	0.0	0.0	0.0
93S	Education and research (state)	0.0	0.0	0.0	0.0	0.0	0.0
93K	Education and research (municipal)	0.0	0.0	0.1	0.0	0.0	0.0
94S	Health and social welfare services (state)	0.0	0.0	0.0	0.0	0.0	0.0
94K	Health and social welfare services (municipal)	0.0	0.0	0.2	0.0	0.0	0.0
95S	Other public services (state)	0.0	0.0	0.1	0.0	0.0	0.0
95K	Other public services (municipal)	0.0	0.0	0.0	0.0	2.2	0.0
P	Private households	0.7	1.7	6.0	0.1	0.1	0.2

1) Incl. emissions from waste incineration plants.

2) Evaporation from storage and handling of gasoline, and from use of solvents, is not included in this table, see table 3.8.

Sources: CBS, SFT.

Table 3.8. Emissions to air by source. 1988. Million tonnes CO_2-equivalents

Sources	NO_x	CO	CO_2	VOC	CH_4	N_2O
TOTAL	3.8	2.5	34.5	0.4	4.1	3.8
STATIONARY COMBUSTION	0.5	0.5	12.6	0.0	0.1	0.6
- Industrial combustion	0.4	0.0	9.1	0.0	0.0	0.3
- Non-industrial combustion	0.1	0.5	3.4	0.0	0.1	0.2
- Incineration of waste	0.0	0.0	0.1	0.0	0.0	0.0
INDUSTRIAL PROCESSES AND EVAPORATION	0.2	0.2	6.7	0.3	3.9	3.0
- Pulp and paper products	-	-	-	-	-	-
- Manuf. of industrial chemicals	0.1	0.1	1.0	0.0	-	1.8
- Mineral products	-	-	1.0	-	0.0	-
- Petroleum refining	-	-	-	0.0	-	-
- Manuf. of metals	0.1	0.0	4.5	0.0	-	-
- Agriculture, liming	-	-	0.2	-	-	-
- Agriculture, domestic animal husbandry	-	-	-	-	1.4	-
- Agriculture, fertilizing	-	-	-	-	0.1	1.2
- Petroleum activities[1]	-	-	-	0.1	0.2	-
- Landfills (waste disposal)	-	-	-	-	2.2	-
- Storage of gasoline	-	-	-	0.0	-	-
- Filling stations	-	-	-	0.0	-	-
- Solvents	-	-	-	0.1	-	-
MOBILE SOURCES	3.3	1.9	15.2	0.1	0.1	0.2
- Motor vehicles	1.4	1.6	7.8	0.1	0.1	0.1
- Light vehicles	0.8	1.4	5.3	0.1	0.0	0.1
-Gasoline	0.8	1.4	4.9	0.1	0.0	0.0
-Diesel	0.0	0.0	0.4	0.0	0.0	0.0
-Heavy vehicles	0.6	0.1	2.5	0.0	0.0	0.0
-Gasoline	0.1	0.1	0.4	0.0	0.0	0.0
-Diesel	0.6	0.0	2.1	0.0	0.0	0.0
- Small motorized tools, motorcycles, mopeds, tractors and motorized equipment	0.2	0.3	1.1	0.0	0.0	0.0
- Railways	0.0	0.0	0.1	0.0	0.0	0.0
- Air transport	0.1	0.0	1.9	0.0	0.0	0.0
- Coastal water transport	0.8	0.0	2.2	0.0	0.0	0.0
- Fishing fleet	0.6	0.0	1.5	0.0	0.0	0.0
- Petroleum activities	0.1	0.0	0.6	0.0	0.0	0.0

1) Including gas terminals.

Sources: CBS, SFT.

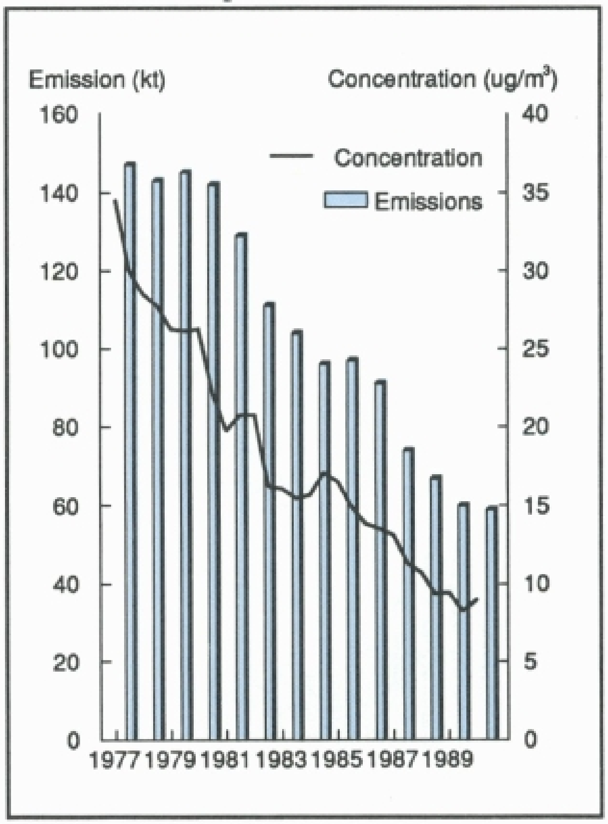
3.3. Trends in regional concentrations of pollutants

During the period from April 1989 to March 1990 air pollution concentrations were measured at 32 stations in 26 towns and urban areas as part of the national pollution monitoring programme (SFT, 1990a). The measurements, which give 24 hour averages for sulphur dioxide, lead, soot and nitrogen oxides, are taken at different times of the year, and the length of the time series for the different components varies. For instance, measurements of NO_2 were not started until 1986. Measurements are also taken at a number of stations in addition to the regular ones, including 9 stations in Sør-Varanger to chart the SO_2 load in the area caused by emissions from the Soviet nickel works in Nikel and Zapoljarnij.

The measurements show that the concentration of all components varies significantly over the year, with higher levels in winter and lower levels in summer. This variation is due to more oil consumption in winter for heating, and therefore increased emissions, plus the fact that pollution is not spread to the same extent in winter as in summer. Figures 3.8-3.10 show seasonal variations and changes in the average concentration of sulphur dioxide, soot and lead as measured at stations in some 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, averaged for several towns, seem to follow variations in national emissions of the polluting compounds.

Figure 3.8 shows a marked decline in the average concentration of sulphur dioxide the last ten years in the towns included in the measurement programme. However, the average values indicate sporadic periods of poor air quality. In the case of some compounds, such as SO_2 and NO_2, greatest harm occurs during brief periods with high concentrations. However, the measurements show only few episodes with high concentrations of SO_2, and low concentrations during the winter of 1989/90. This is partly because this was a very mild winter, especially in Eastern Norway, which meant low consumption of oil for heating. Episodes with high concentrations of SO_2 occur most often in places with high levels of emissions from production processes at local industrial enterprises. The highest SO_2 concentrations are now measured in the counties of Østfold (Sarpsborg and Halden) and Sogn og Fjordane (Årdalstangen and Øvre Årdal). Finnmark experiences high concentrations of SO_2 due to transboundary pollution from the Soviet Union.

Figue 3.8. Average concentration of SO_2 in air in some larger Norwegian towns. µg SO_2 /m³. National emissions of SO_2. 1 000 tonnes. 1977-1990



Sources: NILU, CBS.

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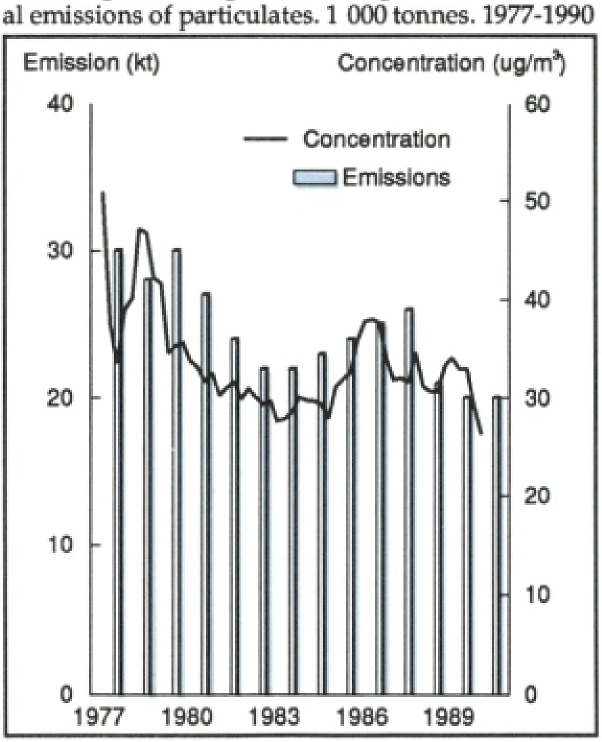
The soot concentration showed a tendency to decline at the beginning of the period, but in recent years has varied around a somewhat higher level, see figure 3.9.

Measurements exceeding the critical level were obtained for soot during the winter of 1989/90. The 24-hour average value (150 µg/m³) was exceeded in Fredrikstad, Oslo, Skien and Bergen. It is safe to assume that most urban areas will experience soot concentrations above the critical level along roads with heavy traffic. Relatively high temperatures and good spreading conditions have led to a clearly lower level of soot concentrations in winter during the last three years than measured in previous years.

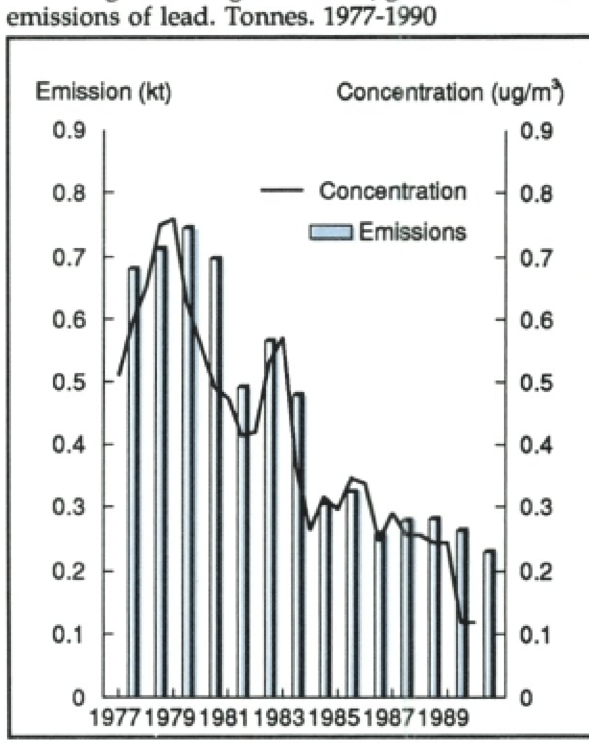
Lead concentrations have been reduced significantly following the gradual changeover to non-leaded gasoline. A period of marked reductions in lead concentrations in urban air early in the 1980s has been followed by smaller reductions in recent years, see figure 3.10. No lead concentrations exceeding the critical level were measured in the air at any station during the winter 1989-1990.

Figure 3.9. Average concentration of soot in air in some larger Norwegian towns. µg soot/m³. National emissions of particulates. 1 000 tonnes. 1977-1990



Sources: NILU, CBS.

Figure 3.10. Average concentration of lead in air in some larger Norwegian towns. µg Pb/m³. National emissions of lead. Tonnes. 1977-1990



Sources: NILU, CBS.

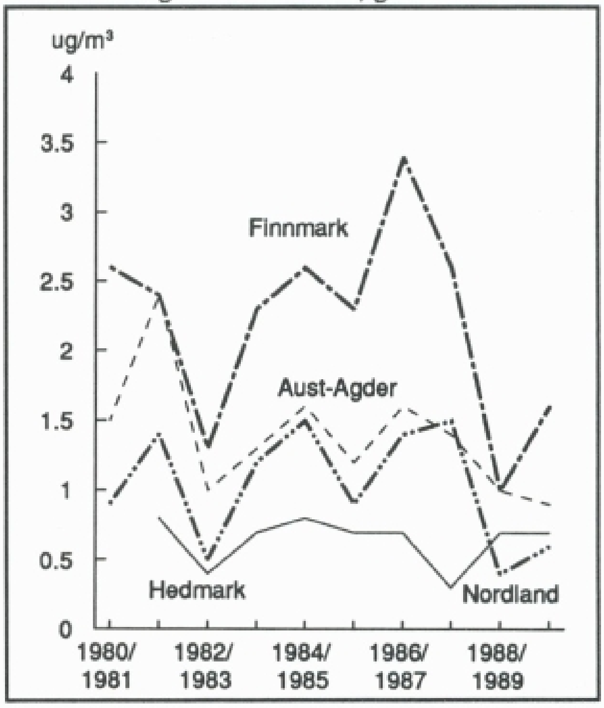
Measurements of NO_2 concentrations did not start until autumn 1986. The results show that, during the winter of 1989/90, the critical level for the 24 hour average (100 µg/m³) was exceeded at 4 out of 13 stations. Despite this, average values were lower than in the year before. The highest 24 hour average values were measured in Drammen, Lillehammer and Bergen. The critical level for the half-yearly average (75 µ/m³) was not exceeded at any of the stations. Emissions from road traffic are the main cause of high concentrations of NO_2.

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. A substantial share of the pollution comes from abroad. It has been estimated, for instance, that Norwegian emissions account for only 8 per cent of depositions of SO_2 in Norway. Figures 3.11 and 3.12 show annual mean of half-yearly average concentrations for SO_2 and particulate sulphate at some of the background stations. The measurements show a slight declining tendency at most stations. The figure also shows that the sulphur load at the background stations varies between regions. The highest average concentrations are measured at stations in southern Norway (Birkenes), south-west Norway (Skreådalen) and East Finnmark (Jergul).

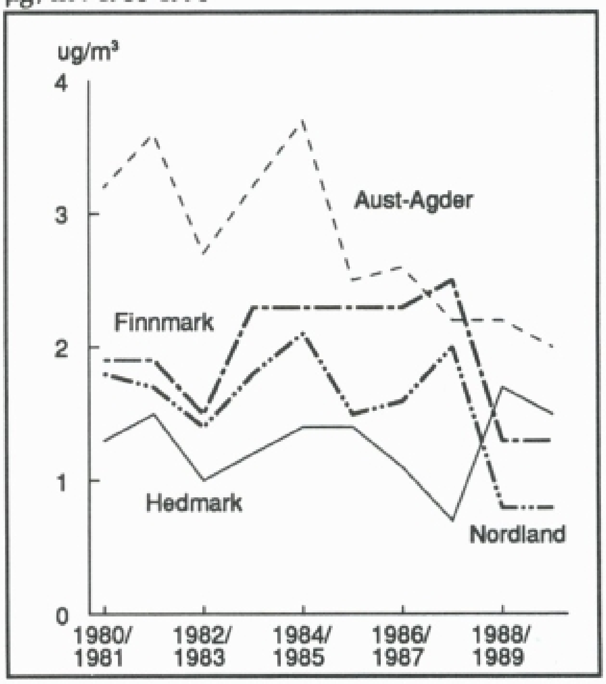
The air quality at the background stations can vary considerably from day to day. A large share of the annual contribution of pollutants often occurs in the course of relatively few days, usually in winter. The highest values are measured when air that has remained fairly stable over heavily industrialized areas in Europe is blown to Norway.

Figure 3.11. Annual average concentrations of SO_2 at some background stations. µg/m³. 1980-1990



Sources: NILU, SFT.

Figure 3.12. Annual average concentrations of particulate sulphate at some background stations. µg/m³. 1980-1990



Sources: NILU, SFT.

3.4. Emissions to air and economic development 1985-1987

Section 3.2 above presents figures for emissions to air distributed between private households and various industrial sectors. These figures show which sectors produce the emissions, but say nothing about the economic mechanisms which contribute to shifts in the composition of industry from year to year. This section considers how annual changes in economic variables such as private consumption, export and investments have led to changes in emissions to air in Norway. The discussion refers to the period 1985-1987 and focuses on total energy consumption, and on emissions of the three polluting compounds SO_2, NO_x and CO_2.

An illustration may serve to make the problem more explicit. There was a strong growth in private consumption in Norway in the mid-1980s. The increase in consumption was strongest from 1984 to 1985, but was also fairly strong from 1985 to 1986. In order to calculate how much the emissions increase as a result of increased consumption it is not enough to consider the trend in emissions from the private households alone. Higher consumption implies increased production of goods and services, which leads to higher levels of emissions. Moreover, the growth in production in its turn requires larger deliveries from the producers of raw materials, and this will lead to higher levels of emissions from these companies too. How much the emissions increase will depend to a large extent on what kind of goods and services the increased consumption refers to.

The effects on emissions of annual changes in private consumption, investments, export and other macroeconomic variables have been calculated using a macroeconomic model coupled with information on energy consumption and emissions to air. The model is a relatively detailed input-output model based on CBS's macroeconomic model MODIS V. It specifies 44 production sectors and 53 different groups of commodities.

The size of the most important components of the demand, the greater part of the import, and production in the public sector, primary industries, petroleum activities, refineries and power supply are determined outside the model. This makes it possible to insert figures for these variables over time. It is assumed that the relationship between input factors and produced quantity is constant for the sector concerned during the whole period, but that emissions and energy use per produced unit vary from year to year. Given these assumptions the model determines the extent of the change in production in each sector following a change in the demand for the different groups of commodities. Coupled with information on the amount of energy used and the amount of emissions per produced unit in each sector, this gives an estimate of increases (or reductions) in energy use and emissions due to changes in demand in a specific year.

This model has been used to break up the annual changes in emissions to air and use of energy. That is to say, it has been calculated how large a share of the changes in emissions and energy use each year can be put down to changes in each of the individual exogenous variables included in the model (the variables determined outside the model). The most important of these variables are mentioned above. Emissions and energy use per produced unit are also regarded as exogenous variables in this connection.

Contributions to emissions from the different components of the demand are calculated on the assumption that increased demand is covered by increased domestic production. A higher demand for products from sectors where production is determined outside the model is not included. This demand is covered by increased import or by drawing on stocks. The fact that the composition and level of import also changes during the period is taken into account as a separate item, "contribution from import". Emissions and energy use in the production of non-competing import (import of goods not produced in Norway) are excluded.

The contributions are further calculated on the assumption that emissions and energy use per produced unit remain constant throughout the year. However, the table also contains an item called "contribution due to changes in emissions and energy use", which states how much of the changes in total emissions and energy use can be put down to changes in energy use and emissions per produced unit during the period.

The economic figures are figures from the National Accounts, measured in 1988 prices, while the emissions figures are taken from CBS's inventories of emissions. Since no figures were available for CO_2 at the disaggregated level required for this analysis these figures had to be estimated specially. This means that the total figures deviate slightly from the total figures in section 3.2. The growth rates given here for aggregated figures in the National Accounts are in 1988 prices.

Emissions from ocean transportation (foreign trading) are not included in the calculations. This sector is responsible for large emissions, and uses as much heavy oil as the rest of the Norwegian economy combined. The figures for the item "contribution from export" especially would have been very different if this sector had been included. However, adequate data on use of energy in this sector are lacking. Furthermore, a large share of the emissions from ocean transportation will take place abroad, which makes it irrelevant, in a number of connections, to include these figures.

The emission inventories show large increases in emissions of SO_2 and NO_x from exploration drilling on the continental shelf during the period, while production in the drilling sector was simultaneously reduced. This has affected some of the results. Some reservation is necessary in regard to the emission figures for this sector, since they may not be completely reliable.

Factors explaining changes in emissions from 1985 to 1987

Tables 3.9 and 3.10 show annual changes in emissions, energy use and production for the periods 1985-1986 and 1986-1987.

According to table 3.9, emissions of CO_2 increased from 1985 to 1986 by almost 10 per cent. Emissions of SO_2 decreased by 7.6 per cent during this year, but emissions of NO_x increased by 9.5 per cent. In the case of all three pollutants, changes in emissions were far more dependent on changes in production than on changes in direct emissions from private households. Note that in tables 3.9 and 3.10, "contribution from production" comprises both changes in the produced volume and the contribution due to changes in emissions and energy use per produced unit.

The extent of private consumption (measured in 1988 prices) increased by 5.5 per cent from 1985 to 1986. This led to increased emissions to air both from the households themselves and from enterprises which increased production in order to meet higher consumer demand. The emissions from a higher level of production to meet increased consumption accounted for about 2 per cent of the total Norwegian emissions in 1985. If the increase in emissions from the households themselves is added to this figure, the total contribution made by private consumers to changes in emissions from 1985 to 1986 is: An increase of 3.0 per cent in total emissions of CO_2, of 1.5 per cent for SO_2, and 3.6 per cent for NO_x.

A factor of even greater importance for changes in emissions, however, was investments, which increased by 23.1 per cent from 1985 to 1986. Due to the increase in production of investment goods and raw materials, the growth in real investments alone led to an increase in emissions equivalent to more than 10 per cent of the total Norwegian emissions of SO_2. Investments also made a large contribution to changes in emissions of CO_2 and NO_x.

Import, which increased by 9.0 per cent from 1985 to 1986, had the opposite effect. This increase led to a 3-7 per cent reduction of emissions in Norway. The model assumes that increased import is matched by a decrease in domestic production.

Export decreased by 0.2 per cent in 1986, leading to a decrease of 2-4 per cent in total Norwegian emissions of SO_2, NO_x and CO_2.

The reason why such a small reduction in export led to this relatively large reduction in emissions is a decrease in export of various goods and services which involve a high degree of pollution during production, for instance metals, and a simultaneous increase in export of other goods and services.

produced unit. An important reason is that, during that year, in some industries, particularly the pulp and paper industry, part of the electricity consumption was replaced by oil, due to a poor supply of surplus power.

Table 3.9. Relative changes from 1985 to 1986 in emissions to air, energy use and production. Contribution from different macroeconomic components. Per cent of total levels of emissions, energy use and production in 1985[1)2)]

	CO_2	Emissions SO_2	NO_x	Energy use	Production[6)]
Total change 1985 - 1986	9.5	-7.6	9.5	1.3	4.7
Comprising					
- Contrib. from direct emissions and energy use in households	1.3	-0.5	1.8	1.3	-
- Contrib. from production	8.2	-7.1	7.7	0.0	4.7
Comprising:					
Private consumption	1.7	2.0	1.8	1.6	2.0
Investments	6.2	10.7	6.3	6.2	6.7
Export [3)]	-2.1	-3.6	-3.3	-2.3	-0.5
Import [3)]	-4.0	-6.8	-3.4	-4.5	-2.9
Changes in stocks[3)]	-1.0	-2.0	-0.9	-1.5	-3.1
Public production and consumption	0.2	0.3	0.2	0.3	0.5
Energy production and primary industries[4)]	1.1	0.1	1.7	-0.1	0.3
Contr. from changes in emissions and energy use[5)]	6.1	-6.8	8.5	-0.7	-
Others	-0.2	-1.0	-3.1	0.9	1.7

1) Inconsistencies in the tables are due to rounding the figures up or down. 2) Not including emissions to air and energy use in ocean transportation. 3) Contributions from export do not include export of natural gas. Contributions from import do not include import of agricultural and forestry products, oil and electricity, or non-competing imports. Contributions from stocks do not include stocks of fish products. 4) Includes petroleum activity, power supply, refineries, agriculture, forestry and fisheries. 5) Emissions and energy use as shares of gross production in each sector. 6) Measured in 1988 prices.

The last important factor explaining the changes in total emissions is changes in emissions and use of energy expressed as a share of the gross production in each sector. In the case of CO_2, this item accounted for 6.1 per cent of the change in emissions from 1985 to 1986. This means that, if production in 1986 had remained the same as in 1985, emissions of CO_2 would have increased by 6.1 per cent even so, because in 1986 industry in general emitted more of this gas per produced unit. There was no similar increase, however, in energy use per

In the case of SO_2, emissions per produced unit generally declined. The reason is cleaning and other measures such as the requirement to change to oil with a lower sulphur content. There was a strong increase in emissions of NO_x per produced unit. However, the uncertainty of the figures for exploration drilling may imply that the reduction in emissions of SO_2 per produced unit was even greater than shown, while the increase in emissions of NO_x may not have been as large as indicated in the table.

Table 3.10, covering the period 1986-1987, shows that emissions to air do not necessarily keep entirely in step with energy use and production. For instance, there was a marked reduction in emissions of sulphur dioxide that year, but an increase in use of energy.

Private consumption (calculated in 1988 prices) decreased by 1.2 per cent from 1986 to 1987. Gross investments were 1.4 per cent lower than in the preceding year. Export was reduced by 0.9 per cent, while import, which had increased substantially the year before, decreased by 7.2 per cent. The increase in the GDP measured in 1988 prices was 1.2 per cent, as against 4.1 per cent the year before.

a slight reduction in emissions from production of consumer goods. All in all, private households caused a slight increase in emissions.

The main reason for the decrease in export was the substantial decrease in production in the ocean transportation sector from 1986 to 1987. The consequent reduction in emissions is not reflected in our figures because, as mentioned above, emissions from this sector are not included. However, export of many other products increased, which led to a slight increase in emissions of CO_2 and NO_x, and a relatively strong increase in emissions of SO_2.

Table 3.10. Relative changes from 1986 to 1987 in emissions to air, energy use and production. Contribution from different macroeconomic components. Per cent of total levels of emissions, energy use and production in 1986[1)2)]

		Emissions		Energy	Produc-
	CO_2	SO_2	NO_x	use	tion[6)]
Total change 1986 - 1987	-3.8	-17.2	4.0	1.0	2.1
Comprising					
- Contrib. from direct emissions					
and energy use in households	0.3	0.6	0.5	0.4	-
- Contrib. from production	-4.2	-17.8	3.5	0.6	2.1
Comprising:					
Private consumption	-0.2	-0.2	-0.1	-0.2	-0.2
Investments	-1.3	-2.3	-2.4	-1.1	-0.8
Export[3)]	2.3	5.5	2.4	3.0	-0.2
Import[3)]	1.6	3.4	0.8	1.8	1.5
Changes in stocks[3)]	-1.7	-4.0	-0.7	-1.8	-0.7
Public production and consumption	0.4	0.4	0.4	0.4	0.7
Energy production and primary					
industries[4)]	2.2	1.5	2.6	1.7	1.1
Contr. from changes in emissions and					
energy use[5)]	-7.5	-21.2	1.3	-2.6	-
Others	0.0	-1.0	-0.9	-0.5	0.8

1) - 6) See footnotes to table 3.9.

From 1986 to 1987 too, changes in emissions were more strongly affected by changes in production, including changes in emission and energy intensities, than by changes in direct emissions from private households. Emissions from the households themselves increased only slightly during the period, and there was

The main reason for the reduction in CO_2 and SO_2 emissions from 1986 to 1987, in spite of the above, is the general reduction in emissions of these two components per produced unit throughout the different sectors. This reduction was due to a number of factors; lower energy intensity in production, change from oil to electricity, and in the case of sulphur emissions, a greater degree of cleaning and other abatement measures. Variations in the volume of production were less important.

Changes in NO_x emissions per produced unit in the different sectors contributed to an increase in total Norwegian emissions from 1986 to 1987. The main reason, however, was increased NO_x emissions in connection with drilling for oil and gas, and, as mentioned above, these figures are uncertain.

To sum up

Changes in emissions per produced unit in the different sectors were the dominating reason for changes in emissions during the period 1985 to 1987. These changes were a result of more extensive cleaning and other abatement measures, and of variations in the distribution of energy consumption between electricity and different kinds of oil. Energy use per produced unit did not vary to nearly the same extent as emissions per produced unit.

Emissions levels during the period were also affected by changes in the level of economic activity. However, relatively speaking, these changes are less important than changes in emissions per produced unit. The strong increase in investments from 1985 to 1986 was an important exception, which alone led to a marked increase in emissions of CO_2, SO_2 and NO_x. Changes in the level of private consumption, however, seem to have been of minor importance in explaining changes in emissions of these gases.

3.5. The impact of a possible international climate agreement on the Norwegian economy

Norway is party to several international agreements on the environment, see box 3.2. None of these regulate emissions of the greenhouse gas CO_2. The greenhouse problem is a global one, and can only be solved by widespread international cooperation. Even if Norwegian emissions of CO_2 account for only about 0.2 per cent of global emissions of CO_2 from fossil fuels, it is only reasonable that Norway also makes an effort to limit the increase in these emissions, or reduce them. Together with the other EFTA countries and the EEC, Norway has defined a provisional national goal to stabilize national emissions at the 1989 level. Lower Norwegian CO_2 emissions can be achieved only by reducing consumption of fossil fuels. The fact that these emissions cannot be cleaned, combined with a very large number of sources of relatively small emissions, means that the most appropriate way to reduce these emissions is to increase environmental taxes. Under certain circumstances a tax in proportion to CO_2 content will lead to cost-effective reductions of emissions. Actors with relatively high costs for marginal reduction of emissions will pay the tax, and actors with relatively low marginal costs will reduce the emissions. Cost-effectiveness is not achieved if not *all* sources of emissions are taxed.

A higher price for fossil fuel will signal to producers and consumers that consumption of this commodity causes disamenity to others in the form of pollution. In this way the price serves as a "conveyer of information". Furthermore, higher prices for fossil fuels will provide an incentive to use more energy-effective capital equipment (including means of transport) and develop alternative sources of energy. Historical data for energy use and CO_2 emissions indicate a close connection between emissions and the price of fossil fuels, see section 3.2. The rise in oil prices in 1973-74 and in 1979-80 both led to a marked decrease in oil consumption and CO_2 emissions. In addition to causing lower absolute consumption, the rise in oil prices led to the use of more energy-saving equipment in both industry and transport.

In addition, a tax on CO_2 opens up for the possibility of easing the taxes on other goods and services. In this way, taxes and duties which lead to loss of efficiency in the economy can be replaced by taxes which lead to better use of resources.

As part of its work for the Interministerial

Committee on Climate, the Central Bureau of Statistics has analyzed the possible impacts of national and international CO_2 emission-abatement measures on the Norwegian economy. A description of calculations carried out using the long-term, general equilibrium model MSG-TAX, described in more detail in box 3.3, is presented below.

The reference path

The reference path used in the calculations describes a possible trend in the Norwegian economy, energy use and emissions to air up to the year 2025. The path is characterized by a relatively moderate increase in production and a somewhat higher, though moderate, increase in private consumption. Table 3.11 shows the trend for some main economic figures in the reference path.

Estimates for the trend in the labour force are based on projections based on CBS's demographic models. The supply of manhours is expected to increase slightly up to 2010, after which it will decrease by about 0.2 per cent per year up to 2025. In relation to the years 1970-88, the increase in the labour force is low. This is due to changes in the composition of the population, with a steadily increasing number of elderly persons.

The total stock of capital is estimated to increase by an average of 1.4 per cent per year up to the turn of the century, and by 2.3 per cent per year after the year 2000. These estimates are also low in a historical perspective, but are about the same as the observed historical increase in stock of real capital in other OECD countries. The rate of technical progress is the same as the average for the 1970s and 1980s. The real increase in the price of crude oil is expected to decline from about 2.5 per cent per year up to the year 2000 to just over 0.5 per cent at the end of the period. The international economy is expected to be marked by continued specialization and a relatively moderate growth in GDP and rise in prices in our trading partner countries.

Due to the expected high rate of technical progress, the increase in the use of input factors in domestic production, including consumption of oil products, is lower than the increase in production. In spite of the increased production, and the increasing real price of oil products, the higher level of activity and higher level of income imply an 80 per cent higher consumption of fossil fuels in 2025 than in 1987. Electricity consumption increases by about 54 per cent or 56 TWh during the period of calculation, to about 159 TWh in the year 2025. The assumptions defined for price trends for natural gas give a price of just under 23 øre/kWh for gas-based electricity delivered from the plant (1987 prices). This means that, in the year 2000, electricity from gas will compete in price with hydropower. It is therefore assumed that after the year 2000 the increased demand for electricity will be covered by electricity from gas. According to the reference path, 42 TWh of the electricity produced in 2025 will be based on gas and 117 TWh on hydropower. As shown in table 3.12, increased electricity consumption leads to a marked increase in emissions to air.

The decrease in emissions of SO_2 and NO_x up to the turn of the century is due to measures that have already been adopted, such as catalytic cleaning of exhaust gases from motor vehicles and closing down several major sources of industrial pollution. In addition, emissions from combustion of oil from petroleum activities in the North Sea are reduced as a result of expected measures to reduce emissions from gas flares. The reason why emissions of VOC do not follow the same pattern as the other polluting compounds is increasing activity in the oil sector up to the turn of the century, and therefore more evaporation. Norwegian oil extraction declines after the year 2010.

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. Remember that 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 red. 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	Stabilise 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 tetrachloride	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
National goals		
	Sulphur	50 per cent red. by 1993 with 1980 as base year
	NO_x	30 per cent red. 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.

MSGTAX is a version of the macroeconomic planning model MSG-4 (Multisectoral Growth Model, Offerdal et al. 1987) used, inter alia, by the Ministry of Finance for long-term calculations of the Norwegian economy. MSGTAX is a general equilibrium model covering about 38 production sectors. It allows substitution between the input factors labour, capital, energy and materials in the production sector. Energy is an aggregate comprised of electricity and oil products, where the composition of the aggregate is determined by the relative prices of electricity and oil.

Economic development is determined in the model mainly by exogenous growth of the labour force, growth in the stock of real capital and the rate of technical change. An assumption is full utilization of available labour. Household consumption is distributed between 18 different consumer goods on the basis of price and income elasticities. Fossil fuels are included in the consumer groups "heating of dwellings" and "private transportation". Unlike in MSG, in MSGTAX the sectoral shares of exports and imports are decided by the relation between prices on the domestic and world markets. Accumulation of real capital and developments in the balance of trade in current prices are determined exogenously in the model.

Boks 3.3 MSGTAX

The decrease in emissions of SO_2 and NO_x up to the turn of the century is due to measures that have already been adopted, such as catalytic cleaning of exhaust gases from motor vehicles and closing down several major sources of industrial pollution. In addition, emissions from combustion of oil from petroleum activities in the North Sea are reduced as a result of expected measures to reduce emissions from gas flares. The reason why emissions of VOC do not follow the same pattern as the other polluting compounds is increasing activity in the oil sector up to the turn of the century, and therefore more evaporation. Norwegian oil extraction declines after the year 2010.

After the turn of the century, the effects of the measures already implemented to reduce NO_x, SO_2 and CO_2 will be fully exploited, and the emissions increase in step with economic activity and use of energy. Emissions of CO_2 are not affected by cleaning, and therefore increase throughout the period. After the year 2000 a large share of the increase is due to introduction of electricity based on gas.

The international agreement to stabilize emissions of NO_x at the 1987 level by 1994, see box 3.2, is fulfilled for some years into the next century but, according to the reference path, is exceeded by more than 26 per cent in 2025. The national target for NO_x emissions is equivalent to a ceiling of 155 000 tonnes for such emissions. According to the projections, emissions will exceed the target by about 25 per cent in the year 2000 and by about 90 per cent in 2025.

The agreement on SO_2 emissions implies a ceiling of just less than 100 000 tonnes. The national target involves reducing national emissions to about 70 000 tonnes. The projections indicate that the international agreement will be fulfilled without any additional measures, while the national target will be far exceeded in 2025.

Table 3.11. Economic trends in the reference path. Fixed prices. Mean percentage annual increase

	1987-2000	2000-2010	2010-2025
Gross domestic product	2.0	2.0	1.5
Import	3.9	2.7	2.2
Total supply	2.6	2.2	1.7
Export	3.7	1.8	1.9
Domestic use	2.1	2.4	1.6
Private consumption	1.8	3.4	1.4
Public consumption	2.2	1.8	1.7
Investments	2.6	0.3	2.1

The Storting (Norwegian National Assembly) has decided, as a provisional target, to stabilize CO_2 emissions at the 1989 level by the year 2000. This is equivalent to an emission level of about 35 million tonnes. The projections indicate CO_2 emissions which exceed this level by about 17 per cent in the year 2000. In 2025 the emissions will be almost twice as high as the target.

Assuming that the international agreements and national targets reflect a seemingly reasonable environmental load in the future, it must be said that the reference path shows a trend which does not conform with environmental considerations.

The agreement scenario

The agreement scenario is intended to show the possible effects on the Norwegian economy of an international agreement to stabilize CO_2 emissions. It is assumed that the intention of the adopted agreement is to achieve almost complete stabilization of global energy-related CO_2 emissions at the 1987 level by the year 2000, followed by an increase in emissions of about 0.6 per cent per year (The "Control Policies Scenario", by the UN Panel on Climate, IPCC, 1990). Reductions in emissions are to be achieved by means of a global tax on CO_2 emissions. The tax on CO_2 is determined exogenously in the MSGTAX, and the model is used to calculate CO_2 emissions. In MSGTAX the tax is added to the purchase price of heating oil and gasoline for consumers and producers. A tax is also imposed on other production materials which cause emissions of CO_2 during the production process. The tax is calculated on the basis of a specific tax per tonne CO_2 emissions.

The size of the tax is calculated on the basis of a number of global and national analyses of the connection between the price of fossil fuel and CO_2 emissions (CBS, 1991). The tax on CO_2 is introduced in 1995 and increases from about NOK 68 per tonne CO_2 to about NOK 1 278 per tonne in 2025, calculated in 1987 prices.

The tax on CO_2 is a source of income to the public authorities, and thus opens up for a reduction in other taxes. In principle, the effect on the Norwegian economy in general, and on distribution of income in particular, will depend entirely on how the rest of the system of taxes is changed as a result of the tax on CO_2. In MSGTAX all resources are fully utilized throughout, and economic adjustment is determined primarily by relative prices. The model automatically transfers the proceeds of the taxes back to the economy in the form of a general reduction in taxes/transfers to households. The tax on CO_2 also implies a reorganization of the tax system, and has no total contractive effect on the Norwegian economy.

Assumptions concerning international conditions

An international CO_2-agreement will influence the trend on the international energy market, and in the international economy and world trade. Higher prices for energy will lead to higher prices of products. It is assumed that the average price rise will be stronger abroad than in Norway. Expenditures on fossil fuel account for a relatively small share of the costs for Norwegian producers in relation to our trade partners. On average, if crude oil, gas and products from energy-intensive industry are excluded, nominal import prices in the agreement scenario are 5 per cent higher than the prices shown in the reference path in the year 2000, and 18 per cent higher in 2025. For the products of energy-intensive industry, the increase in prices on the world market is that same as in Norway (CBS, 1991).

Due to lower demand the price of crude oil is expected to be lower than it would be without an international CO_2-agreement. The nominal prices of crude oil and gas increase to about the same extent as shown by the reference path. In the agreement scenario the real price is about 15 per cent below the level of the reference path in 2025. The price trends for imported gasoline and heating oil are assumed to be the same as for crude oil.

Among our trade partners the annual growth in GDP is expected to be about 0.25 percentage points lower than shown in the reference path throughout the period. This is the same as if the GDP of our trade partners is reduced by 1.4 per cent in 2000 and 7.3 per cent in 2025 as a consequence of the tax on CO_2 (CBS, 1991). This is incorporated into MSGTAX in the form of equivalent reductions in the market indicators for Norwegian products on the world market, and in exogenous import.

than in the reference path.

In the second place the higher price of fossil fuels will lead to more use of bioenergy and heat pumps, and will provide a greater incentive for energy saving, for example, in the electricity sector. Based on calculations by SFT (SFT, 1990b) it is assumed that it will pay to produce 10 TWh bioenergy, that 10 TWh can be saved by using heat pumps, and that 5 TWh can be obtained by refurbishing and upgrading the existing production and transmission system. Energy from these sources is not included in the reference path, and it is assumed that the price of electricity must exceed the highest price in the reference path before the above-mentioned sources are taken into use. This is equivalent to a price of 28 øre/-kWh delivered from the plant.

Table 3.12. Projections of emissions. Levels[1)] and average percentage increase

	Levels				Annual increase		
	1987	2000	2010	2025	1987-2000	2000-2010	2010-2025
SO_2 (kt)	75	72	77	96	-0.3	0.7	1.5
NO_x (kt)	232	209	239	293	-0.8	1.4	1.4
CO (kt)	653	514	543	629	-1.9	0.6	1.0
VOC (kt)	266	305	334	305	1.1	0.9	-0.6
Particulates (kt)	25	23	25	29	-0.6	0.6	1.0
CO_2 (Mt)	35	41	52	68	1.2	2.4	1.8
CH_4 (kt)	286	278	281	278	-0.2	0.1	-0.1
N_2O (kt)	13	14	14	16	0.0	0.7	0.9

1) kt = thousand tonnes, Mt = million tonnes.

Assumptions concerning the electricity market

The tax on CO_2 is expected to lead to a different path for energy coverage and price of electricity than shown by the reference path. In the first place, electricity from gas will be much more expensive in the agreement scenario than in the reference path, because production of electricity from gas generates large emissions of CO_2 which are subject to tax, or costs are incurred for "cleaning" the emissions. The agreement scenario assumes a technology based on an offshore gas fired power station with injection of CO_2 into oil and gas reservoirs. Calculations indicate that this technology can produce electricity at a cost of about 34 øre/kWh (1987 prices) (SFT, 1990b). This price is lower than the price of electricity from traditional gas fired power plants when the tax on CO_2 is included. Therefore, electricity from gas fired power plants becomes competitive at a much later date in the agreement scenario

Estimates from NVE (The Norwegian Water Resources and Energy Administration) indicate a production potential of about 39 TWh from new hydropower sources, excluding protected watercourses and watercourses under development. Thus, data from NVE and SFT have provided the basis for constructing a long-term marginal cost for CO_2-free electricity. For technical reasons the calculations treat all production of energy, including energy saved by use of heat pumps, as conventional hydroelectricity. The price of electricity keeps in step with NVE's estimates of the long-term marginal cost of new hydropower until this becomes equivalent to the price of energy from heat pumps, bioenergy and energy saving in the electricity sector. Once these sources of energy are completely exploited, the price of electricity again follows the long-term marginal cost of hydropower until this price reaches the price of electricity produced at offshore gas fired power plants with injection of CO_2. Electricity over and above this is produced at gas fired power stations based on the above technology.

Effects on the Norwegian economy

Table 3.13 shows changes in some important economic variables in the agreement scenario in relation to the reference path.

In spite of a substantial increase in the price of energy and a marked reduction in energy use, the tax on CO_2 has only a slight effect on the growth of GDP. In 2025, the GDP is 3.2 per cent lower than if no tax had been imposed. That is to say, the same level of production is reached about two years later than would have been the case without a CO_2-agreement, which is therefore no threat to economic growth. In 2025 Norway's disposable real income is reduced by 9 per cent in relation to the reference path.

The trade balance in current prices is presumed to be the same as in the reference path. The real price of oil products is lower than in the reference path, and this reduces the value of exports of oil and gas. Export of oil and gas accounts for a large share of total export at the start of the period, so that a fall in real prices has a strong effect. Thus, to preserve the balance of trade it is necessary either to increase the value of other exports and/or decrease imports. Resources are transferred to the traditional industries exposed to competition from abroad, and there is a fairly sharp reduction in consumption. As time goes on, exports of oil and gas gradually become less important. In the light of the assumed effects of a CO_2-tax on the international economy, the rise in the prices of certain commodities will be higher on the world market than in Norway. This deviation increases into the next century. Imports decline, but production of traditional export goods must still increase at the expense of production of consumer goods. In order to achieve a positive development of traditional export, wage increases must be reduced in relation to the reference path. A lower rate of wage increases, a lower real price of oil and gas, and changes in the terms of trade, lead to a stronger decline in private consumption than indicated by the decrease in the GDP alone.

Table 3.13. Percentage changes in the agreement scenario in relation to the reference path. Fixed 1987 prices

	2000	2010	2025
Gross dom. product .	-2.2	-2.0	-3.2
Import	-7.3	-10.2	-11.2
Total supply	-3.8	-4.6	-6.0
Export	0.4	-0.2	-5.1
Domestic use	-5.7	-6.6	-6.4
Private consumption	-10.3	-11.0	-10.8
Public consumption .	0.6	0.7	0.8
Investments	-0.4	-0.6	-1.2
Disposable real income	-7.2	-8.7	-9.0

It is often maintained in the course of the debate that unilateral measures by Norway would reduce the Norwegian standard of living more than an international climate agreement would. The above analysis indicates that in the long term perspective the opposite is the case, because an international agreement would lead to lower prices for our exports of crude oil and gas. Earlier studies (Glomsrød et al., 1990) indicate that the decrease in consumption is more a result of the fall in petroleum prices than of the decrease in GDP. Thus industrial development shifts towards higher production in traditional industries that are vulnerable to international competition, while the industries that are hardest hit by a tax on CO_2 are the service industries and the industries supplying consumer goods to the home market.

Effects on use of energy

Table 3.14 shows changes in the purchaser price index and consumption of the different sources of energy as a result of a tax on CO_2.

For industry and the public sector the higher price of heating oils averages 144 per cent in relation to the reference path in 2025. For households, the price of heating oil increases by 140 per cent and for gasoline by 60 per cent. In the year 2025 gasoline will cost about NOK 9.70 per litre in 1987 prices, of which the tax on CO_2 accounts for about a quarter.

Since the tax on CO_2 makes "uncleaned" gas-based electricity unsuitable as a source of energy for economic reasons, in the year 2025 the price of electricity for regular consumption will lie about 22 per cent above the price in the reference path. The price of electricity delivered at the plant is then about 32 øre/-kWh in terms of 1987 kroner. The price of electricity for energy-intensive industry increases by about 17 per cent in relation to the reference path.

The growth in the consumption of heating oils in the public sector is expected to decrease by about 0.7 per cent annually up to the year 2000, and by 0.4 per cent annually after that year.

The tax on CO_2 leads to a marked reduction of energy use throughout the economy. As long as the energy demand can be covered by increased hydropower production and new, clean sources of energy, the tax has a greater effect on the price of heating oil than on the price of electricity. In private households some of the oil consumption will be compensated by more use of electricity, but there will also be a large decrease in total energy consumption. In private households, the tax on CO_2 will lead to a reduction of about 11 per cent in the consumption of oil and electricity combined in the year 2025. The energy-saving potential is estimated to be about 13 per cent in dwellings, at a price of energy lower than shown in the agreement scenario, and a decrease in energy use is thus not unrealistic (Report no. 61 (1988-89) to the Storting).

Electricity export is about the same as shown in the reference path.

During the period 1987 to 2025 the demand for electricity (including losses in the transmission network) increases by about 44 TWh. About 25 TWh is produced by means of heat pumps and bioenergy, or is provided through energy-saving measures in the electricity sector. The remainder is covered by traditional hydropower projects. According to the calculations, electricity from gas fired power plants not involving emission of CO_2 will not be a rele-

Table 3.14. Purchaser price index for energy sources and commodities used in production. Consumption of sources of energy and production commodities. Percentage change in the agreement scenario in relation to the reference path

	2000		2010		2025	
	Price index	Consumption	Price index	Consumption	Price index	Consumption
Private consumption						
Gasoline	26	-21	48	-38	60	-48
Fuel	62	-39	84	-66	140	-90
Electricity	10	3	5	6	22	6
Production sectors - total						
Oil products	98	-25	118	-29	144	-37
Electricity	10	-2	5	0	22	-9

vant source of energy until after 2025.

Emissions

Table 3.15 shows the calculated emissions to air based on the assumptions in the agreement scenario, and the percentage change in relation to the reference path.

The graded CO_2-tax leads to a reduction of almost 60 per cent in total CO_2 emissions in 2025 in relation to the reference path.

A large share of the decrease (45 per cent) is due to the disappearance of emissions from gas fired power plants. Emissions of CO_2 from oil and gas production in the North Sea are reduced by about 2.5 million tonnes by changing over to hydroelectricity instead of gas turbines. Emissions from other stationary sources, and from mobile sources, are both reduced by just over 50 per cent, and emissions from production processes are reduced by just over 15 per cent. The reduction of emissions from production processes is smaller than the reduction of emissions from combustion because the materials used in production generate CO_2 emissions in only a few sectors of industry. In these sectors, however, emissions from production processes are reduced considerably. Furthermore, in the agreement scenario, production in industries that are exposed to international competition increases relative to production in other industry, and it is these former sectors which generate the largest emissions of most components of air pollution during the production process.

The tax implies that all emissions caused by use of fossil fuel, as well as emissions from production processes, decrease. The agreement to stabilize NO_x emissions at the 1987 level is complied with. In the year 2025 the level of emissions is only very slightly higher (6 tonnes) than the level comparable to a 30 per cent reduction relative to emissions in 1986. Furthermore, the NO_x emissions are lower than this level for most of the calculated period. Thus, it can be said that the national target for NO_x emissions is achieved.

Table 3.15. Emissions in the agreement scenario and percentage change in the agreement scenario relative to the reference path

	2000		2010		2025	
	Level	Change	Level	Change	Level	Change
SO_2 (kt)	55	-24	54	-30	59	-39
NO_x (kt)	151	-28	155	-35	161	-45
CO (kt)	377	-27	345	-36	349	-45
VOC (kt)	282	-8	301	-10	256	-16
Partikler (kt)	19	- 17	20	-20	21	-28
CO_2 (Mt)	29	-29	27	-48	28	-59
CH_4 (kt)	273	-2	273	-3	270	-3
N_2O (kt)	11	-15	11	-21	10	-38

kt = thousand tonnes.
Mt = million tonnes.

Both the agreement and the national target defined for emissions of SO_2 are fulfilled with a fairly good margin.

The main sources of emissions of methane (CH_4) are domestic animal husbandry and landfills. Therefore the tax does not affect these emissions.

Distributional effects of a tax on CO_2

An argument often used *against* widespread use of taxes in the environmental policy is that such taxes may have unfortunate distributional effects. The concern often refers to families with children, households in outlying districts or households with low income. The distributional effects for private consumers of rises in prices due to an international tax on CO_2 are calculated below. Households are grouped according to total consumption expenditure, type of household and geographical location. An international tax on CO_2 as described in the agreement scenario will lead to a much higher price for most consumer goods. Oil products are an important input factor in the production of a large number of goods and services. Therefore an increase in the price of oil products will lead to higher production costs for both Norwegian and foreign producers, and part of this increase is passed on to the consumer. The price increase depends on how large a share of the production costs of a specific good or service refers to oil products and to what extent the increased production costs can be transferred to the price of the product. The average nominal prices of all goods and services are estimated to be about 28 per cent higher in 2025 in the agreement scenario, i.e. with a CO_2-tax, than shown in the reference path.

The distributional effects of a tax increase can be measured using a Laspeyres cost of living index. The index gives the costs of living after introduction of a CO_2 tax for a household, assuming the same consumption as before the tax was introduced. In other words, the index measures the amount of additional income required by a household to be able to consume exactly the same after introduction of the tax as before. Table 3.16 shows the Laspeyres index for total costs of living with an international tax of NOK 1278 (1987 prices) per tonne CO_2. The households are grouped according to different characteristics and are assumed to have the same pattern of consumption as in 1986-1988 (CBS, 1990b). The index in the reference path, which is the same as the index for unchanged cost of living, is equal to 1.

Therefore, after an international CO_2 agreement, the cost of living will increase by 23 per cent for a household with an average total income of less than NOK 50 000 per year during the period 1986-1988, assuming the pattern of consumption stays the same. For a household with an income exceeding NOK 300 000 the cost of living will increase by 25 per cent. If the distribution of the increase in cost of living is said to express a change in the distribution of income, the CO_2 tax will not be of much significance for distribution of income.

The main reason for this result is that the effects on prices to a large extent offset each other. For example, when the share of the total consumer tax on gasoline (*budget share* for gasoline) increases with income, and a higher price for gasoline thereby leads to the largest increase in the total cost of living for those with the highest income, then a higher price for gasoline will have a levelling effect on income. A price rise for electricity and oil for heating counteracts this levelling effect, because the budget shares of these products decrease with increasing income.

Grouping the households by type implies that the CO_2 tax causes slightly bigger changes in distribution of income, but in favour of the groups one normally wishes to favour. The lowest increase in the cost of living is experienced by single parents and couples with small children. This is because these households make little use of private cars. In the second place, in the agreement scenario it is necessary to lower the interest rate in society in relation to the reference path in order to preserve the balance of trade. This leads to a decrease in the price of housing. The share of the consumer expenditure referring to housing is very high for couples with small children and for single parents. This brings the cost of living index down for these groups more than for other households. The tax has the greatest negative effect for the group "other households", which includes various forms of collectives, because the budget share for housing is particularly low, and particularly high for gasoline.

If the households are grouped geographically, the calculated effects of a CO_2 tax on distribution of income are extremely small. This is because the households' pattern of expenditure on the various goods and services is much the same irrespective of where they live. There is no tendency, for example, for gasoline to account for a larger share of total expenditure among households in sparsely populated areas than among households in Oslo.

Table 3.16. Laspeyres indices for total consumption expenditure as a result of a tax on CO_2. The index in the reference path is equal to 1

All households	1.24
Households grouped by income. Average income 1986-88	
Up to 50 000	1.23
50 000 - 109 999	1.24
110 000 - 159 999	1.24
160 000 - 219 999	1.25
220 000 - 299 999	1.24
300 000 and above	1.25
Households grouped by type	
Single	1.24
Couple without children	1.25
Couple with children under 6 years	1.21
Couple with children 7-19 years	1.24
Single parents	1.22
Other types of households	1.26
Households grouped by geographical location	
Oslo and Akershus	1.24
Remainder of Eastern Norway	1.25
Agder and Rogaland (Southern Norway)	1.24
West Norway	1.24
Trøndelag	1.24
North Norway	1.24
Sparsely populated areas	1.24
Densely populated areas outside Oslo, Bergen and Trondheim	1.25

To the degree that certain groups of households have better opportunities than other households to change their pattern of consumption after the introduction of a tax on CO_2, the distributional effects may differ from those indicated above. However, distribution considerations should be ensured by means of other instruments than those connected to environmental policy and, in principle, all negative distributional effects can be compensated by returning the income from the tax in the form of special tax reductions or transfers.

3.6. Marginal pollution costs and external costs related to road traffic

Norway supports the principle that the polluter shall pay for any environmental damage caused by the pollution. The imposition of a tax is one way to follow up this principle in connection with emissions from combustion. Ideally, the tax can be fixed to equal the cost of the damage caused by an increase in emissions from a particular unit, i.e. equal to the marginal pollution cost.

This section first discusses the marginal pollution cost *per kilo emissions* of important polluting compounds. The figures can be regarded as average estimates for the country as a whole. These estimates are then used to calculate the marginal pollution costs *per litre consumption* of some important types of oil. In the case of autodiesel and gasoline, estimates have also been made of the marginal external costs per litre of oil consumption in road traffic. Finally, the figures for the marginal costs are used to calculate the benefit from a lower level of local air pollution and load of traffic as a result of climate policy measures.

Marginal pollution cost per kilo emissions

Increasing concern about the state of the environment has been gradually followed by extensive research on the damaging effects of air pollution. It is almost impossible to obtain a complete picture of all environmental costs, but considerable knowledge has been acquired about specific damaging effects. An attempt has been made, by amalgamating the results of several studies of partial damaging effects, to estimate the marginal environmental costs due to consumption of fossil fuels. Most of the information on damaging effects used as a basis for the calculations has been obtained from the State Pollution Control Authority

(SFT), the Norwegian Institute for Air Research (NILU) and the Institute of Transport Economics (TØI). It includes estimates of negative health effects of emissions of SO_2, NO_x, CO and particulates, acidification of forest and watercourses caused by national emissions of SO_2 and NO_x, and certain specific types of damage to materials from SO_2.

The methods and assumptions used in the estimates have been described by Brendemoen and Glomsrød (1991). For example, SFT has estimated what it costs if a person is exposed to emissions that are harmful to health, i.e. concentrations exceeding the recommended critical levels of the relevant polluting compounds (SFT, 1987, 1988). This cost has then been multiplied by an estimated figure for the change in the number of persons exposed to concentrations higher than the critical level, due to changes in emissions. It is assumed that, within the relevant range of variation of emissions, the correlation between emissions and the number of persons exposed to concentrations exceeding the critical level is linear, and that this can be expected to apply to the country's five municipalities with the largest population. The estimates of the marginal health costs for the country as a whole assume that the emissions in these municipalities are the only ones that are harmful.

Marginal environmental costs connected to climate and the ozone shield, grime, unpleasant odours and corrosion of buildings and sculptures of cultural value are not included in the estimates of damage presented below. However, the estimates can be said to include the most well-known cost elements connected to local damage from use of fuel.

It must be underlined that the estimates are very uncertain. This applies especially to dose-response functions defining physical damage at a specific level of pollution, and the value awarded to the cost of specific physical damage. Moreover, most of the estimates refer to data and calculations from the years 1986-1988. They are based on the levels of emissions during these years, including geographical distribution between the different kinds of sources of pollution. It is reasonable to assume that the *marginal* damage increases with increased emissions and decreases with reduced emissions. In spite of this, for the sake of simplicity the marginal costs are assumed to be constant in the calculations presented here.

Table 3.17 gives estimates of marginal pollution cost *per kg emissions* for some polluting compounds.

Table 3.17. Marginal pollution cost per kg emissions. Estimates in 1990 prices

	SO_2	NO_x	CO	Particulates
Total pollution costs	22.4	89.8	0.0	65.1
Water acidification ..	0.3	0.3	.	.
Forest acidification ..	0.6	0.6	.	.
Negative health effects	17.8	88.9	0.0	65.1
Corrosion	3.7	.	.	.

The costs connected to negative effects on health are a dominant cost component for emissions of SO_2 and NO_x. These costs are also high per kg particulate emissions. The calculations indicate that the costs connected to emissions of CO_2 are small. NO_x and particulate emissions are linked mainly to diseases of the respiratory system. Particulates are also carriers of carcinogenic substances, see table 3.1. The costs of corrosion caused by marginal emissions of SO_2 are low compared with the costs of negative effects on health. The same applies to the acidification costs per kg local emissions of SO_2 and NO_x.

Marginal pollution costs and road traffic-related costs per litre oil consumption

Based on the specific marginal costs in table 3.17, an estimate has also been made of the marginal pollution cost *per litre consumption* of some of the most important types of oil, see table 3.18. The estimates take into account that consumption of the different oil products generates emissions of several polluting compounds. The calculations are based on emission coefficients from 1987.

Table 3.18 also presents estimates of the additional external costs connected to road traffic, i.e. traffic accidents, queues, wear and tear of roads and noise. The estimates are based on data from SFT and TØI. The traffic-related marginal costs are not directly connected to consumption of fuel, but mainly to use of the roads. The original estimates were in terms of NOK per vehicle-kilometre. However, for the sake of comparison they are converted in the table to NOK per litre of consumed transport fuel. Like the estimates for pollution costs, the estimated traffic-related additional costs are uncertain.

The costs are highest for consumption of gasoline and autodiesel and refer in particular to the negative health effects of NO_x. Diesel consumption also causes certain costs connected to negative health effects of SO_2 emissions and particulates. The calculations indicate relatively high external traffic-related costs per litre consumption of gasoline and diesel.

Figure 3.13 shows the external costs connected to consumption of 1 litre gasoline or diesel in road traffic.

Figure 3.13. Marginal pollution cost and traffic-related cost per litre gasoline and diesel

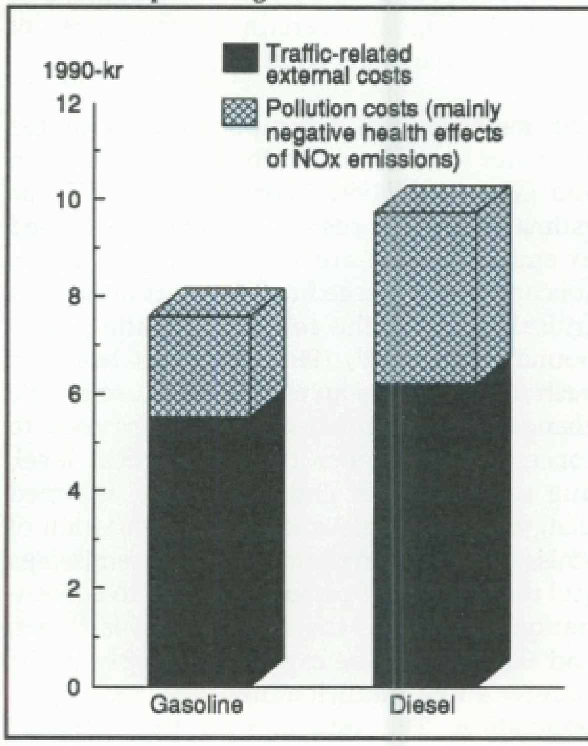


Table 3.18. Marginal pollution costs and traffic-related costs per litre oil product. Estimated in 1990 prices

	Kerosene	Heating oil	Heavy oil	Gasoline	Diesel
Total pollution and traffic-related costs	0.08	0.13	0.47	7.59	9.72
Acidification, SO_2 and NO_x	0.00	0.01	0.02	0.02	0.03
Negative health effects, SO_2	0.00	0.04	0.19	0.01	0.10
Negative health effects, NO_x	0.06	0.07	0.15	2.00	3.26
Negative health effects, CO	0.00	0.00	0.00	0.00	0.00
Negative health effects, particulates	0.01	0.01	0.04	0.03	0.12
Corrosion	0.00	0.01	0.07	0.00	0.01
Total pollution costs	0.08	0.13	0.47	2.06	3.52
Traffic accidents	.	.	.	1.32	1.48
Queues	.	.	.	1.41	1.58
Wear of roads	.	.	.	1.77	1.99
Noise	.	.	.	1.02	1.15
Total traffic-related costs	.	.	.	5.53	6.20

Emissions of NO_x are the main cause of negative effects on health from combustion of kerosene, heating oil and heavy oil. In the case of heavy oil, however, some of the negative health effects are due to emissions of SO_2.

As mentioned above, the cost figures in tables 3.17 and 3.18 can be regarded as average figures for the whole country. Marginal environmental costs will probably vary considerably with the localization of the emissions, depending on the original concentration of the pollution and the density of the population. The estimates indicate the marginal pollution cost of gasoline consumption to be about NOK 12 per litre, but similar estimates for sparsely populated areas lie under the national average, which is NOK 2 per litre, calculated in 1990 prices.

The basic data used to calculate the damage assume a confidence interval for each estimate. These intervals are fairly big. They indicate, for instance, a confidence interval of NOK 2-18 per litre for the estimate of the marginal cost connected to consumption of gasoline, traffic-related costs included, in 1990 prices.

In spite of this uncertainty, the cost calculations in tables 3.17 and 3.18 give some indication of the size of some of the most important external marginal costs. The calculations indicate that the greatest economic benefit is to be obtained from reducing NO_x emissions and improving the organization of road traffic.

Benefits of measures related to climate

The climate policy measures described in the agreement scenario in section 3.5 imply a lower gross domestic product for this alternative relative to the reference path. However, neither of these scenarios take into account the external costs connected to local pollution and traffic. Using the estimates of marginal costs presented above, calculations have been carried out which indicate the value of a reduction in local pollution and better organization of traffic as a result of the climate policy measures. Table 3.19 shows the estimated benefit obtained in the agreement scenario relative to the reference path. The assumptions of the two scenarios and their effects on the economy are described in section 3.5.

The calculations indicate health and environmental benefits in the order of NOK 12 billion (1987 prices) in the year 2000, NOK 18 billion in 2010 and NOK 27 billion in 2025. The greater part of the benefit refers to improved health due to reduced emissions of NO_x and a lower load of road traffic.

Table 3.19. Reduction in pollution and traffic-related costs relative to the reference path through implementing international agreements on climate. NOK billion (1987 prices)

	Year		
	2000	2010	2025
Total reduction of costs	12.3	18.2	27.2
Acidification of forests and watercourses	0.1	0.1	0.1
Total negative health effects	5.1	7.0	10.6
Negative health effects, SO_2	0.2	0.3	0.5
Negative health effects, NO_x	4.7	6.4	9.8
Negative health effects, CO	0.0	0.0	0.0
Negative health effects, particulates	0.2	0.2	0.3
Corrosion	0.1	0.1	0.1
Traffic accidents	1.7	2.6	3.9
Flow of traffic	1.8	2.8	4.2
Wear on roads	2.3	3.5	5.2
Noise from traffic	1.3	2.0	3.0

In table 3.20 the benefit of implementing an agreement on climate is compared with the reduction in the GDP in the agreement scenario relative to the reference path. A large share of the lost production due to the climate policy measures is compensated by benefits connected to less disamenity from traffic and from pollution by substances other than CO_2.

Table 3.20. Changes in GDP in the agreement scenario relative to the reference path. Benefits from reduced emissions in the agreement scenario. NOK billion (1987-prices)

	Year		
	2000	2010	2025
Changes i GDP in the agreement scenario relative to the reference path . .	-15.5	-17.2	-34.3
Economic gain by reducing emissions in the agreement scenario . . .	12.3	18.2	27.2

Although the calculations are uncertain, they show that there are probably substantial economic benefits to be obtained by introducing measures to reduce CO_2 emissions, over and above the impacts these measures are expected to have on climate.

3.7. EEC and emissions to air in Norway

The Norwegian authorities' use of environmental policy measures may be affected in future by Norway's relationship to the EEC. Furthermore, the choice between membership of the European Economic Community, an agreement on a European Economic Cooperation Area (EECA) or some other form of association will influence the development of the Norwegian economy, which will in turn affect emissions to air, water and soil.

This section briefly discusses how Norway's relationship to the EEC could affect emissions of harmful substances to the air. There are many issues that have not been clarified as yet with regard to the EEC policy in the near future. Therefore the following presentation must be regarded as a preliminary summing up of the situation, based on information available at the end of 1990.

According to plan, the EEC's internal market will become effective as from 1 January 1993, a situation which many people expect will lead to stronger economic development in EEC member countries. If this growth leads to larger emissions of sulphur and nitrogen oxides than envisaged if no such internal market were established it will also lead to more acid rain over Norway. It is unlikely, however, that Norwegian adjustment to the EEC will have any marked impact on emissions within the EEC. Therefore the discussion in the following pages focuses on factors which could conceivably influence emissions to air in Norway.

Environmental policy in the EEC and "the four freedoms"

Until quite recently, protection of the environment was a field where each of the EEC countries designed its policy independently of the others. There are still large differences between the EEC countries in this area. In more recent years, however, environmental issues have been considered more as a common concern, and the EEC now takes up common environmental problems to a much greater extent than it did only a couple of years ago. It has been decided to establish a European Environmental Agency with the task of obtaining, coordinating and analyzing environmental data from EEC countries.

In the statutes of the EEC (Treaty of Rome) it is emphasized that all directives relating to harmonization of the legislation of member countries shall be based on a high degree of protection with regard to health, environment, consumer protection and safety. All member countries are free to lay down more stringent rules for the environment than the rest of the EEC, provided that this does not obstruct the principle of free flow of goods.

In addition, there is access to deviate from the provisions concerning free trade if this is necessary in order to take care of important environmental considerations. In such cases, environmental considerations and free trade considerations will be weighed in each individual case by the EEC Court or the EEC

Council of Ministers.

A couple of examples serve to illustrate the above situation: Denmark's deposit return system for bottles favoured the Danish breweries, and was therefore said to obstruct trade. The EEC Court accepted the deposit return system, however, although with certain modifications, because it believed that it was motivated by true environmental considerations. In Greece, the authorities wanted to subsidize cars equipped with catalytic converters by a sum far exceeding the cost of the converter. This case ended by a resolution in the EEC Council of Ministers, deciding that the maximum subsidy used by member states could not exceed the cost of the catalytic converter.

When the internal market is introduced in 1993, the intention is to do away with all border control within the EEC. Goods, services, capital and labour shall pass freely between member countries. It will then be difficult, or impossible, to check whether national provisions are complied with. For example, the abandonment of border control will make it easy to import large quantities of goods for sale which do not comply with national quality criteria, or are subject to lower taxes abroad than at home.

The EEC is therefore in the process of coordinating all provisions which require control at internal borders. This affects the regulations in a number of areas, for example, tax policies and measures to prevent spread of plant and animal diseases. Of greatest interest for emissions to air are the rules concerning quality requirements for products, and tax policies.

If Norway joins the EEC, border control between Norway and other EEC countries will be removed. It has not yet been relevant, however, to do away with border control in connection with an EEA agreement. Therefore, an EEA agreement will allow Norway to maintain special Norwegian provisions, for instance, a different tax policy, than would be possible with full membership.

Today, emissions to air from Norwegian industry are regulated mainly by means of permits from the State Pollution Control Authority. There is nothing to prevent Norway from continuing this practice after Norwegian approximation to, or membership of, the EEC. It may well be that more stringent requirements than those imposed abroad might, if considered alone, impair the competitive ability of Norwegian industry. However, for the enterprises themselves it is not the environmental requirements alone but the costs as a whole that are important. In principle, the increased costs due to environmental requirements can be counterbalanced, for example, by reducing the tax on the company, if this is expedient.

Common product requirements

Before the border control is removed the countries will have to agree on rules for labelling of products, quality standards etc. They will also have to agree which agencies are to have the right to approve a product. The principle is that if a product is approved in one EEC country it can also be sold in all other EEC countries. Therefore, as a general rule, product requirements based on environmental considerations must also be common to the whole EEC area.

Probably the most important provisions affecting emissions to air are those relating to exhaust emissions from private cars. Up to now, the EEC provisions in this respect have been less restrictive than in Norway. It now appears, however, that the EEC is going to adopt a new directive on exhaust gases from motor vehicles, leading to EEC regulations based on about the same level of emissions as the Norwegian provisions. However, the measurement and control routines used by the EEC to ensure compliance with the exhaust emission regulations are not the same as used in Norway. This may be of some importance, partly because exhaust emissions from cars vary considerably with the pattern of driving. It is possible that the EEC's measurement routines give more opportunity to manufactures to "tailor make" the cars to comply with the requirements, without this leading to equally small emissions when the car is driven in traffic.

Harmonization of environmental taxes

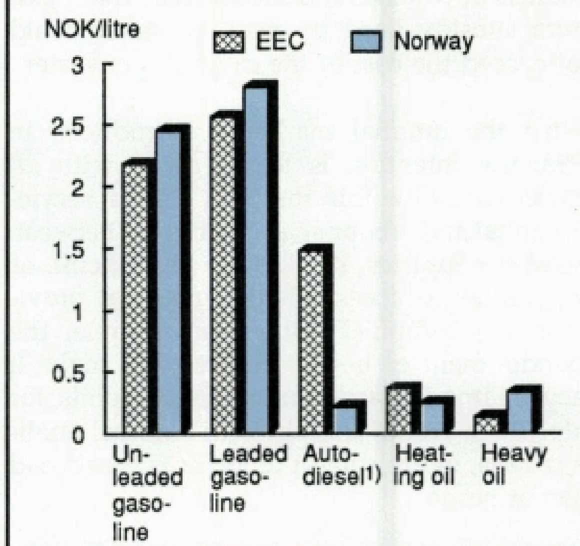
EEC is working to harmonize the rates of taxes in the different countries. As yet, agreement has not been reached on the size of the tax. This question requires a unanimous decision by the Council of Ministers, and the different countries have different interests in this matter.

If Norway becomes a member of the EEC, the Norwegian rates will have to be harmonized to a large degree with the rates fixed by the EEC. An EEA agreement, on the other hand, will not apply to harmonization of the policy on duties and taxes (at least not to start with). Therefore EEC membership will probably limit freedom of action as far as environmental taxes are concerned. However, whether or not this would imply lower environmental taxes than would otherwise have been imposed in Norway depends on the level of the taxes imposed by the EEC.

The most recent proposal from the EEC Commission concerning the level of exhaust emissions was presented in 1989, but has not yet been adopted by the Council of Ministers. The proposal includes guidelines for permitted variations in VAT, as well as special taxes on alcohol, tobacco and mineral oils. It is not proposed to harmonize other taxes. The proposal is based on a level equivalent to the approximate EEC average. In the case of gasoline, a minimum limit has been fixed for the tax, but in the case of diesel oil, heating oil and heavy oil it has been proposed that the taxes can vary between a maximum and minimum limit. It is also proposed to fix "target rates", and that member countries shall be allowed to change their taxes only if this brings the tax level closer to the target rate. So far, no specific level has been proposed for these target rates.

It is difficult to compare the rates of taxes in the EEC and Norway, since both updated figures from the EEC are lacking and figures that have been adopted by the Council of Ministers. However, figure 3.14 presents the rates proposed by the EEC Commission in 1989 compared with the Norwegian rates in the same year. Norwegian taxes on oil products have been increased substantially since that time, a situation which can probably be put down to an increasing will to use environmental taxes. However, a similar change of attitude also seems to have taken place within the EEC, so that it would not be fair to compare the EEC proposal with the Norwegian rates for 1991.

Figure 3.14. Special taxes on mineral oils. Proposal from the EEC Commission, December 1989, and Norwegian taxes in 1989. NOK per litre. (Conversion factor: 1 ECU = NOK 7.60)



1) Kilometre tax not included.

In 1989, the Norwegian taxes on gasoline were somewhat higher than EEC's suggested minimum limits, but the difference is not very big. Denmark, France, Italy and Ireland all had higher taxes on gasoline at that time.

The tax on diesel is difficult to compare, due to the Norwegian tax based on the number of kilometres driven. For an ordinary private car using 1 litre diesel per 10 kilometres the Norwegian diesel and kilometre tax combined was equivalent in 1989 to a tax of NOK 1.69 per litre diesel. This is slightly higher than the interval proposed by the EEC Commission. For consumers of large quantities of diesel, however, (heavy transport and machinery) the tax is lower in Norway.

The Norwegian taxes on heavy oil were higher than in the EEC proposal, but the tax on heating oil, on the other hand, was quite a lot lower.

There is reason to believe that the EEC Commission will submit a new proposal which will deviate in some respects from the one described above. In December 1990 the EEC Commission presented a working document which discusses use of environmental taxes. The idea seems to be a system involving a general tax on energy, plus a tax on CO_2. The general tax on energy is not to apply to renewable sources, but is otherwise the same for all sources of energy. The CO_2-tax is to be graded according to the size of the emission of CO_2 from the particular source of energy. Nuclear power is subject to the energy tax only. It is proposed that part of the income from these taxes should be earmarked for environmental projects.

Harmonization of taxes and emissions to air in Norway

The Central Bureau of Statistics has analyzed the effects on emissions to air in Norway of possible harmonization of taxes to the EEC level. The analysis was carried out using the MODAG W model. The reference path is more or less the same as used in the SIMEN Project (a study of industry, energy and environment) (SIMEN, 1989). The rates in the proposal from the EEC Commission in 1989 were compared with the rates in Norway the same year. Norwegian tax rates which were not compatible with the EEC Commission's proposal were changed in the model, to bring them within the intervals proposed by the Commission. No other changes were made in relation to the reference path. Thus the analysis refers only to changes in the actual taxes - possible changes as a result of membership of, or adjustment to, the EEC are not evaluated.

In this analysis no typical environmental taxes were changed. The taxes on gasoline did not conflict with those proposed by the EEC, although ideally the taxes on heavy oil and heating oil should have been adjusted. However, changes in the taxes on heavy oil and heating oil pull in different directions, and the model does not distinguish between the two types of oil.

Harmonization of the taxes in 1989 would nevertheless have led to a considerable reduction in the level of Norwegian taxes as a whole, mainly due to a marked reduction in the tax on alcohol and tobacco, and of VAT on a number of important products. This would reduce the price of a number of groups of commodities, and would lead to a change in both the level and mix of production and consumption. This in turn could change the pattern of emissions. Therefore it is quite feasible that a harmonization of taxes (in isolation) could lead to a higher (or lower) level of emissions, even if the harmonization did not affect any typical environmental taxes.

Two alternatives were considered: In the first, the changes in taxes led to large loss of income to the public sector, but in the second alternative the lower taxes were neutralized by a higher property tax and reduced transfers to the private sector. Neither of these alternatives led to any substantial increase in emissions. After a ten-year period emissions of NO_x, SO_2 and CO_2 were about 1-2 per cent higher than in the reference path.

General economic development

Increased economic growth in the EEC will lead to more environmental problems unless the degree of cleaning and other measures is increased at the same time, or changes take place in the composition of production and consumption. In 1989, a working group appointed by the EEC Commission (Task Force on the Environment and the Internal Market, 1989) presented a report on the environmental impacts of the internal market. It is estimated that, given no new environmental measures, the introduction of the internal market will lead to a level of SO_2 emissions from the EEC countries in the year 2010 about 8-9 per cent higher than would otherwise have been the case. Emissions of NO_x are estimated to be 12-14 per cent higher in 2010 with an internal market than without one. As mentioned above, these estimates assume that no new environmental measures are introduced, which is a very unrealistic assumption in today's situation.

The task force concluded that changes in the composition of industry are more likely to exacerbate the environmental problems than solve them. This is to a large degree due to the expected large increase in road transport.

It is difficult to say whether such a conclusion is also applicable in Norway's case. Participation in the internal market (as a member of the EEC, or not as a member) will probably lead to increased reciprocal trade and more road traffic. However, it is by no means certain whether the individual sectors of Norwegian industry will gain or lose by the introduction of the internal market. This will depend on whether or not they are able to compete with foreign companies. There are large differences in the extent of pollution from the different sectors, and a shift in the composition of industry will therefore strongly influence emissions - in a positive or negative direction. The extent of the increase in road traffic will depend on developments in other industries which use the services of the transport industry.

Conclusions

The environmental policies of the EEC and of Norway are not very different. On certain points, e.g. requirements for labelling and use of toxic and/or carcinogenic chemicals, the Norwegian regulations are more stringent than those of the EEC. In other areas, e.g. industrial contingency preparedness against serious accidents, and protection of birds, the EEC regulations are more restrictive. As far as provisions concerning emissions to air are concerned, it seems as if the regulations in the EEC and in Norway seldom conflict. Extensive emissions to air from Norwegian companies are regulated at present through discharge permits from the State Pollution Control Authority, and this practice does not present a problem in relation to the EEC regulations.

If Norway chooses to adjust to the EEC through an EEA agreement, it is unlikely that any extensive harmonization of taxes will be necessary. In the case of Norwegian membership of the EEC on the other hand, Norwegian taxes will probably have to be harmonized with those applying in the EEC. This will not, however, lead to lower environmental taxes in Norway if the EEC maintains a lower level than desired by Norwegian politicians. The EEC tax policy has not yet been decided but, in the light of present indications it is not an obvious conclusion that harmonization of Norwegian taxes to the EEC level would imply lower taxes.

Another point is that if Norway became a member of the EEC it would be difficult to stipulate more stringent criteria for exhaust emissions from motor vehicles in Norway than in the rest of the EEC. However, the exhaust emission criteria which are expected to be approved by the EEC are about the same as those which apply in Norway at present.

The choice of type of association with the EEC may affect both economic growth and the composition of industry in Norway. There are large differences in the extent of pollution from the different industrial sectors, so that a shift in composition could be decisive for changes in the level of emissions. More comprehensive macroeconomic analyses are required before it is possible to state whether membership of the EEC, an EEA agreement, or staying outside the EEC internal market, will lead to the lowest emissions to air in Norway.

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4. FISH

The stock of North-East Arctic cod is still estimated as low (about 830 000 tonnes), and the catch quota for 1991 is 215 000 tonnes. Norwegian fishermen are allowed to catch 88 500 tonnes and, in addition, 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 1990. The 1983 year class accounts for about 80 per cent of this stock. There was a marked increase in the stock of Barents Sea capelin in 1990, and fishing of this species is allowed in 1991 for the first time since 1986. The total catch of fish in Norwegian fisheries was about 1.5 million tonnes in 1990. This is about 200 000 tonnes less than in 1989. Including crustaceans, molluscs and seaweed the total catch in 1990 was about 1.8 million tonnes, with a first-hand value of NOK 4.8 billion. The first-hand value is about the same as in 1989. However, the export value of fish products (including reared salmon) increased by 18 per cent in 1990 to just over NOK 13 billion, of which exports of reared salmon accounted for about NOK 4.8 billion. The exported quantity of reared salmon was about 37 per cent higher than in 1989, and the value increased by about 39 per cent.

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).

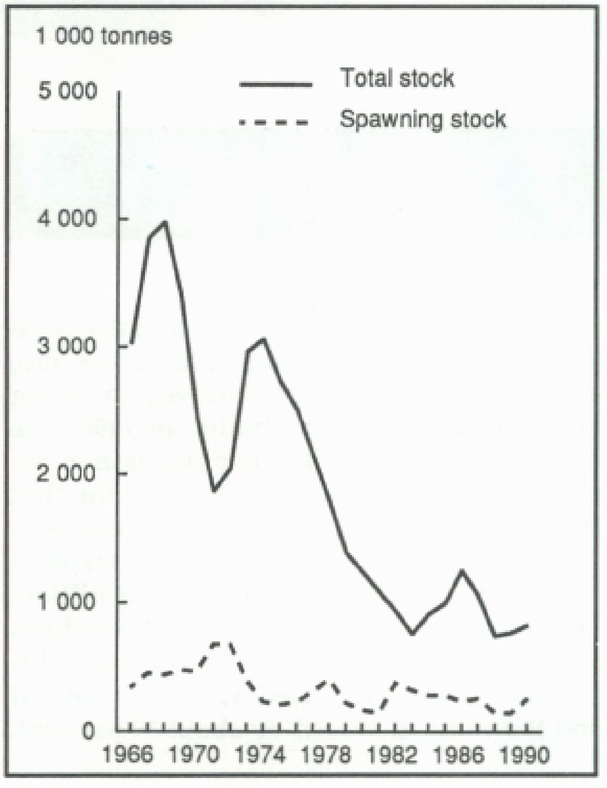
North-East Arctic Cod

The size of the stock of North-East Arctic cod was estimated to about 830 thousand tonnes at the beginning of 1990, see figure 4.1. The stock was slightly bigger than in 1989, but the development of the stock has been much weaker than expected. The estimated spawning stock is about 260 000 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 a recruitment index, where the strength of the year class at the time of inclusion in the accounted stock is used as a measure of the year class when spawning took place. The recruitment index shows that all year classes from the 1980s, except for the strong 1983 year class and the more "normal" year classes from 1981 and 1982, were weak. Cod usually mature when 7 or 8 years old.

The positive development of the capelin stock in the Barents Sea will affect the growth of the stock of cod. Scientists recommend caution, however, in fishing North-East Arctic cod, in order to ensure continued increase of the stock.

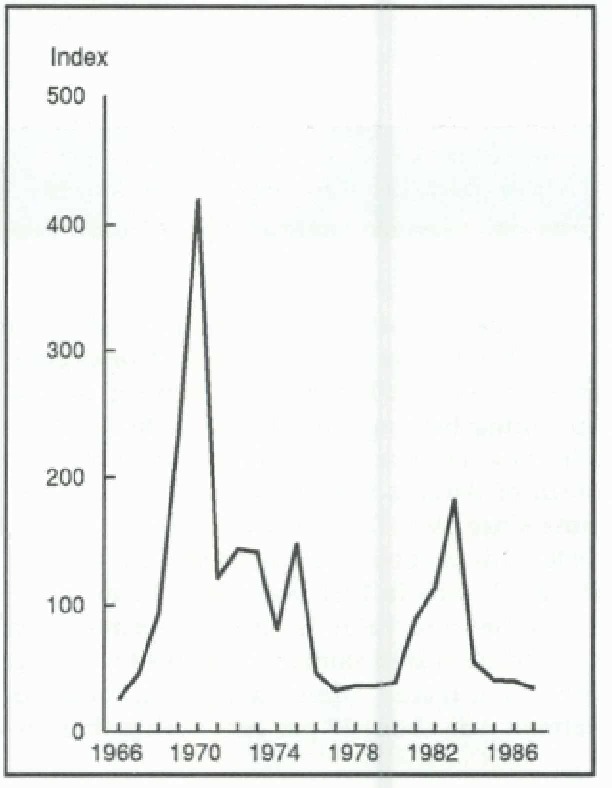
Based on the most recent estimates of the stock, recursive calculations are carried out for development of the stock, using data on the catch and on natural morality. In this way the estimates of the stock size in previous years are re-evaluated. Table 4.1 shows the size of the stock as estimated for the first time each year, and as estimated in 1990. In 1990 the 1987 stock was estimated to have been 1 060 000 tonnes; 440 000 tonnes less than the original estimate.

Figure 4.1. Total stock[1] and spawning stock of North-East Arctic cod. 1966-1990. 1 000 tonnes



1) Fish over 2 years of age.

Figure 4.2. Recruitment index[1]. North-East Arctic cod. 1966-1987



1) Average 1966-1987=100.

Table 4.1. Stock development[1]. North-East Arctic cod. 1975-1990. 1 000 tonnes

Year	Initial estimate (1)	1990-estimate (2)	Re-evaluation (3)=(2)-(1)
1975 ...	3 600	2 740	-860
1976 ...	4 110	2 510	-1 600
1977 ...	2 500	2 150	-350
1978 ...	1 920	1 800	-120
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	760	-200
1984 ...	730	910	180
1985 ...	1 020	1 000	-20
1986 ...	1 880	1 250	-630
1987 ...	1 500	1 060	-440
1988 ...	900	750	-150
1989 ...	680	770	90
1990 ...	830	830	.

1) Initial stock size estimate and estimate in 1990.

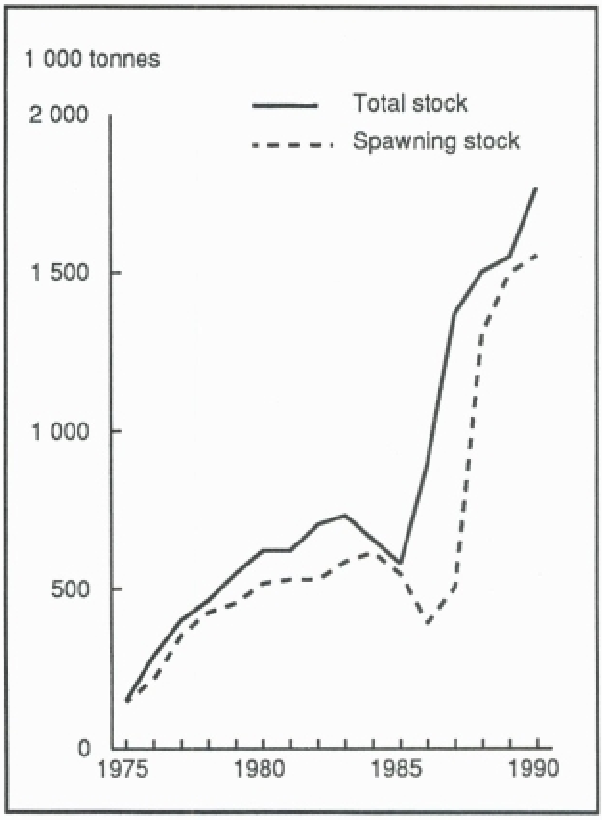
Norwegian spring spawning herring

The stock of Norwegian spring spawning herring was estimated to be about 1.5 million tonnes in 1989, see figure 4.3. A prognosis from ICES estimated the total stock of Norwegian spring-spawning herring to be about 1.8 million tonnes as per 1 January 1990.

The stock was fished down from a level of between 7 and 10 million tonnes in the 1950s to an extremely low level 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 1.6 million tonnes in 1990 is about three times as large as the spawning stock in 1987. The year classes since 1983 are not expected to contribute substantially to the spawning stock, which is expected to decrease in the short term, even if no fishing takes place. The further development of the stock is very uncertain, and is strongly dependent on what happens to the 1983 year class in the next few years. This year class 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.

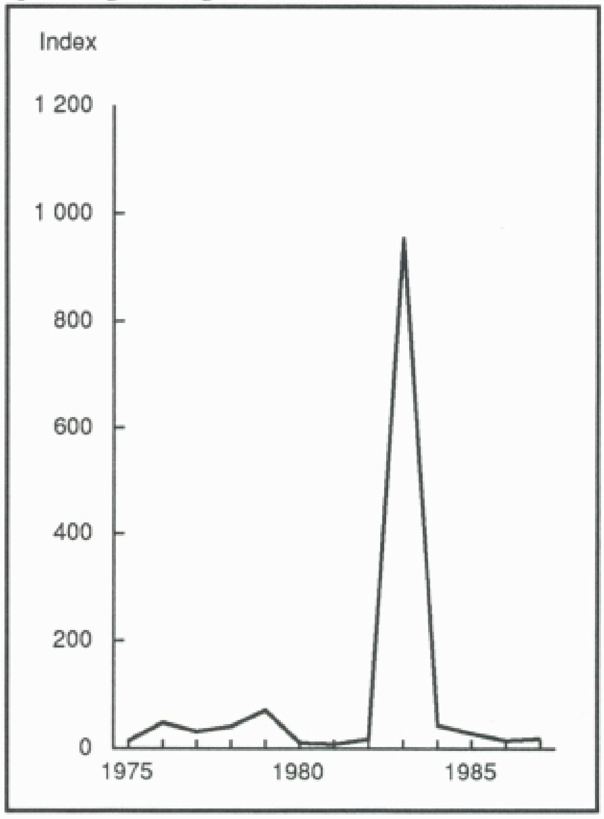
In 1990 the catch quota for herring was 80 000 tonnes. The recommended maximum quota for 1991 is 90 000 tonnes. By comparison, during the period 1964-1967, total annual catches of Norwegian spring-spawning herring varied from 1 282 000 tonnes to 1 955 000 tonnes.

Figure 4.3. Total stock[1] and spawning stock. Norwegian spring-spawning herring. 1975-1990. 1 000 tonnes



1) Fish over 2 years of age.

Figure 4.4. Recruitment index[1] Norwegian spring-spawning herring. 1975-1987



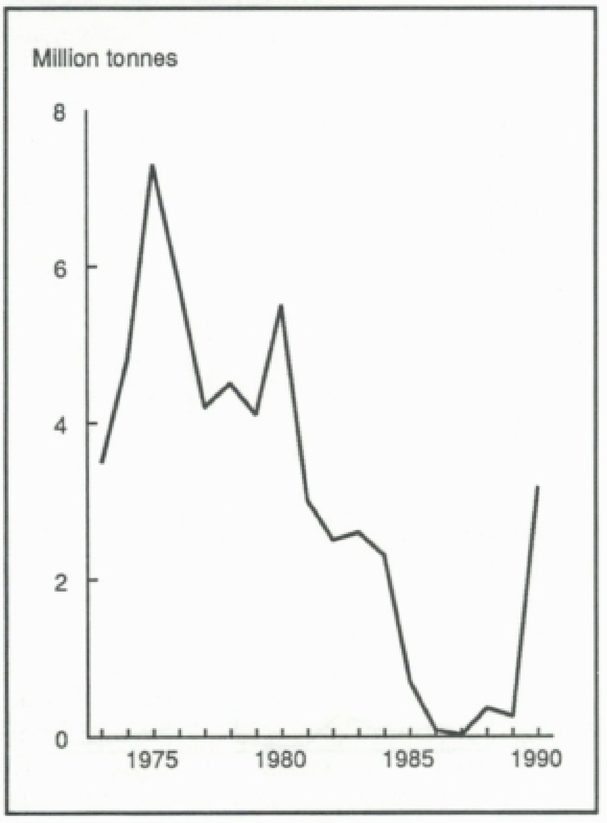
1) Average 1975-1987=100.

Barents Sea capelin

Figure 4.5 gives the estimated size of the capelin stock (fish that are two years old or more) in the Barents Sea based on acoustic measurements in autumn. The estimated size of this part of the stock was 0.36 million tonnes for 1988 and 0.26 million tonnes for 1989, implying a decrease from 1988 to 1989. There was a strong increase in the stock from 1989 to 1990, and in autumn 1990 it was estimated to be 3.17 million tonnes.

The positive development of the capelin stock led to permission to fish this species in 1991 for the first time since 1986.

Figure 4.5. Stock size of Barents Sea capelin[1] in autumn. 1973-1990. Million tonnes



1) Fish 2 years of age and older.

Other important fish stocks

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

The stock of North-East Arctic haddock has undergone a period of serious reduction. In 1984 the stock reached a bottom level of 50 000 tonnes, about 5 per cent of its size in 1973. However, from 1984 to 1985 the stock increased to 160 000 tonnes, and in 1986 to 320 000 tonnes. The size of the stock was estimated to be 160 000 tonnes in 1990, and it is recommended that extreme moderation is exercised in the fishing of haddock.

The estimated size of the stock of North-East Arctic saithe is about 570 000 tonnes for 1990.

Table 4.2. Stock development[1]. 1976-1990. 1 000 tonnes

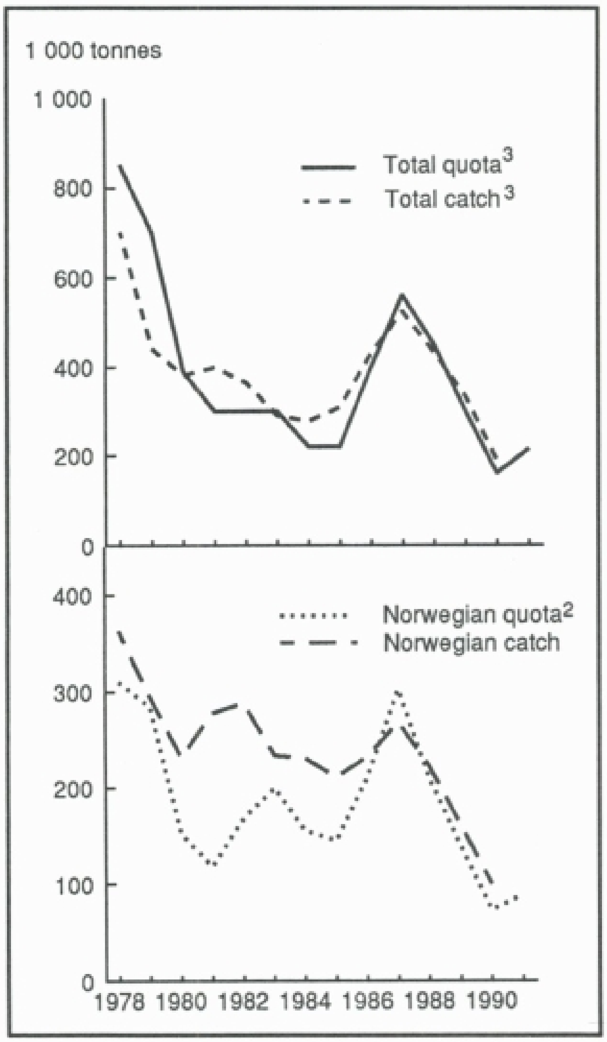
Year	North-East Arctic cod	North-East Arctic haddoc	North-East Arctic saithe	Barents Sea capelin	Norwegian spring-spawning herring	North Sea cod	North Sea saithe
1976	2 510	470	570	6 210	290	240	550
1977	2 150	310	520	4 440	400	240	430
1978	1 800	280	420	3 130	460	200	360
1979	1 390	280	350	3 220	550	290	350
1980	1 240	240	390	3 260	620	270	320
1981	1 090	190	480	4 570	620	280	420
1982	940	120	430	2 465	710	310	430
1983	760	70	450	3 840	730	200	380
1984	910	50	400	1 840	660	200	390
1985	1 000	160	360	1 680	580	170	390
1986	1 250	320	430	..	900	180	390
1987	1 060	280	540	..	1 370	120	320
1988	750	190	530	..	1 500	210	280
1989	770	170	540	..	1 550	150	330
1990	830	160	570	..	1 770	130	390

1) Fish over 2 years of age.

4.2. Quotas and catch

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

Figure 4.6. Quotas and catch. North-East Arctic cod[1]. 1978-1991. 1 000 tonnes



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

Preliminary figures for North-East Arctic cod fished in 1990 indicate a catch of 189 000 tonnes, plus 17 000 tonnes of Norwegian coastal cod.

For 1991 the total quota of North-East Arctic cod is fixed at 215 000 tonnes (including Murman cod). To this is added 40 000 tonnes Norwegian coastal cod. After transfer of part of the Soviet Union's quota to Norway, Norwegian fishermen are allowed to fish 88 500 tonnes of North-East Arctic cod in 1991, plus 40 000 tonnes of Norwegian coastal cod. Figure 4.6 illustrates 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 quota was fixed at 250 000 tonnes in 1987 and 240 000 tonnes in 1988. In both these years, however, the catch was far below the quota; 151 000 tonnes in 1987 and 92 000 tonnes in 1988. The catch was also below the quota of 83 000 tonnes in 1989. The quota of 25 000 tonnes in 1990 was fished. This rather worrying development in the stock of haddock implies that the stock must be fished with caution, and the quota of 28 000 tonnes for 1991 includes haddock by-catches during cod fishing, and limited coastal fishing.

As mentioned above there was a marked increase in the stock of capelin in 1990. A total quota of 850 000 tonnes has been agreed for the winter fishing in 1991; 510 000 tonnes to Norway and 340 000 tonnes to the Soviet Union. Possible autumn fishing will be considered at a later date.

Catches in 1990

Table 4.4 shows Norwegian catches in the years 1986-1990. In 1990 the total catch was about 1.5 million tonnes. This is about 200 000 tonnes less than in 1989. The catch of cod decreased by about 34 per cent, and the catch of haddock by about 42 per cent, in relation to 1989. The catch of saithe decreased by about 22 per cent. About 5 per cent more mackerel were caught in 1990 than in 1989, but the catch of capelin (Norwegian Sea capelin) decreased by 12 per cent.

Table 4.3. Quotas and catch by stock. 1978-1991. 1 000 tonnes

Year	North-East Arctic cod		North-East Arctic haddoc		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	67	120	123
1987	560	523	250	151	90	92	-	-
1988	451	435	240	92	100	115	-	-
1989	300	333	83	55	120	122	-	-
1990*	160	189	25	25	103	105	-	-
1991*	215	.	28	.	90	.	850	.

Table 4.4. Norwegian catch by groups of fish species. 1986-1990. 1 000 tonnes

	1986	1987	1988	1989*	1990*
Total	1 790	1 804	1 686	1 719	1 511
Cod	270	305	252	186	123
Haddock	58	75	63	39	23
Saithe	131	152	148	144	112
Tusk	33	30	23	32	28
Ling/blue ling	28	25	24	28	24
Greenland halibut	8	7	9	12	21
Norway haddoc (red-fish)	24	18	25	28	40
Others and unspecified	24	34	27	26	39
Capelin	273	142	73	107	94
Mackerel	157	159	162	143	150
Herring	331	347	339	273	204
Sprat	5	10	12	5	6
Other industrial fish species[1]	450	500	527	696	648

1) Includes lesser silver smelt/greater silver smelt, Norway pout, sandeel, blue whiting, horse mackerel.

The first-hand value of the fish species included in table 4.4 was the same, however, as in 1989, that is to say, about NOK 3.9 billion. The total first-hand value of the fisheries in 1990 (including crustaceans, molluscs and seaweed) was also the same as in 1989; about NOK 4.8 billion. The total catch was about 1.8 million tonnes; a catch of almost 200 000 tonnes less than in 1989.

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 agreements entered into by Norway are with the EEC on fishing in the North Sea, and with the Soviet Union on fishing in the Barents Sea. The purpose has been to secure a reasonable balance between the fishing carried out by the two parties to the agreement, and to establish rules for cooperation on effective management of common stocks.

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

Stock	Norway	USSR
North-East Arctic cod	50	50
North-East Arctic haddock	50	50
Barents Sea capelin	60	40

Exclusive stocks, that is to say, stocks which occur only in the zone of one particular country, are owned and managed ny 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 Soviet Union, while 60 per cent of the capelin belongs to Norway and 40 per cent to the Soviet Union, see table 4.5.

In the North Sea, the parties have agreed on a zone division of cod, haddock, saithe, whiting, plaice and North Sea herring, see table 4.6, but have not yet reached agreement on the division of North Sea mackerel.

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 the present level of fishing is presumed not to represent a threat to these stocks.

Table 4.6. Division of stocks in the North Sea. Per cent

Stock	Norway	EEC
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 1990 the distribution was 29 per cent to Norway and 71 per cent to the EEC.

The annual fishery negotiations with the EEC, the 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 the 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 4.7. Transfer of fishing rights between Norway and other countries. 1990. 1 000 tonnes cod equivalents

	Transfer to Norway (1)	Transfer from Norway (2)	Balance in favour of Norway (3)=(1)-(2)
Total	121.3	173.3	-52.0
EEC	77.6	79.2	-1.6
Soviet Union	28.8	76.2	-47.4
Faroe Islands	11.7	9.5[1]	2.2
Others	3.2	8.4	-5.2

1) Quotas in the Svalbard zone not included.

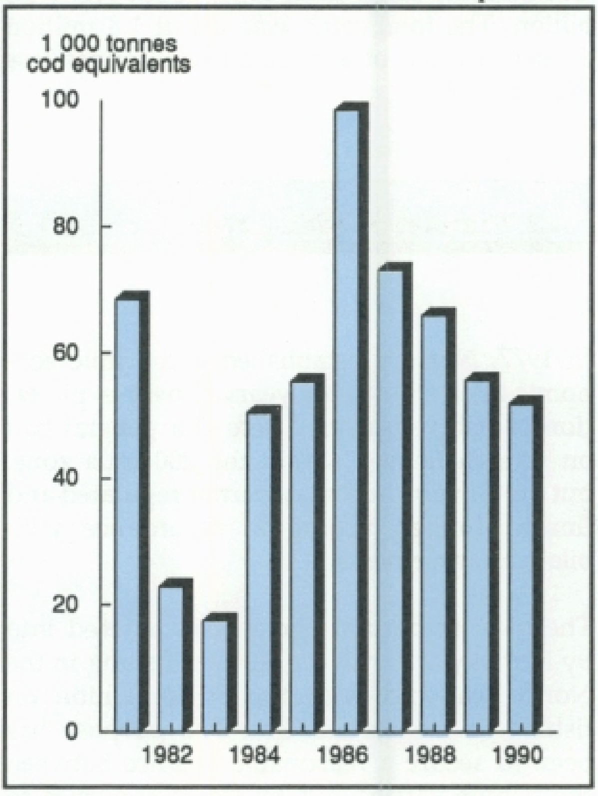
Table 4.7 shows the extent and balance of the exchange agreements between Norway and other countries in 1990. By fixing weight values, the transfers are translated from tonnes of each fish species to equivalent quantities of cod, or cod equivalents.

The table shows that, in 1990, the balance sheet of transfers between Norway and the Soviet Union was in Norway's disfavour. The balance with the EEC was slightly in the EEC's favour. The Soviet Union's gain of 47 400 tonnes cod equivalents is mainly due to a quota for the Norwegian stock of blue whiting. The quota for blue whiting was 290 000 tonnes, corresponding to 36 000 tonnes cod equivalents. The fishery agreement with the Soviet Union also covers sealing, with a Norwegian quota in the White Sea and a Soviet quota in the Jan Mayen area. This part of the agreement is not included in the transfer balance sheet.

Figure 4.7 shows changes in Norway's balance of transfers with other countries during the period 1981 to 1990.

In the agreement with the Faroe Islands it is decided that also the quota assigned to the Faroe 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 4.7.

Figure 4.7. Net transfer from Norway to foreign countries. 1981-1990. 1 000 tonnes cod equivalents



Quotas to other countries include Swedish fishing in the Norwegian part of the North Sea and Skagerrak, and Polish and East German 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 4.7 also includes transfers to Norway from Canada.

4.4. Aquaculture

Production of reared fish has increased substantially since this activity started at the beginning of the 1970s. Figure 4.8 shows the development of the production of reared fish since 1980. 111 000 tonnes of reared salmon were slaughtered in 1989, compared with 79 000 tonnes the year before. Trout production was 3 600 tonnes in 1989. According to preliminary figures, about 160 000 tonnes salmon were produced in 1990, and between 3 000 and 4 000 tonnes trout. Prognoses from the Fish Farmers' Sales Organization indicate a production of about 140 000 tonnes of salmon in 1991.

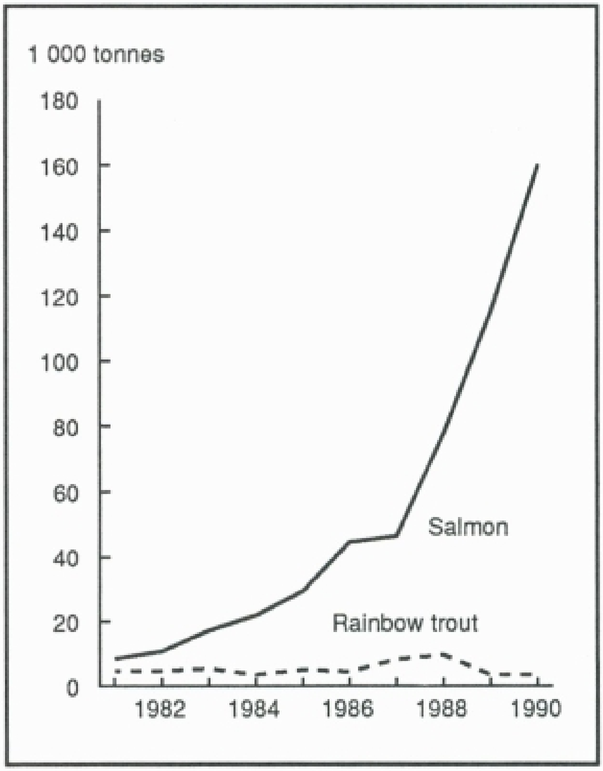
Table 4.8. Rearing of fish for food, by county. 1989

County	Number of stations	Slaughtered quantity Tonnes
Total	709	114 978
Rogaland	50	8 845
Hordaland	130	31 536
Sogn og Fjordane ..	72	15 155
Møre og Romsdal .	106	18 956
Sør-Trøndelag	75	8 002
Nord-Trøndelag ...	53	6 307
Nordland	119	17 906
Troms	56	5 191
Finnmark	30	1 860
Others	18	1 221

Salmon and trout were slaughtered at a total of 709 stations in 1989, see table 4.8. Hordaland was the county with the largest number of production stations and the largest quantity of slaughtered fish.

Investments in fish farming amounted to NOK 476 million in 1989. Of this amount, NOK 165 million was invested in hatcheries and units for rearing fingerlings, and NOK 312 million in units for rearing fish (salmon and trout) for food. A total of 4 993 persons were employed in the fish farming industry in 1989, distributed between 1 221 persons in hatcheries and fingerling rearing units, and 3 780 persons at stations for rearing fish for food.

Figure 4.8. Rearing of fish. Slaughtered quantities of salmon and rainbow trout. 1981-1990. 1 000 tonnes



4.5. Export of fish products

Table 4.9 shows the exported quantities of the most important fish products during the period 1980-1990, including exports of reared fish. Export of fresh fish was 11 per cent higher and export of whole frozen fish 65 per cent higher than in 1989. Export of fish fillets decreased by 25 per cent from 1989 to 1990. Only small changes have been registered in the exported quantities of the other products included in table 4.9. Figure 4.9 shows the export value of fresh fish, whole frozen fish, fillets and dried fish during the period 1986-1990. The total export value of these products increased by about 26 per cent from 1989 to 1990. A decrease in value was registered only for export of fillets.

The export value of reared fish has increased substantially in recent years. Most of the trout is consumed in Norway, but most of the salmon is exported. Table 4.10 shows that 130 700 tonnes of reared salmon was exported in 1990, to a value of NOK 4.8 billion. This equals about 37 per cent of the total export value of fish and fish products in 1990. The exported quantity increased by 37 per cent, and the export value by 39 per cent. There has been a particularly marked increase in exports of frozen salmon.

The total export value of fish products increased to about NOK 13 billion in 1990, see table 4.11. This is equivalent to about 11.5 per cent of the total traditional export of commodities (export of commodities excluding crude oil, natural gas, ships and oil platforms etc.).

Figure 4.9. Exports of fresh fish, frozen fish, fillets and dried fish. 1986-1990. Million NOK

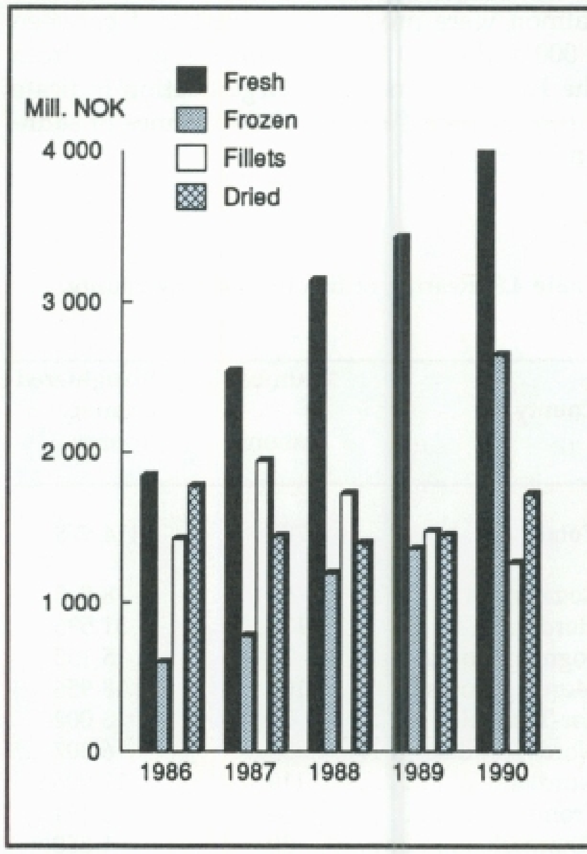


Table 4.9. Exports of fish products. 1980-1990. 1 000 tonnes

Year	Fresh	Frozen	Fillets	Salted or smoked	Dried	Canned	Meal	Oil
1980	19.0	54.6	66.6	14.5	73.3	13.9	275.2	79.4
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	263.0	71.0	34.6	50.6	23.9	45.6	42.7

Table 4.10. Exports of reared salmon. 1981-1990

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	4 834.5	92.8	3 423.8	37.9	1 410.7

Table 4.11. Export value of fish products[1] in million NOK and as percentage of value of other traditional exports. 1980-1990

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	Per cent
1980	5 054	5.5	10.9
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*	13 003	6.2	11.5

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

5. FORESTS

The total area of productive forest in Norway has increased from about 67 000 km^2 in 1979 to about 70 000 km^2 in 1989 (CBS, 1990). In 1989 this area was distributed between almost 125 000 properties with more than 25 decares productive forest.

The Forest Damage Survey Programme has recorded only minor changes in forest health status from 1988 to 1990. In 1990 the average defoliation of conifers was still 15 per cent, and about 45 per cent of all trees were more than 10 per cent defoliated. It is too early to decide to what degree the defoliation is a result of natural variation due to the age and habitat of the forests, and to what degree it is a result of air pollution or other human interference. Most European countries are currently conducting surveys of the health status of forests, and in 1989 the monitoring covered about 65 per cent of the total area of forest. Norway ranks in an intermediate position as regards how large a share of the forest was moderately to severely damaged.

5.1. Forest health status

The health status of Norwegian forests is monitored through a special survey programme. This section describes the programme and the most recent results. It also presents results from the forest damage survey started several years ago in the previous Federal Republic of Germany, or West Germany, and recent results from other parts of Europe.

Monitoring of forest damage in Norway

The Forest Damage Survey Programme was started in 1985 as a consequence of greater awareness of forest damage and a desire to identify negative trends as early as possible. The Norwegian Institute of Forest Research (NISK) coordinates the monitoring programme, which forms part of the International Assessment and Monitoring of Air Pollution Effects on Forests in the FAO/ECE region.

The survey programme has four main parts:

- **Nation-wide yearly recordings** based on systematic sampling provide a basis for regular national reports on forest health. The recordings are made by the Norwegian Institute of Land Inventory (NIJOS), and refer to about 700 permanent plots in a 9x9 km grid. About half the plots were established in 1988, the rest in 1989. The intention is to use the same method of evaluation as used in forest damage surveys conducted in Central Europe.

- **Permanent plots have been established in each county** in order to supplement the nation-wide survey with information on local long-term trends in forest health status. County-wise recordings started in 1988 and refer to 770 permanent plots. The data are recorded by the County Forestry Boards and are coordinated and analyzed at NISK.

- A small number of permanent plots are subjected to **detailed monitoring of forest ecological parameters**. A major objective is to identify criteria and methods for identifying slight changes in forest health status over short spans of time. This part of the programme is managed by NISK, which also handles the plant and soil analyses. Air quality is monitored by the Norwegian Institute for Air Research (NILU).

- Reported forest damage is **inspected** by personnel from NISK when such reports are received.

The yearly reports on forest health status are based on evaluations of defoliation and discolouration of the trees. A sparse or discoloured crown is no specific symptom of damage due to air pollution, but is rather a general symptom of exposure to external pressures. It is difficult, however, to find more direct measures of the effects of pollution. The aim of the programme is therefore two-fold: first a detailed monitoring of trends in forest health status, and secondly the development of methods for analyzing the role played by pollution in these trends.

Forest health status in Norway

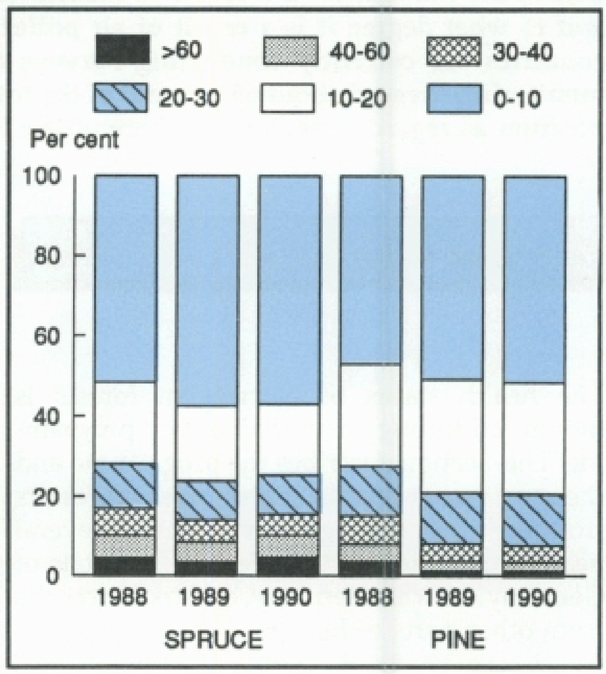
Only small changes have been recorded in forest health status for the second year running, both in the nation-wide and the county-wise surveys. The nation-wide survey showed that average defoliation increased from 14.9 per cent to 15.4 per cent for spruce. There was a slight improvement in the status of pine; defoliation decreased from 14.3 per cent in 1989 to 14.0 per cent in 1990. The results are presented in more detail in figure 5.1, which shows that the proportion of "healthy" trees (with less than 10 per cent defoliation) has remained stable for both species. In the case of spruce, however, there was a marked increase in the number of severely damaged or dead trees (more than 60 per cent defoliation) (NIJOS, 1991).

Surveys of birch were carried out for the first time in 1990. The results, referring only to birch within the permanently established plots, show a higher level of defoliation than found for conifers.

Considered collectively the county-wise surveys also showed only small changes (in the order of 0.5 per cent) in defoliation of spruce and pine. There are large regional variations. For example, in Vestfold there was an improvement from 1989 to 1990, with less defoliation and discolouration, but an increase in both defoliation and discolouration in Møre og Romsdal. In Finnmark there were changes in both directions, with no uniform trend.

The results of both the programmes lead to the conclusion that the forest health status seems to be stable for the time being. It is emphasized, however, that a survey over three years is insufficient basis for evaluating the long-term trend in forest status.

Figure 5.1. Forest health status in Norway as indicated by average defoliation of trees. 1988-1990. Per cent



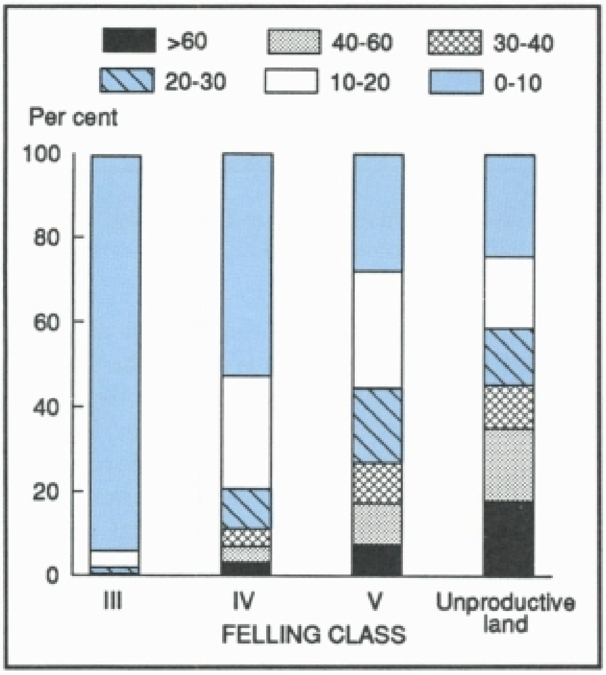
Source: Norwegian Institute of Land Inventory, 1991.

All the recordings made during the last three years show that defoliation increases with increasing age of the forest. Figure 5.2 shows the situation for spruce in 1990. There is also a distinct tendency for defoliation to increase with increasing altitude.

The scientists point out that the pattern of natural variations in forest status is likely to be similar to the pattern observed. The health status of the trees will deteriorate with increasing age. Similarly, trees growing under extreme conditions of soil and climate are subjected to pressures which affect their health. Furthermore, the status of forest today is a result of how it has been handled in the past.

It is reasonable to expect that declining health of forest due to air pollution will appear first in trees already under pressure from natural causes. It is therefore difficult to demonstrate that the observed defoliation is due to air pollution. Scientists do not, however, reject the hypothesis that long-range transboundary air pollution influences the trend of forest health status in Norway.

Figure 5.2. Defoliation of spruce in Norway within different felling classes and by unproductive forest land. 1990. Per cent



Source: Norwegian Institute of Land Inventory, 1991.

Several hypotheses on the effects of air pollution on forests have been proposed in recent years, cf. CBS (1988). The most discussed hypotheses postulate that the main agents of forest damage are emissions of sulphur dioxide (SO_2) and nitrogen oxides (NO_x). It is assumed that the damage is due to effects on leaves, either from acid depositions or high concentrations of SO_2, NO_x and ozone. NO_x contributes to formation of ozone in the lower atmosphere. It is also assumed that SO_2 and NO_x may be an indirect cause of forest damage by affecting the soil through acidification, or by causing higher concentrations of aluminium in the soil, etc.

It is thus important for the health status of forest in Norway and other European countries to reduce emissions of SO_2 and NO_x. An international agreement on reduction of SO_2 emissions was signed in 1985, and an agreement on NO_x reductions in 1988.

Forest health status in Germany (West)

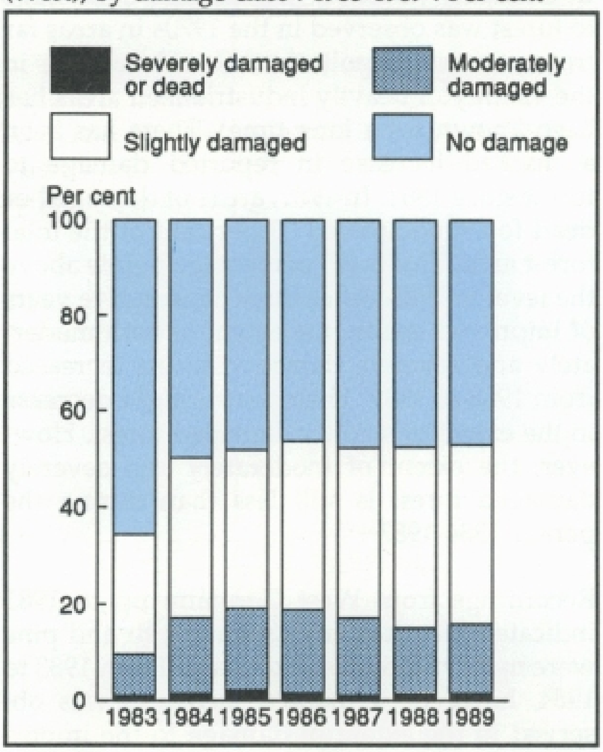
In Germany (West), a new pattern of damage to forest was observed in the 1970s in areas far from sources of pollution. (Local damage in the vicinity of heavily industrialized areas has been known for a long time). There has been a marked increase in reported damage to forest since 1981. In 1989, areas of damaged or dead forest comprised 53 per cent of the total forest area. This is 0.5 percentage points above the level in 1988. After three consecutive years of improved health, the extent of both moderately and severely damaged forest increased from 1988 to 1989. There was a slight decrease in the extent of slightly damaged forest. However, the extent of moderately and severely damaged forest is still less than during the period 1984-1987.

Recordings from West Germany up to 1983 indicated that the conifers spruce, fir and pine were most vulnerable to damage. From 1983 to 1984, however, a marked increased was observed in the extent of damage to the important hardwood species beech and oak. This deterioration continued more or less continually up to 1989, while the status of conifers has improved somewhat. Table 5.1 shows the extent of damage to the most important tree species.

During the first quarter of 1990, large numbers of trees were blown over by wind in several West German Länder. Forest equivalent to 72 million m^3 of timber was destroyed by storms. By comparison the normal felled quantity is just over 40 million m^3. (Bundesministerium für Ernährung, Landwirtschaft und Forsten, 1990).

Because of the large destruction of trees by storms it was impossible to carry out recordings of defoliation and discolouration in the whole of West Germany in 1990. However, the available data indicate a trend towards increased forest damage from 1989 to 1990. The damage to conifers did not decline, and the situation for beech deteriorated. For oak, the picture is more varied, with a distinct improvement in some regions and a distinct deterioration in others.

Figure 5.3. Area of damaged forest in Germany (West), by damage class[1]. 1983-1989[2]. Per cent



1) Damage classes are defined by degree of defoliation:

No damage	Defoliation	0-10 prosent
Slightly damaged	"	10-25 prosent
Moderately damaged	"	25-60 prosent
Severely damaged	"	> 60 prosent

Moderately to severely discoloured trees are placed in a higher damage class than indicated by defoliation alone.

2) Data from 1983 are not directly comparable with data from later years.

Source: Bundesministerium für Ernährung, Landwirtschaft und Forsten, 1989.

In 1990, recordings were carried out for the first time in the new Länder in the East, based on the same methods as used in the West. 36 per cent of the forest, or twice as much as in the West, was moderately or severely damaged. The situation was especially unsatisfactory for beech and oak. 53 per cent of the oak and 69 per cent of the beech were moderately to severely damaged.

Table 5.1. Area of damaged forest in Germany (West), by species. 1986-1989. Percentage of total area for each species

Species	1986	1987	1988	1989
Total	54	52	52	53
Spruce	54	49	49	47
Pine	54	50	53	54
Fir	83	79	73	74
Beech	60	66	63	66
Oak	61	65	70	70
Other tree species	34	37	33	39

Kilde: Bundesministerium für Ernährung, Landwirtschaft und Forsten, 1989.

Forest status in terms of defoliation and discolouration of tree crowns is about the same in Norway as in West Germany, see figure 5.1 and 5.3. This does not mean, however, that the forests are damaged by air pollution to the same extent in both countries. As mentioned above, defoliation and discolouration are general symptoms of trees under external pressure. The measurements in Norway and West Germany will indicate different levels of damage depending on the age, habitat etc. of the forests. More research of the type carried out in the other parts of the Norwegian survey programme is needed in order to ascertain the exact level of damage. Therefore, the yearly recordings of the defoliation and discolouration are intended primarily to identify the trends in forest health status, and figures 5.1 and 5.3 should be interpreted in this context. Research results from Germany show that the deteriorating forest health status can be put down to several causes, among which air pollution is very important. There is also clear evidence that air pollution can change the character and strength of the tree roots. It is too early to say to what extent such changes in the roots have caused more trees to be blown down in storms.

Forest status in Europe

With the support of the Economic Commission for Europe (ECE) and the United Nations Environmental Programme (UNEP), the results form different countries for the period 1986-89 have been compared. In 1989, forest surveys were conducted in all countries of Europe (except Rumania and Turkey), including some regions in the western part of the Soviet Union. The degree of coverage of the surveys is steadily increasing, and was in 1989 about 65 per cent of the total area. In the EEC countries the coverage is 90 per cent. More or less the same ECE-based principles for evaluating forest damage are used in all countries, in spite of large differences in forest structure, mix of tree species and type of air pollution. However, due to the subjective nature of the method of recording, caution is recommended when comparing the data from the different countries.

Forest damage, measured in terms of defoliation, occurs in all countries and regions of Europe. There are large regional differences, and table 5.2 shows the level of damage in the different countries in 1989. There were large variations in status in the western part of the Soviet Union (not included in the table): In White Russia as much as 67 per cent of the forest was moderately to severely damaged in 1989. In Estonia and Lithuania the extent of damage was about the same as in Poland and Czechoslovakia, while in the Ukraine hardly any damage was registered at all (1.4 per cent moderately to severely damaged). It should be added that monitoring did not start in White Russia and the Ukraine until 1989, and covered only a limited part of the total area of forest.

In general, older forest (more than 60 years old) and forest at higher altitudes suffered more damage than younger forest and forest in more low-lying areas. For example, several thousands of hectares of forest in the higher parts of Germany (West) were directly threatened by death, or had died in patches. The same was the case in Czechoslovakia, East Germany and Poland.

Table 5.2. Proportion of area of conifer forest that is moderately to severely damaged (defoliation higher than 25 per cent). European countries. 1989

Less than 10 per cent of the area	Change 1988-89	Between 10 and 20 per cent of the area	Change 1988-89	Between 20 and 40 per cent of the area	Change 1988-89
Spain (3,5)	-	Sweden (12,9)	0	Denmark (24,0)	+
Austria (4,1)	0	Germany (West) (13,2)	0	Czechoslovakia (32,0)	+
Greece (6,7)	-	Hungary (12,3)	+	Bulgaria (32,9)	+
France (7,2)	-	Switzerland (14,0)	-	Great Britain (34,0)	+
Portugal (9,8)	+	Norway (14,8)	-	Poland (34,5)	+
		Germany (East) (17,5)	+		
		Finland (18,7)	+		

+ Increase in damaged area. 0 Small change in damaged area (< 1 per cent). - Decrease in damaged area.

Source: Global Environment Monitoring System (GEMS, 1990).

Eight of the European countries considered air pollution to be the most important factor for deterioration of forest health status. The majority of the other countries regarded "forest death" as a complex phenomenon, where air pollution could be one of many factors.

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6. AGRICULTURE

Agriculture accounts for roughly 18 per cent of the total phosphorus and 28 per cent of the total nitrogen discharges to the areas of the North Sea covered by the National North Sea Plan. In terms of total anthropogenic discharges, the figures are 27 per cent for phosphorus and 48 per cent for nitrogen.

If random variations in the weather are disregarded, the available statistics on land use, domestic animal husbandry and fertilization practices indicate a slight decrease in nitrogen leakage per unit of cultivated land from 1978 to 1988. The reason is lower average fertilization, because fewer farmers use excessive amounts of fertilizer, and because of a slight rise in the expected level of yield. The Central Bureau of Statistics (CBS) and the Centre for Soil and Environmental Research (Jordforsk) are developing a system which can be used to quantify the trend in soil loss and nitrogen and phosphorus runoff from agricultural areas.

In addition to lower intensity of fertilization, the most important strategy for reducing nitrogen leakage is a fertilization practice that is better adjusted to the plants' absorption of nutrients. A tax on nitrogen in commercial fertilizers would probably serve both these purposes. The most important ways of reducing phosphorus runoff are to reduce soil preparation (tillage) and to spread manure only in the growing season.

6.1. Introduction

One of the most serious pollution problems caused by agriculture is discharge to water of nutrients containing nitrogen (N) and phosphorus (P). Large inputs of nutrients contribute to eutrophication and to periodic algal blooming. When the algae die their biomass becomes decomposed, using up the oxygen in the water masses. Sometimes the algal blooming consists of toxigenic algae.

The intention of this chapter is to take a closer look at discharges of nutrients from agriculture. It starts with an assessment of how much of the total discharges originate from agriculture. This assessment is followed by a description of the trend in the discharges, based on the agricultural statistics. The chapter also includes a description of a project carried out jointly by the Central Bureau of Statistics (CBS), the Centre for Soil and Environmental Research, Ås (Jordforsk) and the State Pollution Control Authority (SFT) to analyze discharges from agriculture. Through the North Sea Declaration of 1987 Norway has undertaken to reduce national discharges of nutrients to vulnerable parts of the North Sea by 50 per cent during the period 1985 to 1995. Therefore the chapter ends with a discussion of the relative cost-efficiency of various measures to reduce discharges of nutrients to the North Sea.

6.2. Pollution from agriculture. Share of total discharges

A large share of the total discharges of nutrients in Norway originate from agriculture. Table 6.1. shows the calculated distribution of total nitrogen and phosphorus discharges between the different sectors. The calculations refer to the second half of the 1980s for the counties included in the National North Sea Plan (Ministry of Agriculture, 1990), the so-called "algal counties". The "algal counties" are Østfold, Hedmark, Oppland, Akershus, Buskerud, Vestfold, Telemark, Aust-Agder and Vest-Agder.

Table 6.1. Calculated discharges of nitrogen and phosphorus to the nearest watercourse in the "algal counties". Per cent

Source	Phosphorus	Nitrogen
Total	100	100
Agriculture	18	28
Municipal discharges	44	21
Aquaculture	1	0
Industry	3	9
Other land and depositions in lakes	34	42

Source: Ministry of Agriculture (1990).

The figures for the agricultural sector were calculated by Jordforsk (1989) and the figures for the other sectors by various sections at SFT. The figures must be regarded as estimates. The table shows that as much as 42 per cent of the nitrogen and 34 per cent of the phosphorus comes from runoff from "other land", that is to say, natural runoff from forest and uncultivated land, deposition through rain and snow, or direct deposition from air. Municipal discharges (waste water from households etc.) and agriculture are responsible for the greater part of the remaining discharges, with the largest share of the nitrogen discharges coming from agriculture. The reason for the low figure for aquaculture is that most fish farms are located in Rogaland and counties further north, i.e. not in the "algal counties".

6.3. The trend in discharges of nutrients from agriculture

There are two types of sources of discharges of nutrients; point discharges and diffuse discharges (area runoff). Point discharges consist mainly of effluents from manure stores and silos. Area runoff consists of nutrients (N and P) lost from crop land and meadows. Around 85-90 per cent of all phosphorus discharges and 95-100 per cent of nitrogen discharges are due to area runoff, the rest are point discharges (Jordforsk, 1989). The following discussion is limited to area runoff.

There is no series of measurements showing the trend in area runoff. Therefore, an evaluation of possible changes in discharges must be based on factors which are known to influence the runoff. The single factor exerting the strongest influence on runoff is climate, in particular precipitation and snow-melting. Since variations in the weather from year to year are beyond human control, and have very little impact on farming practices from year to year, the present calculations are based on the determining factors which *are* under human control. Of these factors, the most important for runoff are fertilization practice and soil preparation. No systematic data are available in Norway on soil preparation. As far as fertilization is concerned, information on use of commercial fertilizer for nitrogen fertilization of grain land and meadows can be obtained from the Censuses of Agriculture in 1979 and 1989.

Other relevant statistics are reported figures for domestic animals and areas of agricultural land. At the request of SFT, CBS's section for agricultural statistics has collocated statistics based on data from individual farmers referring to animal numbers and area of land used for the different crops during the period 1983 to 1989, with a view to throwing some light on changes in runoff from agriculture (SFT, 1990). These data alone do not provide an adequate basis for quantifying the discharges.

The following pages include an evaluation of possible changes in pollution from agriculture during the period 1983-89, based on statistics on domestic animal numbers and land use. This is followed by an analysis of use of fertilizer and nitrogen leakage, based on data from the Censuses of Agriculture in 1979 and 1989.

Land use

Agricultural land can be placed into two categories: crop land (land that is normally ploughed each year) and meadow (land with permanent vegetation). More soil, in particular, is lost from crop land than from meadows but, in general, loss of nutrients is also greater from crop land.

Therefore, provided that other conditions remain unchanged, a major change in the ratio between meadow and crop land would indicate a change in discharges from agricultural areas. Table 6.2. shows the use of land for crop land and meadow during the period 1983-1989.

Table 6.2. Land use, crop land and meadows, 1983-89. Relative trend, for the country as a whole and in the "algal counties". 1985 = 100

	1983	1985	1987	1989
Country as a whole:				
Cultivated meadow	101.1	100	100.1	101.1
Crop land	95.1	100	101.3	101.8
"The algal counties":				
Cultivated meadow	100.2	100	99.6	100.4
Crop land	96.4	100	101.6	101.6

The table shows that while the area of cultivated meadow remained very stable there was a slight increase in the area of crop land. The largest increase took place during the period 1983 to 1985. The increase in the area of agricultural land indicates a slight increase in discharges from agriculture.

Animal density

It is of major importance for runoff that animal manure is used in a proper manner. 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. For a specific quantity of manure, the degree of absorption of nutrients is determined by three important conditions: the time the manure is spread in relation to the plant growth, whether the manure is earthed over immediately after spreading, and the amount of manure used per unit of land. There are no statistics on the time of spreading, or on earthing. As far as the quantity of manure per unit of land is concerned, some indication of change can be obtained from calculations based on animal density, that is to say, the calculated relation between number of animals and area of cultivated land. The number of animals is converted into so-called *"animal manure units"* according to the norm defined by the Ministry of Agriculture (Ministry of Agriculture, 1990). It is assumed that the quantity of nitrogen and phosphorus per animal did not change during the period.

The calculations show that farms that reared animals had 6.8 decares of fully cultivated land per animal manure unit in 1983. In 1989 the figure had risen to 7.2 decares. Similar calculations for smaller regions show the same tendency.

Table 6.3 shows the trend in the percentage of farms with more animals than permitted by the spreading area requirement of 4 decares. (According to regulations laid down by the Ministry of Agriculture, each farm must have at least 4 decares of spreading area per animal manure unit).

The calculations of the relation between cultivated area and number of animals refer to individual farms. The table shows a decrease in the percentage of farms with less than 4 decares of spreading area per animal manure unit during the period 1983-88.

All in all, the calculations of animal density indicate that the problem of high concentrations of manure is becoming less serious, giving an indication of less runoff.

takes into account different growing conditions by dividing Southern Norway into 4 yield zones. This is important for the correlation between fertilization, nitrogen leakage and yield).

Table 6.3. Percentage of farms in the different size categories with less than 4 decares fully cultivated land per animal manure unit. 1983-1988

	Farms with less than 10 animal manure units			Farms with 10-19 animal manure units			Farms with more than 20 animal manure units		
	1983	1985	1988	1983	1985	1988	1983	1985	1988
Country as a whole	10.3	11.0	10.7	18.9	17.6	15.0	36.7	33.9	28.2
"The algal counties"	5.1	5.1	5.2	8.9	8.0	5.8	17.5	15.7	12.4
Østfold	2.5	2.6	2.3	6.3	5.3	4.3	13.5	13.5	7.5
Oppland	4.9	4.9	4.7	8.4	7.3	4.5	17.5	15.4	9.1
Telemark	9.4	8.0	9.3	18.0	14.2	12.7	33.6	36.8	30.9
Rogaland	30.9	30.7	29.6	70.6	68.0	63.2	86.1	82.3	73.4
Nord-Trøndelag	3.5	2.9	2.0	4.7	4.0	3.0	10.2	9.4	4.7

Analyses of fertilization and runoff based on the Censuses of Agriculture in 1979 and 1989.

Experiments show a positive correlation between the intensity of nitrogen fertilization and nitrogen leakage. Therefore, information on fertilization is of particular interest when evaluating runoff from agricultural land. In the Censuses of Agriculture in 1979 and 1989 the farmers reported how much nitrogen in terms of commercial fertilizer they had spread on grain land and how much on cultivated meadow in 1978 and 1988. Tables 6.4 and 6.5 show the average fertilization of grain and meadow in a number of selected areas, based on the above mentioned reports. The quantity of manure is calculated for each farm on the basis of reports of animal numbers and areas of land in 1979 and 1989. The calculations were carried out using the model SIMJAR 2 (Høie et al. 1990). (SIMJAR is the Norwegian abbreviation for Simulation Model for Soil Erosion and Area Runoff from Agriculture. SIMJAR 2 applies to the whole of Southern Norway, and

It is seen from the tables that, as a whole, average fertilization decreased slightly in Southern Norway for both grain and meadow land, but there were certain regional variations. There was a slight increase in the amount of fertilizer spread on meadow in Eastern Norway, but a slight decrease in fertilizer to grain. The tendency was the opposite in Rogaland, with a marked reduction of fertilizer to meadow.

The tables show a slight increase in use of commercial fertilizer per decare from 1978 to 1988. For Southern Norway as a whole there was no change in the intensity of fertilization to grain, but a slight increase to meadow. In Rogaland, where the greater part of the agricultural land is meadow, there was a decrease in fertilization of meadow, but an increase in fertilization of grain.

If Nord-Trøndelag is excluded, the calculations for grain and meadow combined show that less manure is spread per unit of land. Even if these figures depend to some extent on how the manure is distributed in the model, the tendency shown in the table is plausible, since the amount of manure as a whole has been reduced, and the grain and meadow areas cover well over 90 per cent of the cultivated land.

grain land and meadow increased even more, by just over 7 per cent. This confirms a decrease in average fertilization.

Table 6.4. Average nitrogen fertilization to grain. 1978 and 1988. Some selected areas. Kg N/decare

	Total fertilizer		Commercial fertilizer		Manure	
	1978	1988	1978	1988	1979	1989
Southern Norway	12.0	11.9	10.6	10.6	1.4	1.3
"The algal counties"	12.2	12.0	11.0	11.0	1.2	1.0
Østfold	13.6	12.9	12.1	11.6	1.5	1.3
Oppland	11.7	11.7	10.0	10.1	1.7	1.6
Telemark	12.5	11.9	11.2	10.9	1.3	1.0
Rogaland	13.9	15.3	7.9	8.1	6.0	7.2
Nord-Trøndelag	10.4	10.6	8.2	8.4	2.2	2.2

Table 6.5. Average nitrogen fertilization to cultivated meadow. 1978 and 1988. Some selected areas. Kg N/decare

	Total fertilizer		Commercial fertilizer		Manure	
	1978	1988	1978	1988	1979	1989
Southern Norway	18.9	18.8	14.3	14.5	4.6	4.3
"The algal counties"	15.7	15.9	12.6	13.1	3.1	2.8
Østfold	18.7	19.1	17.1	17.7	1.6	1.4
Oppland	16.0	16.1	12.3	12.8	3.7	3.3
Telemark	11.3	12.2	8.6	9.5	2.7	2.7
Rogaland	33.4	28.5	21.7	18.7	11.7	9.8
Nord-Trøndelag	20.1	20.9	17.1	17.8	3.0	3.1

All the general tendencies shown in the tables are confirmed by overall reports on sales of commercial fertilizer, animal numbers and areas of land. The total amount of nitrogen supplied from commercial fertilizer and manure to grain and cultivated meadow in Southern Norway increased by just under 6 per cent from 1978 to 1988, while the area of

A slight increase in the average use of commercial fertilizer is confirmed by sales statistics from Norske Felleskjøp and changes in areas of cultivated land: the total quantity of nitrogen sold in the form of commercial fertilizer increased by 8.8 per cent (from 103 000 tonnes to 111 000 tonnes), while, as mentioned above, the area of grain land and meadow increased by just over 7 per cent.

The decrease in quantities of manure per decare is due to two factors; fewer animals and an increase in the area of cultivated land. Other calculations in SIMJAR 2 show that the average quantity of nitrogen accessible to plants from manure ("plant-accessible" nitrogen) in South Norway decreased from 3.7 kg/decare in 1979 to 3.4 kg/decare in 1989.

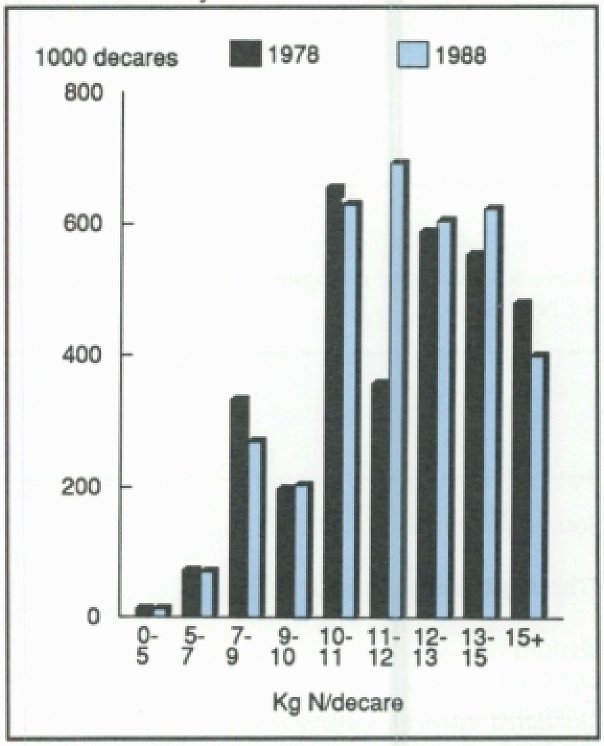
When calculating the amounts of manure, the quantity of nitrogen per animal is assumed to be the same in the two years. There are no data on how the manure is distributed between the different kinds of crops. The model handles this distribution as follows: it is assumed that all the manure on each farm is spread within the boundaries of the farm itself, and is distributed between the different crops in the following order; forage crops, potatoes, vegetables, grain and meadow, depending on the phosphorus requirements of the different plants. The calculations include only the so-called "plant-accessible" nitrogen in the manure (this comprises between a third and half of the total nitrogen in manure), so that, in actual fact, the quantities of nitrogen supplied are much higher.

In the Censuses of Agriculture in 1979 and 1989 a large number of the farmers reported 0 consumption of commercial fertilizer-N, or neglected to report the quantity (this applies in particular to meadow). For these farms the consumption was fixed at the average for the rest of the municipality. Furthermore, there is some uncertainty attached to the reports because it may be difficult for the farmer to estimate the correct quantity. The quality of the reported use of commercial fertilizer in the two censuses has been assessed using other calculations in SIMJAR 2 and sales figures for commercial fertilizer from Norske Felleskjøp. This evaluation indicates that the reports are about equally tenable in both censuses, and that the figures calculated in the model for commercial fertilizer-N to grain and meadow are reasonably correct. The figures for manure to grain and meadow are more uncertain, because no data exist on how the manure is distributed between the two crops. This means that the figures for total fertilization are also more uncertain than the figures for commercial fertilizer-N.

Distribution of the land by intensity categories

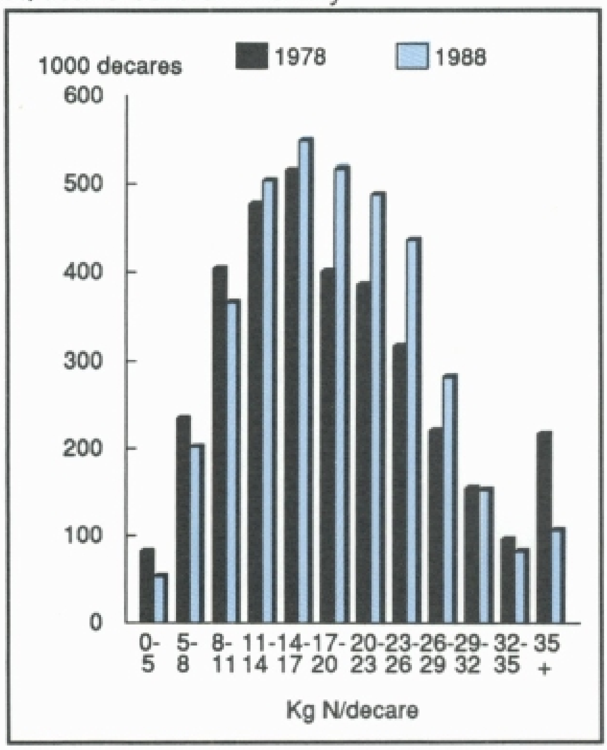
In reality, the fertilizer is not spread out equally over the agricultural land. Some fields are fertilized heavily, others more lightly. Figures 6.1 and 6.2 show the areas of grain land and cultivated meadow distributed between different intensity categories for nitrogen fertilizer.

Figure 6.1. Nitrogen fertilization to grain in 1978 and 1988. Area in decares distributed between different intensity categories by kg N/decare. Southern Norway



The figures show a decrease at both ends of the scale, namely in areas with extremely high and extremely low levels of fertilization. Fewer areas with an extremely high level of fertilization would normally imply a more efficient absorption of the nutrients in the fertilizer, since the plants make use of only a very small share of the "extra" fertilizer at high levels of fertilization. The figures show that, in 1988, the farmers' fertilization practices conformed to a greater degree with prescribed needs than was the case in 1978. The prescribed needs have not changed very much during the period, but vary considerably from one part of the country to another. Since the figure applies to the whole of Southern Norway, it is necessary to calculate changes in fertilization practice in smaller regions in order to establish if there really is a clear general tendency towards more even fertilization.

Figure 6.2. Nitrogen fertilization to cultivated meadow in 1978 and 1988. Area in decares distributed between different intensity categories by kg N/decare. Southern Norway



Calculated nitrogen leakage on the basis of fertilization figures

Experiments show a clear correlation between fertilization level and runoff level. The correlations between N-fertilization and N-leakge are presented in Uhlen and Lundekvam (1988), a study which provided a basis for constructing functions for nitrogen leakage for Southern Norway (Høie et al. 1990). Table 6.6 shows the calculated nitrogen leakage from agricultural land in a number of selected areas based on these functions and on the Censuses of Agriculture in 1979 and 1989. The calculations were carried out using the model SIMJAR 2.

Table 6.6 shows a slight decrease in average runoff per unit of land. In general, however, the decline in runoff is slightly stronger then the reduction in average fertilization (cf. tables 6.4. and 6.5). This is because farmers are following a more similar fertilization practice and, in particular, because fewer farmers are fertilizing at an extremely high level (cf. figures 6.1 and 6.2). Both these changes have the effect of reducing runoff, because the runoff functions on which the calculations are based decrease quadratically with a lower level of fertilization.

The runoff functions on which the calculations are based are uncertain, but the underlying principle is that runoff increases with increasing quantity of fertilizer, and decreases with increased level of yield, given a specific quantity of fertilizer (runoff functions increase more slowly in areas with good growing conditions).

The table does not present runoff from areas other than grain land and meadow. Data are lacking on use of commercial fertilizer on other crops. In addition, the experiments forming the basis of the runoff correlations were carried out on grain land and meadow. Normally, due to high fertilizer intensities, there is a higher level of runoff from land with forage crops, vegetables and potatoes than from grain and meadow land.

The following factors may also influence yield and runoff levels. In the calculations, however, they are assumed to be the same for the two years:

- climate
- original fertility of the soil
- plant material (varieties and species cultivated)
- farming practices (plant protection, soil preparation etc.).

These factors are not included in the calculations for the following reasons: Climate affects runoff both directly (precipitation, temperature and snow-melting) and indirectly (variations in the yield). The fertilizer is usually spread at the beginning of the growing season. Therefore, in practice, the level of fertilization must be adjusted to the expected yield for the year in question. This means that, with today's fertilizing practice, the type of weather must be regarded as a chance factor of influence, even if it has a strong impact on runoff in the year in question. The other factors cannot be quantified in the model, but it is possible to make an assessment based on "expected yield" (Norwegian Institute of Agricultural Research, 1988). The expected grain harvest increased from 340 to 396 kg/decare from 1978 to 1988. For meadow the increase was from 671 to 724 kg/decare. Since there was no increase in the level of fertilization, at least not for grain (cf. tables 6.4 and 6.5) this increase in yield must be put down to other factors affecting growth. This indicates a tendency towards steadily better utilization of the nitrogen in the fertilizer for plant growth, which in itself helps to reduce runoff. In the light of these considerations it is very likely that agricultural progress in the form of better plant material and better farming practices will contribute towards an even greater reduction in runoff than indicated in table 6.6.

To sum up

It is clear from the above that, due to the lack of several important items of information, the analyses of the trend in runoff are uncertain. The analyses based on the Censuses of Agriculture in 1979 and 1989 show a slight decrease in nitrogen leakage per decare. The estimated reduction is so small, however, that it cannot be regarded as anything more than an indication of a decrease in runoff, if climatic factors are excluded. The reason for the uncertainty is that the runoff functions are based on a relatively limited study material, and many factors which affect runoff are not taken into account.

The total area of cultivated land increased by just less than 7 per cent from 1979 to 1989. This is more than the calculated reduction in nitrogen leakage per decare. Therefore the total nitrogen leakage from agricultural land has probably increased slightly during the same period. In SIMJAR 2 it is estimated that the total N-leakage from grain and meadow land in Southern Norway increased from 22.3 million kg N in 1978 to 22.8 million kg N in 1988.

Table 6.6. Calculated nitrogen leakage in 1978 and 1988 based on fertilization intensity. Some selected areas. Kg N/decare

	Grain		Meadow		Average for grain and meadow	
	1978	1988	1978	1988	1978	1988
Southern Norway	3.3	3.2	3.3	3.1	3.3	3.2
"The algal counties"	3.3	3.2	2.7	2.7	3.1	3.0
Østfold	3.6	3.3	2.8	2.9	3.5	3.3
Oppland	3.4	3.3	3.1	3.0	3.2	3.1
Telemark	3.4	3.2	1.7	1.9	2.6	2.6
Rogaland	4.1	4.7	7.0	4.8	6.5	4.9
Nord-Trøndelag	3.5	3.6	3.4	3.5	3.5	3.5

The available data do not permit an evaluation of changes in soil erosion and loss of phosphorus. Therefore CBS, in collaboration with Jordforsk and SFT, has started a project to enable calculation of soil erosion and phosphorus runoff. This project is presented below.

6.4. Analysis: OMJAR - a model for monitoring soil erosion and area runoff in agriculture

In principle, there are two ways to quantify discharges from agriculture in larger areas. One method is to measure the soil and nutrient content in the recipients (lakes, streams and rivers). The other method is to estimate discharges on the basis of farming operations, type of soil, and climate in the area. The first method produces a reasonably reliable estimate of total inputs to the recipients, but if the figures are to apply to larger areas the measurements have to be carried out in the main recipients, for practical and economic reasons. This makes it impossible to distinguish between the different sources of pollution, such as municipal discharges and runoff from agriculture. The measurements are also strongly influenced by climate, in particular precipitation and snow-melting. Furthermore, if the calculations are based on measurements alone, it is also difficult to isolate the effect of any measures that are taken. Therefore, in order to calculate discharges from the agricultural sector in particular, and to assess the effect of any implemented measures, it is necessary to undertake theoretical calculations based on records of land use and farming practices.

CBS and Jordforsk, in collaboration with SFT, are in the process of constructing a model to calculate losses of nitrogen, phosphorus and soil from agricultural land. The model is called OMJAR (Norwegian abbreviation for Model to Monitor Soil Erosion and Runoff from Agricultural Land). The calculations will be carried out on the basis of regular statistics from applications for production subsidies (The Subsidies Register), the Sample Census of Agriculture, and own recordings.

The model can be used to:

Calculate the trend in soil and nutrient runoff

The only way to reduce runoff is to change the way the soil is used. The above-mentioned sources of data make it possible to record how the land is used, soil preparation practices and fertilization intensity. By updating these sources of data at regular intervals it will be possible to follow the trend in runoff due to conditions caused by human influence.

Calculate the potential to reduce runoff

The model that is being developed will also be suitable for analyzing the effects of possible measures (simulation model), and will therefore provide a better basis for recommending what measures to carry out.

Collected data on erosion hazard will provide a picture of variations in erosion hazard in a specific area, and thus of the potential of the different measures to reduce soil and phosphorus loss in the area. If the aim is to reduce soil loss and runoff by a certain amount, the model can be used to make priorities on the basis of erosion hazard, and thus decide on what types of fields to implement the measures. The greater the variation in erosion hazard in an area, the greater the benefit to be obtained from ranking the types of fields. Other information on the farms can also be used to make these priorities. For example, it can be assumed that the existing production on each single operating unit remains unchanged (information on what is produced can be obtained from the Subsidies Register). Such an assumption may conflict with the theoretically most cost-efficient way of reducing soil and nutrient losses (see section 6.5), but may be necessary in order to achieve other objectives in the agricultural sector. Changing methods of operation in a specific production unit (e.g. stopping autumn ploughing) will often have far less drastic consequences for the individual farmer than changing the production itself (e.g. changing over from grain production to domestic animal husbandry and cultivation of meadow).

In the long-term it is possible that attempts will be made to establish correlations between yield, manpower requirement, capital costs and other costs on the one hand, and different operational techniques on the other. Taking into account economy and production in this way will provide a more complete picture of the consequences of measures to prevent soil loss and runoff from land.

Methods and result variables

Calculation of erosion depends on three types of data:

- operating routines (production, soil preparation)
- information on the soil and the terrain
- climatic factors

Soil, terrain and climatic conditions are regarded as constants which do not vary from year to year. Therefore, in this connection, production routines are the factor about which information is collected annually, and which determine the calculated trend over time.

Table 6.7. Content of the three registers in OMJAR

REGISTER	DATA-TYPE	SCOPE	UPDATED
SUBSIDIES REGISTER	- Number of animals by type - Area of each crop	Almost all farms	Annually
SAMPLE CENSUS	- Fertilization - Soil preparation	About 20 per cent of all farms	Annually, or as needed
"MINI-SAMPLE"	- Soil type data (erosion hazard) - Data on farming practices connected to different erosion hazard categories	2-10 per cent of all farms	Annually, or as needed

Loss is calculated using the "Universal Soil Loss Equation" USLE, developed in the United States (USDA, 1978). Soil loss, A, for an area is calculated as follows:

A = R * K * LS * C * P, where
A = soil loss per unit of land through one year
R = climatic factors (precipitation, snow-melting, etc.)
K = erodability factor for the soil (how readily the soil erodes because of its properties)
LS = terrain factor (combination of length and degree of slope)
C,P = factors for cultivation systems and production routines

Since USLE was developed in the USA, the various factors must be adapted to Norwegian conditions.

Phosphorus runoff

Phosphorus is lost from agricultural land either in the form of salts dissolved in the runoff water or adsorbed to particles of soil which are eroded away. Losses of dissolved phosphorus from meadow show an almost linear correlation with fertilization intensity, while dissolved phosphorus from crop land is fixed as a constant in relation to type of soil.

In the case of crop land, most of the phosphorus is lost through erosion, since the phosphorus is adsorbed to the soil particles. The phosphorus loss is thus calculated by multiplying the soil loss by the concentration of phosphorus in the soil. The figures for phosphorus concentration in the soil are obtained from the Soil Data Bank at the Norwegian Institute of Land Inventory (NIJOS). This data bank contains analyses of the P-content in soil carried out in connection with fertilization planning.

Nitrogen leakage

The correlations for nitrogen leakage in SIMJAR 2 (see section 6.3) can be used in the same way in OMJAR. The correlations determining nitrogen leakage are complex, so a thorough evaluation will be undertaken to determine how well they describe the N-leakage.

Basic data

Table 6.7 shows the data obtained from the three main sources of information. The unit used in all three registers is the farm. This means that the data from the three registers can be linked by means of the main land registration number and the property number in the Land Register.

The Subsidies Register: This is the "main" register, because it covers almost all farms. It contains the number of domestic animals and the area of land used for each crop on each farm. This allows calculation of the relationship between amount of manure and spreading area. This register is updated annually.

The sample census: For many years, CBS has carried out annual censuses on agriculture in a sample of farms. These censuses include about 20 per cent of the total number of farms. The 1990 census included questions about soil preparation and fertilization. These questions can be repeated in future censuses.

"Mini-sample": In order to calculate soil erosion it is necessary to obtain information on how susceptible the land is to erosion with different farming practices. For example, how much a change in soil preparation practices will affect loss of soil will vary with the potential erosion hazard (soil properties and slope of the ground). Soil type data providing information on erosion hazard are available for only small parts of the land used for agriculture in Norway (from the soil surveys carried out by NIJOS). Therefore the OMJAR project will include data on erosion hazard in a "mini-sample" of farms. Using maps and information on the type of soil in the sample area, the land of these farms will be divided into smaller units of land depending on potential erosion hazard. Because the different soil preparation practices will have different effects on soil loss, the farmers will be asked about their practices in these different units of land.

6.5. Cost-efficiency of measures to reduce pollution from agriculture in connection with the North Sea Declaration

If Norway is to fulfil the commitments defined in the North Sea Declaration, and in the light of the discharges caused by agriculture (cf. table 6.1), steps must be taken to reduce the discharges. The most expedient way to reduce the discharges from the economic point of view is to implement measures which will give the greatest reduction for each invested unit of money. To achieve this cost-efficiency it is necessary to quantify two conditions with reasonable certainty: to what extent the discharges are reduced by the measure in question, and what the measure costs.

In order to reduce discharges to a specific recipient cost-efficiently it is necessary to evaluate measures within all sectors that produce discharges (e.g. industry and agriculture), compare the different measures within each sector (e.g. sealing manure stores, and reducing soil preparation) and assess how far to proceed with each measure, because the cost-efficiency may vary (e.g. both the cost and effect of sealing silos can vary from farm to farm). It is also necessary when assessing socio-economic cost-efficiency to take into account that the profitability may be affected by possible subsidies and taxes.

In the case of measures to reduce discharges to a recipient such as the North Sea it is especially difficult to achieve a cost-efficient strategy for reducing discharges from all the different countries. The North Sea Declaration states that all countries must make the same percentage reduction in discharges, which conflicts with the principle of cost-efficiency. This problem is discussed in more detail in Johnsen (1990).

In tables 6.8 and 6.9 the measures adopted in the National North Sea Plan and taxes on commercial fertilizer are ranked on the basis of cost-efficiency in the context of discharges to the North Sea (Thus the calculations apply only to the "algal counties"). The calculations take into account retention in watercourses and biological accessibility of phosphorus.

Christoffersen et al. (1991) used SIMJAR 2 (Høie et al., 1990, Sødal & Aanestad, 1990) to calculate the costs and reduction in runoff as a consequence of a tax on nitrogen. For all the other measures the reduction in runoff is based on Jordforsk (1990) and the costs are based on Magnussen & Sandberg (1989).

The units for which cost-efficiency is calculated in table 6.9 apply to a weighted relation between nitrogen and phosphorus discharges to the North Sea and the local effect of phosphorus discharges (Ministry of Environment, 1990).

The table shows that the most cost-efficient measures are "the economically optimal fertilization practice for the enterprise" and "two-phase fertilization". This is because they lead to a cost reduction in themselves due to reduced fertilizer consumption. A low tax on commercial fertilizer-N is also cost-efficient. The least cost-efficient measures are sealing manure stores and silos.

The effect of a tax on nitrogen is based on an assumed economically optimal use of fertilizer on each farm, i.e. that the farmer adds nitrogen until the value of the expected additional yield is equal to the price of the last supplied unit of nitrogen. An increase in the price of nitrogen will imply that the economically optimal level of fertilization is lower, because the marginal yield increment decreases with increasing fertilization. The marginal increment of nitrogen leakage increases with increased fertilization. The cost in connection with this

Table 6.8. Ranking of measures to reduce N-discharges according to cost-efficiency

Measure	Cost mill. NOK	Reduction in tonnes N	NOK/kg reduced discharge
1. Economically optimal fertilization practice for the enterprise (farm)	-47	649	-72
2. Two-phase fertilization to grain (spread of fertilizer twice during the growing season)	-5	814	-6
3. Tax on N in commercial fertilizer, NOK 4/kg N	1	1 286	1
4. Tax on N in commercial fertilizer, NOK 12/kg N	67	3 059	22
5. Alternative crops (meadow) on steep crop land	1	11	84
6. Spreading manure in the growing season only	44	457	95
7. Appropriate measures on levelled land	5	15	346
8. Tightly sealed manure stores	32	84	373
9. No soil preparation in the autumn	43	98	434
10. Tightly sealed silos	29	34	847

Source: Christoffersen et al. (1991).

measure lies in loss of income due to reduced harvest. The value of the yield is calculated on the basis of world market prices (Aanestad & Sødal 1990). For practical reasons a possible tax on commercial fertilizer-N would have to be imposed nation-wide. The calculations do not cover the area outside the "algal counties". This means that the total costs would be higher than shown in the table, and the measure will not be as cost-efficient as shown in the table if the benefit from the reductions in discharges is less in other parts of the country than in the "algal counties".

The ranking of the different measures is based on the effect achieved from each measure if implemented throughout, and if no other measures are taken. This is neither realistic nor particularly cost-efficient.

Some of the measures overlap. For example, if the measures "no soil preparation in the autumn" and "alternative crops on steep crop land" are introduced in the same piece of land they prevent erosion of the same soil. This means that the ranking may be changed if a farmer starts to implement some of the measures.

Table 6.9. Measures to reduce nitrogen and phosphorus runoff to the North Sea. Ranking according to cost-efficiency in units of a weighted relation between nitrogen and phosphorus

Measure	Cost mill. NOK	Reduction in no. units	NOK/unit reduced discharges
1. Economically optimal fertilization practice for the enterprise (farm)	-47	750	-63
2. Two-phase fertilization to grain (spread of fertilizer twice during the growing season)	-5	814	-6
3. Tax on N in commercial fertilizer, NOK 4/kg N	1	1 356	1
4. Alternative crop (meadow) on steep crop land	1	141	6
5. Tax on N in commercial fertilizer, NOK 12/kg N	67	3 216	21
6. Appropriate measures on levelled land	5	199	27
7. No soil preparation in the autumn	43	1 311	33
8. Spreading manure in the growing season only	44	1 044	43
9. Tightly sealed silos	29	165	175
10. Tightly sealed manure stores	32	162	194

Source: Christoffersen et al. (1991).

The calculations of cost-efficiency do not take into account a possible improved degree of utilization of manure. When the price of commercial fertilizer-N rises, the nitrogen in manure increases in value. A possible consequence might be to handle manure in a way which would imply better exploitation of the nutrients it contains. This would lead to even lower consumption of commercial fertilizer and a lower level of runoff (Christoffersen et al., 1991).

The effect of the other measures assumes the same level of yield and distribution of agricultural production as at present.

It must be emphasized that both the calculated effect of the different measures, and the costs, are associated with a high level of uncertainty. There is little reliable information on how far the measures have been already implemented. For example, the measure called "economically optimal fertilizing practice for the enterprise" would have had greater effect in 1978 than it did in 1988, because in 1988 more farmers followed the prescribed fertilization levels (cf. figures 6.1 and 6.2). In the comparison of socio-economic costs there is also some uncertainty due to lack of consistency in the calculations, because the costs have to be calculated in different ways. The costs of a tax on nitrogen refer mainly to increased import due to decreased yield. Therefore, in this case, the factor determining the cost is the price of the additional import. As far as extension and sealing of manure stores is concerned, however, the greater part of the costs refer to labour, which means that, in this case, the factor determining the socio-economic cost is the alternative value of this labour.

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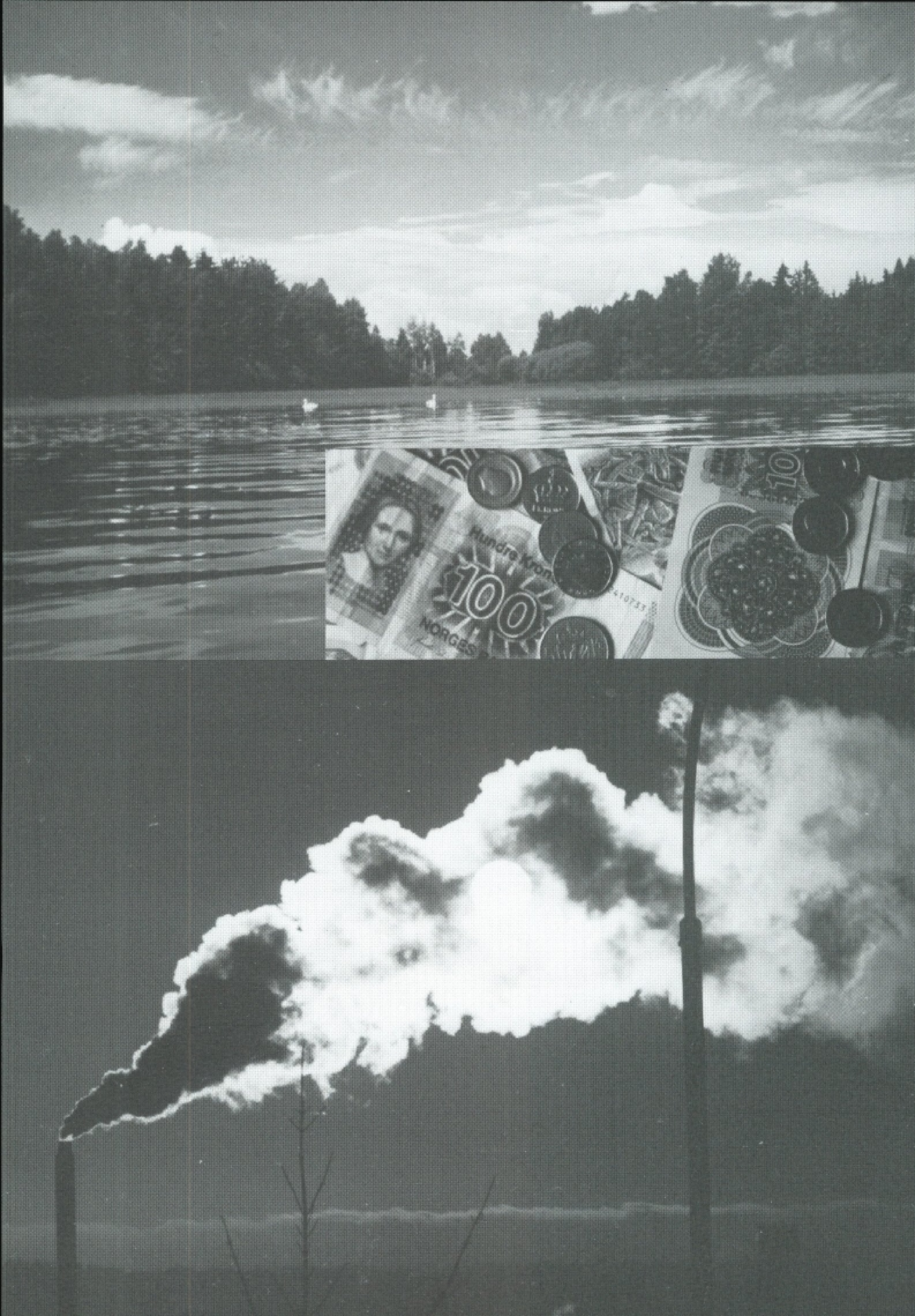
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7. ATTITUDES TOWARDS ENVIRONMENTAL ISSUES

In 1990, the Central Bureau of Statistics (CBS) conducted an interview survey called "Attitudes towards environmental issues". The survey shows that almost half the population think that protection of the environment should take priority over economic growth, even if this implies a somewhat slower rate of economic growth. In summer 1990, a majority of the population were critical of the authorities' environmental policy. A large percentage reported concern about national and international environmental problems; as many as 85 per cent were very concerned about at least one of four international problems. A total of 27 per cent think that they have serious cause to complain about at least one of eight local environmental problems. Water pollution seems to cause greatest concern at local level.

Comparing Norway with EEC countries, a much smaller percentage of the Norwegian population complain about local environmental problems. Similarly, a slightly smaller percentage are concerned about national environmental problems. The high level of concern about international problems seems to be unique to Norway. Neither in the United States, Japan nor any EEC country is such a large percentage of the population very concerned about these problems.

7.1. Introduction

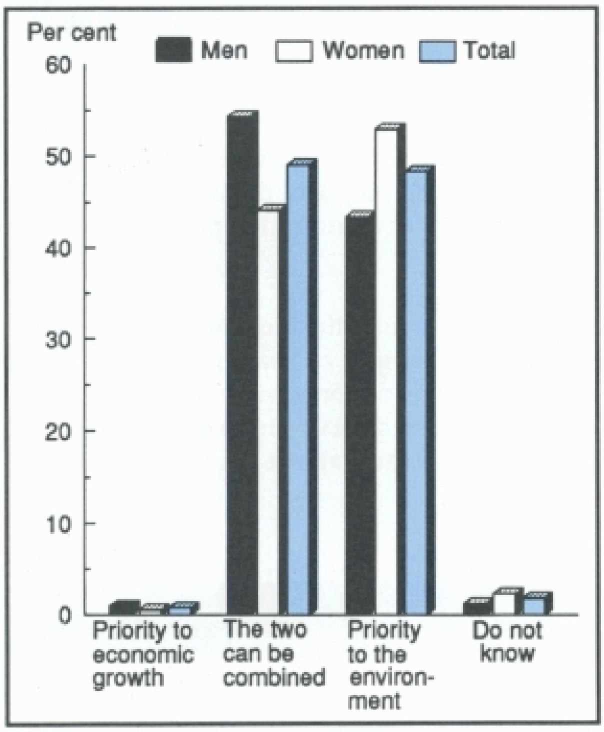
In summer 1990 the Central Bureau of Statistics (CBS) conducted an interview survey on the attitude of the population towards environmental problems. The survey was carried out as a supplement to the Labour Force Sample Survey. A primary objective was to compare public opinion on environmental problems in Norway with opinion in the EEC and other countries. The questions were very similar to those posed in similar surveys in EEC countries. The results of these surveys have been published for many years in OECD and EEC reports.

7.2. Opinions on environmental policy

Protection of the environment or economic growth?

A fundamental topic in the debate on environmental issues has been the relation between economic growth and protection of the environment. Some of the strong proponents of environmental protection have maintained that economic growth is the main cause of environmental problems and that "growth" and "protection" are incompatible. The attitude of the authorities is that environmental protection can be combined with continued economic growth. The population seems to be split in half in regard to the relative importance of environmental protection and economic growth. 49 per cent think that the statement closest to their own standpoint is that *"economic growth and environmental protection can be* *combined"* (figure 7.1), while 48 per cent say that the statement that best expresses their own view is that *"protection of the environment should receive priority even if this means curbing economic growth to some extent"*. Almost none wished to give priority to economic growth at the expense of the environment. Only one per cent of the population meant that their own standpoint was best expressed by the statement *"economic growth should be given priority, even if the environment suffers to some extent"*.

Figure 7.1. Priority to economic growth or protection of the environment. Sex. Per cent



The standpoint on the problem of growth versus protection is difficult to compare with the opinions expressed in surveys conducted in EEC countries because the questions did not have exactly the same formulation. However, in a Finnish survey from 1989 the questions were formulated as in the Norwegian survey. Allowing for the fact that the surveys were carried out at different times, it seems that a larger share of the Finnish than the Norwegian population give priority to environmental protection. Almost two thirds of the respondents in Finland would give priority to the environment, while 26 per cent thought that environmental protection and economic growth are both possible (OECD, 1991b). On the other hand, a larger percentage in Finland than in Norway give priority to economic growth.

In Norway the percentage who have no opinion ("do not know") is very low. This indicates a relatively high degree of awareness of environmental issues. Only two per cent did not know which of the statements conformed best with their own opinion. In the survey conducted in the EEC countries in 1988 the "do not know" percentage ranged from 26 per cent in Portugal to 4 per cent in France and Luxembourg, with an average of 7 per cent.

A larger proportion of women than men wish to give priority to environmental protection (53 as against 43 per cent, see figure 7.1). The association with age is weak and not entirely unambiguous: It is true that protection of the environment receives higher priority in the youngest age group than in all the other age groups combined, but protection of the environment received equally high priority among persons aged 60-73 years as among persons aged 25-44 years (see figure 7.2).

Men in the age group 25-44 years and women in the age group 16-24 years represent the extremes as regards the standpoint on economic growth and protection of the environment (38 per cent of the first group and 58 per cent of the second group agree with the statement that priority should be given to protection of the environment).

The percentage who wish to give priority to protection of the environment varies considerably depending on political affiliation (figure 7.3). The Progress Party and the Socialist Left Party represent the extremes. While one in three of Progress Party supporters wish to give priority to the environment, this applies to 7 out of 10 persons supporting the Socialist Left Party. The attitude among Conservative Party supporters is more or less the same as among supporters of the Progress Party, while the attitude of Labour Party, Christian Democratic Party and Centre Party voters is about the same as the average for the population (48 per cent). The Liberal Party is closest to the Socialist Left Party (61 per cent).

Figure 7.2. Priority to economic growth or protection of the environment. Age. Per cent

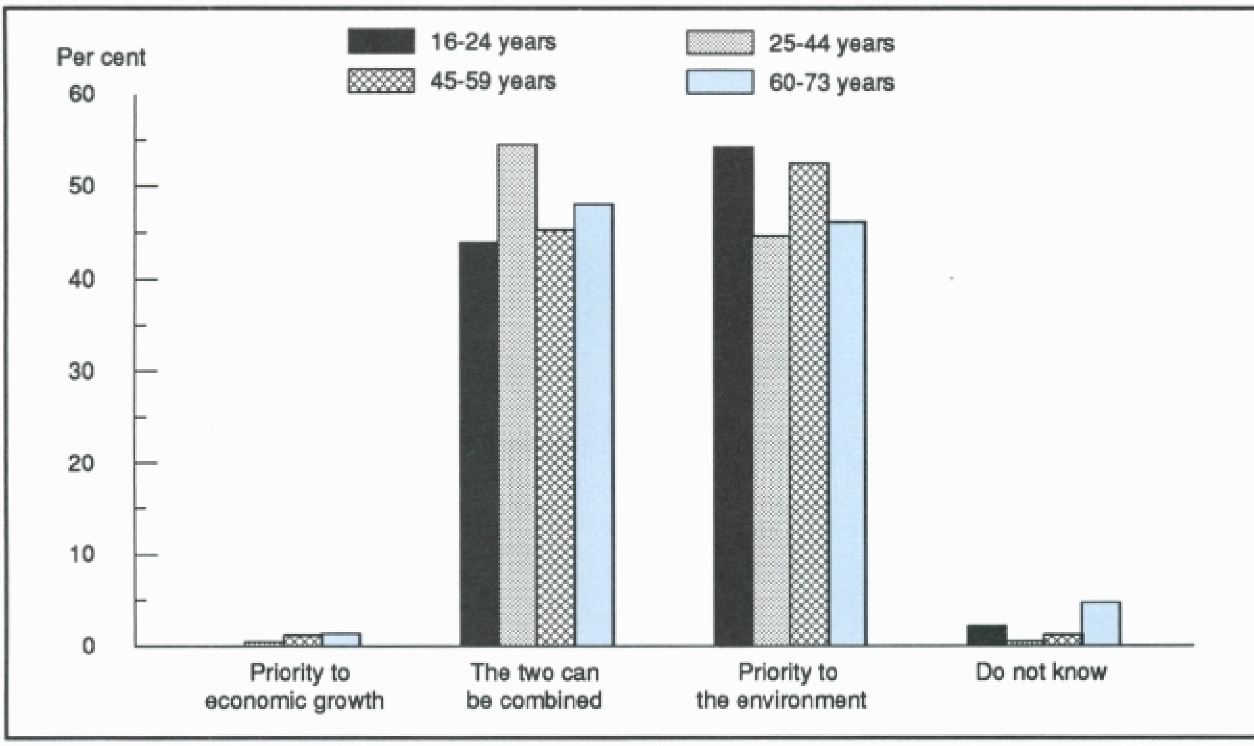
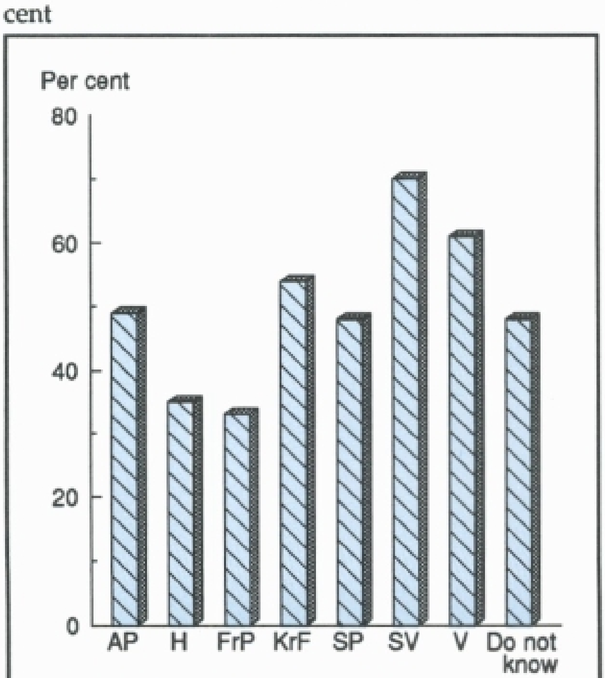


Figure 7.3. Priority to economic growth or protection of the environment, by political affiliation. Per cent



AP = Labour Party, H = Conservative Party, FrP = Progress Party, KrF = Christian Democratic Party, SP = Centre Party, SV = Socialist Left Party, V = Liberal Party.

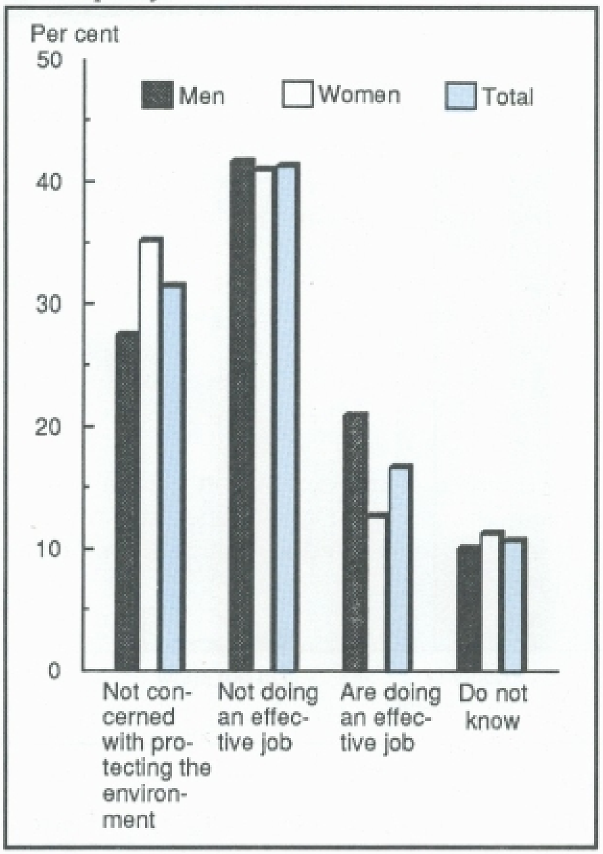
The percentage who wish to give priority to economic growth is below 3 per cent for all parties.

The standpoint on priorities with regard to economic growth and environmental protection varies little with household income, education, and residential locality, except that persons with a higher education who live in urban settlements of more than 100 000 inhabitants tend to give higher priority than other groups to protection of the environment.

Opinion on the authorities' environmental policy

The interviewees were asked to assess the authorities' environmental policy by means of two questions. They were asked whether they thought that "the responsible authorities in Norway are concerned with protection of the environment". Those who answered this question in the affirmative were also asked whether they thought that "the authorities are, or are not, doing an effective job of protecting the environment".

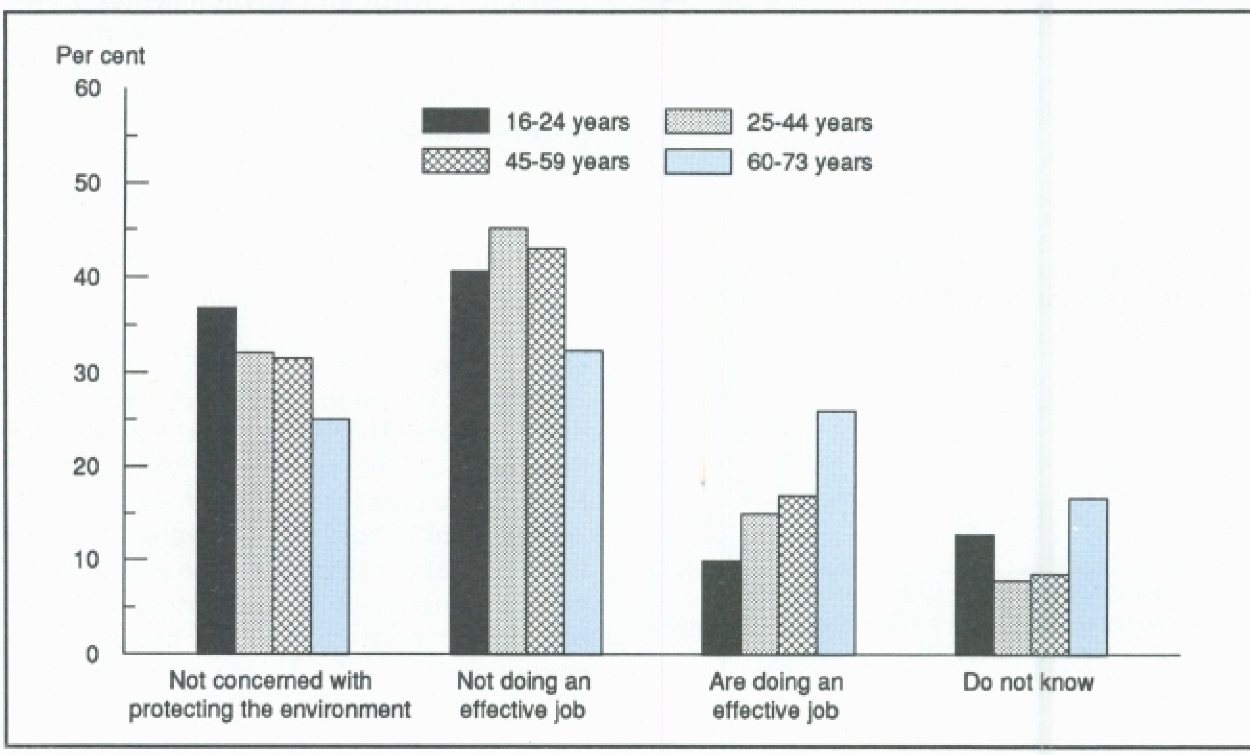
Figure 7.4. Evaluation of the authorities' environmental policy. Sex. Per cent



The majority of the population (64 per cent) thought that the Norwegian authorities are concerned, and 31 per cent that they are not concerned, with environmental protection (figure 7.4). Of those who thought that the authorities are concerned with environmental protection, a majority (65 per cent, or 41 per cent of the total sample) thought that the authorities are *not* doing a good job in this connection. Only 17 per cent gave the authorities the best reference, stating that they were both concerned with environmental protection and were doing a good job. This result agrees with a survey carried out by MMI (Markeds- og Mediainstituttet A/S), also in 1990, where 15 per cent thought that the Government "takes protection of the environment seriously and is doing a lot to strengthen environmental protection", while 38 per cent thought that "the Government was trying, but was powerless" (Bellona Magasin, 1990).

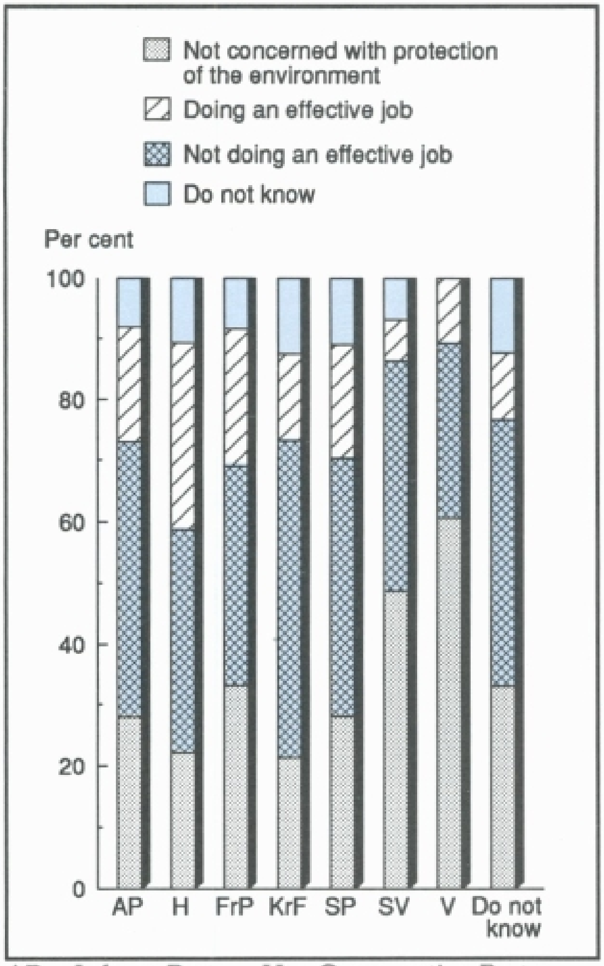
Women are rather more critical than men, and younger persons are slightly more critical than older persons (figures 7.4 and 7.5); 37 per cent of the age group 16-24 years and 25 per cent of the age group 60-73 years expressed the most critical opinion. If sex and age are considered combined, the survey shows that 41 per cent

Figure 7.5. Evaluation of the authorities' environmental policy. Age. Per cent



combined, the survey shows that 41 per cent of the youngest women think that the authorities are not concerned with environmental protection. This is twice the percentage among the oldest men.

Figure 7.6. Evaluation of the authorities' environmental policy according to political affiliation. Per cent



AP = Labour Party, H = Conservative Party, FrP = Progress Party, KrF = Christian Democratic Party, Sp = Centre Party, SV = Socialist Left Party, V = Liberal Party.

Opinions on the authorities' environmental policy naturally vary with political standpoint (figure 7.6). In summer 1990, supporters of the Liberal and Socialist Left parties were much more critical than other groups of voters. 61 per cent of Liberal Party supporters and 49 per cent of Socialist Left supporters thought that the authorities were not concerned with protection of the environment. Only 11 and 7 per cent respectively gave the authorities "top marks". The least critical of the environmental policy were those who, in summer 1990, supported the coalition government parties (Conservative, Centre and Christian Democratic parties) and Labour Party voters. There were certain distinctions, however, between the traditional non-socialist parties. Conservative Party voters were clearly more satisfied with the environmental policy than supporters of the more centre-oriented Centre Party and Christian Democratic Party. There was little difference between the standpoint of these two parties and that of the Labour Party.

There was no clear correlation between opinions on the environmental policy and residential locality, level of education or gross household income.

7.3. Complaints about local environmental problems

The interviewees were asked if they had any cause to complain about eight specific environmental problems in their residential locality. If each problem is considered separately, the general pattern is a large majority who do not think that they have any cause at all to complain (table 7.1). The exception is cause to complain about pollution of rivers, lakes and fjords, where 15 per cent mean that they have *serious* cause to complain about this situation in their residential locality, and 31 per cent state that they have *some* cause to complain.

In other respects there are few who mean that they have *serious* cause to complain about local environmental problems. 5-6 per cent mean that they have serious cause to complain about the quality of the drinking water, noise, air pollution and waste disposal. 4 per cent have cause to complain about deterioration of the landscape, only 2 per cent about loss of good farmland, and 1 per cent about lack of access to open space and countryside. If the share of the sample who had *some* cause to complain is included, 23 per cent complained about air pollution in their locality, and just under 20 per cent about drinking water quality, noise, waste disposal and deterioration of the landscape. Thus water and air pollution are the local problems which give people most cause to complain. 16 per cent found no reason at all to complain about any of the eight specified local problems.

International comparisons

It appears that, compared with other countries, relatively few persons in Norway find cause to complain about local environmental problems (table 7.2). For nearly all the environmental problems the level of complaint in the Norwegian survey is clearly lower than the average level in the EEC survey from 1988, and also lower than the level in the Finnish survey from 1989. The relative difference are most obvious for environmental problems connected to land use. In the EEC countries deterioration of the landscape is the most serious problem at local level, especially in Spain, Greece and Italy. The relative differences are less, but are still apparent, in respect of environmental problems which maybe influence welfare to the largest degree; drinking water quality, noise and pollution. About twice as many persons in the EEC countries as in Norway find cause to complain about these problems. In Finland about 2-3 times as many complain.

Caution is required in assuming that these differences are a clear indication that the environment is better in Norway than in other countries. Firstly, the surveys were carried out at different times. Secondly, the answers are influenced by differing attitudes towards environmental protection. The Norwegian survey shows that those who complain most are those who give priority to the environment rather than to economic growth, even when controlled for sex, age, education and residential locality.

Who complains most?

Who is most inclined to complain about local environmental problems? For the purpose of showing differences in the level of complaint a simple additive index has been constructed, where persons with *serious cause* to complain about a specific problem receive a score of 3, those with *some cause* to complain a score of 2, those with *no particular cause* to complain a score of 1 and those with *no cause* to complain a score of 0. The eight scores for each person are added up and divided by eight, giving an average score for level of complaint ranging from 0 to 3. Extreme scores in the distribution (those who do not complain at all and those who have serious cause to complain about two or more problems) are also taken into account.

Table 7.1. Attitudes towards various local environmental problems in own residential locality. Per cent

Environmental problems	Serious cause to complain	Some cause to complain	No particular reason to complain	No cause to complain	Do not know
Drinking water quality	5	12	13	69	1
Noise	5	13	13	69	0
Air pollution	6	17	16	60	1
Waste disposal	5	14	15	64	2
Lack of access to open space and countryside	1	4	7	88	0
Loss of farmland	2	7	10	74	7
Deterioration of the landscape	4	15	11	68	2
Pollution of rivers, lakes and fjords	15	31	14	36	4

Table 7.2. Percentage of the population in different countries who have serious cause to complain about local environmental problems. Per cent

Country	Year	Local environmental problems: Lack of access to open space and country-side	Loss of good farm-land	Deteri-oration of the land-scape	Waste dis-posal	Drink-ing water quality	Air pol-lution	Noise	Water pollution (rivers, lakes ...)
Japan	1990	29	..	..	..	..	..	..	..
Finland	1989	2	..	15	11	9	20	13	22
Norway	1990	1	2	4	5	5	6	5	15
Belgium	1988	4	6	12	44	6	9	8	..
Denmark	1988	1	3	5	2	2	5	4	..
France	1988	6	11	12	6	8	7	6	..
Western Germany	1988	6	6	11	6	8	14	14	..
Greece	1988	17	15	28	29	14	26	20	..
Ireland	1988	1	1	3	10	6	6	3	..
Italy	1988	10	12	20	15	20	15	11	..
Luxembourg	1988	3	5	13	7	6	14	12	..
Netherlands	1988	2	5	10	8	3	4	5	..
Portugal	1988	9	13	14	15	12	11	12	..
Spain	1988	12	11	17	9	15	14	14	..
United Kingdom	1988	3	5	11	10	4	6	5	..
EEC	1988	7	8	14	10	10	11	9	..

Source: OECD, 1991a.

Women have a slightly higher average score than men (table 7.3). There are quite large differences between age groups. On average, a larger percentage of young people than older persons find cause to complain about local environmental problems. The average scores vary from 0.64 for the age group 16-24 years to 0.47 for the age group 60-73 years. The differences are not as distinct for the extreme scores, but the older age groups contain a relatively large number of persons who do not find any cause at all to complain, and fewer who find serious cause to complain.

As was to be expected, there is also a certain difference in the level of complaint depending on type of residential locality. The level of complaint rises with increasing population density, from 0.46 in sparsely populated areas to 0.69 in the most highly urbanized areas (table 7.4). The exception is localities with between 200 and 2 000 inhabitants, where the average score is somewhat higher than in places with up to 20 000 inhabitants. Here too the differences are not as distinct for the extreme scores.

The level of complaint rises with increasing education. This is particularly obvious in the case of the percentage who find no cause at all to complain. This percentage decreases from 22 per cent in the group with the lowest level of education (compulsory education only) to 11 per cent in the group with the highest level of education (university/college education). On the other hand, the level of complaint does not seem to vary with the gross income of the household.

Table 7.3. Attitudes towards local environmental problems. Sex and age. Per cent and average

	No cause to complain Per cent	Average[1)]	Serious cause to complain[2)] Per cent
Total	16	0.57	10
Men	15	0.55	10
Women	17	0.59	10
Age groups			
16-24 years ..	13	0.64	10
25-44 years ..	17	0.58	11
45-59 years ..	14	0.58	11
60-73 years ..	19	0.47	7

1) Average of indices ranging from 0-3.
2) About at least two problems.

7.4. Specific local environmental problems

Noise and air pollution

It is reasonable to discuss noise and air pollution combined. The correlation analyses show that those who complain about noise often also complain about air pollution, and vice versa. The reason is that these problems depend on the extent of exposure to road traffic, which is the most important source of both noise and air pollution.

The percentage who find cause to complain about these two problems increases with increasing urbanization. In sparsely populated areas, 3 per cent state that they have *serious cause* to complain about noise. In areas with 100 000 or more inhabitants the percentage is 9 per cent (figure 7.7). The percentage who find they have *some cause* to complain about noise is 9 per cent in sparsely populated areas and 22 per cent in areas with the highest degree of urbanization.

Table 7.4. Attitudes towards local environmental problems by type of residential locality. Per cent and average

	No cause to complain. Per cent	Average[1)]	Serious cause to complain about at least two problems. Per cent
Sparsely populated areas ...	20	0.46	8
200-1 999 inhabitants	13	0.57	8
2 000-19 999 inhabitants	16	0.54	8
20 000-99 999 inhabitants ...	16	0.60	12
100 000 inhabitants or more .	14	0.69	13

1) Average of indices ranging from 0-3.

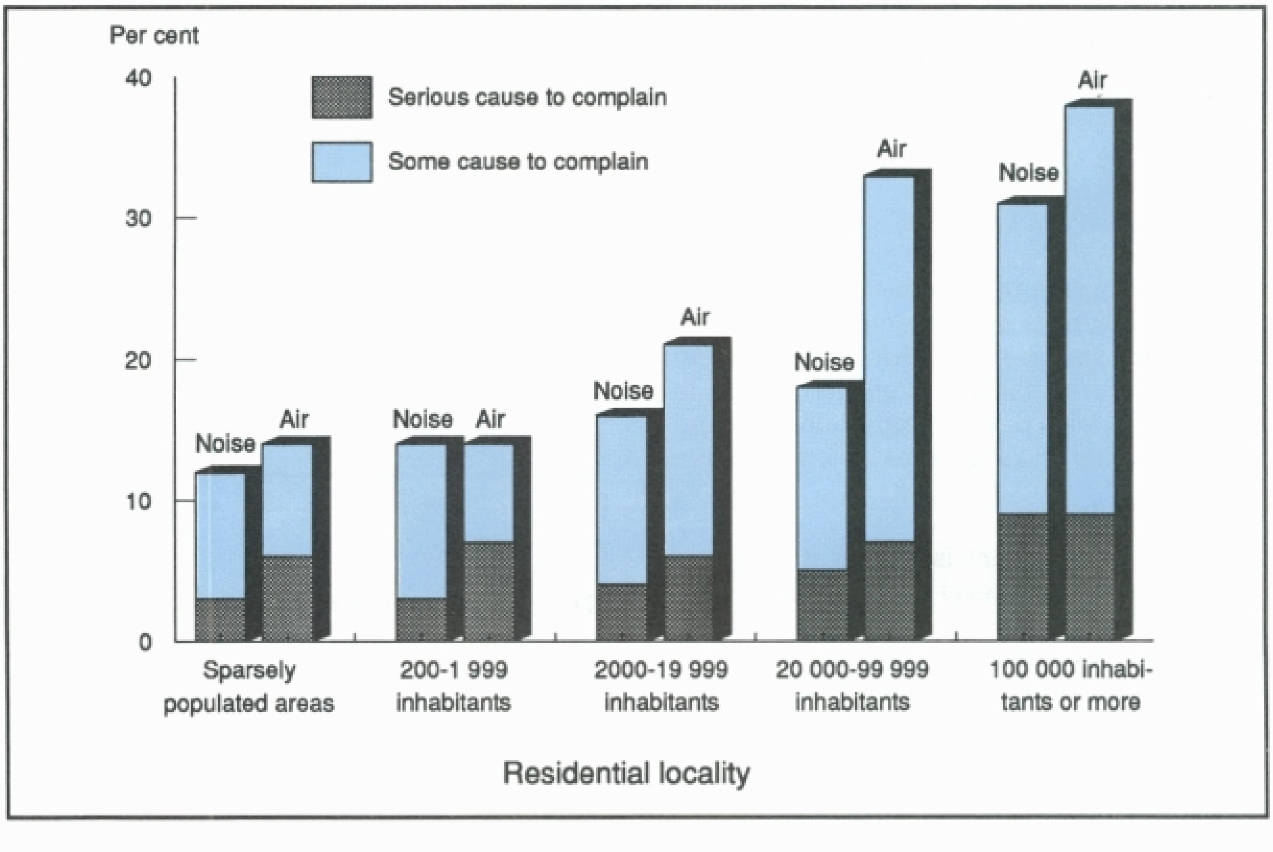
There are only slight differences between sexes and age groups in respect of complaints about noise. The geographical differences in the percentage who have *serious cause* to complain about air pollution are small, but the tendency is towards a higher level of complaint in the most urbanized areas. The differences are more distinct in the case of persons who have *some cause* to complain. The percentage who assert that they have some cause to complain about air pollution is three times higher in places with more than 20 000 inhabitants than in sparsely populated areas. The percentage who find serious cause to complain about noise and air pollution does not vary with level of education, but the percentage who find some cause to complain is slightly higher among persons with a university or college education. There is no systematic correlation between level of complaint and household income.

Land use: Deterioration of the landscape, lack of access to open spaces, loss of farmland

Three of the environmental problems are closely connected to land use in the local environment: Deterioration of the landscape, loss of farmland, and lack of access to open spaces.

The environmental problems connected to land use increase with increasing population density (figure 7.8). In order to simplify the numerical material the following discussion refers only to those who have serious cause or some cause to complain. As shown above, the percentage who have serious cause to complain is small and varies only slightly between different groups. The relative differences between rural and urban areas are greatest in respect of access to open spaces. While almost none of the inhabitants of sparsely populated areas find cause to complain about lack of access to

Figure 7.7. Share of the population who find serious cause or some cause to complain about noise and air pollution, by residential locality. Per cent



open spaces, 10 per cent of those who live in places with more than 100 000 inhabitants find serious cause or some cause to complain about this situation.

Complaints about deterioration of the landscape are most prevalent in urbanized parts of the country (26 per cent), and least prevalent in sparsely populated areas (15 per cent) and in areas with between 2000 and 20 000 inhabitants (14 per cent). The percentage complaining about loss of farmland is highest in places with a medium degree of urbanization. A possible explanation is that these places have a mixed economy, with some farming and some industry, where conflicts between agriculture and other interests are most intense.

Young people complain somewhat more than older people do about deterioration of the landscape, and persons with a university or college education more than people with a lower level of education. The same pattern is observed for access to open spaces, but the tendency is not as strong. Complaints about loss of farmland, on the other hand, do not seem to vary with age or education.

There are no differences between men and women, nor between different income groups.

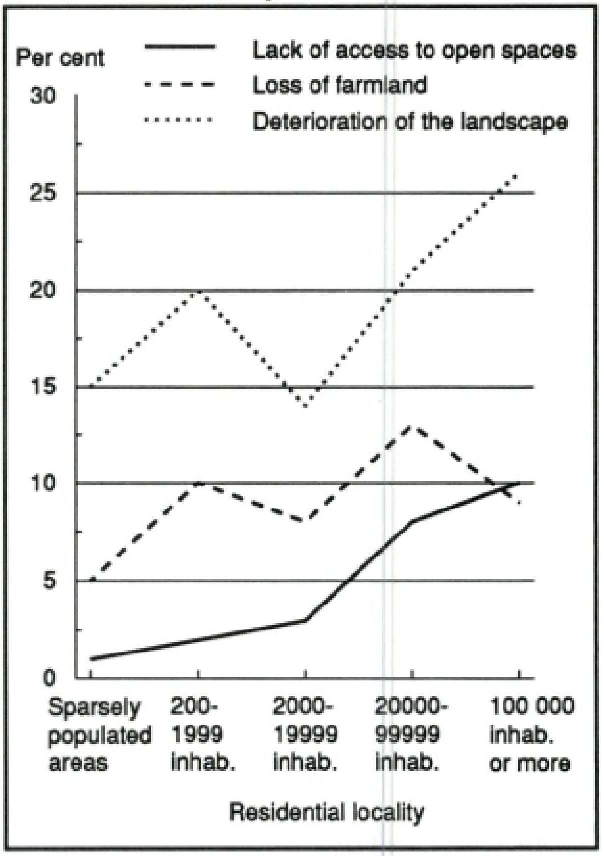
Water pollution and disposal of waste

Unlike in the case of the other environmental problems, there is no systematic correlation between the standpoint on these problems and degree or urbanization. Persons living in sparsely populated areas complain to about the same degree as persons living in large towns.

The level of complaint is higher among persons with a high level of education than among persons with a lower level of education. 57 per cent of those with a university or college education complain about pollution of rivers, lakes and fjords, as against 40 per cent among those with the lowest level of education. However, the only cause of these differences is the difference in the percentage who have *some cause* to complain. Differences in the percentage who have *serious cause* to complain are small and unsystematic.

There are somewhat more complaints among younger than among older age-groups. The tendency is particularly clear among those who have serious cause to complain about pollution of rivers, lakes and fjords. There are only small differences between the attitudes of the two sexes.

Figure 7.8. Share of the population who find serious cause or some cause to complain about local environmental problems connected to land use. Residential locality. Per cent



The fact that young people complain more than older people may be explained partly by differences in knowledge and education, and partly by differences in lifestyle and attitudes. There is a tendency for those who would give priority to protection of the environment at the expense of economic growth to make more complaints than those who believe that the two can be combined.

The survey shows no systematic correlations between any of these environmental problems and income.

7.5. Concern about national and international environmental problems

Two of the sets of questions in the survey asked whether the interviewees thought there was cause for concern about environmental problems. One set of questions referred to national problems and the other to international problems.

The survey shows that a large proportion of Norwegians think there is cause for concern about national environmental problems (table 7.5). As many as 95 per cent think there is cause to be *very concerned* or *somewhat concerned* about pollution of rivers and lakes. The concern is only slightly less in respect of damage to the marine environment and beaches (92 per cent), air pollution (88 per cent) and disposal of industrial waste (87 per cent). Although the differences are small, the percentage who are *very concerned* is largest (45 per cent) for damage to the marine environment and beaches. A total of 67 per cent are very concerned about one or more of the specified national environmental problems.

Only two per cent state that, in their opinion, there is no cause at all for concern about the four specified problems. Moreover, only very few state that they do not know whether there is cause for concern.

Although Norwegians think there is cause for concern about national environmental problems, they believe there is even greater cause for concern about international environmental problems. A much larger number are very concerned about these problems: 69 per cent are very concerned about depletion of the ozone layer, and 65 per cent are very concerned about exhaustion or destruction of natural resources and possible climate changes due to emissions of carbon dioxide and other greenhouse gases. In addition, 64 per cent are very concerned about extinction of animal and plant species. All in all, as many as 85 per cent of the sample are very concerned about one or more of the four international environmental problems.

International comparisons

A sample of the population in EEC countries and some other countries were asked the same questions as described above (table 7.6). The surveys were not carried out at the same time in all countries. In a topic of this kind, where new elements are constantly introduced into the debate and new information is accumulated, it is necessary to be careful when comparing attitudes in the different countries.

As far as national environmental problems are concerned, Norwegians are not among those who find greatest cause for concern. Of the 16 countries in which this question was asked, there are 9 countries where the population is more concerned about damage to the marine environment and beaches than in Norway. 65 per cent of the Finnish population is very concerned about this situation, while the comparable figure in Norway is 45 per cent.

A larger share of the population in 8 of the 16 countries is more concerned than Norwegians are about water pollution in their country. 64 per cent of the United States population are concerned about water pollution. The comparable figure for Norway is 42 per cent. As far as air pollution is concerned, public concern is greater than in Norway in as many as 11 countries. Greatest concern is found in Italy, where the figure is 62 per cent, while the same concern is expressed by 39 per cent of the Norwegian population. Concern about air pollution is least in Ireland, with a percentage of 30 per cent.

The tendency is the same for problems connected to industrial waste disposal. The population in 8 other countries are more concerned than the Norwegian population is. While 43 per cent of the Norwegian population are concerned, the same concern is expressed by 62 per cent of the population in the Netherlands. By comparison, only 32 per cent of the

Japanese population believe there is cause to be very concerned about disposal of industrial waste in their country.

The situation is different as regards concern about international environmental problems. Of all nationalities among whom the survey was conducted, Norwegians express the greatest concern about extinction of plant and animal species, depletion of world natural resources and possible climate change due to emissions of carbon dioxide and other greenhouse gases.

In other respects these figures agree with the results of other comparable surveys carried out in recent years. Norwegians are very informed about and very occupied with international matters. In a survey on people's knowledge about the United Nations (CBS, 1990) Norwegians headed the list of 19 nations as regards naming United Nations agencies or institutions. They are also among the 3-4 nations with the greatest percentage who have heard of the UN, can name the UN Secretary General, and have learned something about the UN at school or in later studies.

Table 7.5. Attitudes towards different national and international environmental problems. Per cent

Environmental problems	Very concerned	Somewhat concerned	Not particularly concerned	Not concerned	Do not know
National problems					
Pollution of lakes and rivers	42	53	3	1	1
Damage to the marine environment and beaches	45	47	5	1	2
Air pollution	39	49	9	2	1
Industrial waste disposal	43	44	6	2	5
International problems					
Extinction of plant and animal species ...	64	30	3	1	2
Destruction of world natural resources ..	65	29	3	1	2
Climate change	65	28	3	1	3
Depletion of the ozone layer	69	24	3	1	3

These figures can be interpreted to mean that Norwegians do not associate environmental problems primarily with their local surroundings, but regard them as an international problem. The figures also show that Norwegians are very occupied with this international problem complex. This may be partly due to the report from the Brundtland Commission and the widespread information to the public in this connection, and to the Bergen Conference on Environment and Development which was held immediately prior to this survey.

Who is concerned about environmental problems?

There is a clear tendency for women to be more concerned than men about national and international environmental problems (table 7.7). 26 per cent of the women are very concerned about all the national environmental problems, and as many as 49 per cent of the women are very concerned about all the international environmental problems. The figures for men are 15 per cent and 36 per cent respectively.

Table 7.6. Share of the population in different countries who are very concerned about national and international environmental problems. Per cent

Country	Year	National environmental problems				International env. problems		
		Accidental damage to the marine environment	Industrial waste disposal	Water pollution	Air pollution	Extinction of plant or animal species	Depletion of world forest and natural resources	Possible climate changes brought about by carbon dioxide
USA	1990	52	..	64	58	..	40	30
Japan	1990	42	32	41	41	25	37	43
Finland	1989	64	43	35	61	43	63	44
Norway	1990	45	43	42	39	64	65	65
Belgium	1988	32	39	32	34	37	28	29
Denmark	1988	55	56	50	45	44	45	54
France	1988	47	44	38	36	40	32	34
Western Germany	1988	46	50	46	45	45	32	48
Greece	1988	55	47	44	53	41	38	45
Ireland	1988	36	38	38	30	27	28	34
Italy	1988	59	58	62	62	43	39	48
Luxembourg	1988	38	45	36	40	49	37	39
Netherlands	1988	57	62	56	54	48	32	36
Portugal	1988	41	43	44	41	43	38	43
Spain	1988	53	53	54	52	58	55	50
United Kingdom	1988	40	47	38	32	39	36	40
EEC	1988	48	50	47	45	44	35	43

Source: OECD, 1991a.

There are relatively small differences between age groups as regards concern about environmental problems. There are no differences worth mentioning in respect of national problems. The oldest age group (60-73 years) are less concerned about international problems than younger people are.

Residential locality or level of education do not seem to have any influence worth mentioning on whether or not people are very concerned about national and international environmental problems.

As far as political affiliation is concerned, greatest concern for one or more of the national environmental problems is expressed by supporters of the Socialist Left and Liberal parties. 82 per cent of the supporters of these parties express such concern. Second on the list are supporters of the Progress Party; 67 per cent of these are very concerned about one or more of the national environmental problems. Next come Labour Party supporters with 65 per cent, followed by Centre Party supporters with 63 per cent, Conservative Party supporters with 58 per cent and Christian Democratic Party supporters with 57 per cent.

More or less the same pattern is observed in respect of concern for international environmental problems. Greater concern is expressed among Socialist Left and Liberal Party supporters than among the supporters of the other parties. The differences between the other parties are small. While about 60 per cent of

Socialist Left Party and Liberal Party supporters (59 and 64 per cent respectively) express concern for the four international environmental problems, the average for the other parties is just under 40 per cent (44 per cent in the Centre Party, 40 per cent in the Labour Party, 39 per cent in the Progress Party, 38 per cent in the Conservative Party and 36 per cent in the Christian Democratic Party).

Table 7.7. Share of the population who are very concerned about national and international environmental problems, by sex and age. Per cent

	National environmental problems Very concerned about		International environmental problems Very concerned about	
	One or more problems	All the specified problems	One or more problems	All the specified problems
Total	67	21	85	43
Men	63	15	81	36
Women	72	26	89	49
Age groups				
16-24 years	70	18	93	45
25-44 years	70	22	84	44
45-59 years	66	22	85	46
60-73 years	62	18	78	35

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