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The State of the Environment in Denmark, 1997

TECHNICAL REPORT

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National Environmental Research Institute

Data sheet

Title:	The State of the Environment in Denmark, 1997
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Department:	Department of Policy Analysis
Translation:	David I Barry, Birkerød
Serial title and number:	NERI Technical Report No. 243
Publisher:	Ministry of Environment and Energy, National Environmental Research Institute ©
URL:	http//www.dmu.dk
Year of publication:	1998
Layout/illustrations	Beatrix Rauch, Britta Munter and Jennifer Aas
Photographs:	Cover photo: Biofoto/Jens Meulengracht-Madsen Other photos: Copenhagen University/Institute of Geography, NERI/Peter Bondo Christensen, 2. maj/Sonja Iskov, Biofoto/Arthur Christiansen
Please cite as:	Holten-Andersen, J., Christensen, N., Kristiansen, L. W., Kristensen, P. & Emborg, L. (Eds.) (1998): The State of the Environment in Denmark, 1997. National Environmental Research Institute, Denmark. - NERI. Technical Report No. 243, 288 pp. Reproduction permitted with clear reference to source
Abstract:	The report summarizes existing knowledge concerning some of the central trends in the state of Denmark's environment and nature, and links these trends with developments in those sectors of society having the greatest impact on the environment
Edition closed:	January 1998
ISBN:	87-7772-407-0
ISSN:	0905-0815X
Printed by:	Scanprint as, Århus, Certified according to ISO 9002, ISO 14001 and the Nordic Ecolabelling scheme. EMAS registered
Paper quality:	Cover: CyclusOffset, pages: CyclusPrint, 100% recycled paper with vegetable oil-based dyes free of organic solvents
	Nordic Ecolabel, printed matter
No. of pages:	288
Impression:	1,750
Price:	DKK 190 (incl. 25% VAT, excl. postage)
Supplementary note:	This report is available in Danish entitled: "Natur og Miljø 1997. Påvirkninger og tilstand." Faglig rapport fra DMU nr. 224
For sale at:	*National Environmental Research Institute* *Frederiksborgvej 399* *Postbox 358* *DK-4000 Roskilde, Denmark* *Tel: +45 4630 1200* *Fax: +45 4630 1114* *Miljøbutikken* *Information and books* *Læderstræde 1* *DK-1201 Copenhagen K* *Tel: +45 3337 9292* *Fax: +45 3392 7690*

Preface

The debate on environmental problems requires continuous updating of our basic knowledge on the state of the environment. As part of Denmark's strategic environmental planning I have asked the National Environmental Research Institute to prepare a State of the Environment Report that encompasses existing knowledge on some central trends in the state of Denmark's nature and environment, and correlates these trends with development within those sectors of society having the greatest impact on the environment. The result is the present report on "The State of the Environment in Denmark, 1997".

The report is the second Danish State of the Environment Report. The first was published in December 1993 entitled "Environment and Society - a review of environmental development in Denmark".

In March 1994 I submitted a position paper to the Parliamentary Committee on the Environment and Regional Planning on "Implementation of strategic environmental planning in Denmark". The two central elements of this are a State of the Environment Report and an Environmental Policy White Paper. Both are to be published every four years, with the White Paper being published 1 to 2 years after the State of the Environment Report, on which the White Paper will partly be based.

The Government's Environmental Policy White Paper was published in 1995, and was the first major White Paper to describe the environmental objectives and the initiatives to fulfil them. The next Environmental Policy White Paper is planned for publication in 1999.

The main aim of our strategic environmental planning is to ensure that future environmental policy is more holistic and goal-oriented. In addition, the Government attaches great importance to ensuring that the population is well informed about the state of the environment and endeavours on the environmental front in order to enable the population to participate in shaping environmental policy. The State of the Environment Reports and the Environmental Policy White Papers provide the public with the possibility to regularly examine the numerous details and interests associated with the environmental area in a more cross-cutting and general context. Corresponding processes are also undertaken in most other European countries and in the EU.

It is my hope that the present report will prove useful as a scientific foundation for the continued debate on nature and environmental issues.

Svend Auken
Minister for Environment and Energy

Introduction

The report on "The State of the Environment in Denmark, 1997" concerns the Danish environment and the Danish society. However, as the Danish environment is affected by the world around us, and as Danish society likewise affects the environment outside our borders, the report draws numerous connections out to the international issues.

One of the main guidelines for the report has been to emphasize the interplay between environment and society. On one hand, we have an environment and nature that are controlled and regulated by a number of natural laws. On the other hand, we have a society that is controlled and regulated by a number of economic, social and political conditions. The main aim of the report has been to describe the mutual interplay between these two systems.

An important question in this connection has been: From what perspective should this description be based?

One may begin in the environment - in the atmospheric environment, the aquatic environment, the terrestrial environment - and draw connections from there to the various societal activities that are the cause of the problems. Alternatively, one may begin in society - in agriculture, industry, the energy sector, the transport sector, households - from where connections can be drawn out to the environment.

The first approach provides a good overview of the state of the environment, while the overview of the pressures and their relation to the structure of society and societal development are more indistinct. If, on the other hand, one approaches the issue from the societal perspective, one will obtain a good overview of the technological, economic and organizational relationships behind the environmental pressures, and which environmental policy seeks to regulate. In this case, however, the overview of the impact on nature and the environment becomes indistinct.

In this report an attempt is therefore made to synthesize these two approaches:

Chapter 2 is based on the environmental problems - i.e. on the state of the environment - and draws connections out to the societal activities that are the cause of the problems. Conversely, Chapter 3 is based on society divided into a number of sectors and describes the relationships between the technological and economic development in society and the resultant pressures on nature and the environment.

The method adopted of presenting the problems from two perspectives - the environment on one side and society on the other - means that there will be some overlap and repetition between the two chapters. On the other hand, it is hoped that the combined product provides a more complete picture of the complex problems that the topic encompasses.

The figure overleaf illustrates the system that the report attempts to describe. In addition to illustrating the general interplay between societal development and environmental state, the figure also illustrates some of the feedbacks from environmental state to society. These feedbacks consist of the environmental objectives and the measures that society decides to implement in order to counteract the undesirable changes in environmental state and the negative effects this has on conditions for human existence. The figure thus encompasses what is termed the environmental policy cycle, which is the basis for environmental policy understanding in international environmental administration. The cycle is designated *D-P-S-I-R*, for *D*riving forces - *P*ressures - *S*tate - *I*mpacts - *R*esponses.

The crux of the present report is the interplay between environmental state (S), anthropogenic pressures (P) and the driving forces behind them (D).

One aspect of this is to what extent environmental policy measures have affected D, P and S, respectively, including to what extent the environmental objectives have been achieved. On the other hand, the report does not include evaluation of whether these objectives are appropriate or what measures should be implemented. These aspects will be examined in other contexts such as environmental action plans and the forthcoming Environmental Policy White Paper, etc.

Scope of the report

"Environment" is a rather elastic term that in its widest sense can encompass everything that relates to conditions for human existence. As a main rule, the term environment in this report means the natural conditions in which man and society exist.

Thus the social and working environments are not included, and health is only touched upon when there is a clear relationship between changes in the state of the environment and human health.

Correspondingly, the term "society" can also be interpreted in many different ways. As a main rule the present report focuses on an economic description of society where society is divided into a number of economic sectors. Finally, the issue of resources is only considered in this report if exploitation of resources places pressure on nature and the environment. The issue of the limited nature of resources is not examined.

The report data

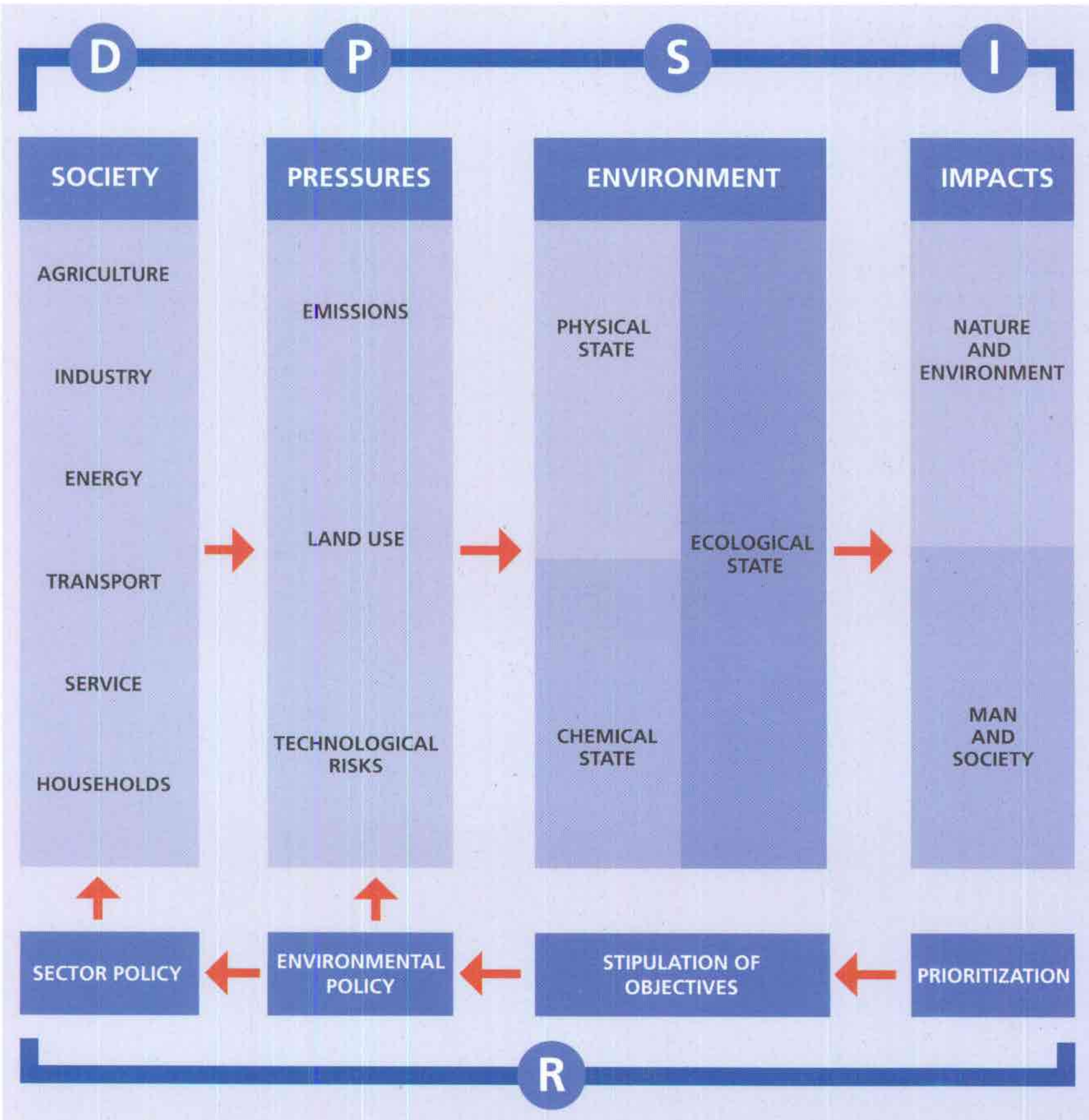
Preparation of the main sections of the report was completed at the end of August 1997, whereafter the report was edited. The data on which the report is based are therefore those available as per 1 September 1997.

In the period thereafter, only selected data series have been updated. This applies to data from the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment, waste statistics, etc. In cases where new data are of significance for the scientific evaluation of the overall trend in a specific area, these figures are mentioned in the text.

Data available on the Internet

The report illustrations and the data on which they are based are available on the Internet via NERI's homepage.

Address: http://www.dmu.dk



The environmental policy cycle (Source: National Environmental Research Institute).

The State of the Environment in Denmark, 1997

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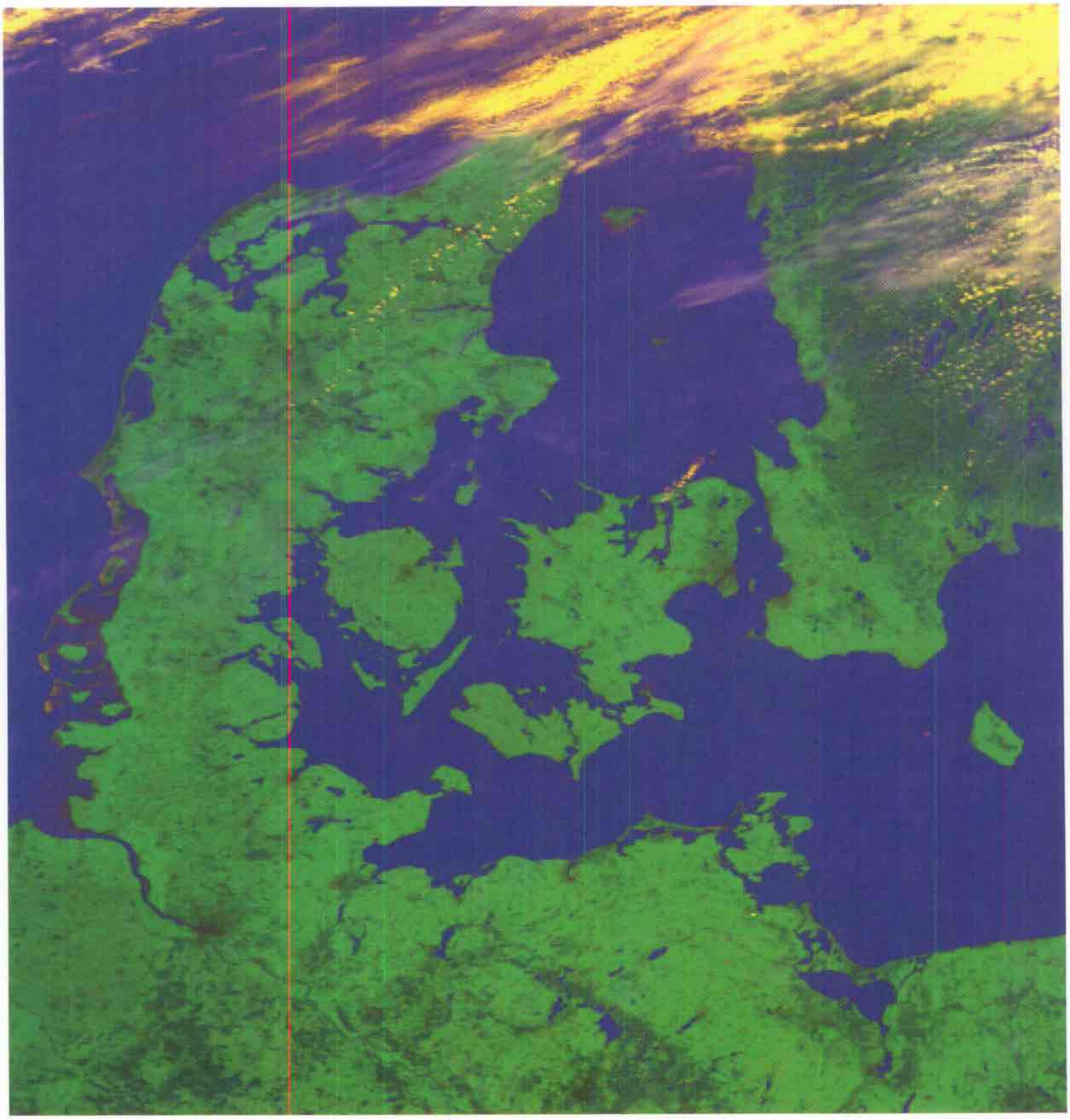
1. Summary



1.1 State of the environment

The atmospheric environment

The greenhouse effect and climate changes

From temperature measurements reaching back to 1860 it is apparent that the temperature of the Earth has increased over the last 150 years. The mean temperature is currently approx. 0.6°C higher than during the preceding centuries. The majority of climate scientists agree that a major factor in this increase is anthropogenic emissions of greenhouse gasses, of which CO_2 (carbon dioxide) accounts for around 65% while CH_4 (methane), N_2O (nitrous oxide) and other substances account for the remainder. The CO_2 concentration in the atmosphere has increased by approx. 30% over the past one hundred years, and the increase is continuing at a rate of approx. 0.4% per year. In a forecast of development up to the year 2100, the UN International Panel on Climate Change (IPCC) predicts a global temperature increase of around 2°C and an increase in sea level of about 50 cm assuming that development follow current trends with respect to population, economy and energy technology. The effects of this are difficult to predict but they include the above mentioned increase in sea level, changed precipitation patterns, changed conditions for plant growth, and greater fluctuations in climate with more frequent occurrence of extreme episodes such as drought on one hand and an abnormally high precipitation on the other. The IPCC believes that if the CO_2 concentration in the atmosphere is to be stabilized at the current level, emissions will have to be reduced by 50-70% immediately with further reductions later.

The greenhouse effect is accorded very high priority on the international political agenda, but major progress has not yet been made on reducing CO_2 emissions on a global scale.

At the UN Climate Conference in Kyoto, Japan in December 1997, the EU proposed that the industrialized countries should reduce their emissions of CO_2, methane and nitrous oxide by 15% before the year 2010 relative to 1990 levels. The result with respect to the industrialized countries was a binding agreement committing them to reduce their emissions by 5.2% up to the years 2008-2012. A few countries are allowed to increase their emissions during the period, while the EU as a whole has to reduce emissions by 8%.

Energy consumption by the EU countries has increased markedly from the beginning of the 1980s to the present. CO_2 emissions fell approx. 4% between 1990 and 1994, however. This is partly due to the economic recession, among other places in the former East Germany. It has not been possible to reach agreement within the EU on a common CO_2 levy, which is considered a decisive instrument for curtailing growth in the consumption of fossil fuels. Denmark maintains its goal of reducing CO_2 emissions 20% by the year 2005 relative to the 1988 level. Up to 1996, emissions had been reduced by 4%.

Depletion of the ozone layer

The layer of ozone in the stratosphere that shields life against ultraviolet radiation from the sun is constantly being depleted, first and foremost in the polar and northern regions. The depletion is primarily due to the presence of man-made chlorofluorocarbons (CFCs), the concentration of which has been increasing since measurements started in 1977. The rate of increase has declined markedly since 1989, however, primarily due to international agreements on their reduction (the Montreal Protocol and follow-up agreements). It has been calculated that depletion of the ozone layer will continue into the coming century, with an expected gradual re-establishment in the middle of the century.

Photochemical air pollution

While ozone in the stratosphere shields against UV radiation, enhanced ozone concentrations at the surface of the Earth give rise to a number of health and ecological effects such as airway irritation and damage to vegetation. Enhanced ozone concentrations near the surface of the Earth (in the troposphere) are an indirect effect. Under the influence of ultraviolet radiation, nitrous dioxide (NO_2) reacts with organic hydrocarbons (VOCs) to form ozone. In urban areas, where the concentration of nitrogen monoxide (NO) is high, the opposite process dominates, and NO reacts with ozone to form NO_2, which in turn contributes to background formation of ozone outside the towns. Episodes of enhanced ozone concentrations occur every summer over most of Europe, especially in the central and southern parts. The episodes typically occur during periods of high pressure with weak winds and much sunlight. Efforts to curb surface ozone formation include a reduction in discharges of nitrogen oxides, which primarily derive from energy consumption, and of VOCs, which partly derive from energy consumption and partly from industrial emissions of organic solvents. In the EU, VOC emissions fell about 9% between 1990 and 1994, while nitrogen oxide (NO_x) emissions fell 8%. The picture is similar in Denmark, VOC emissions having fallen by approx. 20% between 1985 and 1994 while NO_x emissions remained constant until the beginning of the 1990s, since when they have fallen slightly. This reflects a major decrease in emissions from power stations combined with an increase in emissions from traffic.

Acidification and eutrophication

Emissions of the gasses SO_2 (sulphur dioxide), NO_x and NH_3 (ammonia) cause acidification of a large number of ecosystems, and NO_x and NH_3 additionally contribute to airborne nutrient loading, which in some ecosystems can cause eutrophication. Since the beginning of the 1980s, sulphur emissions in Europe have fallen by about 50% as a consequence of reductions in the sulphur content of fuels and the installation of flue gas abatement measures, primarily at power stations. NO_x emissions, which chiefly derive from power stations and transport, were constant up to the beginning of the 1990s, since when they have decreased slightly. NH_3 emissions, which derive from agriculture, decreased slightly during the 1990s. The development in Denmark largely corresponds to that in Europe, the overall effect being that acidification of a number of vulnerable ecosystems has declined. Among other things, clear improvement has been detected in the water quality of a number of Scandinavian lakes. Moreover, monitoring results indicate an improvement in the state of Danish forests.

With respect to airborne inputs of nitrogen (NO_x and NH_3), the development has, as mentioned above, only been characterized by a slight decrease in the 1990s. Loading of a number of oligotrophic ecosystems such as heaths, raised bogs and certain types of forest therefore continue to exceed their "critical load".

The urban environment

85% of Danes live in the towns, which cover 5% of the country. Post-war urban development has led to a many-fold increase in the urban area and caused urban spread, which has disrupted a number of the functional relationships in the towns. Houses, industrial workplaces, office workplaces, shopping facilities and cultural facilities have become spread and congregated in special areas. Urban spread combined with the new structure in and around towns, which is not adapted to the public transport network, has made a significant contribution to the growth in traffic. Traffic is thus the main factor affecting the urban environment, where it causes air pollution, noise, barriers and insecurity among inhabitants. With the changes in heat supply in the towns and abatement measures at the power stations, traffic has become the dominant source of air pollution, with emissions of carbon monoxide, nitrogen oxides, hydrocarbons and particulates. The pressure is greatest in narrow streets with much traffic and declines markedly behind the rows of houses and in the open residential areas. The air pollution from traffic has been increasing over the past 15 years, but is expected to fall markedly in the coming years due to the effects of the introduction of catalytic convertors on cars. Another important environmental pressure from traffic is noise. Noise levels of over 65 dB(A) are considered by most people to be extremely bothersome, and are measured along virtually all roads with through traffic in the central parts of the towns. Particularly high noise levels are found along the major approach roads to the towns. Approx. 165,000 houses are affected by noise levels exceeding 65 dB(A) - chiefly deriving from traffic.

Another major environmental problem in the towns is contaminated sites derived from former industrial activities and diffuse pollution by lead (from leaded petrol) and other heavy metals deposited via the air. It is estimated that there are approx. 14,000 contaminated sites, of which 2,000 are currently used for housing or institutional purposes. Apart from traffic and contaminated sites, the physical organization of towns is also of great importance to urban quality. Green areas, historical buildings and districts, and shopping possibilities near homes are thus important aspects of urban planning.

The countryside environment

Nature and landscape

Geographically, Denmark lies on the boundary between two regions, the Atlantic and the continental, and forms the threshold between the Baltic freshwater/brackish water basin and the salty marine areas of the North Sea and the Atlantic Ocean. This borderline location creates major natural variations across a relatively small area. On the other hand, increasingly intensive human utilization of the land area has reduced the occurrence of many natural habitat types and contributed to a uniform landscape.

Through the development of agriculture and forestry, which account for 61% and 12% of the land area, respectively, the landscape has developed a mosaic structure with small extensively used biotopes surrounded by large intensively used farmland. In addition, the landscape has become fragmented through expansion of the road network and other infrastructure. Natural habitat types such as heath, dry grasslands, meadows and salt marshes have declined considerably during the present century as a consequence of conversion of the land to farmland. Freshwater wetlands such as bogs and springs have declined by 30-90%. Small biotopes such as open ditches and smaller watercourses have declined by 90%, small ponds and marl pits by 75%, and hedgerows and dykes by 40%. These marked changes in the landscape have changed the conditions for wild plants and animals, and a number of species risk extinction. The so-called Red Data Books, which contain inventories of plant and animal species at risk of becoming extinct, contain 3,176 species in need of protection, corresponding to about 1/3 of the registered species. Of these, 456 species are classified as endangered, 880 as vulnerable and 1,146 as rare. Since 1850, 353 species have become extinct in Denmark. In recent years, the populations of aquatic birds, forest birds, arable land bird species, etc. seem to have stabilized, while a number of urban bird species have undergone slight growth. In order to hinder the above mentioned development, which reflects the general international trend, a number of protection measures have been introduced in recent years at both the national and international levels. Together with a number of more specific conventions, the Convention on Biological Diversity spawned by the 1992 UN Conference on Environment and Development in Rio de Janeiro commits signatory countries to protect biological diversity.

In Denmark, 980,000 ha of wetland of special significance for bird life have been designated as protected areas (Ramsar Convention and EC Bird Directive). Under the Nature Protection Act, general protection has been provided to remaining heaths, bogs, wetlands, lakes, watercourses, etc., which account for approx. 9% of the area of Denmark. About 4.5% of the country has been designated as protected areas and preservation orders have been placed on a number of animal and plant species. In addition, afforestation and enhanced commitment to the creation of natural forest together with a number of nature restoration projects aim to re-establish nature in the Danish landscape. Thus over the period 1989-96, 11,000 ha of lake, heath, meadow and forest have been re-established and maintained, and the State has acquired approx. 6,600 ha for nature purposes and approx. 5,500 ha for afforestation.

The terrestrial environment

The soil is an important but often overlooked part of the environment. It serves as the habitat for a large number of animals and plants, is the basis for the production of foods and a number of biological materials, and serves as a filter and a transport medium for many substances. The soil is contaminated by substances that are input via the air as well as directly via man's activities. A nationwide study of the soil content of a number of heavy metals in the countryside has shown generally low levels that do not pose any hazard. Heavy metal contamination of the soil derives from atmospheric deposition, application of sewage sludge and compost, and from commercial fertilizer and animal manure. Animal manure accounts for the major part of inputs of copper, zinc and nickel, while atmospheric deposition accounts for the major part of inputs of mercury and cadmium. Sewage sludge and compost can be major sources locally. Even though heavy metal loading generally only accounts for a minor share of the current heavy metals content of the soil, there is nevertheless good reason to follow the development.

Another problem in relation to the terrestrial environment and soil quality is associated with intensive agricultural exploitation. Studies thus show that the soil content of organic carbon is decreasing and that this can reduce its fertility. Compaction of the soil through the use of increasingly heavy agricultural machinery reduces the number of earthworms, reduces the hydraulic conductivity of the soil and deteriorates its quality. Intensive exploitation of the soil also increases the risk for wind-driven and water-driven erosion.

The aquatic environment

Groundwater

Denmark has a unique groundwater resource comprising large amounts of high quality compared with other countries. 99% of our water consumption is thus met by groundwater. This situation is subject to a number of threats that have become more apparent during the 1990s, however. Thus nitrate has been detected in the primary groundwater aquifers in concentrations exceeding 1 mg/l in 38% of the boreholes included in the Nationwide Monitoring Programme. The average nitrate concentration in these samples was approx. 40 mg/l. Moreover, nitrate concentrations exceeding 25 mg/l have been found in approx. 10% of the 8,000 or so waterworks abstraction boreholes. The nitrate concentration of the primary groundwater aquifers is relatively constant whereas that of the subsurface groundwater is decreasing slightly. Nitrate poses a particular threat to the groundwater in areas with a thin clay cover bed and intensive agricultural production. These areas are mainly located in the northern and western part of Jutland in the so-called "Nitrate Belt".

Since 1990, the groundwater has been monitored for 8 pesticides as part of the Nationwide Monitoring Programme. One or more pesticides were found in just over 12% of the boreholes and the concentration exceeded the limit level for drinking water in just under 4%. The waterworks analyses revealed pesticides in just under 12% of the boreholes. In certain counties, control analyses have been extended to encompass additional pesticides and the results show that the frequency of positive samples increases with the number of pesticides tested for. Pesticides are found in just under 40% of analysed boreholes in young groundwater at a depth of a few metres, as compared with approx. 20% in the case of the deeper-lying groundwater. It is believed that the increased use of winter crops in crop production has enhanced pesticide leaching since the amount of precipitation is greater during the spraying period of these crops.

In addition to nitrate and pesticides, the groundwater is also threatened by a number of organic and inorganic micropollutants. The organic pollutants largely stem from contaminated sites in the towns and from waste depositories. In a number of older urban areas, pollution from such sources is so marked that water abstraction has to be abandoned. The inorganic pollutants largely derive from the soil's natural content of substances such as nickel and zinc, which can be released if the groundwater table is lowered too much.

In general, there is still sufficient groundwater to meet current requirements. In certain areas, however, high consumption results in local lowering of the groundwater table. In addition to the above mentioned effects, this also means that watercourses and wetlands dry out during dry summer periods. In the longer run, attention needs to be directed towards the possibility of periods with lower levels of precipitation, where consumption at the present level could lead to problems with sufficient water resources.

Watercourses

There are approx. 35,000 km of natural watercourse in Denmark, the state of which is particularly affected by the extensive physical regulation in connection with agriculture and urban development. This includes lowering of the groundwater table, drainage, culverting, channelization, obstructions and weed cutting. This has deteriorated the physical conditions in approx. 30,000 km of watercourse (85%).

The environmental quality of the watercourses is determined on the basis of faunal composition, and is summarized in a quality index ranging from I (high quality) to IV (very poor quality). The majority of the watercourses have a quality index of II to III, and 10% have an index of III to IV. During the period 1989-96, a slight improvement was recorded in the overall environmental quality of the watercourses. A number of activities have been initiated aimed at improving the physical conditions in the watercourses. Watercourse maintenance in the form of weed cutting and sediment dredging has thus become far more gentle, and a number of restoration projects have improved conditions locally. Apart from the physical pressures, the watercourses are also affected by organic matter from sewage treatment plants, scattered dwellings, unlawful agricultural discharges, and freshwater fish farms. The unlawful agricultural discharges in particular and discharges from sewage treatment plants have been reduced considerably over the past 10 years, which has improved the environmental quality of a number of watercourses. Finally, ochre pollution remains a problem in a number of watercourses in western Jutland.

Lakes

There are approx. 2,800 lakes exceeding 1 ha in Denmark. Many smaller lakes and ponds have disappeared during the present century - in Aarhus municipality, for example, this applies to 70% of the ponds that existed at the beginning of the century. In general, the environmental state of the lakes remains poor. Of the 182 lakes investigated by the Counties over the past 5-6 years, Secchi depth was less than 1 metre in 60% and between 1 and 2 metres in 25%, with only 15% of the lakes having reasonably clear water. The Secchi depth can generally be related to the lake water phosphorus concentration. Even though phosphorus loading has been reduced markedly as a result of sewage treatment and the diversion of waste water discharges, this has not reduced lake water phosphorus concentrations below the critical level at which noticeable improvement in Secchi depth occurs. This is chiefly due to continued diffuse loading from scattered dwellings and agriculture. In some lakes, moreover, there is a delay between the time that the phosphorus concentration is brought below the critical level and the time that an improvement in quality occurs. This is partly due to slow release of phosphorus accumulated in the sediment and partly to biological resilience.

The marine environment

The main environmental problem in Danish coastal and open marine waters is nitrogen-based eutrophication. This is characterized by enhanced production of phytoplankton in the warm summer months which decompose in the late summer, consuming large amounts of oxygen during the process. Under unfavourable weather conditions characterized by high temperature and poor wind, the oxygen concentration is reduced to such low levels that the fauna cannot survive, such as happened in Mariager Fjord in August 1997. The enhanced nutrient concentrations shift competition conditions in favour of rapidly growing filamentous algae, reduce the opacity of the water and deteriorate conditions for perennial benthic marcophytes. Nitrogen loading of the marine environment depends partly on the level of runoff and partly on nitrogen discharges from agriculture, industry and households. The agricultural sector accounts for around 85% of total nitrogen discharges and even though these have been reduced by about 17% during the 1990s, no significant improvement has been observed in the environmental quality of the estuarine fjords and inner Danish marine waters. Model computations show that a 50% reduction in nitrogen loading as stipulated in the Action Plan on the Aquatic Environment would markedly improve oxygen conditions in both the fjords and the inner Danish marine waters. In contrast, a reduction in inputs to the North Sea will have little effect on the inner Danish marine waters.

In addition to nitrogen-based eutrophication, the marine environment is also affected by a number of other factors. Construction activities, gravel and sand pumping, and extraction of stones mainly have local effects. Monitoring of projects such as the construction of the Great Belt Fixed Link indicates that the environmental effects are of limited duration. A number of environmentally hazardous substances end up in the marine environment. With the reduction in discharges of a number of heavy metals and persistent organic compounds, pressure of this type has decreased, however. The substances will continue to be present in sediment etc., from where they will be released for a long time in the future. A particular problem is that posed by antifouling agents for ships, which can occur locally in concentrations known to affect snails, oysters, etc.

Environmentally hazardous substances

There are between 15,000 and 20,000 different chemical substances on the Danish market distributed among just under 100,000 different products. At the global scale, there are around 100,000 different chemical substances, of which the majority are only used in small amounts. The so-called high-volume substances are substances produced in amounts exceeding 1,000 tonnes per manufacturer per year. In the EU, there are approx 3,000 different chemical substances which fall into this category. The majority of chemical products are used in cleaning agents and in paints/varnishes.

The main commercial branches using chemicals are the iron and metals industry followed by the chemicals industry and the repair and service sector. In the case of new substances to be placed on the market, manufacturers have to provide the authorities with information on such factors as the substances' toxicity, degradability in the environment and ability to accumulate in biological matter. Similar requirements do not apply to substances that were on the market prior to 1981. With regard to the above mentioned high-volume substances, however, corresponding data is currently being gathered in the EU. Based on the information submitted, a risk assessment is being undertaken that encompasses both an assessment of the substances' inherent hazards and an assessment of their possibilities for dispersal and occurrence in the environment. Both assessments are complicated and involve many uncertainties. This is particularly so in the case of newly discovered effects, for example the hormone-like properties of certain substances.

Systematic monitoring of discharge to and occurrence in the environment is only possible in the case of a minority of substances. Such monitoring is to some extent undertaken for certain heavy metals, organic pollutants and pesticides. As regards the heavy metals lead, cadmium and mercury, there has been a clear reduction in their use over the last 10 years, while nickel consumption has been increasing. It is estimated that releases to both the air and the water have decreased considerably in the case of the four substances mentioned above, partly due to the reduced consumption and partly due to abatement and treatment measures at power stations, waste incineration plants, enterprises and waste water treatment works. A nationwide survey of the heavy metals content of soil outside urban areas revealed generally low concentrations. High concentrations can be found locally in the vicinity of waste deposits, old polluting enterprises, busy roads, etc. The concentration of lead, cadmium and mercury is also declining in foods, while there is no clear trend in the case of nickel.

As mentioned in the section on groundwater, pesticides are found with varying frequency in groundwater filters and water abstraction boreholes. In Ringkjøbing and Funen counties, watercourses have also been analysed for a large number of pesticides, several of which were detected. The occurrence of pesticides is particularly high in watercourses in clayey agricultural catchments and in urban areas. Several pesticides, especially herbicides, have also been found in rain water. Control of pesticides by the authorities has been tightened in the 1990s in that all pesticides approved prior to 1980 have been re-evaluated. In the wake of this the Danish Environmental Protection Agency prohibited the use of seven active substances in 1994, 12 in 1996 and a further 9 in 1997.

At the same time, the amount of active substance used has decreased such that it is now close to the Pesticide Action Plan target of a 50% reduction in consumption by 1997 relative to the average for the period 1981-86. The goal of a corresponding 50% decrease in application frequency is far from being fulfilled, however, and pressure on the flora and fauna has not been reduced. The 1998 Government Budget has strengthened efforts on this front, though, among other things by doubling the pesticide levy and tightening the approval procedure.

New research results indicating that chemical substances can have hormone-like properties have further focused attention on environmentally hazardous substances.

Genetically modified organisms

It is now possible to genetically modify the majority of organisms in the laboratory: Viruses, bacteria, fungi, algae, plants, fish, and mammals. Society's use of genetically modified organisms currently focuses on genetically modified microorganisms in industry and genetically modified plants in agriculture.

Industrial uses include the production of pharmaceuticals and enzymes from a number of different organisms. Both the organisms used, the products manufactured and the production methods have to be approved by the authorities on the basis of a risk assessment of the effects on man and the environment. 50 different products manufactured by genetic engineering have currently been approved, and the monitoring hitherto undertaken has not demonstrated any associated environmental effects. In the plant area, the work focuses on the development of three types of trait:

1. Resistance to herbicides, insects, viruses or fungal infections.
2. Tolerance to such factors as drought, cold, salt or low soil nutrient levels.
3. Quality traits such as colour, keeping qualities or taste.

The first generation of genetically modified plants was dominated by herbicide- and insect-resistant plants. The second generation will additionally contain genes that endow resistance to viruses or fungi, or change the quality of the plant. Such crops are already on the way in the form of "package solutions" where several characteristics are incorporated in the same plant. In the third generation of plants, development is expected to accelerate with the introduction of tolerance to drought, cold, etc.

Genetically modified plants are subject to the same risk assessment as microorganisms. In this area, risk assessment is considerably more complicated as use of the organisms does not take place in a closed and controlled production system. The risks examined include 1) The plant's possibilities to disperse in the surrounding nature and cross genes with closely related species. In cases of herbicide resistance, both the plant itself and its hybrids will be able to exist as herbicide-resistant weeds. In addition, such dispersal might alter the ecological structure of the plant community. 2) The development of insect resistance might for example alter the food resource for arable bird populations and hence affect biodiversity. 3) The development of the more advanced plants with tolerance to drought, cold, etc. might fundamentally alter production conditions, and the plants in question will be competitive outside the field environment.

The use of genetically modified plants is so far restricted to just a few traits, and the total area involved is limited. However, the tendency is towards a much greater number of traits and widespread areal use. In line with this, the overall risk assessment will become increasingly complex.

The cultural environment

The cultural environment encompasses all the physical elements of cultural history that man creates and leaves behind in the towns, in the countryside and in the sea. In the 1995 Environmental Policy White Paper the cultural environment was emphasized as a third dimension of environmental policy, alongside pollution control and nature protection. The traditional means of protecting the physical elements of cultural history are the preservation of ancient monuments and buildings. There are currently approx. 33,000 listed ancient monuments such as dolmens, rune stones, ruins, fortifications, settlements, etc. spread out over the land and water - some of our ancient monuments now lie under water. However, the major changes that have taken place in our society during the present century have placed great pressure on the historical features and characteristics of the landscape and urban environment. In future, efforts will therefore also be made to protect preservation-worthy cultural environments such as villages, fishing hamlets, smallholding districts, etc. With regard to buildings, there are currently around 9,200 listed buildings. In this area too, current efforts tend to focus on the protection of historical environments, including preservation-worthy buildings, representing particular traditions and distinctive features that endow a feeling of identity.

The preservation of the cultural environment is accorded high priority at both the national level and locally in the counties and municipalities. On the other hand, it is apparent that extensive changes to the landscape and urban environments caused by more intensive land use, changed settlement patterns and increased traffic threaten many valuable cultural entities and environments.

Box 1.1 *Contribution of the various sectors to a number of the environmental themes that are summarized in Section 1.1 and which are examined in more detail in Section 2.*

a: Sector contributions to CO_2 emissions in 1985 and 1995.

b: Sector contributions to NO_X emissions in 1985 and 1995.

c: Sector contributions to acidification in 1985 and 1995. Total acidification pressure is calculated as the sum of atmospheric deposition of NH_3, NO_X and SO_2 expressed in acid equivalents.

d: Sector contributions to eutrophication of terrestrial ecosystems in 1985 and 1995. Total eutrophication pressure is calculated as the sum of atmospheric deposition of NH_3-N and NO_X-N.

e: Sector contributions to nitrogen loading of Danish marine waters in 1985 and 1995.

f: Sector contributions to phosphorus loading of Danish marine waters in 1985 and 1995.

(Source: National Environmental Research Institute on the basis of EMEP, 1996 and CORINAIR database).

1.2 Environmental impact of society

General development of society

The general development of society is characterized by a weakly increasing population and general growth in production and consumption. After a period with an almost constant population in the 1970s and 1980s, an increase of 0.33% per year is expected up to the year 2010 such that the population will reach approx. 5.5 million people. Over the past 20 years, production has increased by about 50% in real terms while consumption has increased by 30%, a trend that is expected to continue. The growth in production mainly took place within industry and private service, while public service and agriculture have experienced less growth and the building and construction sector has stagnated. Consumption has been characterized by marked growth in consumption of services, transport and tourism, minor growth in the consumption of material consumer goods and a fall in the consumption of fuels for heating. These tendencies are expected to continue up to the year 2010.

Energy

Final energy consumption, which is the consumption registered at the level of the consumers within the commercial, transport and household sectors, has been increasing steadily since the repercussions of the oil crisis at the beginning of the 1980s. Since 1990, final energy consumption has increased 0.9% annually. This growth encompasses a marked fall in energy consumption for heating, a marked increase in energy consumption for transport, and a slight increase in energy consumption by the commercial sectors. Within the production and service sectors, electricity consumption increased markedly in the 1990s, while that in the household sector has been constant. In contrast to final energy consumption, gross inland energy consumption, which represents consumption of primary energy by the energy supply system, has remained constant since the mid 1980s, with a weak tendency towards an increase in the mid 1990s. The difference between the development in final energy consumption and gross inland energy consumption is attributable to increased efficiency of the energy supply system, primarily through the expansion of combined heat and power production. CO_2 emissions associated with energy consumption have fallen 4% from 1988 to 1996, a fall that despite the slight increase in gross inland energy consumption has been achieved partly through increasing use of natural gas as a substitute for coal and oil, and partly through a doubling of renewable energy production from 1990 to the present time. SO_2 emissions have been declining markedly since the 1980s, while NO_x emissions increased until the beginning of the 1990s, thereafter to decline. The overall environmental goals in the energy area were laid down at the UN Climate Conference in Kyoto, Japan in December 1997, cf. the sections on the greenhouse effect and climate changes in *Sections 1.1 and 2.1.*

Denmark's goals for CO_2 emission are stabilization at the 1990 level by the year 2000 and a 20% reduction relative to the 1988 level by the year 2005.

Based on the development so far, not least in energy consumption by the transport sector, it is estimated that the measures implemented will be inadequate to achieve the national goal of a 20% reduction by the year 2005. It should be possible to fulfil the goal of stabilization by the year 2000, however.

Transport

Passenger transport increased by approx. 60% between 1980 and 1995. Motorized traffic accounted for 94% of total passenger transport while private car traffic accounted for 74%. The growth in passenger transport is mainly attributable to the fact that journey distances have increased markedly due to changes in settlement patterns. The private car fleet also plays a role, having increased by just under 20% since 1980 and steeply in recent years. With regard to freight transport, there has been a corresponding tendency towards longer transport distances. On the other hand, the amount of freight lifted and the number of lorries have decreased.

Following growth in the 1980s, freight moved has remained constant during the 1990s. International traffic has generally increased markedly during the period, although precise figures are not available. An indicator of part of the international traffic is the international bunker aircraft and ship traffic, the CO_2 emissions of which have more than doubled since the mid 1980s. Total CO_2 emissions from domestic transport have increased by approx. 30% between 1980 and 1996. While the car fleet became more energy-efficient in the 1980s, the trend in recent years has been the opposite due to the fact that car purchasers have generally selected larger models. NO_x emissions increased through the 1980s but fell by approx. 18% in the 1990s, among other things due to the introduction of catalytic convertors on new cars.

Emissions of carbon monoxide (CO) and hydrocarbons (HC) have also fallen during the 1990s. A marked fall in emissions of NO_X, CO, HC and particulates is expected in the future. The Ministry of Transport expects a fall of between 50 and 60% by the year 2010. In the case of CO_2, a 1994 Ministry of Transport forecast predicts a 16% increase between 1988 and 2005. However, there has been a considerable increase in CO_2 emissions from traffic, especially during the last two years. Thus the Energy Statistics show that a 16% increase in CO_2 emissions from transport had already been achieved in 1996. In addition, the Ministry of Transport's 1994 forecast is based on the assumption of an improvement in energy efficiency, an assumption that has not been realized in recent years. All in all, it is therefore estimated that the increase up to the year 2005 will exceed the 16%. The goal in the Government's 1990 Transport Action Plan and in "Traffic 2005" was stabilization of CO_2 emissions from traffic by the year 2005 relative to 1988.

Agriculture, forestry and fishery

Agriculture

During the 1990s, agriculture has been characterized by moderate overall growth in production encompassing a minor fall in the dairy/cattle sector, marked growth in pig production and a varying but generally increasing crop production. The structural development towards fewer, larger and more specialized holdings has continued, as has the tendency towards regionalization of the production sectors with dairy/cattle farms in western Jutland, crop farms in eastern Denmark and pig farms chiefly in Jutland. Consumption of nitrogen fertilizer per ha has been roughly constant during the whole period from 1980 to the present, with a slight fall in commercial fertilizer and growth in pig slurry. Increasing crop production during the same period implies improved utilization of the nitrogen content of livestock manure.

The utilization efficiency of nitrogen in livestock manure has thus increased from approx. 10% in 1985 to approx. 30% in 1995. Consumption of phosphorus fertilizer per ha has been declining markedly over the whole period from 1980 to the present, and the difference between phosphorus input and removal has narrowed. According to model computations, improved utilization of the nitrogen content of livestock manure has reduced nitrogen leaching from the root zone by 17% between the end of the 1980s and the present. As runoff of nitrogen to watercourses, lakes and marine areas also depends on weather conditions and as there is a certain delay in the system from the root zone to the inland and marine waters, a reduction in leaching is not immediately detectable in the measured concentrations in watercourses, lakes and marine waters. The monitoring undertaken in preceding years has not demonstrated any significant changes in the occurrence of nitrogen in the environment. The latest results from 1996 indicate a reduction in watercourse nitrogen content of between 5 and 10% in clayey catchments, however. Even though the trend in agricultural use of nitrogen is moving in a positive direction, there is nothing in the hitherto development to indicate that the goal specified in the Action Plan on the Aquatic Environment of a 50% reduction in nitrogen loss from agricultural sources will be achieved. In connection with the 1998 Government Budget, a framework agreement was entered into that includes such measures as a reduction in nitrogen fertilization norms and tightened livestock density limits, as well as enhanced efforts concerning afforestation and nature restoration programmes.

In the case of phosphorus, former fertilization practice has led to the accumulation of a large phosphorus pool in the soil which causes considerable diffuse loading of the lakes. This will continue despite the fact that overfertilization has been reduced considerably. Agriculture places other major pressures on the environment than nitrogen and phosphorus loading of the aquatic environment. Ammonia volatilization fell in the 1980s and has been constant during the 1990s. The same applies to agricultural emissions of the greenhouse gasses methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). Pesticide pollution is examined in the section on environmentally hazardous substances. In addition, land use by agriculture affects nature quality in the countryside.

Drainage of wetlands, elimination of small biotopes, borders and hedgerows together with intensive operation contribute to the general reduction in the nature quality of the landscape. In this area, there are opposing tendencies: On one hand, the tendency towards larger and more specialized farms is reducing the diversity of the landscape. The decline in the dairy/cattle sector and hence the area of permanent grass to the benefit of pig production and cereals/rape production will contribute to this. On the other hand, enhanced awareness of nature and the environment pulls in the other direction, where afforestation, the establishment of coverts, small plantations and hedgerows will increase the nature content of the landscape.

Forestry

The total area of forest in Denmark has doubled since the end of the last century from around 200,000 ha then to 417,000 ha today. Since the mid 1960s, the forest area has remained virtually constant with a tendency towards a slight increase in recent years. Most of the growth is accounted for by coniferous forest, which currently accounts for about 65% of the forest area. Just over 80% of the coniferous forest is located in Jutland, while just under 60% of the broadleaved forest is located on the island part of Denmark. The forests are of great significance for nature and the environment. The extensive nature of forestry means that pressure on the environment from fertilizer and pesticides, etc., is low. Moreover, the forests comprise important habitats for animals and plants and form the framework for recreational activities. The forests protect the groundwater against pollution and filter dust, salt, etc. from the air. With the help of solar energy, the forests produce an important raw material - wood. Finally, many ancient monuments are preserved in the forests because of the extensive nature of forestry. For these and other reasons, the Danish Parliament has decided that the forest area is to be doubled over a tree generation. Realization of this goal will necessitate afforestation of approx. 5,000 ha annually, which is considerably more than the approx. 2,500 ha that were planted annually in the 1990s. In addition, some forest areas will be converted to natural forest and virgin forest, and environmentally sound forms of forestry will be practised in other areas.

Fishery

Annual landings from Danish marine waters - the North Sea, Skagerrak, Kattegat, the Belt Seas and the Baltic Sea - amount to 1.5-2 million tonnes fish and shellfish, a figure that has been roughly constant over the last 10 years. If one looks a little further back in time, landings have changed markedly. Total North Sea landings have thus increased from approx. 1 million tonnes at the turn of the century to over 2 million tonnes around 1960, peaking at over 4 million tonnes at the end of the 1960s. Thereafter landings declined to a level of around 2.5 million tonnes during the last 10 years. In the period since 1950, there has been a marked decline in spawning populations of a number of commercially important fish species such as herring, mackerel, cod and plaice.

Apart from affecting the fish populations, fishery also affects the marine environment in other ways. The selective catch of specific species and sizes changes the balance between small and large fish, between predator and prey fish and between competing species. In the long run, this changes the structure of the food chains. In addition, equipment such as beam trawls, which are drawn along the seabed, can destroy conditions for benthic invertebrates and hinder the growth of eel grass. Studies show that between 15 and 55% of the animals left in the wake of a beam trawl are dead or dying. Even though the marine ecosystem is complicated and is affected by many natural factors, it is clear that man's activities have a decisive impact and that a number of commercially important species are overfished.

Industry

Over the period 1985 to 1996, industrial production has increased 20% in real terms while employment is currently at the same level as in 1985. Industrial energy consumption accounts for just under 20% of total final energy consumption and has been increasing steadily since the beginning of the 1980s. 150 very heavy industrial enterprises account for 75% of energy consumption in the industrial sector. Industrial consumption of water and raw materials is high. Water consumption amounts to approx. 166 million m^3, of which approximately half is pure groundwater. The food, drink and tobacco industry, the chemicals industry and the stone, clay and glass industry annually consume 21, 14 and 14 million tonnes of raw materials, respectively. In the food, drink and tobacco industry in particular, there is considerable material loss in the form of production waste. Industrial emissions of CO_2 and NO_X largely follow the development in energy consumption, while emissions of SO_2 fell up to 1990, thereafter to stabilize at a low level. VOC emissions amounted to around 24,000 tonnes at the end of the 1980s and are expected to decrease to around 14,000 tonnes by the year 2000. Organic matter, nitrogen and phosphorus discharges to the aquatic environment have been reduced by 70%, 50% and 80%, respectively, and industry has thus met the goals stipulated for industrial emissions in the Action Plan on the Aquatic Environment. Discharges of a number of environmentally hazardous substances have been reduced correspondingly. In contrast, waste generation by industry increased approx. 16% between 1993 and 1995. Environmental initiatives on the industrial front currently focus not just on the direct discharges and emissions, but also on the environmental pressure from industrial products during their life cycle.

Service

The service sector represents about 2/3 of total employment in the country. The share has been increasing since the 1960s, and is expected to continue to increase. The service sector encompasses many different branches, of which trade, tourism and communications are important examples. The retail trade is characterized by marked concentration, with about 1,600 department stores, discount shops and supermarkets accounting for around 60% of grocery sales. Over the period 1987 to 1994, more than half of all new shop floor space was established outside town centres, often on the outskirts of towns where access by car is easier. At the same time, over half of all new shop space was built in towns with over 20,000 inhabitants. The consequence is an ailing retail shopping network in the smaller towns and increased transport needs in connection with grocery shopping. The tourist industry is another important part of the service sector. This underwent marked growth up to the beginning of the 1990s, whereafter it has stagnated. Tourism is concentrated along the coasts. Out of 44 million tourist bed-nights in 1995, 70% were made along the coasts. 15% of the coastal region is currently reserved for holiday cottage districts and tourist facilities, and the pressure on nature is considerable in several places. A third important branch of the service sector is communications (media, telecommunications, advertising, etc.) which employs around 150,000 persons and is undergoing marked growth.

The service sector does not turn over raw materials like agriculture, industry and the energy sector, but nevertheless contributes directly and indirectly to a number of pressures on the environment. The service sector accounts for around 1/3 of commercial energy consumption. This seems somewhat low given that the sector employs 2/3 of the workforce. However, if one examines the indirect energy consumption that the activities within the service sector generate among the sectors' suppliers, private service lies at nearly the same level as direct and indirect energy consumption by industry. In contrast, energy consumption in public service is low. The service sector makes a major contribution to the increase in traffic, generates increasing amounts of waste and consumes increasingly large amounts of chemicals. The sector accounts for about half of the growth in commercial floor space, and along the coastal zone and in other attractive areas of open countryside, an increasing amount of land is being used for holiday cottages, hotels and recreational facilities. While discussion has arisen as to whether the transition to a service society is an expression of dematerialization of the economy - a transition to a less resource-demanding society with less impact on the environment, there is nothing to indicate that this is the case. Activity within the service sector generates increasing production in agriculture and industry, as well as new demand for their products. The transition to a less resource-demanding society does not come automatically, but requires deliberate effort. In this connection, certain parts of the service sector can make a positive contribution.

Households

Development in the household sector is characterized by three main trends: A decreasing number of persons per household, an increasing frequency of employment, and increasing consumption, the latter having grown by just under 30% between 1980 and the present. The overall effect is that instead of being societal units with many independent functions, households have become far more integrated in and dependent on society and its goods and services. The households have become consumption units with production largely occurring externally. It is therefore becoming increasingly interesting how household lifestyles and demand for goods and services affect the environment in the preceding stages in the cycle. A survey of lifestyle and energy consumption reveals very great variation between different family types. An "American" lifestyle at one end of the spectrum consumes 8.5 times more energy than a "green" lifestyle at the other end of the spectrum.

The average family uses a diminishing share of its budget on food, clothing and household furniture and fittings, and an increasing share on transport, housing costs and holidays. The environmental impact associated with "eating" is high, in contrast, which reflects the fact that although foods have become cheap, the environmental impact of their production is great. Transport, leisure and heating also account for a considerable part of household environmental impact.

Household energy consumption has fallen since 1980, although there has been a tendency towards an increase in recent years. The fall is due to savings on heating, while electricity consumption has been increasing. Household water consumption fell by 20% between 1984 and 1994, and 90% of households are currently connected to municipal sewage treatment works. The amount of household waste has increased by just over 30% since 1985, and by just under 15% between 1993 and 1995. The waste is mainly disposed of by incineration (74%) and recycling (15%). The household sector uses many different chemical substances and products for washing, cleaning, painting, car maintenance, weed control, etc. Of these, household use of textile detergents is considered to have the greatest environmental impact.

Outdoor recreation and tourism

Outdoor recreation and outdoor tourism are on the increase in both Denmark and internationally. On one hand, this has great value for the physical and mental welfare of the population. On the other hand, it imposes increasing pressure on the natural ecosystems.

The share of the adult Danish population that participates in sport and exercise has increased from 15% in 1964 to 47% in 1993. Forest visits are among the most popular leisure activities in that approx. 91% of the adult population visits a forest at least once a year. Over the period 1989-95, tourism increased 48% from approx. 29.8 million registered tourist bed-nights to 44.2 million. Growth here has mainly been within the holiday cottage sector. Outdoor recreational activities are most intensively undertaken close to home in parks and green spaces and in forests and natural countryside close to towns. Outdoor tourism is concentrated in less built-up areas with special natural qualities such as water, forest, dunes, etc. As a shift is taking place towards more intensive outdoor recreation, one must expect pressure on nature to increase in future. Moreover, local environmental problems are enhanced by the fact that tourism is highly concentrated both spatially and temporally.

Waste water and waste

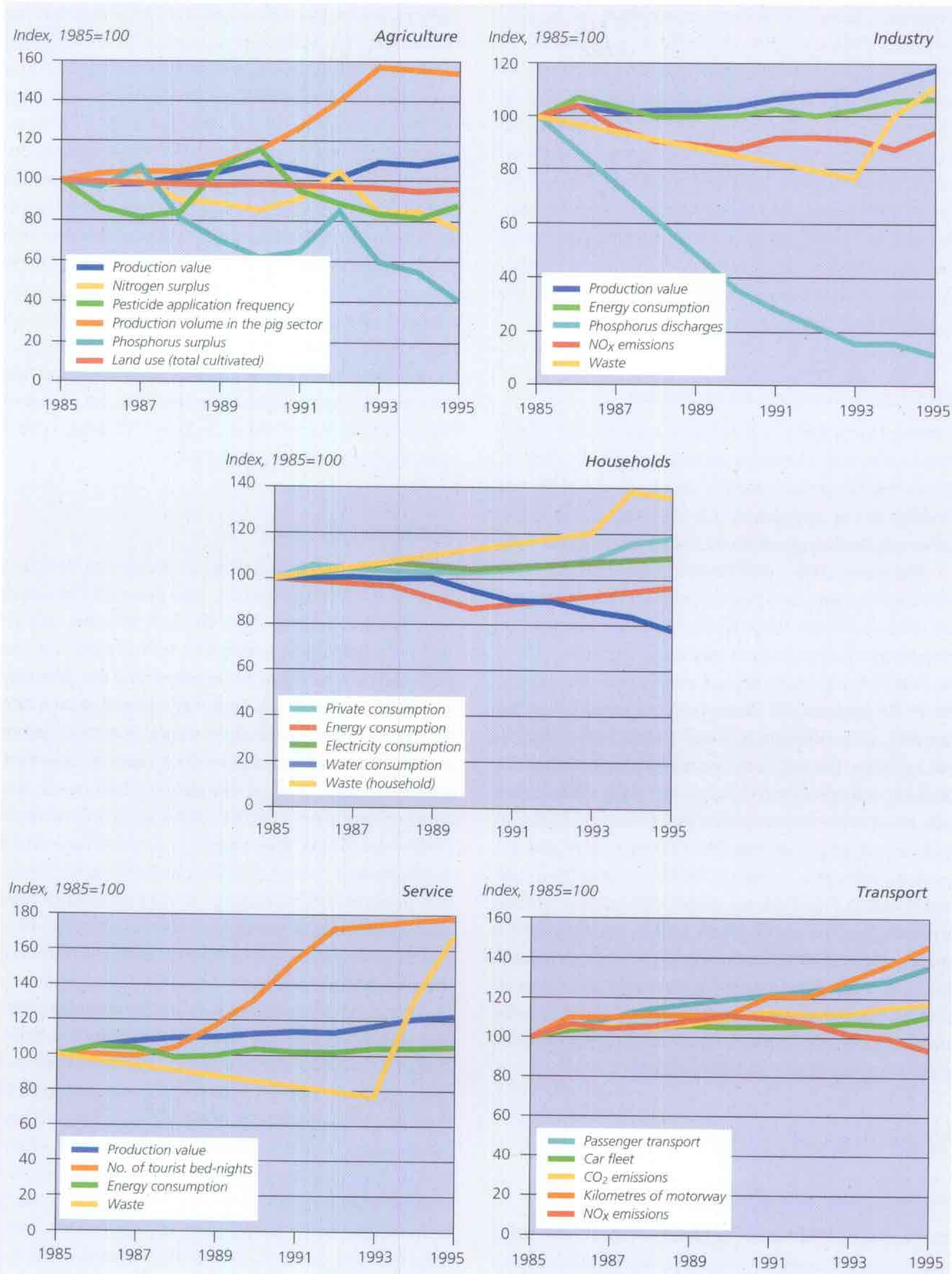
Waste water management

In the 1970s, 1980s and beginning of the 1990s, large sums were invested in an effective public sewage and waste management system. Less has been spent on maintaining the sewer network, however, and in several places, it is leaky, allowing the infiltration of large amounts of water and thereby reducing the efficiency of the waste water treatment works. It is estimated that 20% of the sewer network needs renovating. The waste water treatment works now remove over 90% of the organic matter in sewage, over 60% of the nitrogen and nearly 80% of the phosphorus. They therefore fulfil the goals stipulated in the Action Plan on the Aquatic Environment. The waste water treatment works also receive a number of environmentally hazardous substances in the waste water. Some of these are degraded by the microorganisms within the treatment works. However, the persistent substances end up in the sludge unless they are water-soluble, in which case they are discharged into the recipient with the treated effluent. Because of the high degree of treatment at the municipal treatment works, scattered dwellings outside the sewerage system now comprise a major source of nutrient loading of watercourses and lakes, especially with respect to phosphorus.

Waste management

In 1996, waste generation in Denmark totalled approx. 13 million tonnes. The amounts of waste have been increasing over the last 10 years. About 60% is recycled, just under 20% incinerated and just under 20% landfilled. In addition to the primary waste from enterprises, households and power stations, secondary waste from waste water treatment works and waste incineration plants is also processed. Approx. 77% of the sludge from waste water treatment works is currently reused on farmland (1995), and 92% of the residual products from energy production is reused as filling material in construction projects (1995). If sludge is to be recycled it may only contain small amounts of environmentally hazardous substances, a requirement that is not met at some treatment works.

There are different types of environmental problem associated with the three treatment forms: Recycling, incineration and landfilling. The treatment and processing of returned materials causes pollution in the same way as with all other types of production. Waste incineration results in the atmospheric emission of a number of substances harmful to health and the environment. Moreover, it generates slag, which can contain heavy metals. Landfilling causes problems with regard to the selection of suitable sites, the emission of gasses to the atmosphere and the formation of percolate. Based on an overall assessment of the benefits and disadvantages it is generally considered that recycling is the most appropriate waste management solution while landfilling is the least appropriate.



***Box 1.2** Key figures for societal and environmental development in selected sectors over the period 1985-95. Index 1985=100. Production value is in real (1980) prices. Surplus nitrogen and phosphorus in agriculture represents the difference between total inputs to and outputs from the Danish agricultural area calculated as the field balance. Pesticide application frequency is a measure of pesticide consumption. The vehicle fleet encompasses private cars and delivery vans under 2 tonnes. NO_x emissions from industry solely encompass direct emissions (from process energy). Phosphorus discharges from industry encompass both direct discharges and discharges via municipal sewage treatment works (Source: National Environmental Research Institute, on the basis of data in Chapters 2 and 3).*

1.3 Cross-cutting summary

The pressures that society imposes on the environment and nature can be divided into three different categories: 1) Pressures related to societal *turnover of resources*, and which give rise to changes in a number of major natural cycles and balances. 2) Pressures associated with *land use* by society, and which alter the landscape's structure and physical conditions and hence shift a number of ecological balances. 3) Pressures associated with man's development of new technologies, and which pose *risks* to man and nature.

The major natural cycles

In general, Danish society has become more efficient in its turnover of resources. The increasing production in all sectors of society has not resulted in corresponding increases in emissions to the environment. In many areas, they have fallen, in some cases even markedly, cf. *Box 1.2*. Since the end of the 1980s, the agricultural sector has reduced its fertilizer consumption, improved the utilization efficiency of nitrogen in livestock manure and reduced nitrogen leaching by 15-20%. During the same period, industry and the waste water treatment works have reduced discharges of nitrogen, phosphorus and organic matter by 60% to 90%. Despite the increasing amounts of waste, enhanced recycling has reduced landfilling by approx. 40% since 1985. Emissions of SO_2 from power stations have been reduced by 70% since the beginning of the 1980s, and NO_x emissions have fallen by around 25% since 1990. Following an increase in the 1980s, emissions of NO_x, hydrocarbons and particulates from traffic are now beginning to fall, and are expected to have decreased 50-60% by the year 2010. CO_2 emissions associated with energy consumption have fallen by 4% since 1988 despite growth in energy consumption, not least by the transport sector. This increase in the efficiency of resource turnover has been achieved through a broad range of initiatives within all sectors of society. In a number of key areas, however, the initiatives hitherto implemented have been inadequate to achieve the environmental goals. This applies to agricultural nitrogen losses to both water (NO_3) and air (NH_3). In addition, there is a need for a further reduction in phosphorus loading of watercourses and lakes if the environmental quality objectives for lakes are to be met. In the CO_2 area, it is unlikely that it will be possible to achieve a 20% reduction in emissions by the year 2005 relative to the 1988 level. The problem is largely the increasing CO_2 emissions from traffic. In the waste area, the total amounts of waste exceeds the goals stipulated in the Action Plan for Waste and Recycling. A characteristic feature is that the areas where achievement of the goals has been difficult are the areas where appropriate treatment and abatement technologies are lacking and where it is therefore necessary to change production technologies and behaviour.

Land use

Land use and localization is another important factor as regards pressure on nature and the environment. Physical conditions have been affected in 85% of our watercourses as a result of watercourse regulation and exploitation of riparian areas. High water consumption in some areas lowers the groundwater table and dries out watercourses and wetlands. Intensive and specialized agricultural production reduces the nature content of the open countryside. Intensive use of large coastal areas for tourism imposes considerable pressure on vulnerable natural ecosystems. Urban development and large infrastructure facilities create a fragmented landscape with deteriorated habitat conditions for part of the fauna. Dispersed urban development destroys the functional relationships in towns and enhances the amount of traffic.

In this area too, many initiatives have been taken during the past 10 years: Gentle watercourse maintenance, nature restoration projets, enhanced protection of the coastal zone, afforestation, regulation of the retail trade and shopping centre development, etc. This area generally lacks quantitative goals such as is the case with emissions. The goals are formulated as intentions with respect to enhanced quality, and are not immediately quantifiable. It can nevertheless be ascertained that the pressure on nature and the environment from intensive land use remains high, and that a long-term effort will be needed if appreciable reductions are to be achieved.

Technological risks

The technological risks relate to the use and dispersal in the environment of radioactive substances, environmentally hazardous substances and genetically modified organisms. In this report, only the latter two types of risk are examined. Considerable efforts have been made to reduce the dispersal in the environment of a number of environmentally hazardous substances for which scientific assessment has shown clear negative effects. Examples of this include the phase-out of ozone-depleting substances, the reduction in the use of heavy metals and organic solvents, and the prohibition of the use of a number of pesticides and persistent organic compounds. In addition should be added the reduction in discharges of a number of environmentally hazardous substances due to the introduction of treatment/abatement measures at municipal waste water treatment works, power stations, waste incineration plants and enterprises, as well as close control of the use of genetically modified organisms. On the other hand, it is apparent that the technologically advanced society uses and continues to develop a large number of technologies whose effects on man, nature and the environment are very complicated, and where scientifically based risk assessment has great difficulty in drawing unambiguous conclusions. Examples are the so-called oestrogen-like substances and the introduction of an increasing number of genetically modified plants in agriculture.

Scope of the environmental problems

The environmental problems have a temporal and geographic scope that separates them from most other policy areas in society. The reaction time of the physical, chemical and biological processes in the environment is such that it often takes decades and sometimes even centuries from the time that an impact is exerted on the environment until this manifests itself in the form of clear effects. At the same time, many of these processes are regional or global in character. Moreover, the environmental problems are caused by societal activities that are increasingly part of or driven by international development. Through the import of goods, Denmark thus contributes to environmental pressures in other countries, and vice versa. As a country poor in raw materials and with a high level of consumption, the pressure Denmark places on natural resources and its contribution to pressures on the environment abroad are considerable. Ideally, therefore, a thorough description of the Danish environment should encompass these international dimensions. This has not been possible in the present report, however.

General conclusion

The general conclusion is that numerous steps have been taken at all levels and areas of society to reduce the pressures on the environment and that in a number of areas the state of the environment has been improved. However, there are still a number of key areas where initiatives to date have been inadequate to achieve the environmental goals set, or where opposing forces in societal development reduce or completely eliminate the impact of the environmental initiatives. It remains characteristic that these areas are exactly the areas "where man and society are faced with the fundamental choice between on one hand, our present pattern of consumption and production, and on the other hand, nature and the environment", as was also the conclusion of the preceding State of the Environment Report.

2. State of the Environment

2.1 The atmospheric environment

2.1.1 Introduction

Pollution of the atmosphere is far from a new phenomenon associated with the industrialized world. Historical records and literature abound with references to the poor quality of town air. However, the problem has grown both geographically and temporally in step with global population growth and industrialization. At the same time, development and growth of traffic and industry led to the presence of new substances.

It has been known for centuries that vegetation fails to thrive near sources of air pollution, that health is affected and that materials are degraded. It was not until the 1960s, however, that the local and regional effects of long-range air pollution were acknowledged, firstly for sulphur and nitrogen compounds and later for photochemical oxidants.

The result is apparent as acidification of watercourses and lakes, forest die back and changes to natural ecosystems. In recent years attention has been directed towards global effects: Depletion of the ozone layer caused by man-made chlorine and bromine compounds, and enhancement of the greenhouse effect by increased anthropogenic emissions of carbon dioxide and other greenhouse gasses. These types of air pollution threaten to change conditions for life on the whole planet. The air pollution problems cannot be viewed in isolation as they are to a greater or lesser extent interrelated through a number of basic atmospheric chemical processes, all of which take place in the same atmosphere.

The atmosphere is divided into layers characterized by decreasing or increasing temperature (*Figure 2.1.1*). The pattern is the same over the whole planet, but the individual maxima and minima are greater at the equator than at the poles. It is only the lowermost layers that are of interest in connection with air pollution. The so-called ozone layer, which contains about 90% of all atmospheric ozone, is localized in the lowermost layer of the stratosphere at an altitude of 15-30 km. This ozone protects us against ultraviolet light from the sun.

The ozone in the troposphere near the surface of the planet is a so-called secondary pollutant (photochemical oxidant) that is not directly emitted from specific sources, but is instead formed in the atmosphere when air pollutants such as nitrogen oxides and volatile hydrocarbons react with the oxygen in the air under the influence of sunlight. Among other things, this "ozone pollution" is harmful to health.

The greenhouse effect, depletion of the ozone layer and photochemical air pollution are examples of air pollution problems that have to be considered jointly. Thus tropospheric ozone is not just an air pollutant near the surface, but is also a greenhouse gas. Moreover, if the ozone content of the stratosphere decreases, UV radiation increases, and the photochemical activity in the troposphere increases leading to the formation of more tropospheric ozone, thereby enhancing the greenhouse effect.

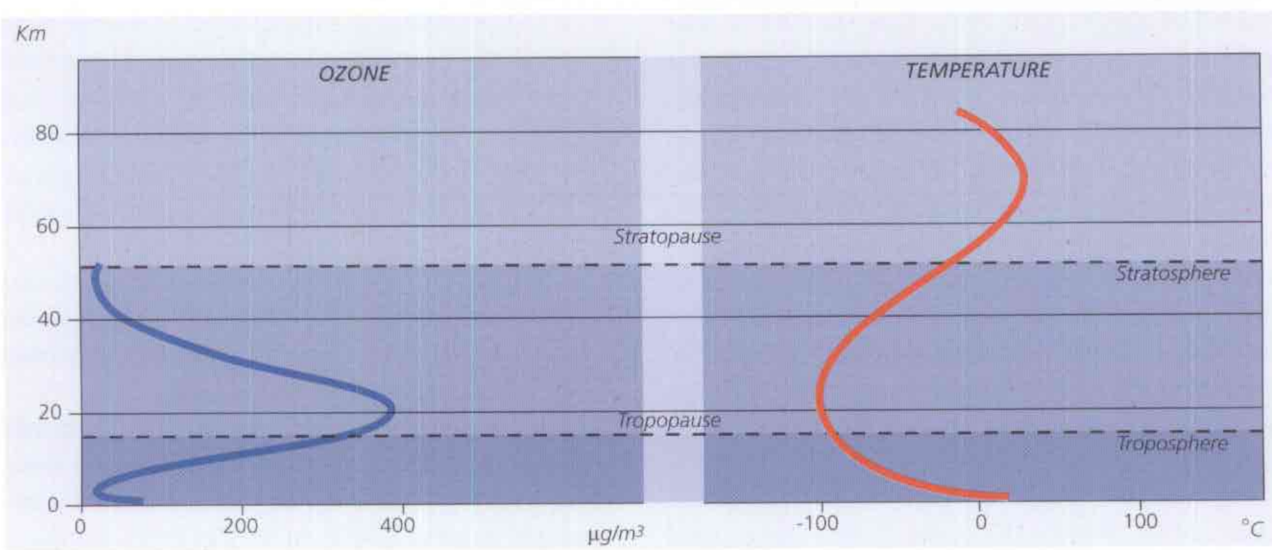


Figure 2.1.1 Ozone concentration and temperature distribution in the lower part of the atmosphere. Energy absorption in the ozone layer causes the temperature inversion (increasing temperature with increasing altitude) that creates the stratosphere. In the troposphere - the layer closest to the Earth where the weather phenomena take place - the temperature generally decreases with increasing altitude. The boundary between the troposphere and the stratosphere is termed the tropopause.

This is complicated by the fact that while depletion of the ozone layer supposedly results in cooling of the Earth's surface, thereby counteracting the greenhouse effect, the substances that deplete the ozone layer are concomitantly greenhouse gasses.

In general, the greenhouse effect of these substances is the net result of a direct positive component and an indirect negative (cooling) component. Thus the net greenhouse effect of the CFCs is probably positive whereas that of halons is negative. Furthermore, ozone can also react with nitrogen dioxide to form nitric acid, thereby coupling photochemical air pollution to acidification.

As the same air pollution often plays a role in many different environmental problems, a reduction in emissions to alleviate one problem can also have a beneficial effect on other problems. For example, reduced emissions of the greenhouse gas carbon dioxide will have the "side effect" of reducing the emissions of sulphur dioxide, nitrogen oxides and carbon monoxide, thereby helping to alleviate the acidification, tropospheric ozone and urban air quality problems.

2.1.2 Greenhouse effect and climate changes

Introduction

The greenhouse effect of the Earth's atmosphere is a natural phenomenon and a necessary precondition for the maintenance of life on Earth. Without an atmosphere, the average temperature of the Earth would be approx. 33°C lower than the current temperature of approx. 15°C. What in this context is meant by the greenhouse effect is therefore the enhanced effect of anthropogenic emissions of greenhouse gasses and the effects of other activities. Thus it is no longer a question of to what extent the Earth's temperature has increased over the last 100 years, but to what extent this increase is anthropogenic and will continue or to what extent it is due to natural climate variation, and how serious the consequences of a continued temperature increase will be in various parts of the world. The most important greenhouse gasses are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and substances that deplete the ozone layer. The general increase in the ozone concentration of the troposphere also contributes to global warming, whereas the anthropogenic sulphate aerosols have a cooling effect.

The anthropogenic greenhouse effect - an overview

The UN panel of experts on climate questions (Intergovernmental Panel on Climate Change, IPCC) concluded in 1990 that the hitherto observed global warming over the preceding 100-year period was largely in accordance with the predictions of the climate models, but that it was also of the same magnitude as the natural climatic variation. The IPCC also concluded that the observed increase could well be attributable to natural variation. Alternatively, this variation and other anthropogenic factors could have masked even greater anthropogenic greenhouse warming.

Since the IPCC's first evaluation report in 1990, so much progress has been made in the search for a demonstrable anthropogenic effect on the climate that in its second report (1996), the IPCC now concludes that "The balance of evidence suggests a discernable human influence on global climate".
The IPCC also concludes that:

- Taken together, model calculations suggest that the changes in emissions of greenhouse gasses and aerosols will change regional and global climate-related parameters such as temperature, precipitation, soil moistness and the sea level. Changes with potentially serious consequences have been identified in some regions, including increased frequency of episodic drought, heat waves and flooding with impacts such as forest fires, changes in ecosystem composition, structure and function, including their primary production.
- If CO_2 emissions are maintained at their present level, the concentration in the atmosphere will increase at a constant rate over a period of at least two hundred years, and reach a level in the second half of the next century that is approx. twice the concentration during the preindustrial era.
- Stabilization of the CO_2 concentration at its current level can only be achieved through an immediate 50-70% reduction in emissions followed by subsequent further reductions.

Any impact that man might have on the climate will be superimposed on the background noise of natural climatic variation caused by both internal fluctuations and external effects on the climate system such as variations in the solar energy and volcanic eruptions.

The natural and anthropogenic forces behind the climate changes are summarized in *Box 2.1.1*.

Driving forces behind climate change

Throughout world history, the climate has varied as a result of a number of more or less well-known natural causes. Over periods of tens of thousand years, the climate varies considerably - there are glacial periods and interglacial periods, the slow changes between them being explained by variations in the Earth's orbit around the sun, which leads to changes in seasonal and latitudinal distribution of solar radiation.

Over a 10- to 100-year time frame, the climate exhibits natural variations that cannot be explained in detail. As a consequence, possible anthropogenic climate changes can be difficult to detect or demonstrate. Nevertheless, on the basis of numerous studies the IPCC has now reached the conclusion that the climate changes that have taken place since industrialization are not solely attributable to natural causes.

The increase in the concentration of greenhouse gasses will reduce the effectiveness with which the Earth looses heat to outer space. A greater part of the outgoing long-wave radiation from the surface will be absorbed by the atmosphere and emitted at greater altitudes and lower temperatures. The result is a positive radiative effect that warms the lower atmosphere and the surface of the Earth. This is the enhanced greenhouse effect, i.e. amplification of an effect that has occurred in the Earth's atmosphere for thousand of million years due to the naturally occurring greenhouse gasses: Water vapour, carbon dioxide, ozone, methane and nitrous oxide.

Anthropogenic aerosols (small airborne particles) in the troposphere, mainly formed by the emission of sulphur dioxide in connection with the combustion of fossil fuels, can absorb and reflect solar radiation and change the amount of cloud and its ability to reflect radiation. In the majority of cases, the net result is a negative radiative effect and a cooler climate. The aerosols have a far shorter lifetime (days to weeks) than the majority of greenhouse gasses (decades to centuries), so their concentrations react far more rapidly to changes in emissions.

Volcanic activity can send large amounts of sulphurous gasses (primarily sulphur dioxide) into the stratosphere, where they are converted to aerosols. This can have a major but short-lasting (a few years) negative radiative effect which cools the lower atmosphere and surface of the Earth for periods of a few years.

Solar emission of energy varies slightly (0.1%) over an 11-year period and can also vary over longer periods (22 and 76 years). In an attempt to better differentiate between natural and anthropogenic climate changes, the Danish Meteorological Institute is working on theories of how periodic variation in the sun's impact on the Earth's atmosphere and resultant effects on cloud formation can lead to climate variations of the same magnitude as observed over the last couple of hundred years.

While these theories do not receive wide support in the IPCC, they are not inconsistent with the conclusions of the 2nd IPCC evaluation report in that the IPCC acknowledges that variation in solar radiation can explain some of the temperature changes that have taken place.

Climate variations can also arise in the absence of change in external influences as a result of complex interactions between the components of the climate systems, e.g. the atmosphere and the oceans. The ENSO or El Niño phenomenon is an example of such internal variation. El Niño is a well-known cyclic phenomenon lasting 1-3 years that starts with warming of the sea and air in the eastern tropical Pacific. This warming spreads, leading to enhanced cloud formation.

***Box 2.1.1** The driving forces behind climate change (Source: Danish Meteorological Institute, 1996; Intergovernmental Panel on Climate Change (IPCC), 1996a).*

Observed climate changes

Temperature

The climate of the Earth has changed measurably during the period in which the greenhouse gas content of the atmosphere has increased as a result of human activities. Based on the development in a number of indirect climate indicators, it is estimated that global mean temperature in the 20th century is the highest for any century since the year 1400. Data for the period prior to 1400 are too limited to allow a reliable estimate of the global mean temperature. The oldest direct temperature measurements are from 1600-1700, but reliable measurements covering the whole world did not become available until approx. 1860.

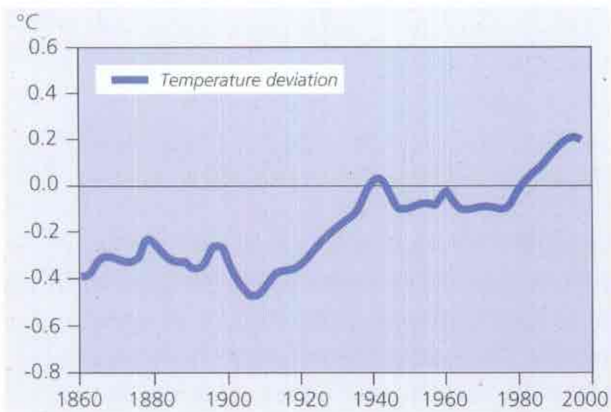


Figure 2.1.2 Development in global mean temperature since 1860 expressed in terms of deviation from the mean temperature for the period 1961-90 (Source: Intergovernmental Panel on Climate Change (IPCC), 1996a).

The development in global mean temperature since 1860 is shown in *Figure 2.1.2.* The temperature increased over the period, especially from 1910-40 and again from the 1970s. 1995 was the warmest year during the period. The temperature increase has not been even throughout the world, however, and some areas around the North Atlantic have actually experienced a temperature decrease.

Precipitation

According to the IPCC, precipitation has increased over land in high latitudes, especially in winter. A stepwise reduction in precipitation took place in the 1960s in the tropics and subtropics in areas from Africa to Indonesia. Annual precipitation over land has increased from the turn of the century until approx. 1960, but since 1980 has been decreasing. In Denmark, however, precipitation has increased slightly. Cloud cover over the oceans seems to have increased since the 1950s. In many terrestrial areas, where the daily temperature span has decreased, cloud cover has increased - especially over the period from the 1950s to the 1970s. Since 1988, the extent of snow cover on the land mass in the northern hemisphere has been less than the 21-year average for the period 1974-94. The feedback between snow and radiation has enhanced the warming over terrestrial areas in the spring in medium and high latitudes in the northern hemisphere. The temperature indicators for the observed development in climate are summarized in *Figure 2.1.3.*

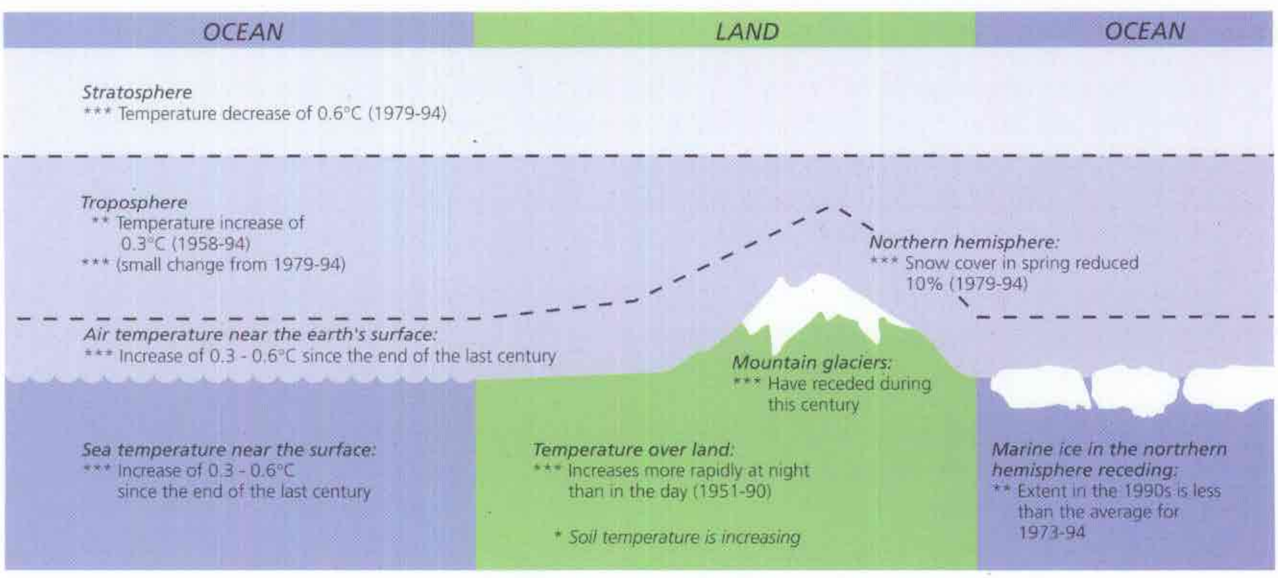


*Figure 2.1.3 Temperature indicators. Summary of the observed climate development for selected indicators over the last 120 years corresponding to the so-called instrumental period, i.e. since the introduction of "instrumental" measurement series. The degree of certainty associated with the assessments is indicated by asterisks: *** very certain, ** moderate certainty, * uncertain (Source: Intergovernmental Panel on Climate Change (IPCC), 1996a).*

Sea level changes

The global sea level has also risen over the last 100 years, partly due to thermal expansion of the sea water and partly due to increased melting of mountain glaciers and inland icecaps. Based on sea level measurements, the IPCC estimates that the sea level has risen between 10 and 25 cm. The relatively great uncertainty range is due to the fact that the measurements also include changes caused by vertical movements in the Earth's crust, which have to be filtered from the measurements. Of the observed rise, 2 to 7 cm is due to thermal expansion of the sea water, while 2 to 5 cm is accounted for by the observed retreat of the world's glaciers and icecaps. The rate of the observed rise in sea level indicates an overall positive contribution from melting of the inland icecap in Greenland and the Antarctic ice sheet.

Extreme weather situations

Many climate effects can be attributed to an increased frequency of extreme weather situations, or a direct or indirect consequence of changes in climate variation. Because of insufficient data it is not possible to decide whether global changes in these conditions have taken place during the 20th century. At the regional level, however, there are strong indications for changes in certain indicators of extreme weather situations and climate variation, e.g. less frost in many areas and an increase in the part of precipitation in the USA that derives from extreme weather situations.

Causes of climate changes

The most important natural greenhouse gasses are water vapour and carbon dioxide, although methane, nitrous oxide and ozone are also of importance. Human activities lead to the direct emission of carbon dioxide, methane and nitrous oxide, as well as the emission of other substances (nitrogen oxides and hydrocarbons) that affect ozone formation in the lowermost part of the atmosphere. To this should be added industrially produced halogenated hydrocarbons (CFCs, etc.) which not only deplete the ozone layer, but are also effective greenhouse gasses. Of the anthropogenic greenhouse gasses, carbon dioxide is by far the most important. In the global carbon cycle, approx. 200,000 million tonnes carbon circulates annually between the atmosphere, vegetation, soil and oceans through processes such as respiration, photosynthesis and physical dispersal and diffusion processes. Annual global carbon dioxide emissions of approx. 6,000 million tonnes carbon in connection with the consumption of fossil fuels such as coal, oil and natural gas comprise only a small part of the circulating pool, but nevertheless have an impact on the climate. The consumption of fossil fuels also contributes to emissions of methane and nitrous oxide (N_2O).

Clearance of the world's forests - especially those in the tropics - in order to satisfy an increasing demand for timber products and to provide more land for agricultural purposes is another major source of CO_2. Forests build up their biomass using carbon dioxide via photosynthesis. In the mature tropical forest, production and consumption of CO_2 are in equilibrium. If the forest is felled or burnt off, however, this results in the net release of CO_2 from the cleared areas through the degradation of organic matter in the soil. It is estimated that net release of CO_2 in connection with these changes in the use of tropical land accounts for just under 25% of the total anthropogenic CO_2 emissions of approx. 7,000 million tonnes carbon - a figure that decreases to approx. 15% if account is taken of CO_2 uptake in connection with enhanced forest growth in the northern hemisphere. The CO_2 concentration has increased from around 280 ppmv (parts per million by volume) in the preindustrial era to 358 ppmv in 1994 (*Figure 2.1.4*). The rapid increase in CO_2 concentration associated with the consumption of fossil fuels is particularly clear in the period following the Second World War. Prior to this increase, the CO_2 concentration in the atmosphere had only varied by approx. 10 ppmv around a level of 280 ppmv over the preceding 10,000-year period - a period in which the global climate was relatively stable. The current annual rate of increase in CO_2 concentration is 0.4% per year.

Production of foods is a third important cause, and is estimated to account for approx. 70% of anthropogenic methane emissions and a considerable part of nitrous oxide emissions. These emissions have increased concomitantly with the increase in the total area cultivated with rice, the increase in the number of livestock and the increased use of animal fertilizer. Methane (CH_4) is formed through the degradation of organic matter in wet paddy fields, etc. under anaerobic conditions, and is also formed in the digestive tract of ruminating livestock. Methane is also formed naturally in many wetlands. N_2O forms when nitrogen-containing fertilizer increases the soil concentration of nitrate, which under anaero-

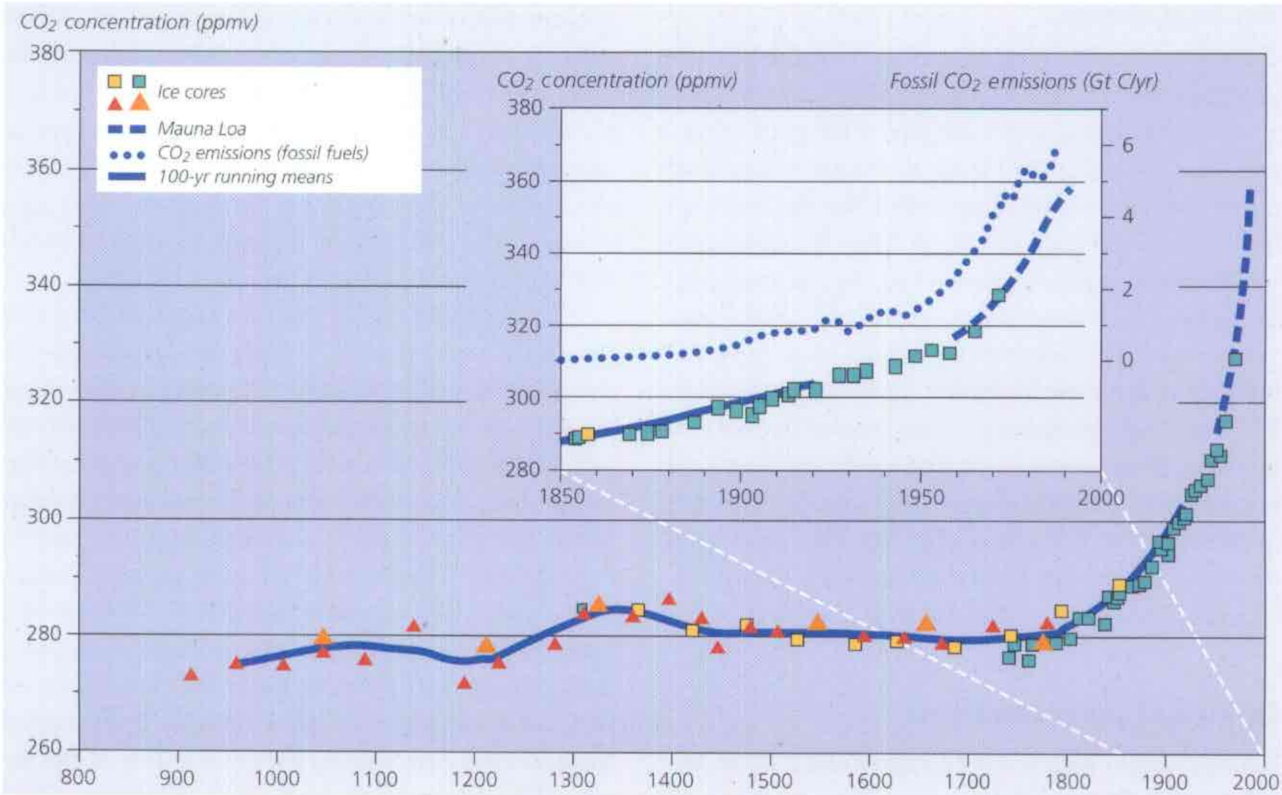


Figure 2.1.4 *CO_2 concentration in the atmosphere over the last 1,000 years. The time series is based on measurements made on ice cores from the Antarctic, and from 1958 onwards from the Mauna Loa Observatory on Hawaii. The smooth curve indicates the 100-year running mean (Source: Intergovernmental Panel on Climate Change (IPCC), 1996a).*

bic conditions is converted to gaseous N_2O. The most important anthropogenic sources of N_2O are agriculture and a number of industrial processes. An uncertain estimate of total anthropogenic sources of N_2O is 3-8,000 million tonnes per year. The natural sources are estimated to be twice as great as the anthropogenic sources. The atmospheric concentrations of methane and nitrous oxide are increasing annually by 0.6% and 0.25%, respectively.

With one exception, all the CFCs and other so-called ozone layer depleting substances are purely anthropogenic and degrade very slowly in the atmosphere. The substances that contain chlorine and bromine are able both to enhance the greenhouse effect and deplete the ozone layer.

However, their greenhouse effect is partly counteracted by depletion of the ozone layer, which has had a negative (cooling) greenhouse effect over the last 15-20 years. HFCs and perfluorocarbons (PFCs), which replace CFCs in some uses, and sulphur hexafluoride (SF_6) currently only make a small contribution to changes in the energy balance, but at the predicted rate of growth they might account for a noticeable percentage of the global warming potential of greenhouse gasses during the course of the 21st century.

Global warming potential (GWP). There is no simple relationship between changes in the concentration of the greenhouse gasses and their effect on the energy balance because they absorb radiation at different wavelengths and with different efficiency. In addition, the concentration of some of the gasses is so high that radiation at certain wavelengths is already absorbed almost completely: An increase in the concentrations will therefore only have a limited effect. When evaluating the impact of changes in the concentrations of the various gasses one has to take both this and the lifetime of the different gasses in the atmosphere into consideration. The term global warming potential (GWP) is therefore used, the GWP of a greenhouse gas being defined as "the time-integrated warming effect due to an instantaneous release of 1 kg of the gas in today's atmosphere relative to the warming effect of 1 kg CO_2 measured in W/m^2 with a lifetime of 150 years". The effect of the various greenhouse gasses can thereby be converted to an equivalent amount of CO_2, i.e. to the amount of CO_2 that will yield the same climatic effect. Calculated on a weight basis and over a 100-year period, methane is approximately 21 times as effective as carbon dioxide, and nitrous oxide approximately 310 times as effective

(*Table 2.1.1*). While CFCs can be several thousand times as effective, their impact is attenuated by the fact that depletion of the ozone layer counteracts their greenhouse effect.

The choice of time horizon is of consequence for political intervention to reduce emissions of greenhouse gasses: If the purpose of climate policy is protection against sudden non-linear climate effects in the relatively near future, or if it is the rate at which potential climate changes takes place that is of the greatest interest, then a 20-year time horizon is most relevant, and the significance of reducing emissions of substances such as CH_4 with a short lifetime in the atmosphere is relatively great.

If the emphasis is on safeguarding the world against long-term changes, which are perhaps irreversible, a 100-year or 500-year time horizon will yield a GWP index that is relevant for choosing greenhouse gas reduction strategies. The 100-year GWP index is the one most commonly used in the international climate negotiations and in the international literature because it balances between the two above mentioned considerations. Anthropogenic effects on the Earth's energy balance are summarized in *Figure 2.1.5*.

Climate changes - Scenarios

Evaluation of the consequences of future development in the climate starts with forecasts of emissions and resulting atmospheric concentrations of greenhouse gasses and aerosols. Based on assumptions as to population growth, economic growth, energy efficiency and availability of energy sources,

Compound	Chemical formula	Lifetime (yr)	Global Warming Potential 20 yr	100 yr	500 yr
Carbon dioxide	CO_2	Variable	1	1	1
Methane	CH_4	12+/-3	56	21	6.5
Nitrous oxide	N_2O	120	280	310	170

Table 2.1.1 *Global warming potential (GWP) for carbon dioxide, methane and nitrous oxide (Source: Danish Meteorological Institute, 1996; Intergovernmental Panel on Climate Change (IPCC), 1996a). NB: In contrast to methane etc., the lifetime of carbon dioxide in the atmosphere is variable, CO_2 being transferred to a number of sinks via a number of processes that operate under different time scales. The most rapid process is uptake in the terrestrial vegetation and the surface layer of the oceans, which takes place over a few years. Transfer to the humus pool of the soil and the deeper layers of the oceans takes place considerably slower. As a consequence, the excess CO_2 in the atmosphere relative to the level in the preindustrial era will first be removed over a one to two hundred-year period, and a minor part will remain in the air for thousands of years before finally being transferred to the final sink: The ocean sediments.*

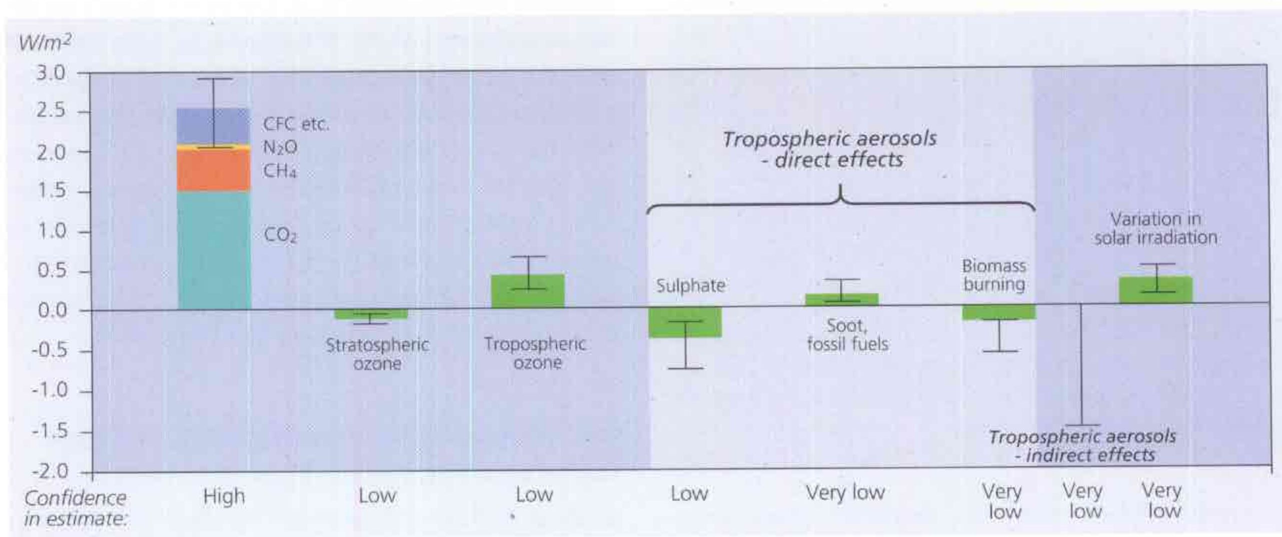


Figure 2.1.5 *Summary of the annual global anthropogenic climate change in W/m² as a result of changes in the greenhouse gas and aerosol concentrations from the beginning of the industrial era until the present (1992), together with the effect of changes in insolation from 1850 until the present. The height of the columns indicates the estimated mean values while the bars represent uncertainty of the mean values (Source: Intergovernmental Panel on Climate Change (IPCC), 1996a).*

the IPCC established six detailed scenarios (denoted IS92a to IS92f) for the future emissions of greenhouse gasses and aerosol-forming substances up to the year 2100 (Intergovernmental Panel on Climate Change (IPCC), 1992). These scenarios also assume that measures are not taken to reduce emissions other than those agreed upon in the Montreal Protocol together with the supplement for CFCs and the OECD reduction targets for CO_2 emissions.

The central scenario - IS92a "business-as-usual" - assumes improvements in the effectiveness of energy exploitation in line with technological development, a moderate economic growth without drastic interventional measures against emissions of greenhouse gasses, and a population growth that follows an intermediate scenario from the UN and World Bank yielding a population of 11,300 million in the year 2100.

It is this scenario that the IPCC uses as the basis for model calculations of the future climate. The change in the global mean temperature and global mean sea level from 1990 to 2100 is shown for selected IS92 scenarios in *Figure 2.1.6*.

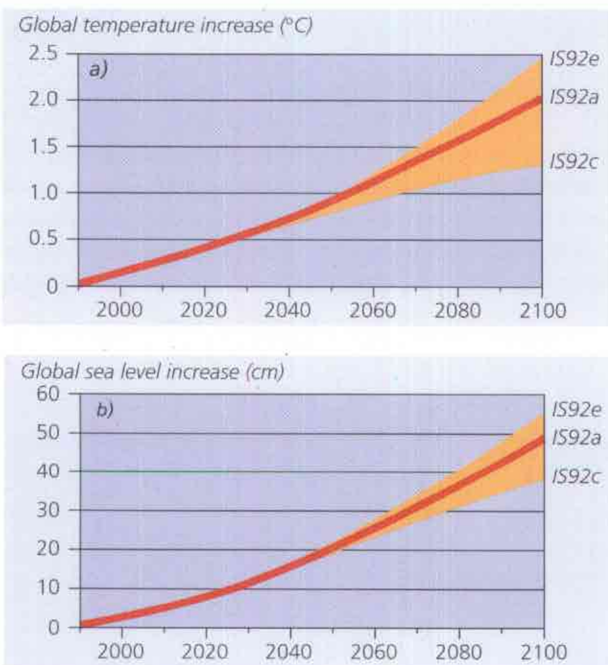


Figure 2.1.6 *Predicted change in* ***a)*** *global mean temperature and* ***b)*** *global mean sea level over the period 1990 to 2100 for selected IS92 scenarios (Source: Intergovernmental Panel on Climate Change (IPCC), 1996a).*

In the IS92a scenario, the temperature increases about 2°C by the year 2100 and the sea level rises about 49 cm. In 1990, in comparison, the best assessment of the rise in global sea level by the year 2100 was about 66 cm according to the IPCC. Even taking into account the negative radiative effect of aerosols, all the scenarios indicate considerable climate warming, probably the greatest that has ever occurred over the last 10,000 years. Despite the fact that carbon dioxide is the most important greenhouse gas, the other greenhouse gasses make a considerable contribution (approx. 30%) to global warming.

The IPCC's IS92 scenarios do not go beyond the year 2100, and the carbon dioxide concentration and hence the climate will not have been stabilized by then. The IPCC has therefore also set up a number of scenarios which show that stabilization of the atmospheric concentration of carbon dioxide at 450, 650 and 1,000 ppmv can be achieved if anthropogenic emissions are reduced to the 1990 level in 40, 110 and 240 years, respectively, and thereafter reduced to considerably below the 1990 level (*Figure 2.1.7*).

As is apparent from the figure, considerable reductions in emissions are required. The "natural" CO_2 level is approx. 280 ppmv and stabilization at twice this level requires that emissions be reduced to the present level by the year 2100, and to a quarter of the present level in the couple of hundred years thereafter. If one can accept a doubling of the present level of 360 ppmv, the reduction requirements will not be so stringent, but will still be considerable.

The stabilization scenarios shown do not indicate how the reductions are to be achieved nor how they are to be shared between the individual countries. The Danish Energy Agency has calculated an example for stabilization at 450 ppmv based on the assumption that all the inhabitants of the world will emit the same amount of CO_2 at the end of the next century. This will require Denmark to reduce annual per capita emissions from approx. 12 tonnes to approx 1.2 tonnes (Danish Energy Agency, 1996). This corresponds to an energy consumption of approx. 100 PJ/year from fossil fuels. In comparison, fossil fuels accounted for 790 PJ of Denmark's total energy consumption of 817 PJ in 1994.

Emissions of greenhouse gasses - international and national sources and trends

Carbon dioxide followed by methane and nitrous oxide are globally the most important greenhouse gasses, and world consumption of fossil fuels is the single most important factor. Thus in 1990, world energy consumption resulted in total CO_2 emissions

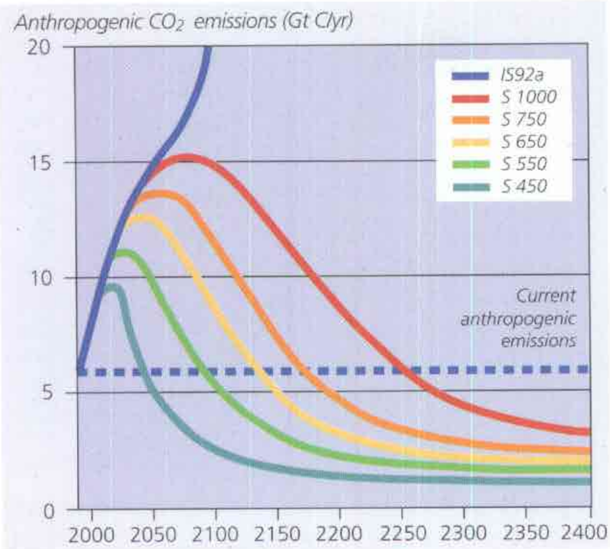


Figure 2.1.7 *IPCC stabilization scenarios. The relationship between requirements as to global anthropogenic CO_2 emissions and stabilization of the atmospheric CO_2 concentration at between 450 and 1,000 ppmv, which corresponds to doubling of the natural CO_2 level (280 ppmv) and the present CO_2 level (360 ppmv). The IPCC business-as-usual scenario (IS92a) is included for comparison (Source: Intergovernmental Panel on Climate Change (IPCC), 1996a).*

of 6,000 million tonnes carbon, of which West European and North American countries accounted for approximately 1/3. Industry, households and energy consumption by the service sector and transport sector accounted for 45%, 29% and 21% of these emissions, respectively. Of all the sectors, the increase in energy consumption over the last two decades was greatest in the transport sector.

In Europe, total emissions from the so-called EU15 countries amounted to 3,100 million tonnes CO_2 in 1994, which represents a 2.7% reduction relative to 1990. The weak fall during this period is considered to be transient as it is chiefly due to temporary fall-off in economic growth in several countries, reconstruction of the industry in the former East Germany, closure of the coal mines in England and increased use of natural gas in power stations. If natural gas is used instead of coal, CO_2 emissions are reduced by approx. 40% per energy unit produced.

Per capita CO_2 emissions from the combustion of fossil fuels in 1990 for the EU15 countries and certain other countries and regions for which comparable figures are available are shown in *Figure 2.1.8*. It is apparent that at 10 tonnes per year, per capita emissions in Denmark are half that in the USA, but approx. 10% greater than the EU15 average of 9 tonnes per year.

Development in Danish CO_2 emissions over the period 1975-95 is shown in *Figure 2.1.9*. It can clearly be seen that Danish trade in electricity affects the national energy consumption and hence CO_2 emissions. In 1990, Denmark was a net importer of electricity (7,056 GWh), and CO_2 emissions were consequently relatively low compared with say 1994, when Denmark was a net exporter of electricity. Preliminary calculations by the Danish Energy Agency for 1996 show an increase in CO_2 emissions of more than 13 million tonnes due to extraordinarily high electricity exports to Norway and Sweden necessitated by the very low precipitation in these two countries where hydroelectric power stations are common. The total or actual CO_2 emissions are a measure of the emissions from the Danish land mass, while the corrected emissions are an expression of the actual developmental trend in domestic energy consumption. It is the figures for corrected emissions that are used in the routine monitoring of Denmark's national reduction targets for CO_2 emissions. In 1994, total Danish greenhouse gas emissions amounted to 70 million tonnes CO_2 equivalents. Of this, the energy sector accounted for 68%, while the transport and agricultural sectors each accounted for approx. 16% (*Figure 2.1.10*). As is apparent from *Figure 2.1.11*, CO_2 is by far the main type of emission, followed by methane and nitrous oxide. The relationship between the different types of emissions in 1994 was the same as in 1988, but there was a minor decrease in emissions of approx. 2% during that period.

Objectives and policy measures

One of the provisions of the 1992 UN Climate Convention is that by the year 2000, the industrialized nations are to stabilize their emissions of carbon dioxide and other greenhouse gasses not covered by the Montreal Protocol at 1990 levels. The EU countries consider this provision legally binding, but the majority of other industrialized nations only consider the provision as a recommendation. The EU Member States agreed on the stabilization of total EU carbon dioxide emissions relative to the 1990 level by the year 2000 as a target.

At the first conference under the UN Climate Convention in March 1995 it was decided that the stabilization goal was inadequate. At the third conference in December 1997 in Kyoto in Japan, a legally binding agreement was reached committing the industrialized nations to reduce their emissions of six greenhouse gasses by 5.2% up to 2008-2012. Emissions of the greenhouse gasses carbon dioxide, methane and nitrous oxide have to be reduced by 5.2%

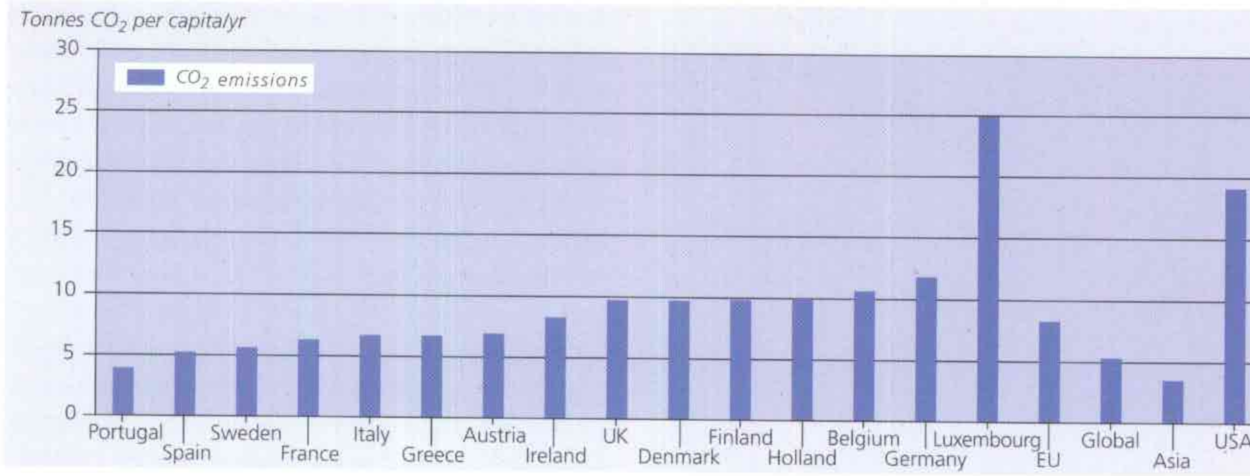


Figure 2.1.8 Per capita emissions of CO_2 from the combustion of fossil fuels in the EU15 countries in 1990 as compared with the corresponding figures for the world, the USA and Asia (Source: European Topic Centre on Air Quality and European Topic Centre on Air Emissions, 1997). NB: The data presented are the total emissions of CO_2, and have not been corrected for national electricity imports/exports or climate variations, i.e. correction of the energy consumption for temperature fluctuations relative to a normal year. If these factors are corrected for, Danish per capita emissions in 1990 were just under 12 tonnes as electricity imports were relatively high and 1990 was a very warm year. It is the corrected emissions that are used in the routine monitoring of Denmark's national reduction targets for CO_2 emissions.

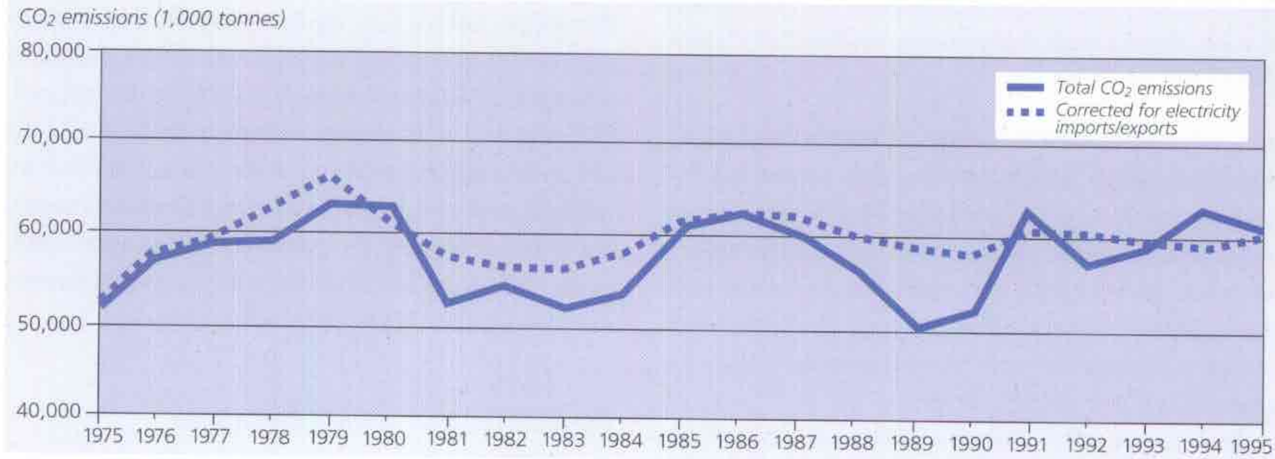


Figure 2.1.9 Danish carbon dioxide emissions for the period 1975-95. The broken line represents CO_2 emissions corrected for Danish electricity imports/exports. The unbroken line represents total CO_2 emissions (Source: National Environmental Research Institute and Risø National Laboratory, data from the CORINAIR database).

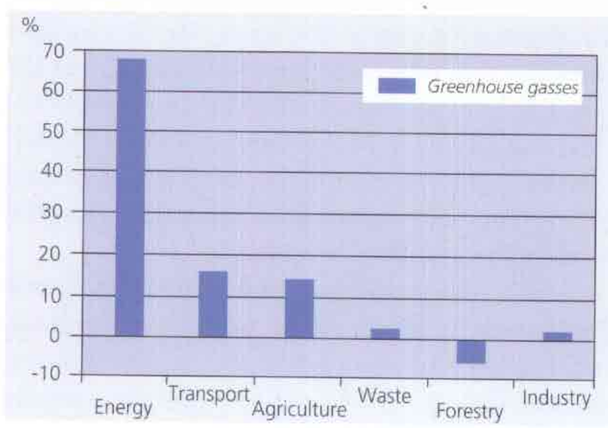


Figure 2.1.10 Sector profile. Greenhouse gas emissions in 1994 apportioned by sector in percent of total emissions (70 million tonnes CO_2 equivalents). Transport only encompasses domestic transport and industry only encompasses industrial processes (Source: Fenhann et al., 1997).

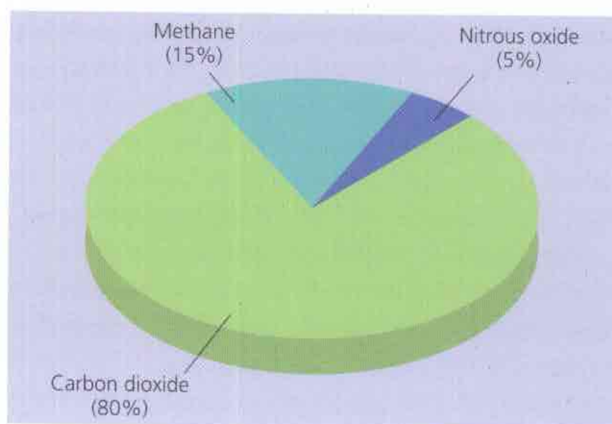


Figure 2.1.11 Danish greenhouse gas emissions in 1994 apportioned by type in percent of total emissions (70 million tonnes CO_2 equivalents) (Source: Fenhann et al., 1997).

relative to the level in 1990. Emissions of the other three gasses, the so-called industrial gasses HFC, SF_6 and PFC, also have to be reduced by 5.2%, but nations can freely choose between 1990 and 1995 as the reference year.

A few nations are permitted to increase their emissions. Thus Iceland may increase its emissions by 10%, Australia by 8% and Norway by 1%. Nations such as Ukraine and Russia just have to stabilize their greenhouse gas emissions relative to 1990. Emissions from both these countries have decreased considerably since 1990 due to economic recession.

As it is not expected that Russia and Ukraine will reach their 1990 levels in 2008-2012, this opens up the possibility for them to sell their "CO_2 deficit" in a few years' time when, as is expected, international trade in CO_2 quotas becomes permissible. Rules for trade in quotas, for "CO_2 sinks" and rules for transboundary joint projects (joint implementation) are to be discussed at the next conference in November 1998. An example of a "sink" is CO_2 uptake by forests, which has to be included in the overall balance.

The majority of East European countries have to reduce their emissions by between 6% and 8%. Japan and Canada have to reduce their emissions by 6%, USA by 7% and the EU as a whole by 8%. Prior to the Kyoto Conference, the EU Member States proposed a combined 15% reduction in CO_2, methane and nitrous oxide emissions by the industrialized nations, and had agreed on the internal allocation of the first 10% of that reduction. This allocation among the EU Member States allowed some countries to increase their emissions during the period, while others had to reduce emissions. Germany and Denmark, for example, had to reduce their emissions by 25%. At the forthcoming EU Council Meetings this internal allocation is expected to be adjusted as the Kyoto Protocol only requires emissions to be reduced by 8%.

The Kyoto Protocol has to be ratified by the national parliaments. When the 55 signatories who together account for 55% of 1990 CO_2 emissions from the industrialized nations have ratified the Protocol, it will enter into force. The next meeting under the Climate Convention takes place in Buenos Aires in Argentina in November 1998.

In addition to the international agreements, Denmark has a national goal of reducing CO_2 emissions from the energy and transport sectors by a total of 20% before the year 2005 relative to 1988 levels. This and other goals and the proposed measures are described in the Government's energy action plan from April 1996 "Energi 21": By the year 2005, CO_2 emissions from the transport sector have to be stabilized, and the percentage of total energy consumption accounted for by renewable energy sources has to increase to 12-14%. The action plans in the energy and transport areas are discussed in greater detail in *Sections 3.2* and *3.3*.

2.1.3 **Depletion of the ozone layer**

Introduction

The so-called ozone layer is located in the stratosphere, the concentration being maximum at an altitude of approx. 20 kilometres (*Figure 2.1.1*). The stratosphere contains approx. 90% of all atmospheric ozone. Prior to the beginning of the 1970s, no-one had thought of the possibility that man's activities could threaten the ozone layer. It had long been known that ozone absorbs the harmful ultraviolet radiation from the sun (UV-B radiation), and that the ozone layer could periodically thin out. However, this was considered a phenomenon involving natural regeneration of ozone and where the concentration remained constant in the long term. Since the end of the 1970s, though, several incidents of extreme thinning of the ozone layer have been observed over the Antarctic - the so-called ozone hole. Thus in recent years, thinning of the ozone layer by 50% or more has been recorded. In the northern hemisphere, moreover, the ozone layer has been depleted 5% since 1980. As in the southern hemisphere, the decrease is greatest in the winter and early spring, which are also the periods when there is least UV radiation from the sun. Since 1978, the thickness of the ozone layer has been measured over Denmark via satellite measurements. As is apparent from *Figure 2.1.12*, the ozone layer has been depleted by 10% over the period 1979-96.

Causes of ozone layer depletion

The main cause of ozone layer depletion is anthropogenic emissions of chlorinated and brominated compounds (CFCs and halons). In the stratosphere, these compounds are cleaved by UV radiation with the resultant release of free chlorine and bromine which break down ozone molecules through a chain reaction.

An atmospheric chlorine concentration of 2 ppbv, which was the former level, is regarded as a critical threshold and the long-term goal to be attained

Figure 2.1.12 *Thickness of the ozone layer over Denmark. Index 1979 = 100 (Source: Danish Meteorological Institute, in Statistics Denmark, 1997). NB: The thickness of the ozone layer is measured in Dobson units, which indicate how many hundredths of a millimetre thick the ozone layer would be if it was present at the surface of the Earth at a pressure of 1 atmosphere. The annual mean thickness of the ozone layer over Denmark was 356 Dobson units in 1979 and 320 units in 1996.*

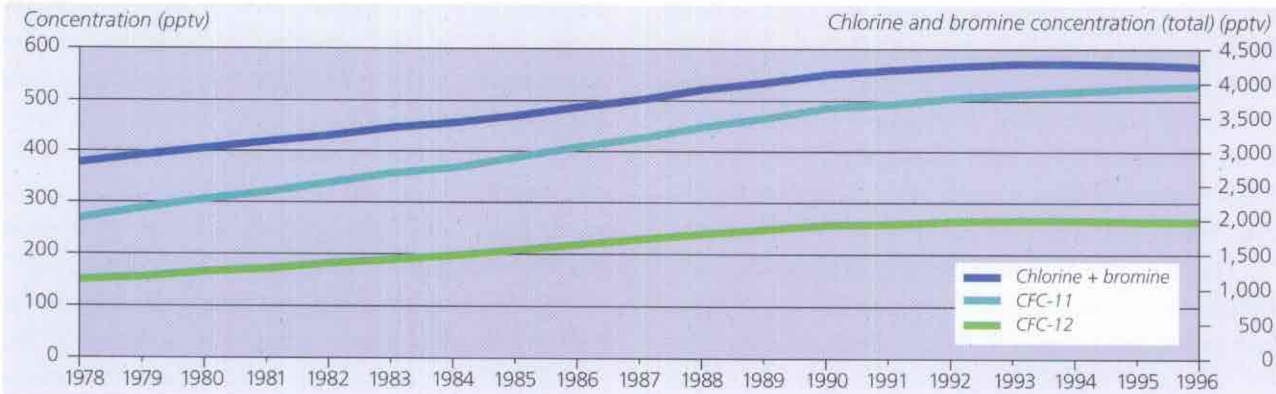


Figure 2.1.13 *Development in the atmospheric concentration of CFC-11, CFC-12 and chlorine/bromine over the period 1978-96 (Source: Elkins, 1997).*

through the international agreements on emission reductions. The atmospheric concentrations of CFC-11 and CFC-12 have been increasing since measurements started in 1977. The rate of increase has declined since 1989, however, as an expected effect of the international agreements (the Montreal Protocol), and CFC-11 even seems to have peaked (*Figure 2.1.13*). It has been calculated, though, that depletion of the ozone layer will continue during the remainder of this century, gradually to be restored sometime in the middle of the next century.

Effect of increased UV radiation

The total amount of ozone through which the sunlight passes determines how much UV radiation reaches the surface of the Earth. In the absence of cloud, a 1% reduction in ozone will enable the passage of 1.3% more UV-B radiation (the most harmful form). In man, short-term exposure can cause sunburn and snow blindness. Long-term exposure can lead to aging of the skin, skin cancer (*Figure 2.1.14*), cataracts and suppression of the immune

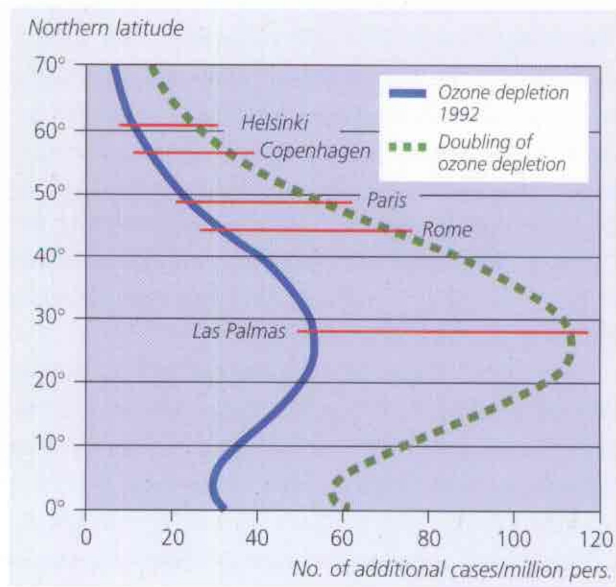


Figure 2.1.14 *Calculated risk for enhanced incidence of skin cancer in Europe. The risk of skin cancer as a result of depletion of the ozone layer depends on the latitude. The unbroken curve indicates the number of cases of skin cancer per million persons corresponding to the situation in 1992. The broken curve indicates the number of cases that would be expected if depletion of the ozone layer doubled relative to 1992 (Source: Wahlström et al., 1996).*

defence. Enhanced UV radiation can also affect other life forms such as agricultural crops and marine plankton. As primary production by marine plankton comprises a major sink for carbon dioxide, any change in UV radiation will affect the carbon dioxide content of the atmosphere and hence the global climate.

Consumption and emissions

Of necessity for their industrial use in foamed plastic, refrigerators, fire extinguishers, etc., ozone layer depleting substances are typically chemically stable and hence have a long lifetime in the atmosphere.

In the case of CFC-11, the lifetime is approx. 60 years. As a result, considerable time can pass before a reduction in emissions results in a reduction in concentrations. In addition, there can also be a long latency period between cessation of industrial use and a reduction in emissions as this depends on the industrial products' residence time or lifetime in society, an example being the use and eventual disposal of refrigerators containing phased-out CFCs.

Global emissions of the two most used CFCs, CFC-11 and CFC-12, thus grew from an insignificant level immediately following the Second World War to more than 700,000 tonnes at the beginning of the 1970s. Even though emissions have now fallen as a result of the international agreements, the concentration in the atmosphere has increased, apparently to have stabilized in recent years (*Figure 2.1.13*).

The atmospheric lifetime of the various ozone layer depleting substances differs, and they are not equally harmful per unit weight. To enable the substances to be compared, their effect is converted to ODP units (ozone depletion potential), a measure of their long-term effects on the ozone layer relative to CFC-11, which has been allotted an ODP of 1. The effects on the ozone layer of the consumption of these various substances can therefore be expressed in terms of tonnes CFC-11. The various ozone layer depleting substances and their uses are summarized in *Figure 2.1.15*.

Objectives and policy measures

The work on drawing up an international framework convention on protection of the ozone layer started in 1980, and resulted in the so-called Vienna Convention, which was signed in 1985.

In 1987, the so-called Montreal Protocol was signed. This commits signatories to halve consumption of the five most important CFCs by 1998 relative to 1986 levels, as well as to stabilize consumption of three halons by 1992. Developing nations could wait 10 years to comply with the agreements, however.

At subsequent meetings in London (1990), Copenhagen (1992) and Montreal (1997), regulation has been tightened to also include the phase-out of all known important ozone layer depleting substances in both the industrialized nations and the developing nations.

In the case of the industrialized nations, the consumption of halon had to cease in 1994 and that of CFC, trichloroethane and tetrachloromethane in 1996. Methyl bromide is to be phased out in 2005 and HCFC in 2030.

The Danish Government has decided upon a more rapid phase-out of the various uses of all the substances over the period 1992-2002. Thus the use of CFC and tetrachloromethane has been prohibited since 1 January 1995, while the use of methyl bromide and HCFC is to cease by 1 January 1998 and 2002, respectively.

As is apparent from *Figure 2.1.16*, total Danish consumption of ozone layer depleting substances has fallen markedly and reached 110 tonnes in 1996. This corresponds to a 98% decrease relative to 1986. By far the majority of total consumption in 1995 was accounted for by the CFC substitute HCFC.

The calculated effect of the international agreements on the atmospheric concentration of chlorine (*Figure 2.1.17*) first becomes apparent after a considerable delay, and the concentration will not fall below the critical threshold until the middle of the next century. Because of the increasing consumption of CFC substitutes such as HCFCs one can, as would

Ozone-depleting substances	Halons	CFC	Trichloroethane and tetrachloromethane	HCFC	Methyl bromide
Use	Fire extinguishers	Foamed plastics, refrigerants	Degreasing agents and solvents	CFC substitute	Pesticides

Figure 2.1.15 *Summary of ozone depleting substances and their uses (Source: Danish EPA).*

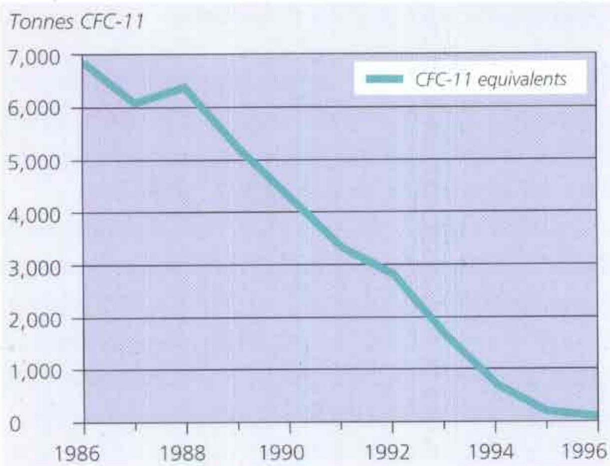


Figure 2.1.16 *Development in Danish consumption of ozone layer depleting substances expressed in tonnes CFC-11 equivalents over the period 1986-96 (Source: Danish EPA).*

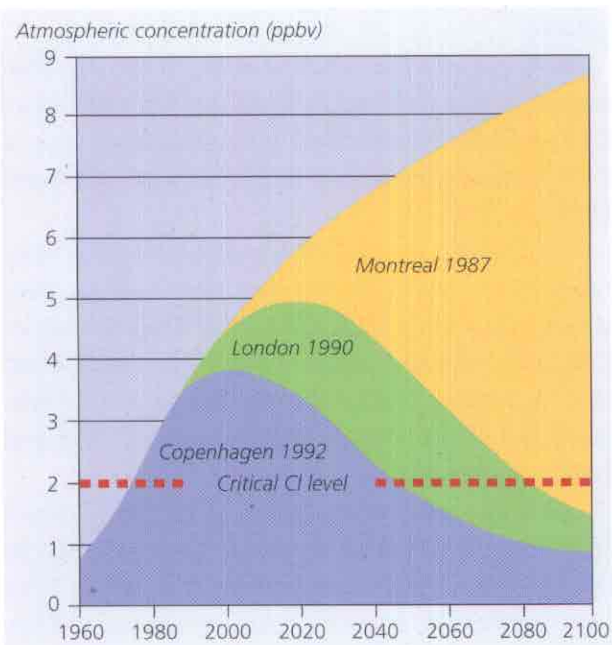


Figure 2.1.17 *Atmospheric concentration of chlorinated compounds (expressed in terms of chlorine equivalents) measured up to the present time and calculated for the future assuming implementation of the international agreements on the phase-out of CFCs and other ozone layer depleting substances (Source: World Meteorological Organization, 1995).*

be expected, detect increased atmospheric concentrations of these substances.

They typically have a short lifetime in the troposphere, which reduces their impact on the ozone layer relative to CFCs and halons, but some of them are potent greenhouse gasses. This applies to for example the HCFCs, which are regulated in accordance with international agreements, as well as to the greenhouse gas HFC-134a, Danish consumption of which increased from 20 to 565 tonnes over the period 1992-95.

2.1.4 Photochemical air pollution

Introduction

Many air pollutants contribute to more than one pollutional problem, as discussed in the introduction to *Section 2.1*. Thus nitrogen oxides contribute to the formation of ozone, which is a greenhouse gas, and together with ammonia from agriculture, contribute to the overfertilization (eutrophication) of many of our nutrient-poor ecosystems and the aquatic environment *(cf. Section 2.4)*.

While ozone in the stratosphere comprises a necessary shield against excessive UV radiation, at low altitudes it is an air pollutant with a number of harmful effects. Ozone is the main component of the so-called photochemical air pollution, which was first observed in California in the mid 1940s, but which now also occurs in all other industrialized nations.

Ozone is a secondary air pollutant that is spread across national borders in Europe. Under the influence of ultraviolet sunlight the nitrogen oxides react with a number of volatile organic compounds (VOC) to form ozone (O_3), which is a potent oxidant. In pure air, ozone has a lifetime of several weeks and can therefore mix into the air and spread over virtually the whole of the northern hemisphere before it is chemically degraded or physically removed.

In a European context, nitrogen oxide emissions are responsible for much of the ozone formation in thinly populated areas of the countryside. In the more densely populated areas, especially close to the towns, ozone formation is enhanced by VOC emissions. In man, ozone can harm or affect respiratory function. Ozone can also damage vegetation. Threshold levels and recommended limit levels stipulated by the EU and the World Health Organization with a view to protecting human health, vegetation and ecosystems are periodically reached or exceeded in the majority of European countries.

Ozone - dispersal and occurrence

Episodes of enhanced ozone levels occur every summer in most of Europe. The episodes typically arise under high-pressure weather conditions, when there is little vertical mixing, weak winds and much sun. During these periods, which can last several days in a row, the ozone concentration can increase to several times the background level. The episodic high concentrations can overlie or add to the background concentration, which has increased by a factor of 2-3 since the beginning of this century.

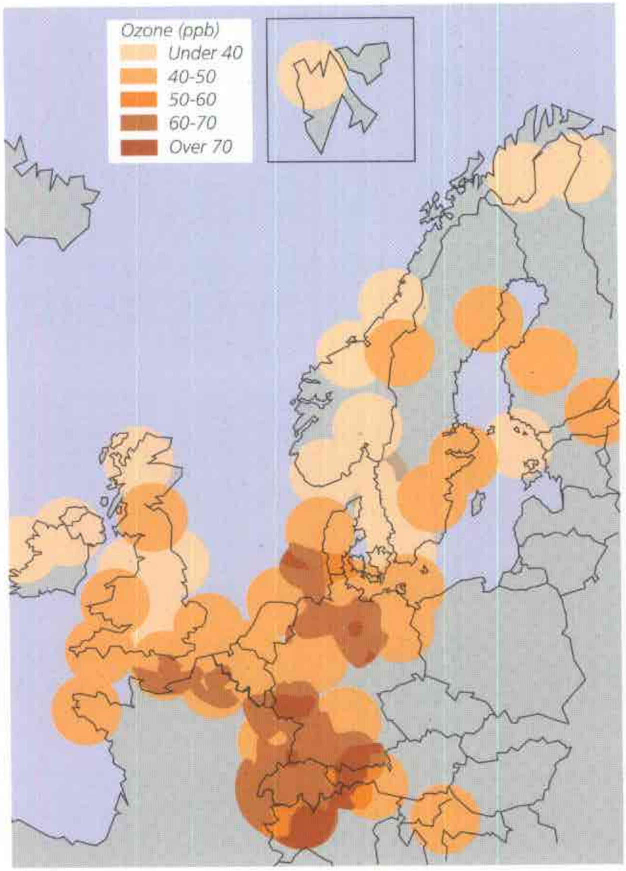


Figure 2.1.18 Average daily maximum ozone concentrations typically registered in the afternoon. Ozone is measured as mean hourly values expressed in ppb for the summer season April-September 1989 (Source: Beck and Grennfelt, 1994).

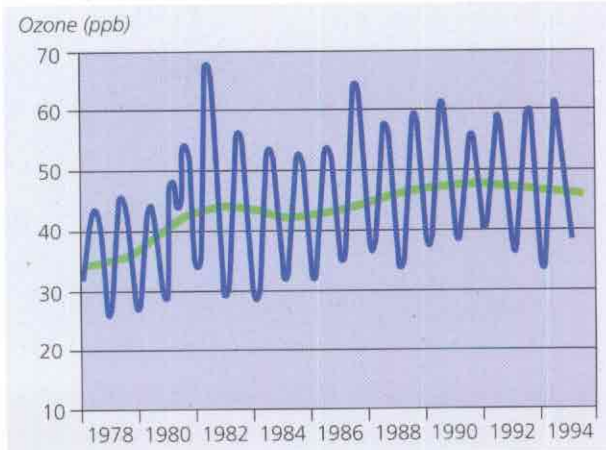


Figure 2.1.19 Monthly mean ozone concentration measured in ppb at Zugspitze (2,962 m a.s.l.) in southern Germany. The ozone level is seen to stabilize after the mid 1980s (Source: Sladkovic et al., 1994).

The distribution of enhanced ozone concentrations at the European level is illustrated in *Figure 2.1.18*. The concentrations generally increase from the northwest towards the southeast, with levels of 30-40 ppb in Norway, Sweden, Ireland and Scotland, 40-50 ppb on the west coast of the Continent and 50-70 ppb in Central Europe. The tendency towards an increasing background concentration during the present century up to the mid 1980s has been recorded among other places at a monitoring station in southern Germany *(Figure 2.1.19)*. Thereafter the background level seems to have stabilized.

Various countries report a slight increase or decrease, and the general picture for Europe as a whole seems to be that the ozone level has stabilized in recent years, but that there is no significant trend towards a decrease. The longest time series available for Denmark only reaches back about 10 years, and does not reveal any clear trend.

This development is in accordance with the fact that European emissions of nitrogen oxides and VOCs have increased markedly since the last century, stabilizing in the 1980s and thereafter decreasing slightly during the period 1990-94 (*Figure 2.1.20*).

Formation and development of the background ozone concentration is mainly a NO_x-driven process and a regional problem at the European level. The conditions that determine ozone levels in the towns deviate from this pattern. Here the dominant chemical reaction in the atmosphere is the oxidation of the local nitrogen monoxide (NO) emissions from vehicle exhausts to nitrogen dioxide (NO_2) via a reaction with externally derived ozone. The result is that the ozone concentration at low altitudes is generally lower in the towns than in their surroundings. Another paradoxical result is that a reduced emission of nitrogen oxides from vehicles can lead to an enhanced ozone concentration in the towns, whereas reduced emission of hydrocarbons always leads to reduced ozone levels *(cf. Section 2.2,* The urban environment).

VOC and NO_x emissions

The reactive hydrocarbons, the VOCs, or more specifically the NMVOCs (Non-Methane Volatile Organic Compounds), are primarily emitted from vehicles and other means of transport and in connection with the use of organic solvents (industry, households). Natural (biogenic) sources are also considerable, however, in particular emissions of terpenes and other volatile organic compounds from conifer forests. Combustion of fossil fuels is the main source of nitrogen oxide emissions, with the transport and energy sectors being the most important individual sources.

Development in NMVOC emissions in the so-called EU15 countries exhibited an increasing trend right up to the end of the 1980s, whereafter it de-

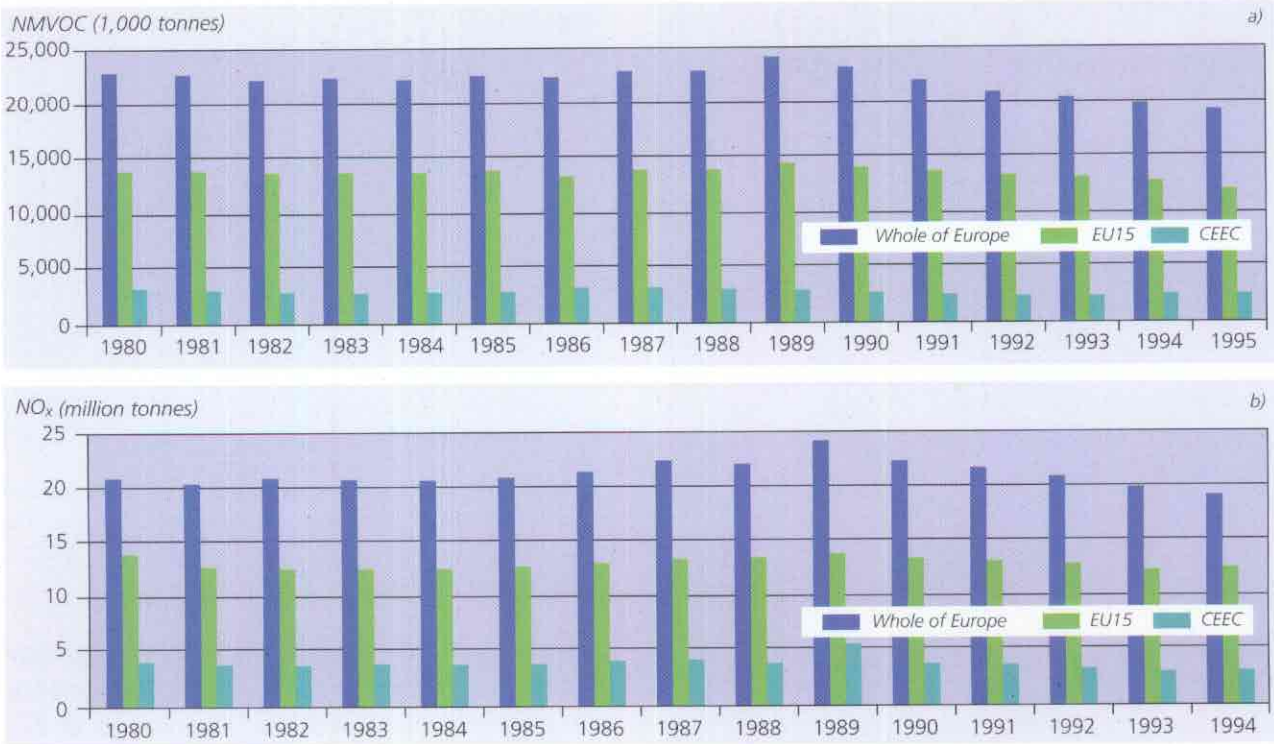


***Figure 2.1.20** Development in emissions of a) hydrocarbons (NMVOC) and b) nitrogen oxides in Europe over the period 1980-95. "Whole of Europe" encompasses the so-called EMEP countries (members of the UN-ECE Convention), "EU15" encompasses the Member States of the European Union, and "CEEC" encompasses the Central and East European Countries (Source: European Topic Centre on Air Quality and European Topic Centre on Air Emissions, 1997).*

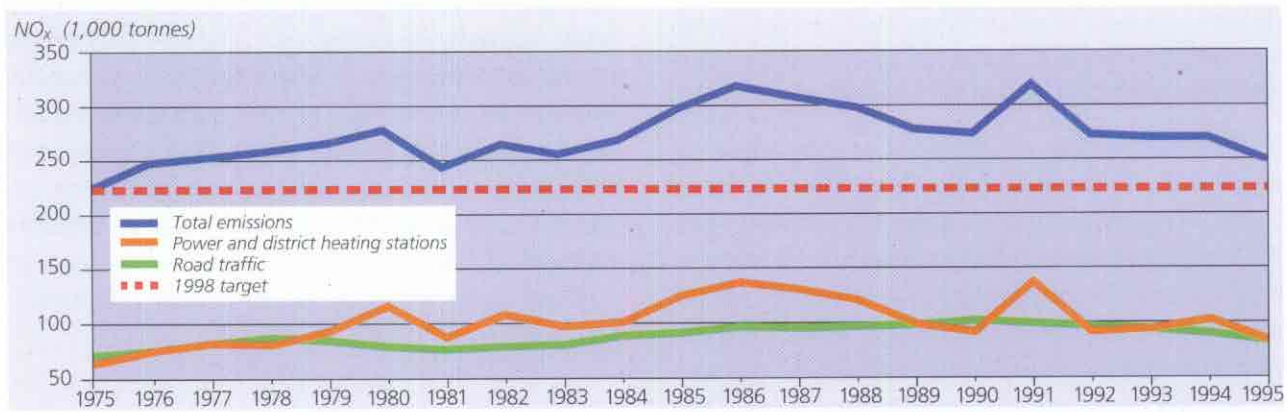


***Figure 2.1.21** Development in Danish NO_X emissions apportioned by the main sources over the period 1975-95. The emission target for 1998 is included for comparison (Source: National Environmental Research Institute and Risø National Laboratory, data from the CORINAIR database).*

creased approx. 9% between 1990 and 1994 (*Figure 2.1.20a*). The same developmental trend is seen with NO_x emissions (*Figure 2.1.20b*), which exhibit a 14% decrease for Europe as a whole (the so-called EMEP countries), but a smaller, 8% decrease for the EU15 countries. The relatively great decrease seen in the Central and East European countries is attributable to the effects of economic fall-off and the reconstruction of these countries. The development in NO_x emissions in Denmark is shown in *Figure 2.1.21*.

Since the beginning of the 1980s emissions have been rather constant, with a tendency towards a decrease in the first half of the 1990s. Emissions from power stations have fallen slightly over the last 10 years, however, while emissions from traffic increased during the 1980s. NO_x emissions from international transport, especially international ship transport are not included in the total emissions shown in *Figure 2.1.21*. Emissions from this part of the traffic, which are determined from the domestic sale of fuel for this activity, are increasing markedly, and together with other mobile sources and the national road traffic account for 70% of total emissions (*Figure 2.1.22*).

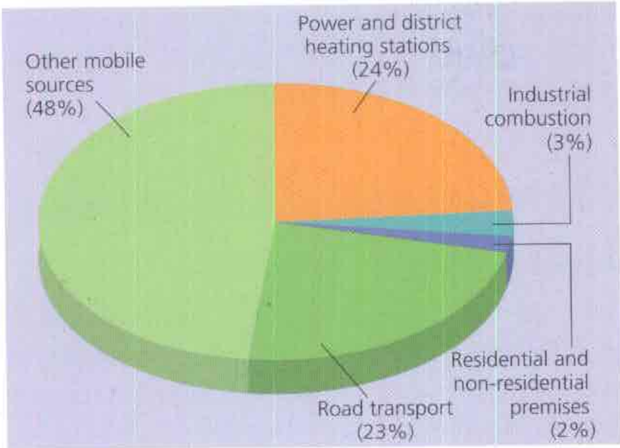


Figure 2.1.22 Relative source apportionment of Danish NO_x emissions in 1995. The category "Other mobile sources" encompasses emissions from the railways, national and international air and sea traffic, and off-road emissions from agriculture, forestry, industry, gardens and households (Source: National Environmental Research Institute, data from the CORINAIR database).

Danish emissions of hydrocarbons (NMVOC) exhibit the same developmental trend as for Europe as a whole, although with a more clear trend towards a decrease after 1985. Thus emissions fell from approx. 200,000 tonnes in 1985 to approx. 175,000 tonnes in 1990 and 156,000 tonnes in 1994, corresponding to a 20% reduction relative to 1985. By far the most important individual source is road transport followed by emissions resulting from the use of organic solvents.

Harmful effects of ozone and other oxidants

Damage to vegetation

Ozone-induced damage to vegetation was observed as early as during the first photochemical pollution episodes in California in the 1940s, in particular in the vineyards. Effects on vegetation have now been observed in many parts of Europe, including Denmark.

In 1995, extensive exceedence of the EU threshold level of 65 µg/m^3 (daily mean) for the protection of vegetation against ozone damage was recorded in Member States, in some cases by up to a factor 3. This picture has been confirmed through model calculations of the exceedence of the critical ozone concentration for agricultural crops and forests, AOT40.

The critical concentration is 40 ppb, and the exceedence measure AOT (Average Above Threshold) indicates the accumulated sum of hours during the growth season when this critical concentration is exceeded. The units are ppb-hours. An example of the exceedence of AOT40 for conifer forests in the Nordic countries is shown in *Figure 2.1.23.*

Calculations show that for Europe as a whole in 1994, AOT40 for crops was exceeded in an area of 4 million km^2, corresponding to 83% of the total cultivated area of Europe. A large number of Danish crops have proven to be sensitive to ozone, among others, beans, clover, potatoes, spinach, tomatoes and wheat. In contrast, barley has proven to be more resistant. A rough estimate based on foreign studies (among others, Swedish studies) indicates that Danish losses in agricultural yield amount to about DKK 1,000 million per year.

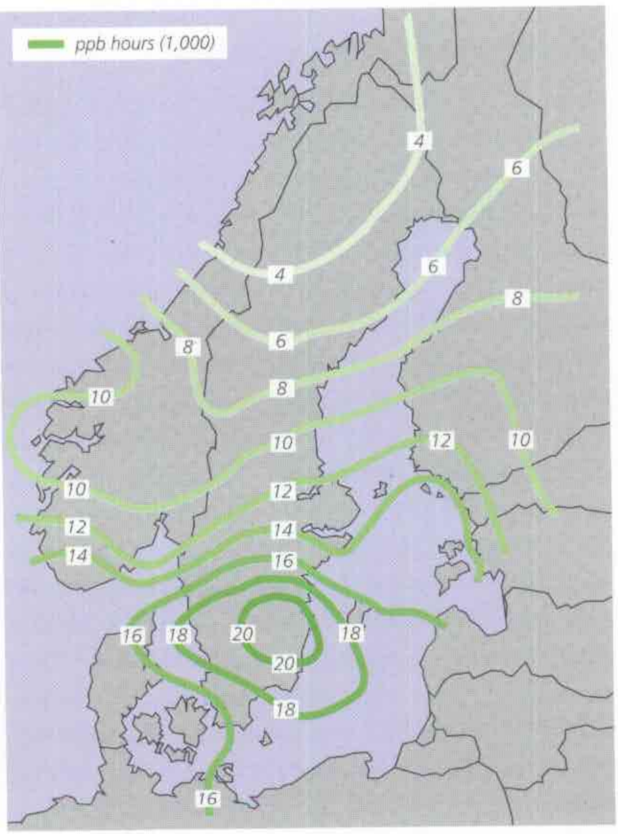


Figure 2.1.23 AOT40 exceedence for common spruce forests in the Nordic countries in 1992 expressed as ppb-hours (1,000). The exceedence is calculated for 24 hours daily exposure during the growth season (April-September), and a critical limit is reached at 10,000 ppb-hours (Source: Strandberg and Mortensen, 1996).

Effects on man

In man, ozone is a respiratory tract and eye irritant. According to the World Health Organization, health effects are not seen at hourly mean concentrations of less than 50 ppb. In Denmark, the street level in towns seldom exceeds this level, and ozone therefore does not pose any great health problem *per se.* Nevertheless, ozone is of significance in that it determines the conversion of nitrogen monoxide to nitrogen dioxide, which has somewhat the same respiratory effects as ozone. In 1994, though, the ozone concentration at several Danish monitoring stations exceeded the EU hourly mean threshold level of 180 $\mu g/m^3$ - a limit whose exceedence is required to be notified to the public as a warning. Based on 1995 measurements it has been calculated that for Europe as a whole, 78% of the urban population of 58 million is exposed to ozone concentrations at least once yearly that exceed the EU threshold for health effects of 110 $\mu g/m^3$ (8-hour mean). According to the European Environment Agency, such exceedence occurs in all Member States.

Objectives and policy measures

Ozone is a secondary air pollutant that is not emitted directly from a source, but is instead formed in the atmosphere from primary air pollutants - first and foremost nitrogen oxides and hydrocarbons. Thus photochemical air pollution can only be combatted by reducing emissions of these substances. At the international level, a number of agreements have been reached under the UN Economic Commission for Europe (UN-ECE) regulating nitrogen oxides and hydrocarbons in order to reduce transboundary air pollution. These agreements (Protocols) are examined more closely in *Section 2.1.5*. Denmark is already in compliance with the goal stipulated in the so-called NO_x Protocol of reducing emissions to the 1987 level by 1994 at the latest. Together with 12 other countries, including the Nordic countries, Denmark has further committed itself to reduce emissions by 30% over the period 1986-98. The EU countries have also to reduce emissions by 30% relative to the 1990 level before the year 2000. For the EU as a whole, emissions have so far (1994) been reduced by approx. 5% relative to 1990 and 13% relative to 1987. It is rather uncertain whether the targets will be attained, however, especially given the expected growth in road traffic and the fact that the more stringent EU vehicle NO_x emission standards are not expected to have an impact until after the year 2000.

Emissions of hydrocarbons (VOCs) are also regulated under the UN-ECE in accordance with a VOC Protocol. According to this Protocol, emissions from all national sources have to be reduced 30% by the year 2000 relative either to 1985 or to a baseline year between 1984 and 1989 freely selected by the country in question. Danish hydrocarbon (NMVOC) emissions have been reduced by approx. 20% between 1985 and 1994, while European (EU15) emissions have been reduced by 9%.

2.1.5 Acidification and eutrophication

Introduction

When air pollutants spread across national boundaries to a wider geographic area, they become part of the so-called transboundary air pollution. The regional effects of this pollution can be roughly divided into direct effects arising as a result of direct contact with the airborne substances at a given concentration in the air, and indirect effects which first develop after the substances have been deposited on land or waterbodies. Examples of direct effects are damage to trees or crops that have absorbed high concentrations of gaseous air pollutants through their leaf stoma. The main indirect effects are acidification or eutrophication effects caused by atmospheric deposition of sulphur and nitrogen.

Atmospheric deposition of sulphur and nitrogen compounds mainly derives from emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3). Deposition of these substances or chemically transformed compounds of them (sulphate, nitrate and ammonium compounds) can acidify the soil as well as lakes and watercourses, and thereby indirectly affect many chalk-poor and nutrient-poor natural ecosystems, as well as forest productivity and the biological state of forests. Together with ammonia, nitrogen oxides also contribute to overfertilization (eutrophication) of many natural ecosystems, and to eutrophication of the marine environment.

The effect of acidification depends on a combination of two factors: The amount of acid deposition and the natural capacity of the terrestrial or aquatic ecosystem in question to counteract the acidification (i.e. the ecosystem's buffering capacity). In areas where the soil minerals easily weather or has a high chalk content, acid deposition will be relatively easily neutralized. Thus the lakes in southern Scandinavia where the effects of acidification were first observed were located in areas where both deposition and vulnerability were high.

In the 1960s, a relationship was observed between European emissions of sulphur and acidification-induced fish mortality in Swedish lakes. As early as 1968, Sweden stipulated its (and the world's) first target level for sulphur: The sulphur content of oil was not allowed to exceed 2.5%. Since then, international agreements and conventions have considerably reduced sulphur emissions to the atmosphere. In the European context the problem is not yet solved, although it has been reduced in extent and impact.

The importance of deposition of nitrogen compounds has increased relatively, and in Denmark, ammonia emissions from agriculture are presently the major cause of both acidification and eutrophication.

Emissions and levels of pollution

European sulphur emissions have been increasing steadily since the end of the previous century, except for a fall during the Second World War. Since 1975, though, emissions have been decreasing markedly (*Figure 2.1.24*). Thus sulphur emissions from the EU15 countries decreased 50% between 1980 and 1994. European emissions of nitrogen oxides increased right up until the end of the 1980s, but decreased slightly over the period 1990-94 (8% for EU15, cf. *Figure 2.1.20b*). In the case of ammonia emissions, calculations for Europe are only available from 1990 onwards. Emissions from the EU15 countries decreased slightly from 3.5 million tonnes in 1990 to 3.2 million tonnes in 1994.

Danish emissions of sulphur dioxide are shown in *Figure 2.1.25*. The trend in Denmark largely corresponds to that in Europe as a whole, emissions peaking at 463,000 tonnes in 1977, thereafter decreasing to approx. 150,000 tonnes in 1995 - a fall of 67% during that period. The reduction is mainly due to more stringent legislation on the use of fossil fuels, enhanced flue gas abatement measures at the power stations, and a general increase in energy efficiency. In 1995, national emissions of sulphur dioxide from the transport sector (road traffic and other mobile

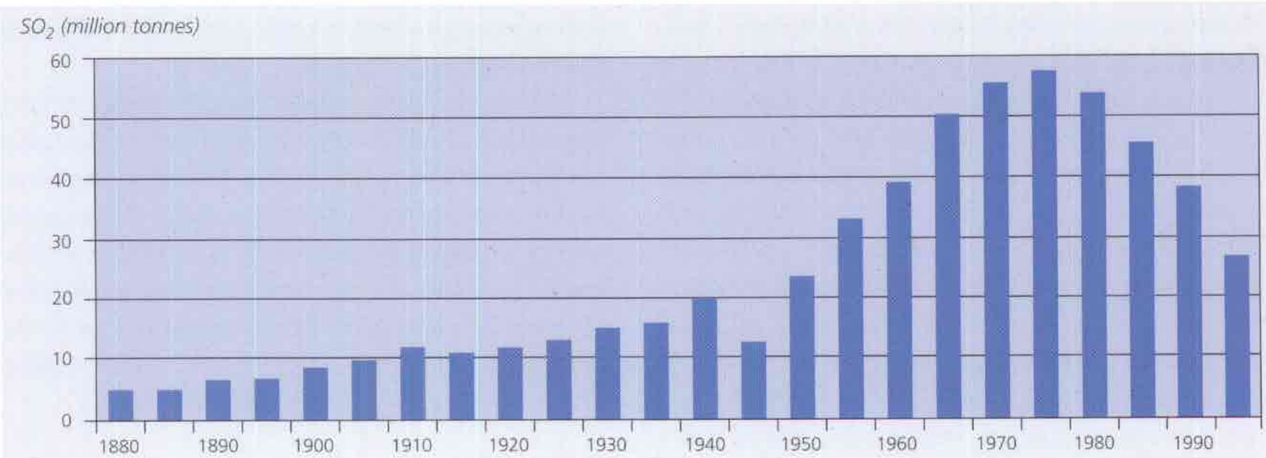


Figure 2.1.24 *Historic development in European emissions of sulphur dioxide from the end of the previous century to the present time. The time series encompasses the whole of Europe, i.e. the so-called ECE/EMEP countries, including the Central and East European countries (Source: European Topic Centre on Air Quality and European Topic Centre on Air Emissions, 1997).*

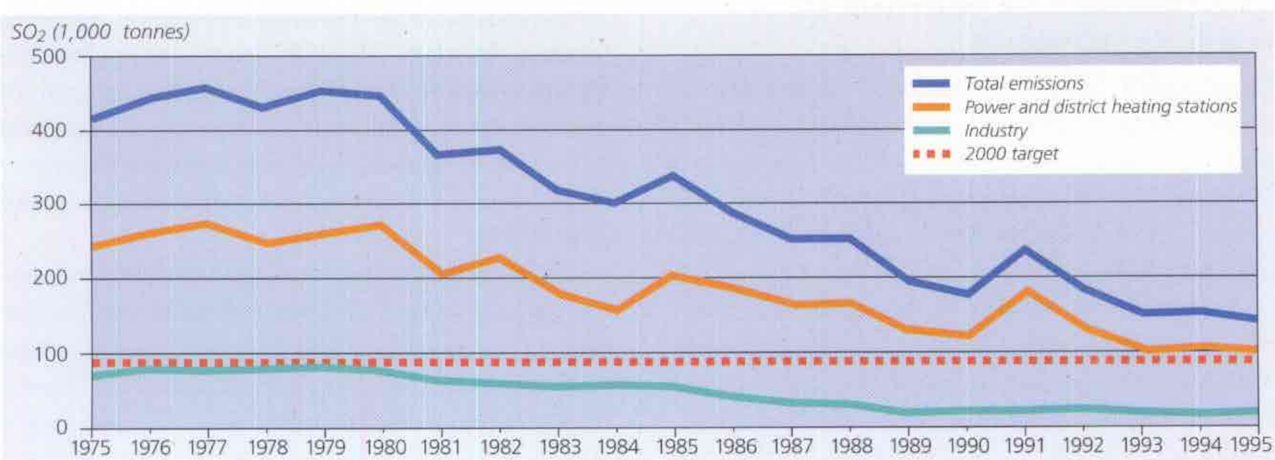


Figure 2.1.25 *Total and selected sectoral emissions of sulphur dioxide in Denmark over the period 1975-95. "Total emissions" excludes emissions associated with international transport. "Industry" only encompasses the category "process energy" (Source: National Environmental Research Institute and Risø National Laboratory, data from the CORINAIR database).*

sources) accounted for only approx. 6% of total emissions. However, if account is taken of emissions connected with Danish sales of fuels for international air and sea transport, the figure increases to 39%.

A large part of the sulphur that is deposited in Denmark derives from England and countries to our south. The sulphur that Denmark emits is transported away by the wind and mainly deposited in Sweden, Poland and Russia. Only 13% of Danish emissions (1996) is deposited in Denmark.

Danish NO_x emissions peaked at 319,000 tonnes in 1991, and have since been decreasing, reaching approx. 253,000 tonnes in 1995, which is 21% lower than in 1991 (cf. *Figure 2.1.21* and *Section 2.1.3*). It should be noted, though, that emissions of nitrogen oxides were extraordinarily high in 1991 due to a high net export of electricity and hence a higher level of electricity production and associated emissions.

With respect to nitrogen oxides, the same applies as for sulphur, namely that only a small part of Danish emissions are deposited within Denmark's borders (10% of total emissions in 1996). While there is some uncertainty associated with determination of total Danish emissions of ammonia, this is calculated to be 128,000 tonnes in 1995, which corresponds to the level in recent years. Ammonia nitrogen and ammonium nitrogen are only transported over short distances, and approx. 80% of the total deposition derives from sources in Denmark. Of the nitrogen that deposits on Danish territory, 2/3 derives from ammonia emissions. Of this, the majority derives from Danish agriculture, while the remainder derives from abroad via long-range transboundary transport.

Development in the deposition of acidifying substances

Development in the deposition of sulphur and nitrogen compounds in Europe is closely correlated with the changes in emissions. Total deposition of sulphur (EMEP countries) thus declined from approx. 17 million tonnes in 1985 to 11 million tonnes in 1994.

Deposition of sulphur compounds (SO_2-S and SO_4-S), nitrogen oxides, ammonia nitrogen and ammonium nitrogen can be expressed in terms of acid units or acid equivalents, thereby enabling the potential acidification effect of the substances to be compared and the total acidification pressure to be calculated (*Figure 2.1.26*). Total acid deposition in Denmark in 1996 amounted to approx. 7.5 tonnes

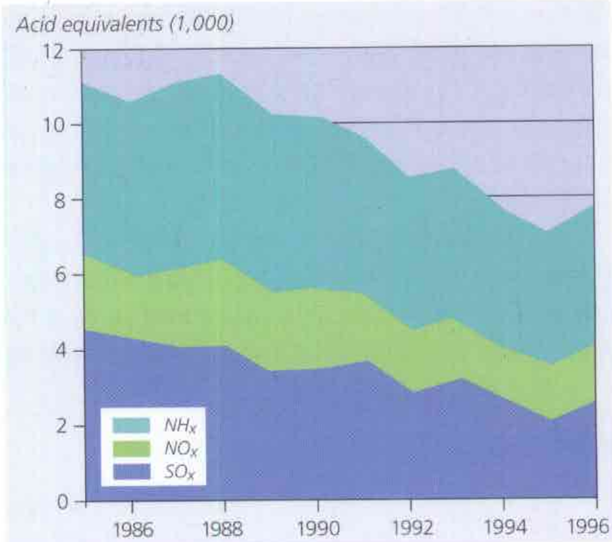


Figure 2.1.26 *Deposition of sulphur and nitrogen compounds in Denmark expressed in terms of acid equivalents (tonne-equivalents)(Source: National Environmental Research Institute, calculated from data in: EMEP, 1997).*

acid equivalents, corresponding to a fall of 33% over the 10-year period 1985-96.

During the same period, the percentage of total deposition accounted for by nitrogen compounds has increased from 60% to 70%. The most important acidification factor in Denmark today is ammonia nitrogen, largely derived from agriculture. On the European scale, the percentage of total deposition (expressed in acid equivalents) accounted for by the nitrogen compounds has increased from approx. 35% to 50% over the period 1980-94.

Environmental impact - critical loads

Critical loads are an important tool in the international efforts to combat the effects of transboundary air pollution and to reach agreement on reducing national emissions. The critical load concept has enabled mathematical modelling of long-range transport and deposition of sulphur and nitrogen compounds to be used to quantify how much emissions have to be reduced in order to reduce exceedence of a given critical load.

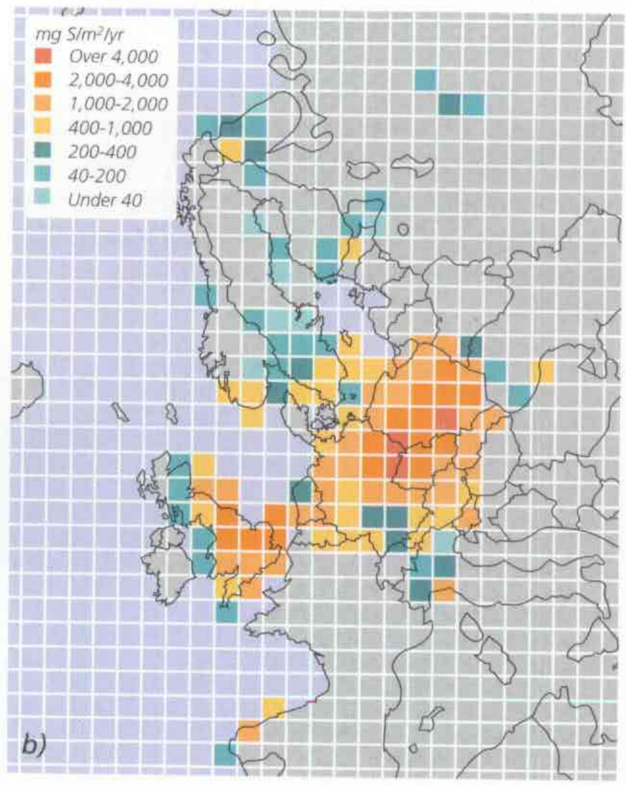
Within the framework of the UN-ECE Convention on long-range transboundary air pollution, continuous efforts are being made to establish and adjust critical loads. In the period 1986-88, critical loads were established for acidification effects on forests, lakes and watercourses, while in the ensuing period efforts have largely focused on establishing critical loads for ecosystems vulnerable to nitrogen loading.Examples of such critical loads are shown in *Figure 2.1.27*.

Ecosystem	Acidification keq/ha/yr	Eutrophication kg N/ha/yr	Method
Planted oak and beech	0.8-2.7	17-28	Calculated vs model
Conifer forest	1.4-4.1	7-15	Calculated vs model
Heath		15-20	Expert assessment
Raised bog		5	Expert assessment
Oligotrophic fen		5-10	Expert assessment
Dry grassland	0.9-2.4		Calculated vs model

Figure 2.1.27 Critical loads for acidification and nitrogen eutrophication in various ecosystems. The critical loads for acidification are expressed in kilo-equivalents per hectare per year (Source: Strandberg and Mortensen, 1996).

The critical load is in some cases indicated as a range. This is because many ecosystems are located on a wide range of different soil types. The lowest critical load applies for the soil types that are most vulnerable to acidification or eutrophication. In Denmark, these are mainly acidic nutrient-poor sandy soils or peaty soils. The critical load for atmospheric acid deposition is defined as the amount of acid input that a given ecosystem can tolerate over a longer period without being harmed. In practice, the critical load for acid is set at the critical load for sulphur assuming a given deposition of acidifying nitrogen compounds, or as a function of it. The critical load for nitrogen eutrophication is set as a constant independent of sulphur deposition.

Exceedence of the critical load for sulphur is calculated for the whole of Europe (the EMEP countries) in a 150 km x 150 km quadrant net, with the total area of vulnerable ecosystems being charted for each quadrant. The area in which the critical limit is exceeded has been calculated each year since 1980 as a percent of the total area (*Figure 2.1.28a*). As is apparent from the figure, the area subject to critical load exceedence has roughly halved over the period 1980-94. At present (1994), exceedence of the critical load for acidification is mainly a problem in the eastern part of Central Europe (*Figure 2.1.28b*).



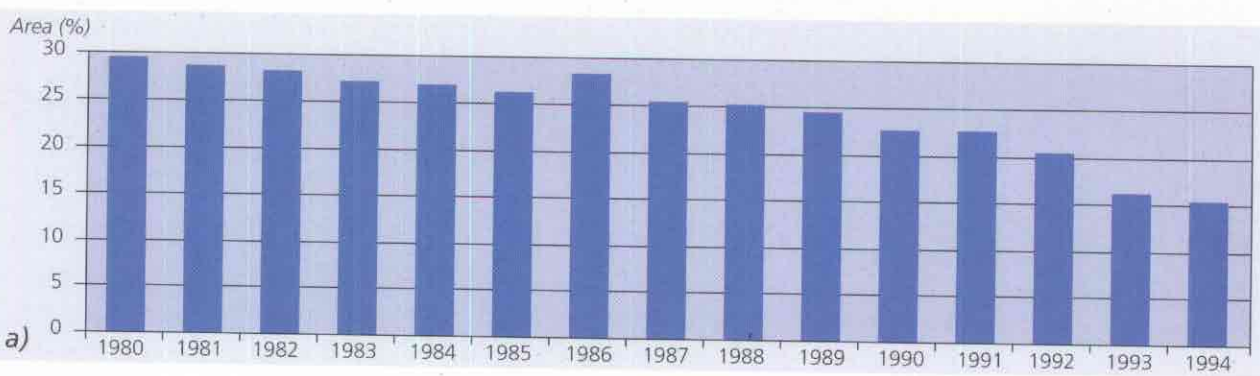


Figure 2.1.28 Exceedence of the critical load for sulphur. a) Trend in the total area of exceedence of critical load over the period 1980-94 expressed in percent of the total area. b) Quadrant net chart of critical load exceedence in Europe in 1994 expressed in mg sulphur per m² per year (Source: EMEP, 1997).

In contrast, the area in which the critical load for nitrogen eutrophication is exceeded has remained rather constant over the same period, this being in accordance with the fact that emissions of nitrogen compounds (NO_x and NH_3) have only varied slightly during the period.

Trend in acidification of lakes

The trend in acidification of vulnerable lakes in Europe and North America has been monitored through the 1980s and 1990s within the framework of the UN-ECE Convention on monitoring (EMEP, ICP Programme). In accordance with the fact that deposition of sulphur has been falling, trend analyses have revealed that lake water sulphate concentrations have been falling at nearly all locations, the fall in the 1990s nearly always being greater than that in the 1980s (*Figure 2.1.29*).

Lake alkalinity or buffering capacity against acidification is a measure of a lake's vulnerability. In many European countries, including Finland, Norway and Sweden, the situation has improved, there having been an accelerated increase in alkalinity in the 1990s in particular (*Figure 2.1.29*).

Danish lakes also exhibited an increase in alkalinity in the 1980s, although without an accelerated increase in the 1990s. The improvement in water quality has resulted in the partial restoration of the original invertebrate fauna in many lake ecosystems in both Europe and North America.

The nitrate concentration in the lakes increased during the 1980s, thereafter to stabilize in the 1990s. Being the second most important acidification factor after sulphate, the role of nitrate has therefore become relatively more important. However, the nitrogen status of lakes is not solely determined by atmospheric deposition of nitrogen compounds.

Effects on terrestrial ecosystems in Denmark

Exceedence of the critical load for acid is calculated in Denmark for beech, oak, pine and spruce forests and for grassland as part of European efforts to chart critical loads and their exceedence. In accordance with the decreasing atmospheric deposition of acid in Denmark (*Figure 2.1.26*), the area in which the critical load is exceeded is also falling. However, the critical load is still exceeded in some conifer forest

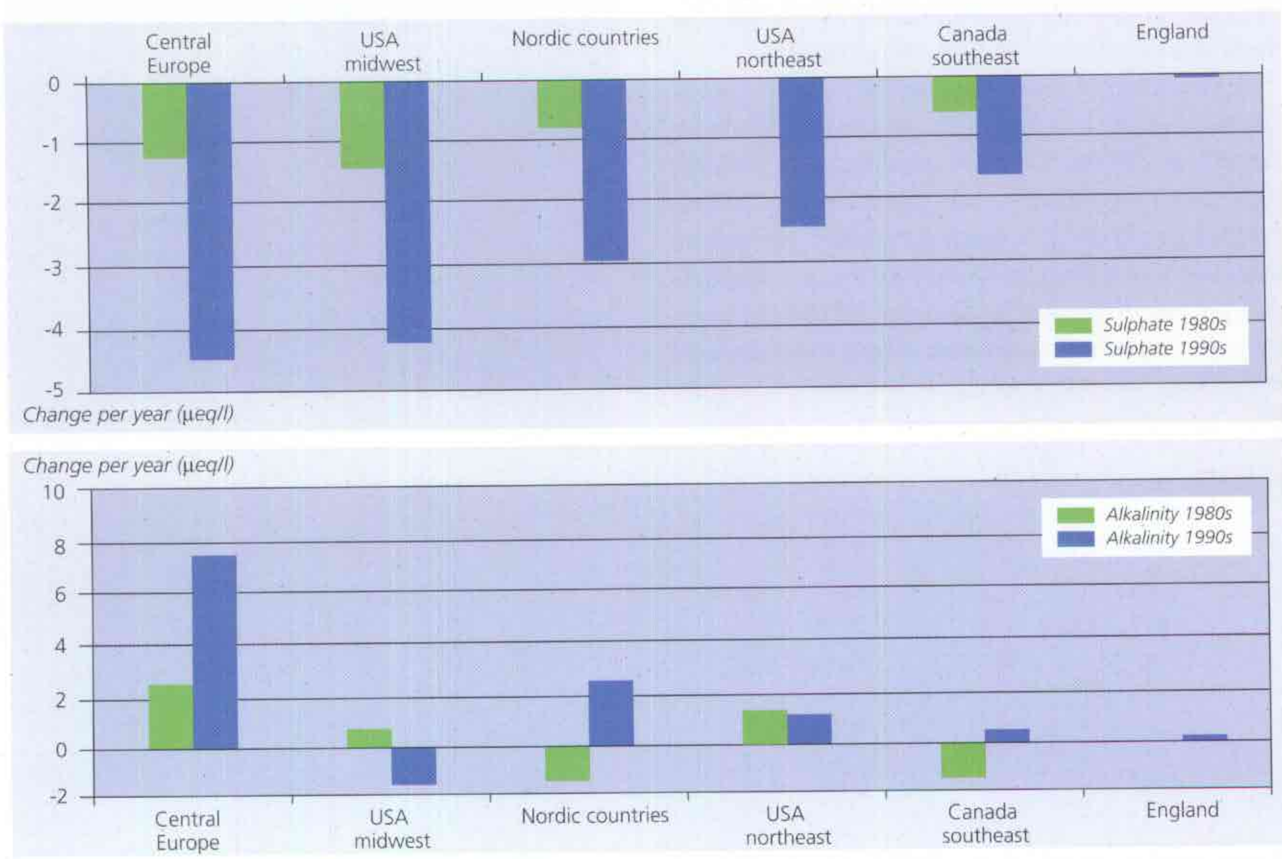


Figure 2.1.29 *Average annual change in lake sulphate content and alkalinity in the 1980s and 1990s in various regions of Europe and North America (Source: Lückewille et al., 1997).*

areas of mid and southern Jutland on sandy soil (*Figure 2.1.30a*). Exceedence of the critical load for nitrogen eutrophication of forests is illustrated in *Figure 2.1.30b*.

Calculations made during the 1990s show negligible variation despite the fact that nitrogen deposition in Denmark has been slowly decreasing since 1988. Mean nitrogen deposition in Denmark has increased from approx. 5 kg/ha in the 1950s to the present level of approx. 20 kg/ha. Considerably higher deposition has been measured in mid and southern Jutland, though, where livestock density and hence ammonia emissions are high. It is also in these areas that the critical load for nitrogen input to forests, which ranges from 10-25 kg N/ha depending on soil type and tree species, is mainly exceeded. Nutrient-poor ecosystems such as heaths and upland bogs are particularly vulnerable to nitrogen loading (cf. *Figure 2.1.27*), and Danish heaths can be expected to react to increased loading.

However, this ecosystem can accumulate considerable amounts of nitrogen bound in an inaccessible form in the peat, and the effect of eutrophication on the Danish heaths is therefore delayed. Thus, clear changes in the vegetation are not yet apparent, but are expected to become so when large amounts of nitrogen have been supplied to the heaths over a long period of time. The initial signs are apparent in some areas, however. In Holland, where nitrogen availability for the plants is greater, 1/3 of the heaths are presently dominated by grasses. In the case of Danish upland bogs, which are the most vulnerable ecosystem type, the critical load is estimated to be 5 kg N/ha. This level is already exceeded throughout the whole of the country.

State of Danish forests

The state of health of selected forests has been monitored in Denmark since 1987. This is undertaken as part of a major European programme that presently encompasses approx. 80% of European forests. Both the Danish and European monitoring programmes define a tree as being damaged if it has lost more than 25% of its needles or leaves, while loss in the range 10-25% is considered a warning signal for incipient damage.

Needle/leaf loss is a symptom that can have many causes, e.g. fungal or insect infection, climate effects, nutrient status, soil conditions, forestry, and

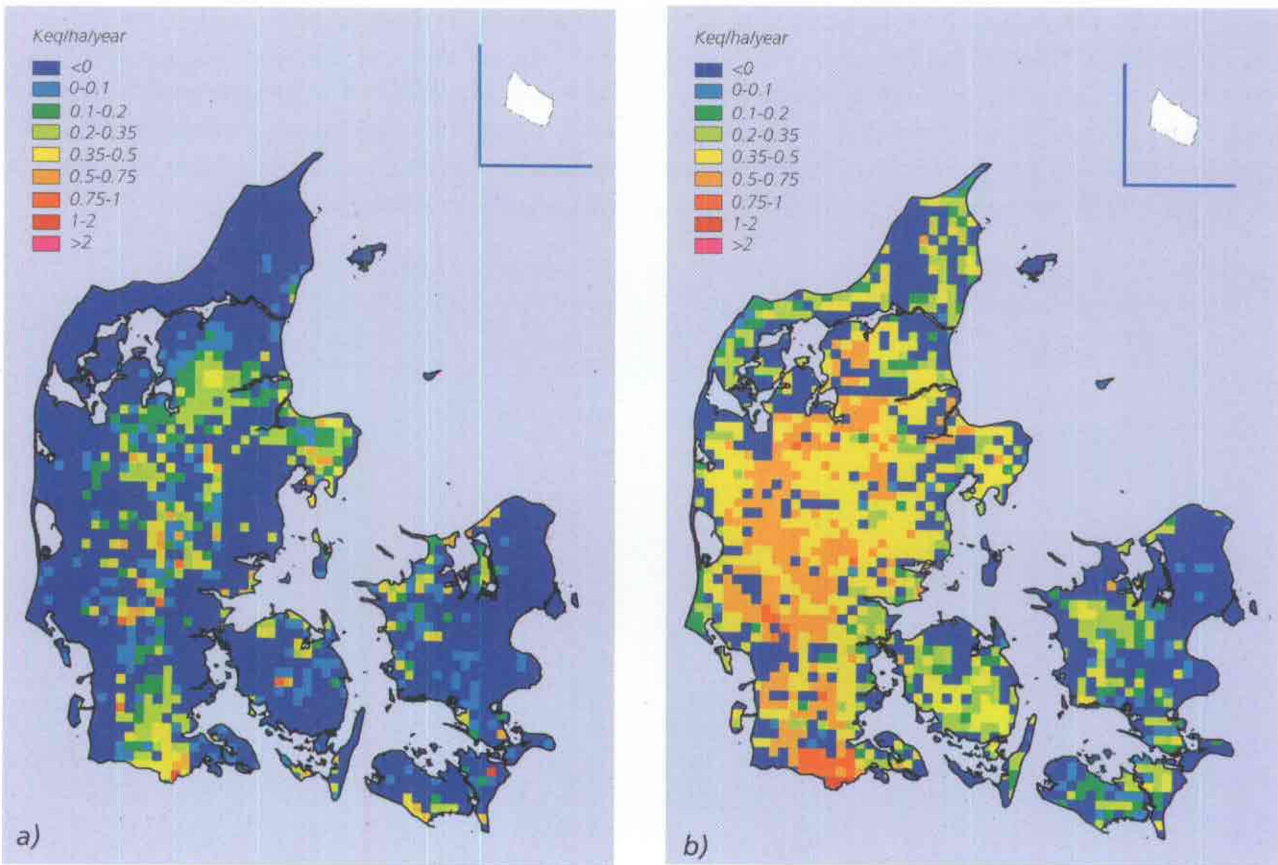


Figure 2.1.30 a) *Exceedence of the critical load for acidification with nitrogen and sulphur.* ***b)*** *Exceedance of the critical load for nitrogen eutrophication of forests (Source, National Environmental Research Institute, calculations, 1997).*

air pollution. Thus loss and discolouration of needles and leaves are not specific effects of air pollution, and monitoring cannot usually indicate the causes of the observed changes in the state of health of the trees.

In a European perspective, however, there seems to be agreement that acid rain, enhanced nitrogen deposition and photochemical oxidants are partially responsible for the damage to the forests recorded in Europe through the 1980s and 1990s.

The monitoring results and the 1996 reports by the State Forestry Districts indicate a general improvement in the health of Danish conifer forests (*Figure 2.1.31*). The negative tendency seen for conifers with increasing needle loss over the years seems to have been broken in the last few years, and a positive trend seems to have emerged. In the case of beech and oak forests, however, no clear trend is detectable.

Objectives and policy measures

A number of Protocols under the UN-ECE regulate transboundary air pollution. According to the 1985 Sulphur Protocol, European countries have to reduce their sulphur emissions 30% by 1993 relative to 1980. This target has been more than met as European sulphur emissions have been reduced 50% over the period 1980-94. In Denmark, emissions have been reduced 67% (1977-95). In the latest sulphur Protocol from 1994, Denmark has committed itself to reduce sulphur emissions to 90,000 tonnes by the year 2000, corresponding to an 80% reduction relative to 1980. As a consequence of the reduced sulphur emissions, the area in which the critical load for acidification is exceeded has been reduced. For Europe as a whole the reduction amounts to 50%. The area in which the critical load for nitrogen eutrophication is exceeded has remained largely unchanged, this being attributable to the fact that NO_x and NH_4 emissions have not been reduced to any great extent.

The 1988 NO_x Protocol committed signatory countries to stabilizing nitrogen oxide emissions at the 1987 level by 1994. Together with 11 other countries, Denmark further committed itself to reduce emissions by 30% in 1998 relative to 1986. Denmark strives to attain this goal through national action plans in the energy and transport areas. It is thus expected that Danish emissions of nitrogen oxides will be reduced by 35% in the year 2005, and that sulphur emissions will be reduced by at least 60% relative to 1988.

In March 1997, negotiations were initiated in Geneva on a new nitrogen Protocol to replace the old Protocol from 1988. The new Protocol will focus on reducing exceedence of the critical loads for acidification, eutrophication and the effects of photochemical air pollution (ozone). The Protocol will consequently encompass regulation of national emissions of ammonia in parallel with further reduction in emissions of sulphur, nitrogen oxides and volatile hydrocarbons (NMVOC). Both this Protocol and the forthcoming EU acidification strategy are thus expected to lead to considerably more stringent requirements on emission reductions.

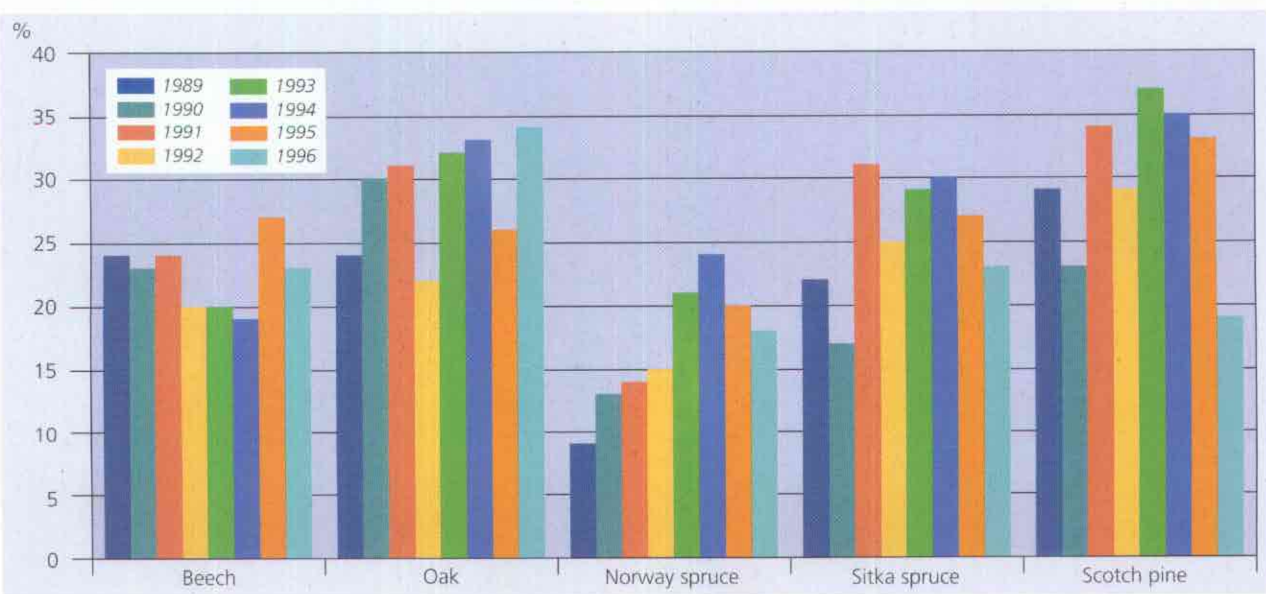


Figure 2.1.31 *Trend in average needle/leaf loss over the period 1989-96 shown for the main tree species. The tendency is positive for the conifers, with loss having declined in the last few years, whereas the picture for beech and oak is less clear (Source: National Forest and Nature Agency, 1997).*

2.2 The urban environment

2.2.1 Introduction

The towns are home to 85% of the Danish population and cover 5% of the country. Society's turnover of a number of important resources is concentrated in the towns whose structure, buildings and infrastructure themselves constitute an important resource and form the framework for a cultural environment that it is important to protect and preserve.

The high population density and level of economic activity render the urban environment attractive and create possibilities for rational solutions such as public transport, energy and supply systems and various urban ecology measures, just as they reduce pressure on our landscape and nature resources. At the same time, though, the high population density causes special environmental problems such as air pollution, noise, barrier effects, contaminated sites, contaminated groundwater, etc., and makes it difficult to preserve sufficient green spaces. It was for these reasons that deterioration of the environment was first recognized in the towns of Europe. Until a few decades ago, air pollution was considered as a purely urban phenomenon that could be solved by dispersing the pollution from sufficiently high smokestacks.

The towns also contribute to the regional and global environmental problems that reach considerably beyond the towns themselves. Concentration of the population in towns thus creates an environmental policy dilemma. On the one hand, a high impact on the environment per unit area locally and considerable pressure on the surroundings, and on the other hand, the possibility for effective utilization of resources, which reduces the per capita global impact on the environment. The environmental impact of transport is a good example of the environmental paradox associated with towns.

2.2.2 Urban structure and function

Post-war urban development has led to a many-fold increase in the urban area. Urban development has been characterized by an increasing standard of living with an increased housing area and the new possibilities for increased mobility provided by the car. Light, clean air and green surroundings have been accorded high priority with all types of housing, whether detached houses, terraced houses or blocks of flats. The result has been hitherto unseen urban development around the largest towns which has entailed long travelling distances, high energy consumption and associated CO_2 emissions, and in many cases a lack of urban quality. Many of the new housing areas, especially the housing estates, are difficult to service with public transport. More than half of the urban population now inhabit built-up areas established after 1950.

Urban spread is also reflected in other ways. Around the largest towns, people have settled in villages and other nearby towns also with resultant growth in both the amount of commuting and the distances commuted. Differences in the price of housing far exceed differences in the cost of transport. Of all working Danes, 40% (or over 1 million people) work in a municipality other than the one they inhabit.

In addition, the towns have become functionally divided with housing and places of work being segregated in independent districts. Originally, one of the reasons for this functional segregation was the environmental problems that manufacturing enterprises caused for neighbouring homes. However, segregation unintentionally led to new problems such as enhanced need for transport between work and home, deserted commercial and shopping centre districts in the evening and nighttime, and lifeless housing districts during the daytime with a poor selection of social and cultural activities. Other types of commercial enterprises than manufacturing enterprises have also moved outside the former structure of the towns, however. Thus many offices have sought locations with good access by car, often in the vicinity of green spaces. The retail trade has become concentrated in larger centres and in this case too, the demand for good access by car has resulted in them being placed in the periphery of the towns.

Actual urban growth has now declined, although the urban spread continues. Work places and larger retail centres are often placed outside or in the periphery of the towns, and the tendency for people to reside at increasing distances from work places continues. However, we also see increased interest for residing in towns and for the quality of the urban environment, including the cultural environment. Among other things, the long-standing decline in the population of Copenhagen municipality has switched to growth in recent years.

A good example of continued urban spread is office and housing development in Greater Copenhagen. According to the regional planning objectives, town functions should be localized near the under-ground and regional railway traffic hubs. Nevertheless, nearly 60% of the office complexes constructed in Greater Copenhagen over the last 15 years have been built more than 1 km from the nearest public transport hub or more than 500 metres from the nearest station, these being the limits for appropriate localization stipulated in the existing Regional Plan for Greater Copenhagen.

Neither is new housing being built in accordance with the main structure for Greater Copenhagen stipulated in the Regional Plan. Thus more than 70% of the housing developments in the 1990s are located more than 1 km from the nearest station, and more than 50% lie over 2 km from a station

2.2.3 Urban commerce

In the post-war period there has been a marked trend towards translocation of manufacturing industries away from the centre of the larger towns. In addition, production as a whole has tended to shift from eastern Denmark to western Denmark (Jutland) and from the larger towns to the smaller towns. Industry's centre of gravity has moved from Copenhagen to Jutland. This has affected the distribution of environmental problems.

There are many reasons for this redistribution of industry between the parts of the country. Translocation from town centres to new industrial districts in the periphery of the towns was driven by such factors as the lack of possibilities for expansion and the environmental problems associated with proximity to housing. Due to subsequent urban spread, however, the problem has sometimes arisen again. Cleaner production methods and improved treatment and abatement technology can help solve these problems, though.

As a result of industry's great mobility, the older commercial districts - especially in the larger towns - have sometimes become completely or partially devoid of traditional industrial and trade enterprises, and land occupied by harbours, the military and railways has been released for new purposes.

From the point of view of resources and the desire to avoid urban spread and degeneration of town centres, it is important that these town areas are re-used for town functions, including recreative purposes. However, conversion often causes problems because of pollution, land ownership and land registry problems, conflicts between new and existing uses, and because the supply of sites is usually far greater than demand. As they are located far from public transport hubs, several of the localities are unsuitable for the growth industries traditionally able to pay most for the sites.

The result is that commercial areas under conversion often lie like scars in the towns - in some cases as cleared sites or sites with derelict buildings, in other cases just as empty buildings and vacant commercial properties. A very large share of these sites is unlikely to be developed for many years in the future. Demand is low and the trend is towards accelerated degeneration of these parts of towns. A particular problem is comprised by registered contaminated sites. These sometimes lie unused and require special attention in connection with urban renewal and development.

2.2.4 Urban contaminated sites

Over the years, the authorities' perception of the nature of the soil pollution problem has changed, primarily as a result of administration of the 1983 Waste Deposits Act. This required preparation of a nationwide inventory of chemical waste disposal sites and initiation of their remediation. Work on drawing up the inventory continued under the 1990 Contaminated Sites Act, and remediation efforts were enhanced, see *Figure 2.2.1*. It has become apparent that many cases of soil pollution cannot be described as well-defined "waste deposits" but rather as "contaminated sites". Here the soil pollution is dispersed in the upper soil strata as a result of long-standing human activity, with pollution from different sources being mixed, cycled, transported and spread in the environment. In larger towns, enhanced levels of heavy metals are commonly recorded in the old parts of the towns as a result of human activity, among other things, ordinary building activity and construction projects involving the use of filling materials.

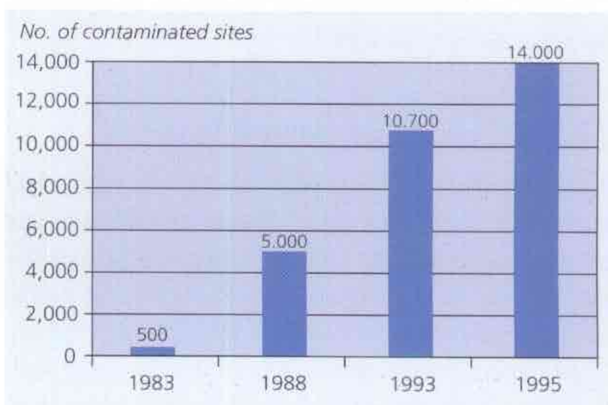


Figure 2.2.1 *Development in estimated number of contaminated sites (Source: Danish Environmental Protection Agency).*

In connection with the work of the Waste Committee it has been estimated that there are a total of approx. 14,000 contaminated sites, of which 1,900 to 2,300 are currently used for housing or institutions. The majority of the contaminated sites are located in or in the vicinity of urban areas. The most common sources of soil pollution in urban areas are industrial activity and former waste disposal sites. Examples are wood impregnation firms, tanneries, galvanization plants, vehicle repair shops, petrol stations, chemical industries, etc. The sites are mainly contaminated with organic solvents, tars, pesticides, oils and petrol, but also with heavy metals and cyanides.

In addition, there is pollution of a more diffuse character. This occurs in the towns and is due to pollution from vehicles run on leaded petrol, as well as to other sources such as industrial smokestacks, construction projects involving the use of filling materials, and dispersal of waste. As a result of diffuse pollution, the soil quality criteria for lead, chromium, copper, zinc, arsenic and mercury can be exceeded.

Lead is by far the most commonly detected pollutant in contaminated areas. It is estimated that 80% of the diffusely contaminated area consists of lead-contaminated land alongside roads in towns and the country. The concentrations measured in point sources are generally considerably higher than the concentrations present in the form of diffuse pollution in towns.

As a result of the agreement between the Government and the Counties concerning the 1997 county budgets, DKK 270 million has been set aside for public efforts to remediate contaminated sites. In addition, a DKK 75 million appropriation for remediation of contaminated sites is included in the 1997 Government Budget.

2.2.5 **Urban traffic**

Car traffic is the main source of pressure on the urban environment, being the main source of air pollution, noise, traffic accidents, barrier effects and insecurity in the towns.

Total traffic increased approx. 50% over the period 1984-95, although the increase was more modest in the towns. Only a few towns are designed to cope with the present intensive road traffic. In step with the growth of car traffic the towns have tried to adapt to the new needs. Traffic facilities occupy approx. 1/4 of the area of towns, approx. 40% of road traffic currently takes place in urban areas, and the nuisance caused by traffic is greatest in the towns.

A further problem is that the part of the population that does not have access to a car often also lacks satisfactory possibilities for mobility in the form of an effective public transport network in combination with cycling and walking.

The concentration of housing in towns provides a unique possibility to reduce the overall impact on the environment and total energy consumption by reducing traffic and through the transferral of car traffic to public transport, cycling and walking. Nevertheless, the trend has been towards greater urban spread with resultant consequences for transport, environmental impact, etc.

A study of 52 larger offices in Greater Copenhagen (Copenhagen and Frederiksberg municipalities, and Copenhagen, Frederiksborg and Roskilde counties) thus showed that average daily commuting to and from these work places amounts to about 20 km in each direction, irrespective of where in Greater Copenhagen they are located. This is a two-fold increase compared with 20 years ago. With respect to choice of transport mode and the magnitude of car transport, however, location in the urban structure is of great significance. Thus while 10-25% of employees in offices located in the inner city commute by car, the corresponding figure is 75-85% for employees of offices located more than 1 km from public transport hubs and 40-50% for employees of offices located near public transport hubs, see *Figure 2.2.2* and *Figure 2.2.3.*

A similar study of 24 offices in Aarhus, Odense and Aalborg also showed marked differences in employee commuting by car depending on whether the office was located in or outside the town centre.

There are large differences in transport patterns between larger and smaller towns, particularly with respect to shopping and commuting journeys. Transport for commuting is 45-65% higher in smaller towns than in larger towns while transport for shopping is two-fold greater. At the same time, far more people use public transport and bicycles in the larger towns than in the smaller towns.

Inhabitants of the small towns drive twice as many kilometres to work and educational establishments by car as inhabitants of the largest provincial towns, and three times as many as in the three main municipalities of Greater Copenhagen. In connection with shopping, the difference is even more marked.

In the suburbs of Greater Copenhagen, average transport and car use are equivalent to that in the smaller and medium-sized provincial towns. In contrast to both commuting and shopping, the length of

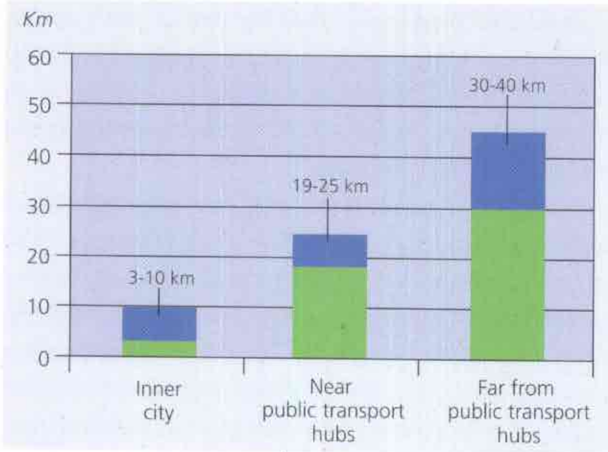


Figure 2.2.2 Commuting by car. Average daily transport per employee in offices differently located with respect to public transport hubs in Greater Copenhagen (Source: Ministry of Environment and Energy, 1996).

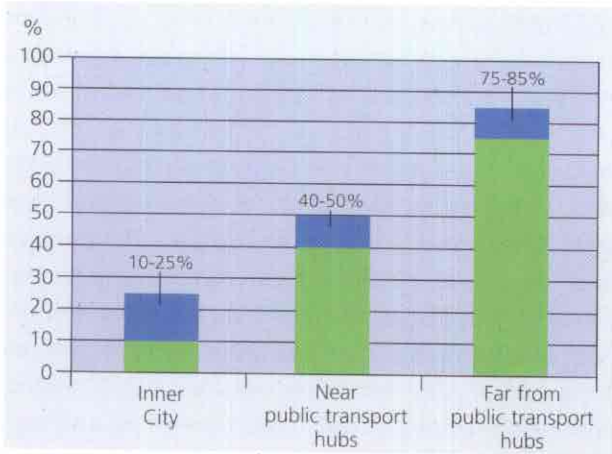


Figure 2.2.3 Commuting by car. Percentage of employees who commute by car to and from offices differently located with respect to public transport hubs in Greater Copenhagen (Source: Ministry of Environment and Energy, 1996).

leisure journeys is independent of where people live. On the other hand, the settlement pattern is of significance for the mode of transport selected.

In the central municipalities of Greater Copenhagen, the car accounts for 60% of transport (expressed in person-kilometres) for leisure purposes. The corresponding figure in the thinly populated regions is 90%. The tendency for people to drive more by car in the thinly populated regions than in the large towns applies to all income groups. Within all sizes of towns, car travel increases with increasing income, however.

The overall lesson from the above studies is thus that town size, density, form and structure are of considerable significance with respect to the amount of passenger transport and distribution among modes of transport, and hence for the environmental impact of transport.

The supply of goods and freight to towns comprises a special problem. Even though freight traffic only accounts for 15-20% of the total traffic in towns, it accounts for considerable pollution. For example, lorries account for approx. 2/3 of particulate emissions from traffic and approx. 1/3 of NO_x emissions. In addition, lorries are often experienced as a dominant element in the townscape.

The distribution of goods is undertaken by numerous actors without much coordination of transport. For example, shops are supplied by different vans and lorries from different suppliers. The transport firms typically service a considerably larger area than just the town and hence do not usually optimize the routes in relation to the towns. Studies from Aalborg show, for example, that just over half of all goods distribution could be undertaken in a more environmentally optimal manner through effectivization of the individual transport trips and establishment of transshipment facilities.

2.2.6 **Urban noise**

Road traffic is by far the most widespread source of noise nuisance, although noise from railways and aircraft also contributes to noise pollution in some towns. The many different types of noise from neighbours and building and construction work can also cause considerable noise nuisance locally. There are no noise limits applying to noise from neighbours, but building regulations require sound insulation between homes in the same building.

Traffic noise can affect the individual person's health, functional ability and well-being, but not all people are equally sensitive to excessive noise strain. Sound impressions will often be measurable in the form of stress and headache, which typically can lead to elevated blood pressure and resultant sequelae and cardiovascular disease. Experience shows that in the case of road noise, 10-15% of the population feel strongly bothered by an outdoor noise level of 55 dB(A), while more than half of the population feel strongly bothered at noise levels of 65 dB(A) or over.

The mentioned percentages for outdoor noise are assumed to correspond to an indoor noise level of 25 dB(A) lower since windows in the existing housing stock are thought to provide sound insulation of 15-35 dB(A). By improving the windows it will be possible to reduce the indoor noise level by a maximum of 45 dB(A). In the case of rooms with windows that can be opened, however, the reduction in noise level will probably only be 35 dB(A).

New buildings are subject to the provisions in the building regulations on insulation against external noise from roads and railways. These specify a noise limit of 30 dB(A) in rooms designed for habitation.

Noise levels over 65 dB(A) are recorded along virtually all roads with through traffic in the central parts of towns. Noise levels are particularly high along the old approach roads to the towns. Approx. 165,000 homes are affected by noise levels exceeding 65 dB(A). Of these, approx, 145,000 are affected by road noise. Among the largest towns, 70,000 homes are affected by noise levels exceeding 65 dB(A) in Copenhagen municipality, 11,000 in Aarhus, 5,200 in Aalborg and 4,900 in Odense.

2.2.7 **Urban air pollution**

Most air pollution is found in the towns, where the majority of pollution sources are found. Cars make a particularly great contribution as they emit air pollutants at a low altitude. The impact of air pollution on health is thus also greatest in the towns.

The load varies, however. In narrow busy streets the level of air pollution will be many-fold greater than behind the rows of houses, above the roofs and in open-plan housing districts and green spaces. Thus exposure to air pollution greatly depends on where one lives, works and travels. The levels of certain air pollutants exhibit both temporal and spatial variation, whereas others are more constant.

Air pollution in the towns used to be dominated by household heating (stoves, oil furnaces, etc.), small power stations and local industrial plants. However, pollution from these sources has fallen markedly in line with the centralization of energy and power production up through the 1970s and 1980s, the introduction of stricter emission limits and the introduction of natural gas.

On the other hand, air pollution from traffic has increased due to the marked growth in traffic. Improvements in automotive technology, etc. were initially unable to counterbalance the increase. In recent years, however, there has been a decrease or less of an increase in pollution from traffic. In the coming years, in contrast, an actual fall in pollution from traffic is expected due to stricter vehicle emission limits, e.g. the installation of catalytic convertors on all new cars.

In the largest Danish towns, road traffic is the completely dominant source of air pollution. A number of pollutants are emitted, the most problematic of which are nitrogen oxides, volatile and particulate organic compounds, inorganic particulates and carbon monoxide.

Of the nitrogen oxides, nitrogen dioxide (NO_2) has the greatest impact on health. Moreover, in a few Danish towns it is present in concentrations close to the levels considered harmful to health by the WHO.

Nitrogen oxides are involved in a multitude of chemical processes, among other things contributing to the formation of ozone and hence to the photochemical air pollution that is a regional problem at the European level (cf. *Section 2.1.3*).

The atmospheric chemical reactions that determine the ozone concentration in towns differ from the regional pattern. Of the nitrogen oxides emitted from cars, 90-95% are in the form of nitrogen monoxide (NO). This reacts with regionally formed ozone to form NO_2. As a result, the ozone concentration in towns is generally lower than in their surroundings.

As virtually no ozone is formed in urban air in Denmark, it is the regional background concentration of ozone that is the limiting factor. Given the ozone concentrations found in Denmark, the amount of NO_2 formed will maximally reach approx. 200 µg/m^3. To this must be added NO_2 emitted directly from traffic and other sources. A reduction in NO_X emissions will therefore have only a limited effect on the NO_2 concentration in urban streets.

At some distance from very busy streets and outside the towns, ozone is no longer the limiting factor for the NO_2 concentration, and a reduction in NO_X emissions will therefore be immediately detectable. An isolated reduction in Danish NO_X emissions will not reduce the ozone level in Denmark. In the long run, however, the ongoing and planned initiatives to reduce European emissions of NO_X and volatile organic compounds will lead to a reduction of the ozone level, among other places in Denmark. This will also lead to a reduction in the NO_2 concentration in urban streets.

The organic compounds include the volatile organic compounds such as benzene, which is carcinogenic. Particulates are currently believed to play a significant role in the harmful effects of air pollution, especially the carcinogenic substances such as polycyclic aromatic hydrocarbons (PAH) which mainly derive from diesel vehicles and wood-burning stoves. In addition, particulates are believed to be harmful *per se*, especially particulates smaller than 2.5 µm as these are able to penetrate deeper into the lungs than coarser particulates.

Air pollution levels in Danish towns

The air pollutants nitrogen oxides, particulates, lead and sulphur dioxide have been monitored in Copenhagen, Aalborg and Odense since 1982. The measurements show that pollution with sulphur dioxide and particulates, which primarily derive from power and heat production, have been decreasing for more than 10 years. *Figure 2.2.4* shows the development in sulphur dioxide pollution in Aalborg. Exactly the same trend has been seen in other Danish towns.

Pollution with nitrogen oxides (NO_X) has been decreasing since October 1990 due to the introduction of catalytic convertors on all new petrol-driven cars in Denmark. This development is clear for nitrogen monoxide (NO) (*Figure 2.2.5*), but has not yet led to a clear decrease in pollution with nitrogen dioxide (NO_2) in busy streets, where ozone is the limiting factor for NO_2 formation.

In areas with busy streets, the levels of NO_2 pollution are close to the current air quality guidelines. It is expected, though, that these guidelines and limit values will be tightened in the EU in accordance with the recommendations of the WHO.

Pollution with volatile organic compounds has only been measured at a few locations in Denmark, among other places at one of the major roads (Jagtvej) in Copenhagen. Most of the VOC pollution measured derives from traffic and a clear correlation has been demonstrated between levels of VOCs and other pollutants from traffic, especially CO.

One of the substances that has attracted greatest attention is benzene, which is carcinogenic. In very busy streets, benzene has been measured in concentrations exceeding the limit value of around 10 µg/m^3 which is expected to be applied in the EU. In 1994, benzene concentrations exceeding 15 µg/m^3 were measured and calculated at the Jagtvej monitoring station. Benzene and other aromatics are present

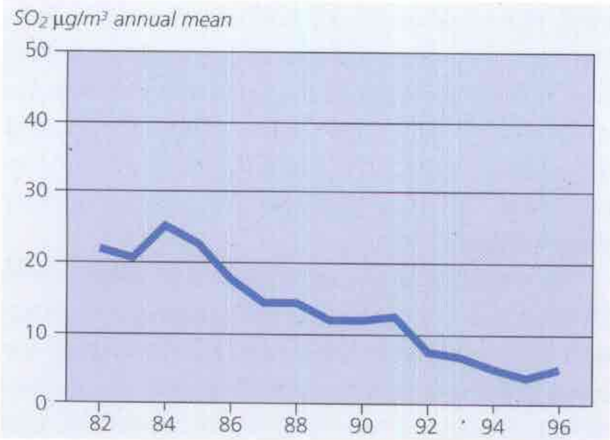


Figure 2.2.4 Development in concentration of sulphur dioxide (annual average) in Aalborg over the period 1982-96 (Source: Kemp et al., 1997).

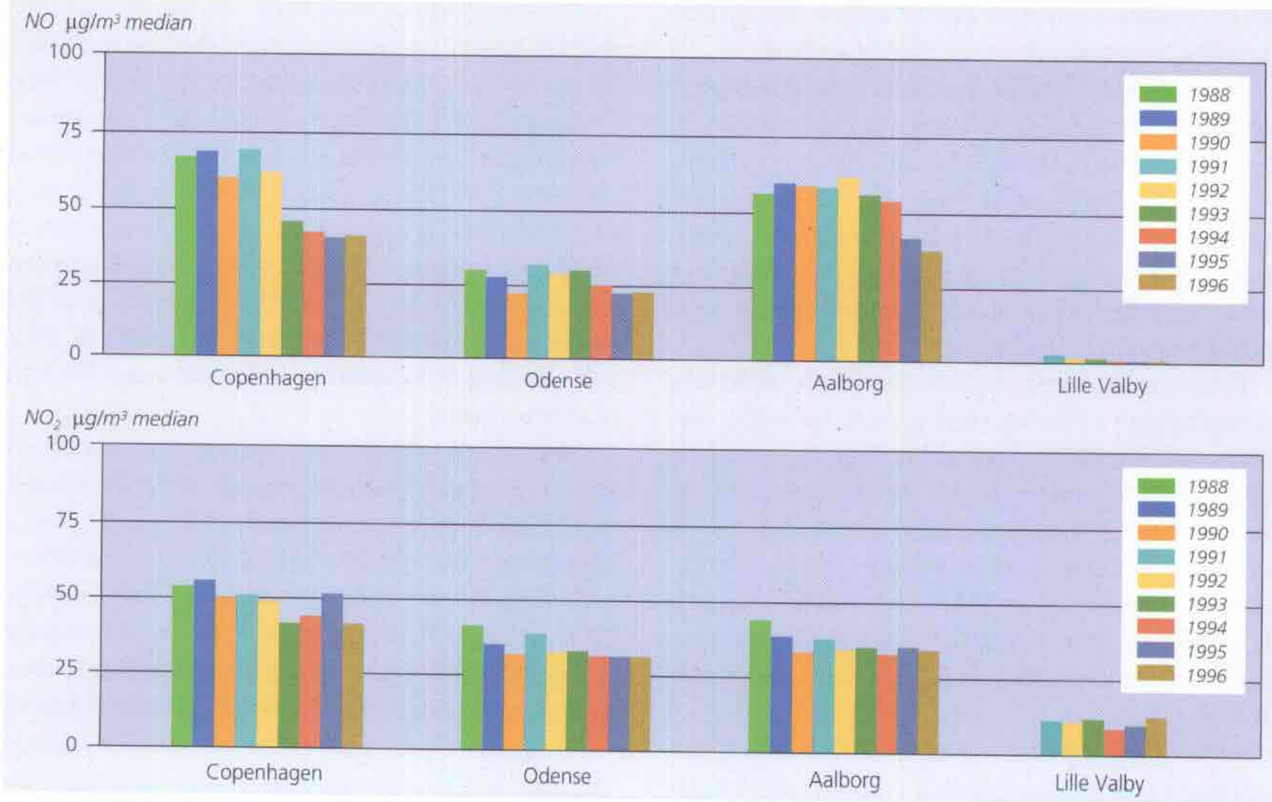


Figure 2.2.5 Development in the concentration of nitrogen oxides in Copenhagen, Odense and Aalborg over the period 1988-96 and at a background station (Lille Valby) over the period 1991-96 (Source: Kemp et al., 1997).

in crude oil. Under normal production conditions, petrol contains 3-4% benzene. The benzene content is lower in petrol produced at certain newer refineries, however. For example, a new unit opened at the Statoil refinery in 1995 supplies crude petrol with a benzene content of approx. 2%. As Statoil produces a very large part of the petrol for the Zealand market, this has led to an approx. 20-30% reduction in the benzene content of air measured at the Jagtvej monitoring station. In order to achieve the same octane rating, it is necessary to add certain additives, e.g. MTBE (methyl tertiary-butyl ether), which is considered to be less harmful to health.

The PAH content of the air has been measured over the period 1992-94 at a number of the National Environmental Research Institute's monitoring stations. It has not been possible to attribute this type of pollution to a specific type of source. Traffic is believed to play an important role, but many different forms of incomplete combustion probably contribute. It turns out - in contrast to other forms of pollution from traffic - that there is considerable seasonal variation in all PAH concentrations. This could be due to chemical degradation in the summer and/or the contribution from home heating in the winter, for example from wood-burning stoves. The study is expected to be repeated in a few years time.

Lead pollution in Danish towns and those of other western countries has decreased markedly in line with the introduction of unleaded petrol (*Figure 2.2.6*). The level of lead pollution in Danish towns is now very low as the major oil companies no longer use lead as a petrol additive.

2.2.8 **Urban green spaces**

The majority of urban green spaces are accessible to the public, for example in the form of parks and gardens, playgrounds, urban forests and natural areas, sports fields and churchyards. By far the majority of these areas are administered by the Municipalities. Parks policy is thus a municipal task with a very limited degree of state regulation.

Many of the oldest parks in the towns were established at the beginning of the present century, primarily as parks for promenading and later with flower gardens and lawns for the more physical activities. Wear and tear on the central urban parks is considerable as many people use the parks, when they live and work in the town centres. A considerable maintenance effort is therefore required to keep up the standard of the old parks.

Over the last 20 years, the total area of urban green spaces has increased. The total park area, i.e. the total area of parks, gardens and playgrounds, has doubled since 1976 - mostly in the medium-sized municipalities (8-30,000 inhabitants), where extensive urban development took place in the 1970s and 1980s. The "new parks" are green communal areas in residential districts or low densely built-up areas, where residents also have their own garden connected to the house.

Concomitantly with the increase in park area on the outskirts of the towns, pressure has steadily increased on the areas in the town centres. In many places, this has affected the old parks, which have had to yield land to other town functions. Examples are expansion of the National Museum for Art in

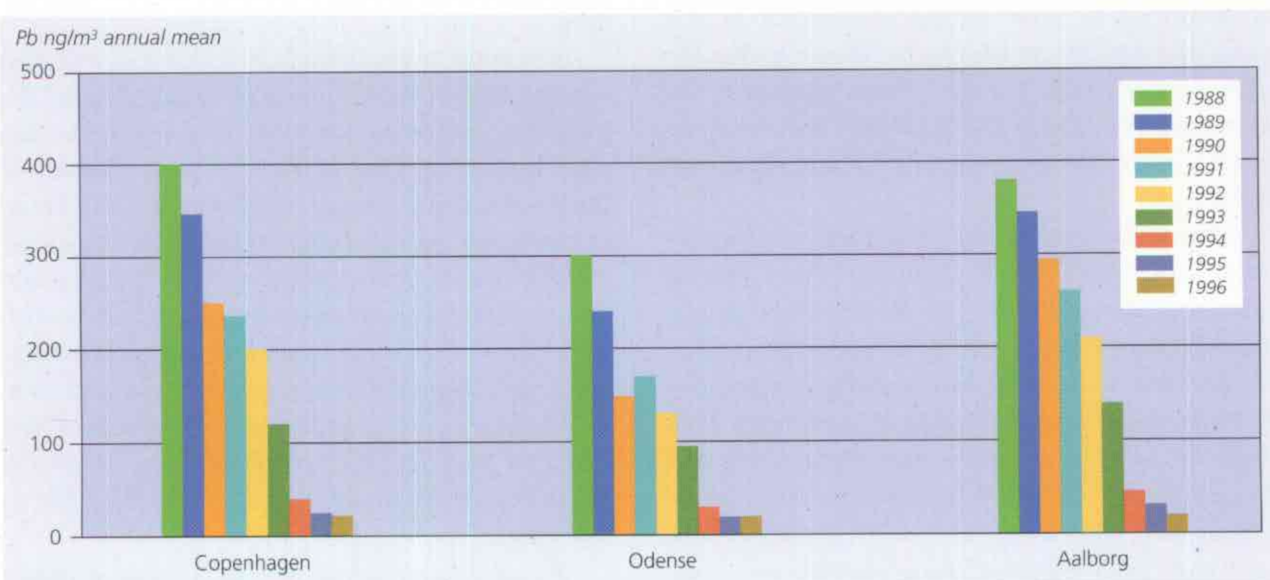


Figure 2.2.6 *Development in the concentration of lead in air (annual average) in Copenhagen, Odense and Aalborg over the period 1988-96 (Source: Kemp et al., 1997).*

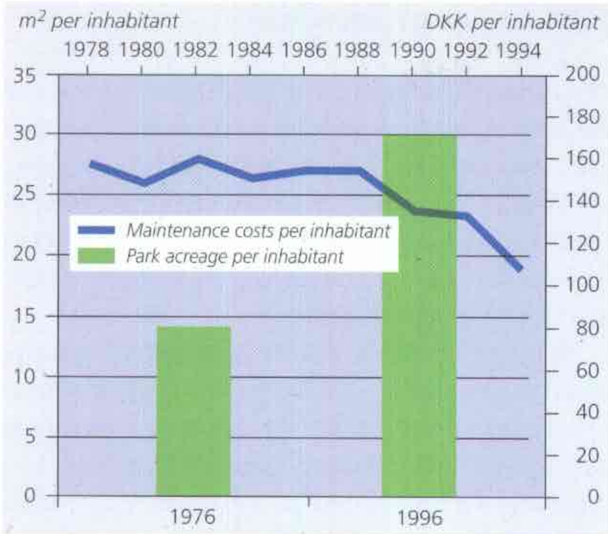


Figure 2.2.7 Development in park acreage and maintenance costs in real terms (1995 prices) over the period 1976-96 (Source: Anderson et al., 1976; Juul and Nuppenau, 1996).

Østre Gardens in Copenhagen and the establishment of the Concert Hall in Esbjerg City Park.

There are many other examples of larger or smaller areas being converted from park use to other functions. The above mentioned increase in the area of urban green spaces thus reflects both growth in the area of green spaces outside town centres and stagnation or even decline in the area of green spaces in town centres.

In step with the increasing leisure time available to the population, the municipal authorities have established stadiums and sports facilities. Since 1976, the total area of stadiums and sports facilities administered by the Municipalities has increased by just under 70%. The increase in area is greatest in the municipalities with over 16,000 inhabitants. Taking parks and stadium and sports facilities together, the increase in area has generally been greatest in the municipalities west of the Great Belt Sea. Good examples of this development are Billund, Ikast and Holstebro.

Concomitantly with the more than two-fold increase in park area between 1976 and 1996, operating costs have been reduced by more than 25%, see *Figure 2.2.7*. Part of the gap between park area and operating costs can be explained by methodological improvements and rationalization of operations. Park operation has to some extent been mechanized, and the use of various chemical substances has saved on both labour and resources. Cut backs on funding have had visible effects on the appearance and quality of the parks, however. For environmental reasons, many Municipalities now want to return to managing their parks without the use of chemicals. Budget considerations often present a major barrier to reduced consumption of pesticides, however.

The appearance of the parks can also comprise an indirect barrier with respect to reducing pesticide consumption. This is because the non-chemical methods are more time-consuming and therefore make it more expensive to maintain the existing standard of maintenance. This tendency illustrates the need to prioritize in the management of green spaces.

2.2.9 **Objectives and policy measures**

Urban structure and function

Efforts are currently being made to improve the urban environment and living conditions in the towns through spatial planning at the various political and administrative levels - national, regional and municipal - as well as through various urban renewal initiatives. The Town and Country Planning Act requires that all Municipalities draw up a Municipal Plan dealing with the urban environment. The Counties' obligatory Regional Plans are also of relevance for the urban environment, especially in Greater Copenhagen. Consideration for the environment is increasingly incorporated in town and country planning. The EU Directive on Environmental Impact Assessment has been implemented in Denmark through the town and country planning legislation. Environmental impact assessment in connection with major building and construction projects is therefore undertaken as an integral part of town and county planning.

In several areas, though, it is being questioned whether the Town and Country Planning Act and the planning system are adequate. One example is the retail trade area. Thus in May 1995, the Ministry of Environment and Energy established a Retail Trade Committee to consider whether the Town and Country Planning Act and its administration are adequate for controlling the development in connection with the localization of major stores and shopping centres. The Committee published its report on 1 April 1996. As a follow-up to the report, the Minister for Environment and Energy submitted a proposal for amending the Town and Country Planning Act to Parliament.

The question also applies to continued urban spread. There is so much space available throughout the country that it is difficult to control urban development. The most recent analyses show that considerable urban spread is still taking place. Among other things, this increases dependence on the car and makes it difficult to exploit the considerable investments made in public transport - not least in the Greater Copenhagen area. The Government has therefore emphasized to the Municipalities and Counties in the Greater Copenhagen area that building in the office and service sectors has to be channelized towards locations with good public transport access (cf. the state remarks on the 1997 revision of the Regional Plans).

A special issue is that of citizen participation in planning, including the local work with Agenda 21. A local Agenda 21 is a municipal or county strategy specifying how Municipalities and citizens can jointly contribute to sustainable development. A number of the country's Municipalities and Counties have followed the Ministry of Environment and Energy's request to implement a local Agenda 21 process. In connection with the Agenda 21 work, a considerable number of projects have been initiated, among other things on urban ecology. Many of the projects concern local recycling and local cycles as these have proven to be areas where it is easiest to implement the ideas locally. In 1996, a Danish Urban Ecology Centre was established in Aarhus municipality with the task of initiating projects and disseminating knowledge.

Traffic

While the Town and Country Planning Act ensures the overall framework for the environmental endeavour in the towns, a number of initiatives have been started to improve more specific aspects of the urban environment and living conditions. One of the main problems is car traffic and the accompanying pollution and other drawbacks.

As formulated by the Government in the Traffic 2005 Action Plan, the national objectives are in part to be reached through local efforts in the municipalities and counties. Of the approx. 90 larger urban municipalities, 73 are in the process of or have drawn up a traffic and environment action plan. The plans typically contain a description of the traffic-related problems and an inventory of environmental and traffic policy objectives, the possible means and a prioritized list of measures. In many municipalities, a holistic planning system has thus been established, where traffic and the environment are incorporated into their ordinary town and country planning.

The action plans make use of a wide range of means such as the promotion of bicycle traffic and public transport, restrictions on motoring, the interplay between the various modes of transport (terminals), localization, etc.

With support from the Danish Environmental Protection Agency's Traffic and Environment Pool and the Ministry of Transport's Traffic Pool, a number of research projects have been initiated aimed at reducing traffic-related environmental problems in towns. The 1997 Government Budget includes a DKK 84 million appropriation to continue the Ministry of Transport's Traffic Pool which co-finances research and development projects pertaining to traffic. The appropriation is primarily expected to be used for initiatives in continuance of the Government's action plans on CO_2 emissions from the transport sector and on traffic safety. The Danish Environmental Protection Agency has a pool of DKK 5 million annually over the period 1996-99 to promote consideration for the environment in municipal planning.

The Government has invited the four largest urban Municipalities to enter into a dialogue on the overall traffic development in the municipalities. The purpose is to assess to what extent the present means are sufficient to attain the environmental objectives. If the dialogue indicates a need for new means - for example toll fees or other forms of payment for driving in towns, environmental zones or rationalization of freight transport (city logistics) - the Government will consider helping establish the necessary framework. Copenhagen Municipality has suggested initiating an analysis of motoring charges that could form the basis for further measures in this area.

Traffic and the associated environmental problems are examined further in *Section 3.3.*

Air pollution

Urban air pollution will decrease considerably in the future due to tightened vehicle emission requirements. As a follow-up to the Government's Action Plan to reduce CO_2 emissions from the transport sector, a number of analysis studies have been initiated on the introduction of an energy levy on public transport to strengthen the energy aspect in connection with the planning of public transport systems. A number of measures to reduce air pollution from traffic have already been implemented in the EU and Denmark. These measures will be further strengthened in the coming years. In summer 1996, the EU

Commission thus put forward the first part of the so-called auto/oil package. The proposal includes more stringent requirements to private cars and fuels with effect from the year 2000. Supplementary proposals concerning delivery vans were put forward in the beginning of 1997 and proposals concerning lorries and busses are expected to be put forward at the beginning of 1998.

The Commission's calculations show that as a result of measures already implemented (catalytic convertors, etc.), emissions of regulated pollutants (CO, HC, NO_x and particulates) will have decreased to approx. 50% of the 1990 levels by the year 2010. These calculations take into account the expected growth in traffic. If the auto/oil package is adopted in its present form, the reduction in pollutant emissions is expected to increase to approx. 70%. Even though this represents considerable reductions in pollutant emissions, the Commission's calculations show that supplementary measures will be needed in the most polluted areas (especially busy streets) in order to fulfil the expected future air quality standards within the EU.

Noise

The Government's objective is to reduce the number of strongly noise-plagued homes from 165,000 to 50,000 by the year 2010. With a view to subsequently drawing up an action plan to protect particularly noise-plagued homes located along roads, an analysis study has just been initiated to draw up criteria for prioritization of these efforts.

There are also a number of more general instruments for alleviating noise problems. These range from noise limitation of vehicles, trains and aircraft (the EU imposes emission requirements on vehicles and aircraft) to town planning (rerouting of traffic, land use, noise abatement, etc.), speed regulation and more even driving style, regulation of the amount of traffic and choice of mode of transport to the use of low-noise road surfaces and vehicle tyres, control of vehicles in use, noise screens, sound proofing and the most appropriate organization of housing.

Contaminated sites

In order to strengthen efforts to deal with soil pollution, the Government is to submit a bill to Parliament on contaminated sites in 1997-98. As a follow-up to the Waste Committee's report, the Danish Environmental Protection Agency has undertaken a major analysis and development work and a number of scientific assessments. These will result in four Guidelines and a Statutory Order that are expected to be published at the beginning of 1998.

Green spaces

The majority of urban green spaces are accessible to the public and administered by the Municipalities. Parks policy is a municipal task and with very limited state regulation. Management of the green spaces is not an obligatory task for the Municipalities and there are no requirements as to the collection and reporting of data on the area.

In the majority of larger municipalities, a special administrative unit has been established to take care of green tasks. However, the available information on operation of green spaces is highly variable, even in these municipalities. In other words, there are large differences in the way the various Municipalities manage their green spaces. The development of common reference material for municipal management of green spaces, for example in the form of key figures and tools for assessing the quality of the green spaces is therefore an obvious task for the future.

2.3 The countryside environment

2.3.1 Introduction

Denmark is among the countries with the most intensive land use. Historically, the development has taken place on three fronts:

1) Within the last century, changes in land use have primarily taken place through expansion of built-up areas, traffic infrastructure and quarries - mainly at the expense of the natural areas - and expansion of the forest area.
2) Many areas have radically changed character due to effectivization of agriculture, including drainage, conversion from extensive grazing to cultivated fields, and the enhanced use of chemical fertilizers and pesticides.
3) Increasing pressure on natural areas and the soil in the form of waste products and nutrients, atmospheric deposition, etc.

When undertaking an overall assessment of this development, it is important to take into account the interaction between ecosystems and their biological contents at several levels: Microbial life, biotopes in the landscape, and their interaction in a landscape context. The development is also of significance for the soil as a basis for cultivation. This is considered to be threatened on several fronts, among others through the removal of biomass and humus, the use of chemical fertilizer, the application of sewage sludge and increased soil erosion. The overall result has been a somewhat drastic deterioration in the quality of both nature and the environment.

Sustainable exploitation of the country is therefore extremely important in order to preserve well-functioning ecosystems in both the short and long run. Only in this way can one safeguard habitats for the many specialized plant and animal species, preserve the fertility of the soil, and enhance the recreational value of the landscape. To facilitate this, the authorities have established a number of protection schemes, behavioural restrictions and quality criteria at both the national and international levels.

2.3.2 Nature and landscape

Introduction

Denmark is situated between two bioclimatic regions, the Atlantic Region and the Continental Region. The country forms the threshold between the Baltic freshwater and brackish water basin and the salty waters of the North Sea and Atlantic Ocean. It also serves as a bottleneck on bird migratory flyways between summer foraging sites and wintering quarters. Within relatively short distances, the country encompasses highly varied landscape elements and has a changeable climate with considerable regional differences. One example is the coastal zone, where conditions vary from high salinity and strong winds at the North Sea to protected coasts and waters with low salinity in the Baltic Sea and in the inner parts of the estuarine fjords (*Figure 2.3.1*).

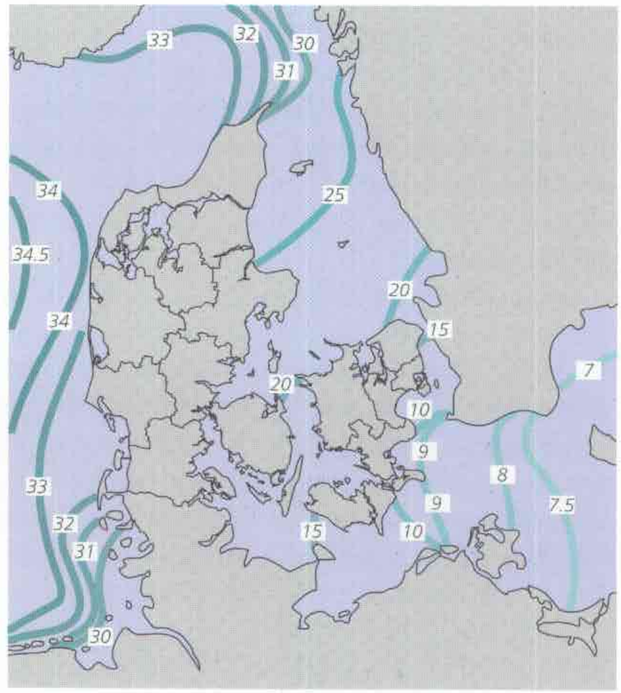


Figure 2.3.1 *Average sea water salinity (‰) (Source: Petersen and Vestergaard, 1993).*

As a consequence of these conditions, Denmark is inhabited by a great number of different species of wild plants and animals relative to its size. It has been estimated that approx. 30,000 indigenous, introduced or adventive species exist in Denmark - excluding bacteria, unicellular algae and certain lower groups of animals. This is the highest number since the last Ice Age and reflects the fact that the disappearance of species has been more than outweighed by the import of exotic species in agriculture, forestry and horticulture or passive dispersal in connection with transport.

Biodiversity

Biodiversity is the variation of life forms in our surroundings, whether those surroundings are natural or man-made. This encompasses not only the number of different species, but also the variation in the different levels of organization of which the species are a part:

1) The variation in the genetic pool within a species or population, 2) the complex of species that defines an ecosystem, 3) the ecosystems or habitats that comprise large landscape ecological units, and 4) as the uppermost level, the whole global biosphere.

It should be emphasized that the variation at all these levels is a fundamental part of and a precondition for the preservation of biodiversity. Many types of environmental changes, whether anthropogenic or natural in origin, will be to the advantage of some species but the detriment of others. Falling population size increases the vulnerability of species to environmental changes. Relatively large fluctuations in population size caused by external factors are concomitantly a natural part of population dynamics. A long-term assessment is therefore necessary in order to be able to determine whether or not a given species is advancing or declining, and whether this threatens the species' existence.

From the protection point of view, high nature quality is associated with the presence of well-functioning ecosystems. In connection with the criteria for nature quality, factors such as originality and temporal and spatial continuity play an important role. It may take an ecosystem many years, and possibly even centuries or millenniums, to attain a stable or almost stable state where the system's components are in equilibrium with one another and with external pressures.

On the other hand, changes in external pressures can rapidly throw the system out of equilibrium and destroy its natural value for an extended period or permanently. The time factor is also the reason why ecosystems most often react with considerable delay to improvements in environmental conditions. As a consequence, both positive and negative effects of nature protection projects etc. often do not become apparent until a number of years have passed.

Appraisal of biodiversity

The preservation of biodiversity can be assessed and appraised from several different points of view - economic, ecological, aesthetic and ethical.

The loss of biodiversity can be related to a number of economic factors, including man's direct exploitation of a number of species as natural resources for the production of raw materials. Living organisms can also have an indirect economic value through the provision of a number of "ecological services". Examples are maintenance of the hydrological cycle for the production of drinking water, preservation of the fertility of the soil, etc.

From the ecological point of view it is important to preserve habitats of a high quality as areas for life to exist and further develop. In contrast, the prevention of species extinction is not in itself a goal. The problem is, however the markedly increased rate with which extinction is currently occurring because this indicates a qualitative deterioration or disappearance of complete ecosystems. As species loose their habitats, their genetic variation decreases, thereby diminishing their potential to adapt and develop.

To many people, the aesthetic point of view is the one closest to heart as expressed in the correlation between the appearance of the landscape and its recreational value. This aesthetic point of view also encompasses consciousness of the presence of "beautiful" animals, for example the whales in the oceans or otters in Denmark. In contrast, most insects and reptiles do not enjoy the same favour.

Biodiversity can also be appraised from a purely ethical point of view whereby all forms of life are valued and ranked equally. Nature and all its life forms have a value in themselves that should be respected independently of mankind, and in principle without consideration to their possible significance to humanity.

This basic principle is championed by the UN Charter on Nature and the 1992 Rio Convention. Thus biodiversity cannot just be considered as a precondition for human activity or an ethical goal, but must also be seen as a product of the fact that man has been affecting the Earth for millenniums, and that the objective of a preservation strategy should therefore be the continuance of this co-evolution in a sustainable manner.

Danish landscapes, habitat types and biotopes - state and development

Since the end of the last Ice Age, the Danish landscape has developed through the interplay between natural development processes and man's exploitation of the land. In step with glacial retreat and climatic changes, wild plants and animals spread through the country and plant communities established themselves in accordance with local conditions. Herbivores gradually immigrated and helped preserve a partially open forest landscape. The introduction of domestic animals and the subsequent introduction of crop farming has gradually converted the country into a mosaic of cultivated fields around the villages, surrounded by extensively managed grazing areas, forests and other types of natural countryside.

Development in agriculture has been and still is of decisive significance for the spatial distribution and state of a number of natural habitat types and hence for conditions of life for the wild flora and fauna. Former grazing and cutting of meadows and dry grasslands and the cultivation of heaths thus created new habitats for plants and animals that are naturally associated with open areas.

The past one hundred years or so of intensified agricultural production leaves less and less room for these extensively managed types of habitat, just as naturally moist areas have been drained and small biotopes such as marl pits, ditches, hedgerows, etc. have been eliminated.

At the same time, many heaths have been planted with conifer plantations, and many naturally dynamic areas have been stabilized in order to stop drifting dunes, breaches and coastal erosion. Intensification and specialization within agriculture since the 1950s have resulted in increasing homogeneity of agricultural areas, not least in cultivated fields. This has reduced their quality as habitats for wild plants and animals. Today, many of the remaining anthropogenically conditioned semi-natural habitats are threatened by overgrowing as intensification and specialization of agricultural production makes grazing unprofitable.

The result is that large parts of the landscape have developed a mosaic structure comprised of minor areas with extensively exploited biotopes surrounded by large intensively exploited production areas, often with monocultures. Moreover, fragmentation of the landscape has diminished and isolated many habitats and reduced the value of the landscape as an ecosystem. Living organisms in the remaining habitats, especially organisms with low mobility, are not sufficiently capable of exchanging genes or recolonizing from neighbouring areas, and hence are more vulnerable to local extinction.

Agriculture and horticulture together exploit approx. 61% of the land area while forestry exploits approx. 12%. Towns, traffic infrastructure and scattered dwellings account for approx. 13%. Natural habitat types such as dunes, bogs, watercourses and lakes now only cover approx. 6% of the country. It is estimated that less than 1% - mainly in coastal and forest areas - is not directly affected by man's activities. The remaining 8% of the country is covered by extensively managed semi-natural areas (meadows, salt marshes, heaths and dry grasslands) which have developed over many years of extensive agricultural exploitation (see *Figure 2.3.2*). Both natural and semi-natural areas usually require a long time to develop a good nature quality, and in many cases, lost areas cannot be rapidly replaced through nature restoration projects, land set-aside, etc.

Figure 2.3.3 illustrates land use in the counties and in the country as a whole subdivided into three main land use classes: Farmland areas, forest areas, and natural and semi-natural areas. It can be seen that there are regional differences in the nature of the countryside. Thus the share of annual crop land relative to the other types of agricultural areas is generally larger on the island part of Denmark than in Jutland. Moreover, the forest area is clearly unevenly distributed, with an excess of conifer forest in western Jutland and on Bornholm and an excess of broadleaved and mixed forest in the remainder of the country. Heaths account for a considerable part of the natural and semi-natural areas in the counties of western Jutland and on Bornholm.

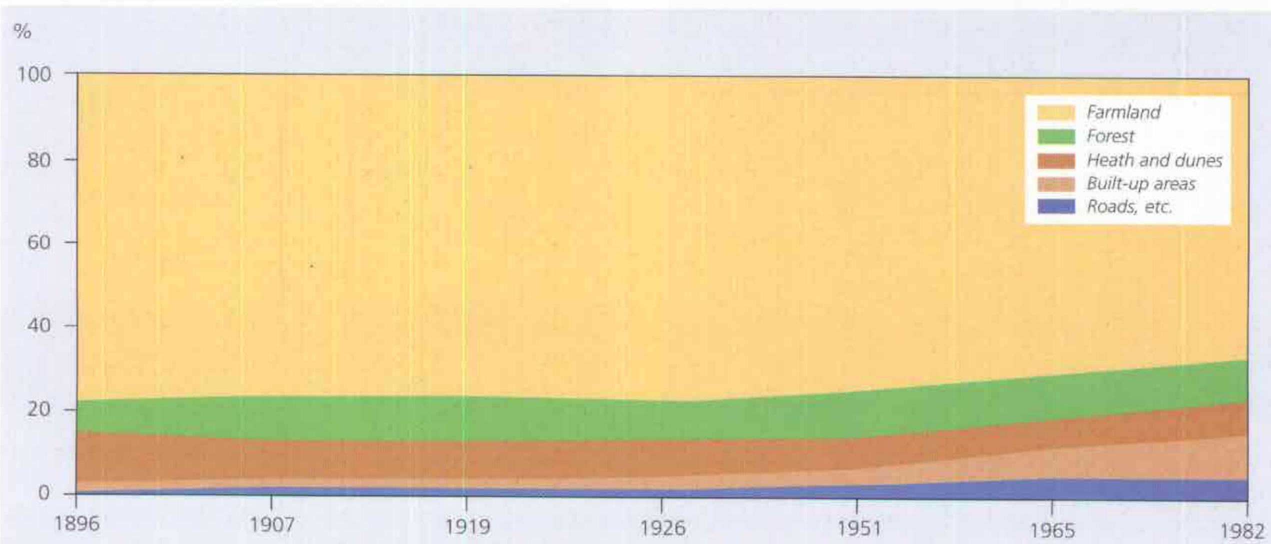
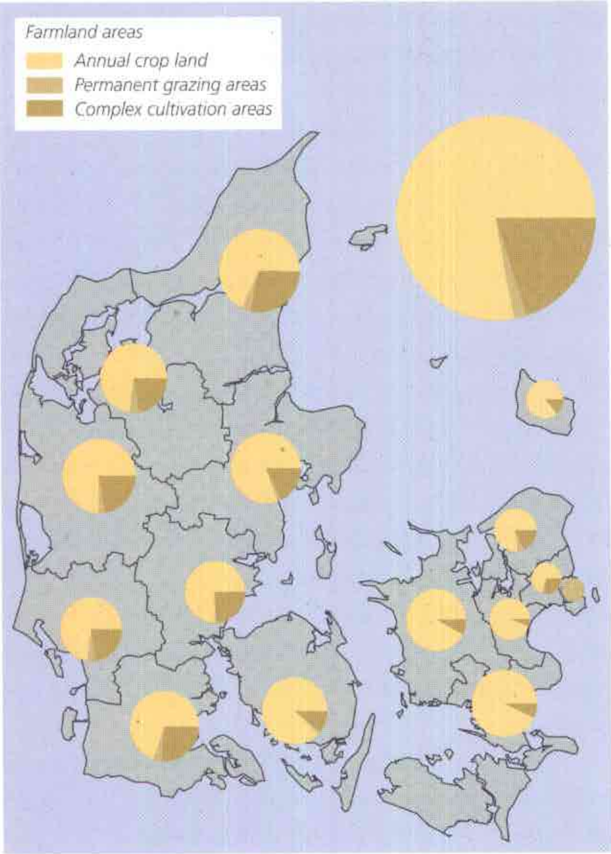


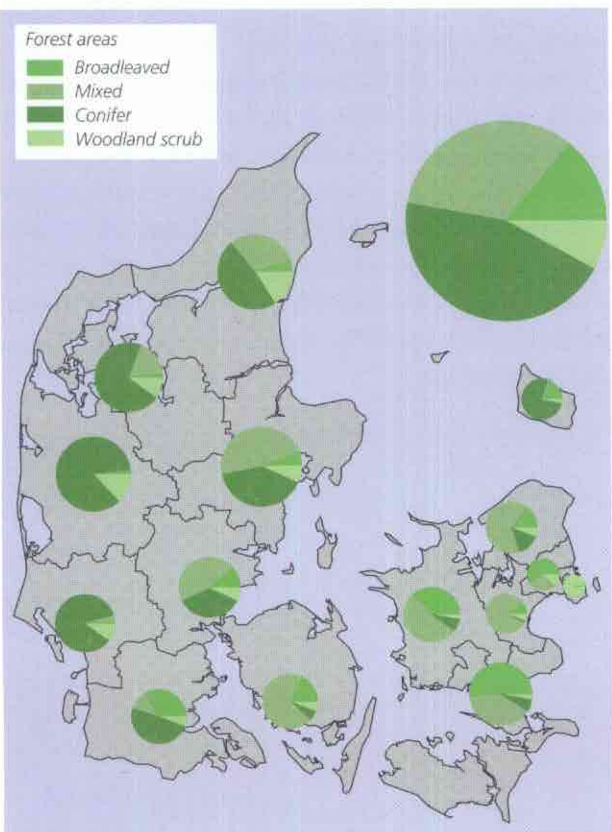
Figure 2.3.2 *Development in land use in Denmark over the period 1896 to 1982 (Source: Statistics Denmark, 1996).*



Small biotopes

Small biotopes can be defined as small areas of uncultivated countryside no greater than 2 ha in area. They can be subdivided into two main groups: The linear biotopes such as hedgerows, dykes, field boundaries, ditches, smaller watercourses with their uncultivated border zones, field tracks, roadside verges, etc., and the non-linear biotopes such as small ponds, small bogs, burial mounds, small forests, coverts (i.e. thickets or woodland providing shelter for game), marl and clay pits, etc.

The presence of small biotopes is of decisive importance to the existence of numerous wild plants and animals in arable landscape in that they also comprise reserves for the arable land flora and fauna. Moreover, together with small natural habitats, the small biotopes also serve an important function as dispersal/migration corridors or as "stepping stones". In this way they can help facilitate the spread of species between the larger contiguous natural habitats. No more than one quarter of the small biotopes are the remnants of former larger natural habitats such as small natural ponds, bogs and watercourses. The re-



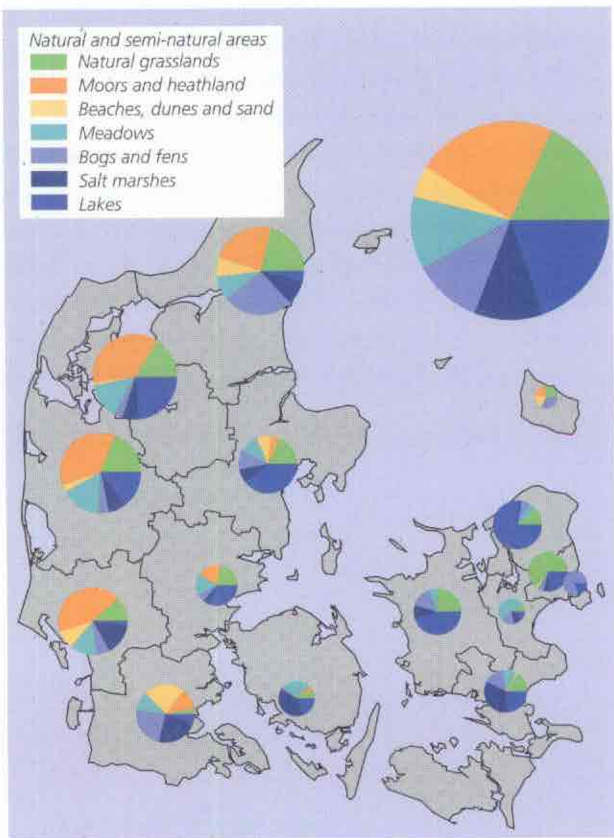


Figure 2.3.3 *Land use in the counties and in the country as a whole (upper right corners). The maps are divided into three main land use classes each showing the main tendencies in the regional distribution of land use types. The size of the pie diagrams is proportional to the total area of the land use class in the county in question, e.g. the total area of forest (note though, that the diagrams have a minimum size). The figures are derived from the CORINE land use database. This only includes areas larger than 25 ha and therefore underestimates land use types that are typically only small in size (Source: CORINE Land Cover, 1996).*

maining three quarters are the direct or indirect products of present day or former agricultural practices, including marl pits, hedgerows, field boundaries, ditches and field tracks. As a general rule, the suitability of the small biotopes as habitats increases with their age. Thus small biotopes cannot be erased and then re-established without some resultant loss of quality. A survey of the fate of the small biotopes at five selected sites on Funen and Zealand shows that in addition to a reduction in the total number of small biotopes, the number has also fluctuated considerably during the past century. As is apparent from *Figure 2.3.4*, many dykes and ditches have disappeared completely, while the remainder have been subject to considerable fluctuation. Of the 128 hedgerows which existed around 1884, virtually none have been preserved in an unchanged state. In the case of the non-linear biotopes, it is particularly the wet biotopes that have suffered, many having disappeared or changed.

Repeated studies of the small biotopes in 1986 and 1991 at 26 sites all over the country excluding western Jutland show general stabilization or slight progress.

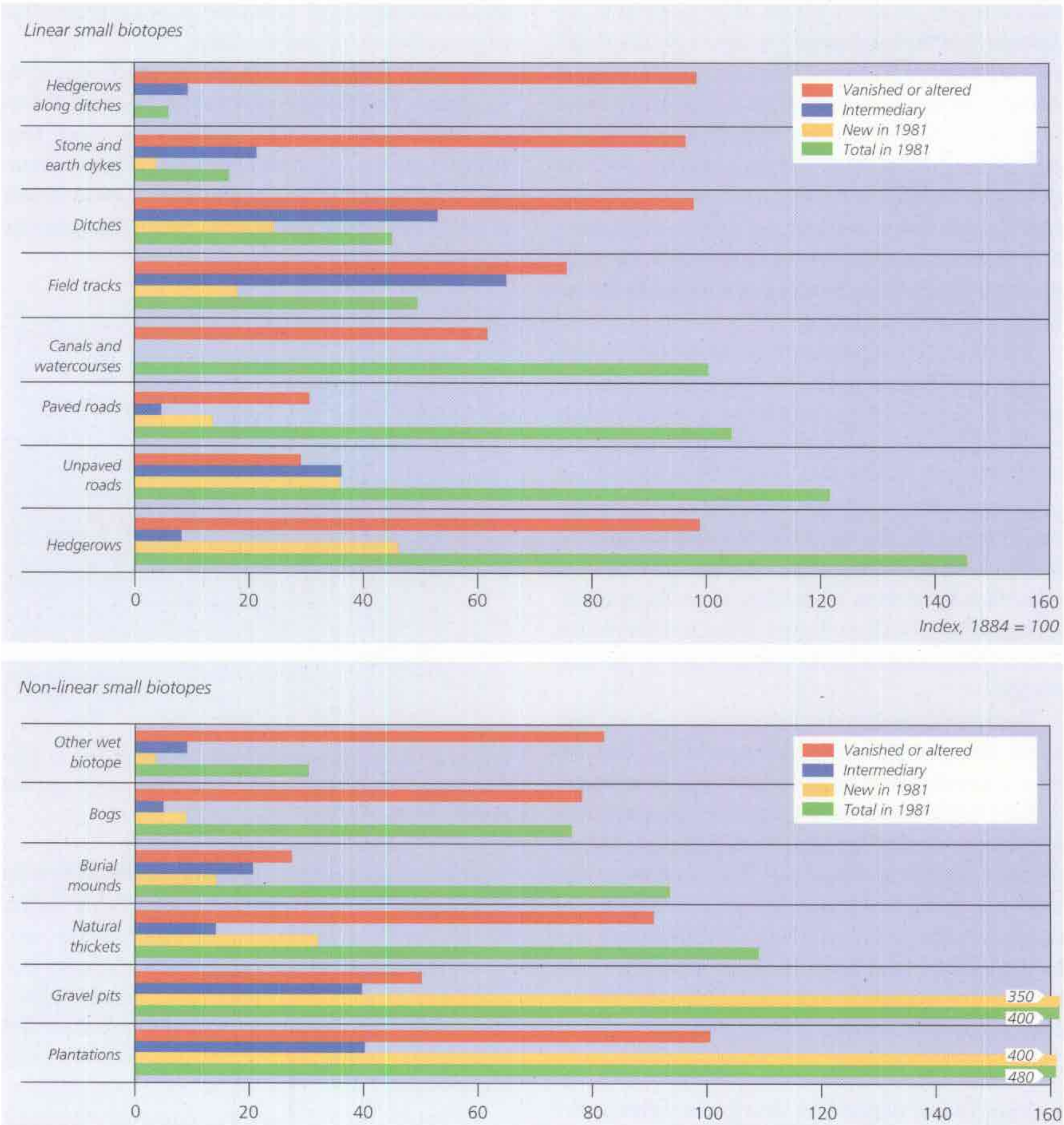


Figure 2.3.4 *Historic development in selected small linear and non-linear biotopes from around 1884 to 1981 at five selected sites on Funen and Zealand. Intermediary biotopes were only present in the intervening surveys (approx. 1907, 1939, 1954, 1968 or 1974) but could not be re-detected in 1981 (Source: Agger et al., 1986).*

A number of types of small biotype are still threatened, though, including bogs, marl pits and not least dykes, of which some have since become protected by the provisions of the Nature Protection Act. On the other hand, the dry non-linear biotopes are generally advancing, especially coverts and similar small biotopes of significance for hunting.

No comprehensive analysis of the development of small biotopes is available at the national level, but estimates have been made of how much has disappeared within the past century. Effectivization of agriculture has resulted in increasing field size through field mergers. In many places, this has been to the detriment of the small biotopes, especially the smallest and the wet biotopes. The total length of open ditches and smaller watercourses is estimated to have been reduced by 90%. Many watercourses have been culverted or channelized and their uncultivated borders have become narrower. Marl pits and similar small ponds that prevent more rational exploitation of fields have been filled in and the surrounding scrub has been felled. Three quarters of such ponds are believed to have disappeared.

Furthermore, approx. 75% of all ancient monuments have disappeared since 1853, including the destruction of approx. 80% of the burial mounds, usually in connection with cultivation of the land. Of the dry small biotopes approx. 40% of the dykes and hedgerows have disappeared in connection with field mergers. To some extent this loss has been counterbalanced by the planting of hedgerows - though often in areas other than those from where they have disappeared. Overgrowing of hitherto barren dykes and ditches has also helped counterbalance the decrease in the total number.

In step with the increased motorization, many field tracks have lost their original importance. They are now incorporated in the cultivated area, where agricultural traffic largely takes place along the same tram lines across the field surfaces. Moreover, expansion of the road network and especially of the motorway network has been accompanied by the establishment of wide roadside verges both alongside the roads and between the carriageways. These areas are often covered by dry grassland vegetation, although this has often been sown and the bushes planted.

Salt marshes, meadows, dry grasslands and heaths

Salt marshes, meadows, dry grasslands and heaths are among the most threatened habitat types in Denmark. Many of the animal and plant species that depend on these habitat types are therefore threatened or on the decline, and some of the species have already disappeared from the Danish countryside. Were it not for man's intervention in the form of grazing, cutting and burning, however, many of these sites would radically change character by becoming overgrown with bushes and trees.

The dry habitat types, dry grasslands and heaths, have experienced the greatest areal decline due to cultivation. Many of the wet habitat types have dried out, either through direct drainage, or as a result of the channelization of watercourses or the abstraction of groundwater or surface water.

In 1800, when the total area of heath was at its maximum, heathland accounted for just over 25% of the Jutland area. In 1950, however, the figure had fallen to approx. 2%. Apart from conversion to farmland, the decline is also attributable to afforestation of heathland, which accounts for much of the increase in forest area (*Figure 2.3.5*).

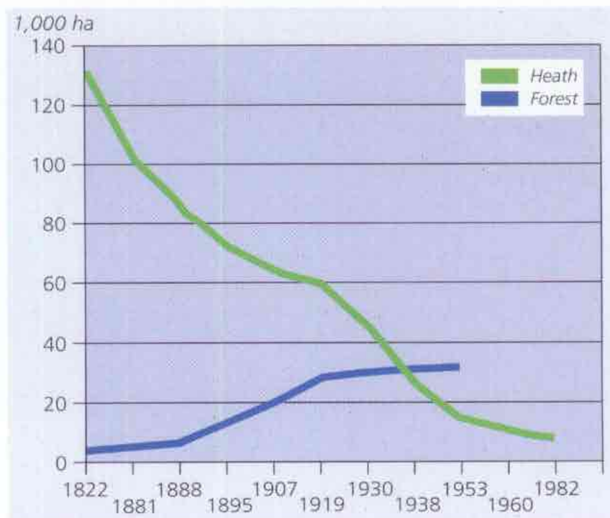


Figure 2.3.5 *Development in heath and forest area in Ribe county over the period 1822-1982 (Source: National Forest and Nature Agency, 1991a).*

On the island part of Denmark, heaths have been of little significance as a habitat type. On Bornholm, though, heaths accounted for up to 20% of the area.

In connection with the introduction of general protection provisions under the Nature Protection Act, the Counties have registered the protected habitat types bogs, meadows, dry grasslands, heaths, salt marshes and lakes (*Figure 2.3.6* and *Table 2.3.1*).

Of the dry habitat types, the heaths are mainly associated with the sandy, nutrient-poor soils, which are primarily located in western Jutland. On the nutrient-rich soils of the moraine landscape of eastern

Protected habitat types		
	Area (1,000 ha)	Area (% of Denmark)
Bogs	91	2.1
Meadows	104	2.4
Dry grasslands	26	0.6
Heaths	82	1.9
Salt marshes	44	1.0
Lakes	57	1.3
Total	*404*	*9.3*

Table 2.3.1 *Total area of habitat types protected under the Nature Protection Act (Source: National Forest and Nature Agency, 1996a).*

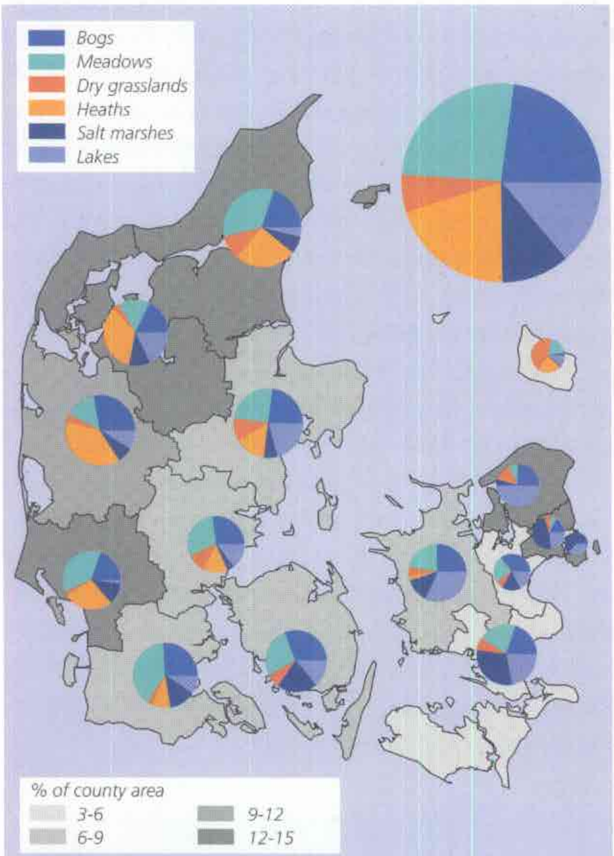


Figure 2.3.6 *Distribution of protected natural ecosystems in the individual counties (Source: National Forest and Nature Agency, 1996a).*

Jutland and the island part of Denmark, they are being replaced by dry grasslands.

The marked decrease in the total area of each of the dry habitat types has resulted in a corresponding decline in the flora and fauna associated with these areas. For example, arnica (*Arnica montana*), which is a heathland character species, has declined considerably in the eastern part of Jutland. On the island part of Denmark, the species has almost disappeared. Sites with arnica are only numerous in northern and western Jutland.

Species only rarely found in Denmark in habitats other than heathland include black grouse, golden plover, wood sandpiper, curlew, crane, short-eared owl and great grey shrike. Of these, the black grouse has either become extinct or at least almost extinct, while wood sandpiper, short-eared owl and great grey shrike have declined markedly.

The population size of the golden plover is stable, whereas curlew and crane have small populations that seem to be growing. In the case of curlew, the development in Denmark differs from that of the European population as a whole, which is declining markedly.

Freshwater wetlands

The freshwater wetlands can be divided into bogs, fens, springs, watercourses and lakes, including reed swamps, alder swamps, etc.

Raised bogs are defined as bogs that only receive water and nutrients from the atmosphere. The number of raised bogs has declined markedly in recent times, mainly because of drainage and cultivation, and because of peat extraction. Thus in 1919, there were 668 raised bogs in which all or part of the bog surface was still in a natural state and exceeded 5 ha. In 1996, however, only 21 raised bogs remained, of which 10 were larger than 5 ha in area.

In contrast to raised bogs, fens receive water and nutrients from the surrounding groundwater. Fens are usually classified as either nutrient-rich (mesotrophic) or nutrient-poor (oligotrophic) according to the amount of nutrients available. The fens have probably followed the general decline seen with the more extensively exploited habitat types, but no concrete data are available.

Springs are a vulnerable and threatened element of the intensively cultivated landscape, many having disappeared as a result of the falling groundwater level, land drainage and subsequent overgrowth. In addition, the majority of freshwater fish farms have been placed in areas with springs. The golden saxifrage and the moss *Paludella squarrosa* are character species for springs. These plant species, which are considered relics from the Ice Age, only occur in Denmark in association with summer-cool springs. The golden saxifrage is a protected species, and is included in the Danish Red Data Book (*Figure 2.3.7*).

By comparing the former and current number of registered finds of biotope character species, it is possible to estimate the reduction in the number of habi-

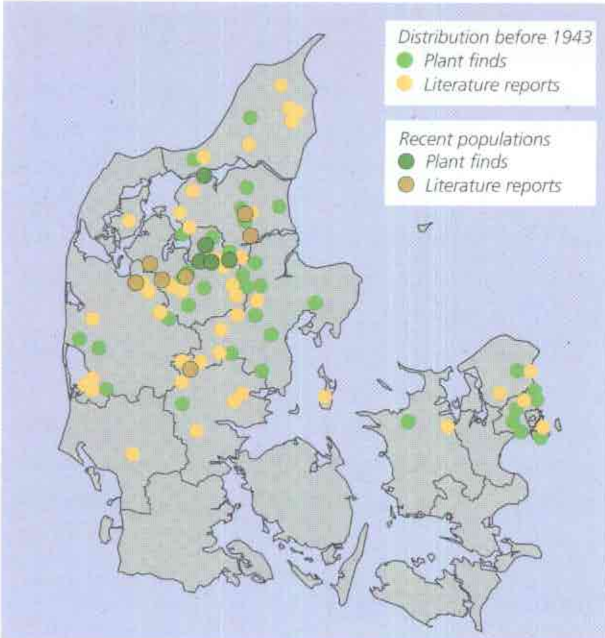


Figure 2.3.7 Distribution of the golden saxifrage prior to 1943 and at present (1988) (Source: Wind, 1988; Hansen et al.,1989).

tats. This has been done for lobelia lakes, oligotrophic (extreme poor) fens, raised bogs, mesotrophic (extreme rich) fens and paludella springs (i.e. springs characterized by the occurrence of the moss *Paludella squarrosa*) (see *Table 2.3.2*).

It is apparent that all five habitat types have declined, in some cases markedly. From the list of present threats it can be seen that despite regulatory measures to protect them, these types of vegetation are still threatened, among other things by changes in groundwater table and airborne eutrophication.

Coasts and sand dunes

Apart from the beaches, the coastal areas also encompass land areas along the coast which are mainly characterized by the effects of sea and wind. They harbour a considerable part of Denmark's remaining wild nature, where the anthropogenic effects only play a subordinate role. Salt marshes are usually dependent on grazing and have thus been discussed under the semi-natural areas.

Man's interference has also left its mark on the coastal areas. Thus 6% of the coast is currently protected by dykes or included in harbour areas. In addition, long stretches are protected from erosion by breakwaters or other structures such as stone dykes and concrete structures. About 14% of the original coast has disappeared during the latest 125 years, typically in connection with reclamation and drainage of estuarine fjords, inlets and coves for agricultural purposes. In recent years, a few of the dyked areas have been restored to wetlands, among other things in connection with nature restoration projects (*Figure 2.3.14*).

A 1994 survey revealed that dunes, including dune plantations, account for 3% of the area of Denmark. The majority of this (95%) is situated in Jutland, primarily in coastal areas with 15% being inland dunes. The decline in the dune area over the last hundred years due to planting and exploitation for recreational purposes (built-up areas/facilities) is estimated at 35%.

The vegetation of grey dunes and dune heaths encompasses many lichens adapted to the oligotrophic conditions in these dune areas. Thus even a low level of nutrient input will affect the composition of the vegetation. In recent years, damage has been observed to lichens in these areas. One cause could be the deposition of nitrogen from the atmosphere. Furthermore, sand drift prevention measures in coastal and inland dunes have stabilized most drifting dunes and breaches, which were formerly an important site for pioneer plants.

Five freshwater habitat types

Habitat type	Registered No.	Estimated reduction	Present threats
Lobelia lakes	67	20-30%	Changes in water level, recreational activities, nutrient input, acidification, overgrowing of banks
Oligotrophic fens	109	50-75%	Permanent change in groundwater table, overgrowing, eutrophication, change in agricultural practice
Raised bogs	40	90-98%	Drainage, overgrowing, airborne eutrophication
Mesotrophic fens	334	50-75%	Permanent change in groundwater table, change in agricultural practice, input of nutrients, terrain changes
Paludella springs	19	70-85%	Permanent change in groundwater table, change in agricultural practice, input of nutrients, terrain changes

Table 2.3.2 Present number, estimated reduction over 50 years, and current threats for five types of freshwater habitat (Source: Wind, 1994).

The State, the Counties and the Municipalities only pay for coast protection in the case of particularly exposed stretches. This primarily encompasses the Jutland west coast, where coast protection is undertaken in order to preserve the present coastline or bring the receding coastline under control. Attempts are being made to employ more nature-friendly coast protection methods, e.g. sand feeding, instead of hefty solid breakwaters. At the same time, higher priority is now being accorded to the preservation of a number of coastal stretches in a natural state rather than to protecting all locations where coastal disintegration and migration are taking place.

During the last few decades, the coastal areas have been subject to an increasing recreational pressure. The increased traffic causes damage to the vegetation on the dunes and dune heaths, especially around car parks, hotels, camp sites and holiday cottage districts. Wear of the dune vegetation can cause sand drift, and walking in the dunes damages the lichen vegetation.

Several birds and the common seal have their breeding sites along the coasts. During the breeding season, many of these animals are particularly vulnerable and shy when disturbed by human beings. Thus seals have largely been ousted from many of their breeding sites, even on isolated islets, and the tern and plover populations have declined. The population of the common seal has increased markedly since it was declared a protected species in the late 1970s, however, and the present population is larger than prior to the 1988 epidemic that decimated a large part of the population.

Woodland

Since the introduction of forest preservation regulations and organized forestry at the beginning of the preceding century, the forest area has increased fivefold. The organized cultivation of the areas protected as forest due to the Forest Reserve Order of 1805 naturally resulted in drainage of a considerable part of the then very widespread wetlands. Thus the majority of the wet biotopes in forests, including the small biotopes, have now disappeared. An example is illustrated in *Figure 2.3.8*, which concomitantly shows that a mosaic of wetlands has been partially preserved in this managed forest.

The main expansion of the forest area over the last 150 years has taken place through planting of the extensively exploited heath areas, especially in northern and western Jutland. Both afforestation and the cultivation of the old forest areas have been under-

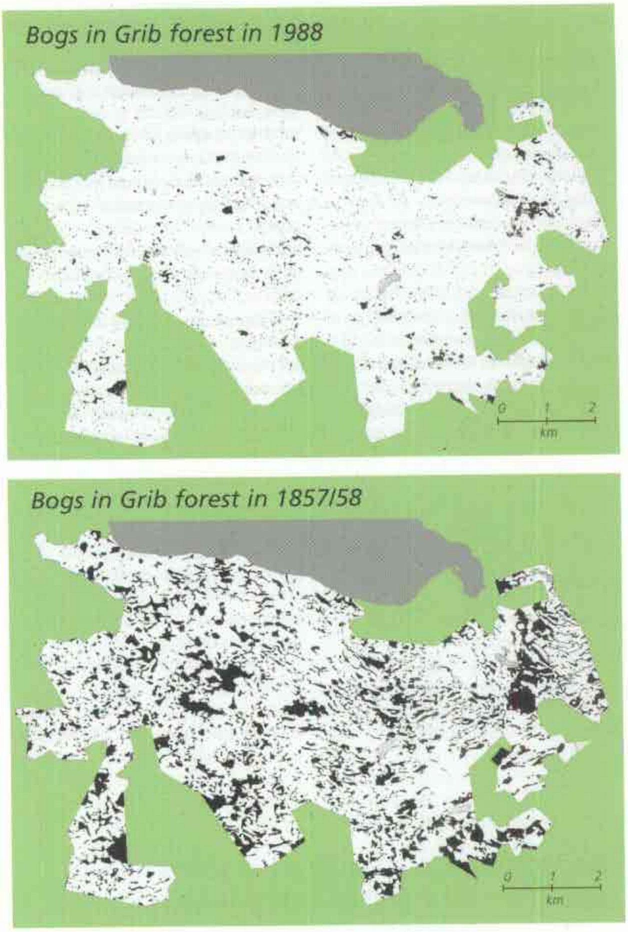


Figure 2.3.8 *Example of bog disappearance through drainage. Grib forest between 1857/58 and 1988 (Source: Petersen and Vestergaard, 1993).*

taken using selected seeds from indigenous tree species as well as from introduced species. Heath planting has hitherto mainly been undertaken using a rather limited number of tree species because of the difficult growing conditions.

In the old woodland areas, the forests are far more varied, but only small, dispersed areas exist with populations directly descended from the original forests in the area in question. It is estimated that only about 30,000 ha of such forest remain, of which 1,800 ha are located in state forests.

The productive exploitation of the forest areas over the last 200 years has changed the habitats for animals and plants, and in case of the old woodland areas, has led to a general reduction in biodiversity compared to the worn but varied landscape that then existed.

At the last forest area survey in 1990, the total area of forest in Denmark amounted to approx. 417,000 ha, which represents an increase of almost 3% since the previous forest area survey in 1976 (*Figure 3.4.20*). In relation to 1976, the total area of broadleaved forest was just over 4% greater in 1990. The area of conifer forest remained basically unchanged during that period, although it is considerably greater than at the turn of the century. There have been considerable shifts in species composition within these two types of forest, however. For example, the proportion of broadleaved forest accounted for by beech continues to decline, while oak is still advancing.

The 1990 forest area census was undertaken prior to implementation of various forest promoting measures under the Nature Protection Act and the Forestry Act. It can therefore be expected that the total forest area will increase further in coming years, and that the proportion of broadleaved forest and natural forest will grow. The State has acquired approx. 750 ha annually for afforestation since 1989, or approx. 5,500 ha in all. About 70% of the area acquired is planted, while the remaining part is preserved as a mosaic of different open biotopes such as meadows, lakes and dry grasslands. In recent years, other public authorities (i.e. Municipalities, the Ministry of Defence, parish councils, etc.) have carried out afforestation totalling around 200 ha per year.

Danish populations of wild plants and animals - state and development

Breeding birds in arable land, towns and forests

Since 1976, fluctuations have been recorded in the populations of a large number of species based on observations made throughout the country. It is difficult to distinguish between the long-term trend and the influence of short-term changes such as variable weather conditions, etc., however. Many of the smaller sedentary birds and short-distance migratory birds such as the wren and the goldcrest decline in number following a hard winter. Weather conditions during the summer can also have an effect on breeding success.

With respect to arable land, a bird index has been prepared on the basis of point counts of 7 characteristic arable land bird species (lapwing, skylark, swallow, whitethroat, linnet, corn bunting and house sparrow) (*Figure 2.3.9*). The overall trend has been a population decline over the period 1976-82, followed by relative stability and then partial improvement. From *Figure 2.3.9* it can be seen that despite a number of mild winters, the majority of the arable land character species are still below the level when the counts started. This is especially the case for sedentary birds and short-distance migratory birds, whereas the situation is largely unchanged for the birds that migrate to Africa.

The use of pesticides, expressed in terms of application frequency, has not been reduced to any great extent since the mid 1980s. This might have contributed to preventing the birds from being able to exploit the mild winters to restore populations to the 1976 level.

Some of the character species for arable land show a clear preference for certain crops. A shift from spring cereals to winter cereals since the mid 1970s might have led to the decline of some of the short-distance migratory birds over the period 1976-96. Finally, the conditions during migration and in the winter quarters also contribute to the bird population fluctuations.

Development in urban bird populations may provide an indication of how urban areas have developed. Particularly clear progress has been seen for species such as collared dove and greenfinch which

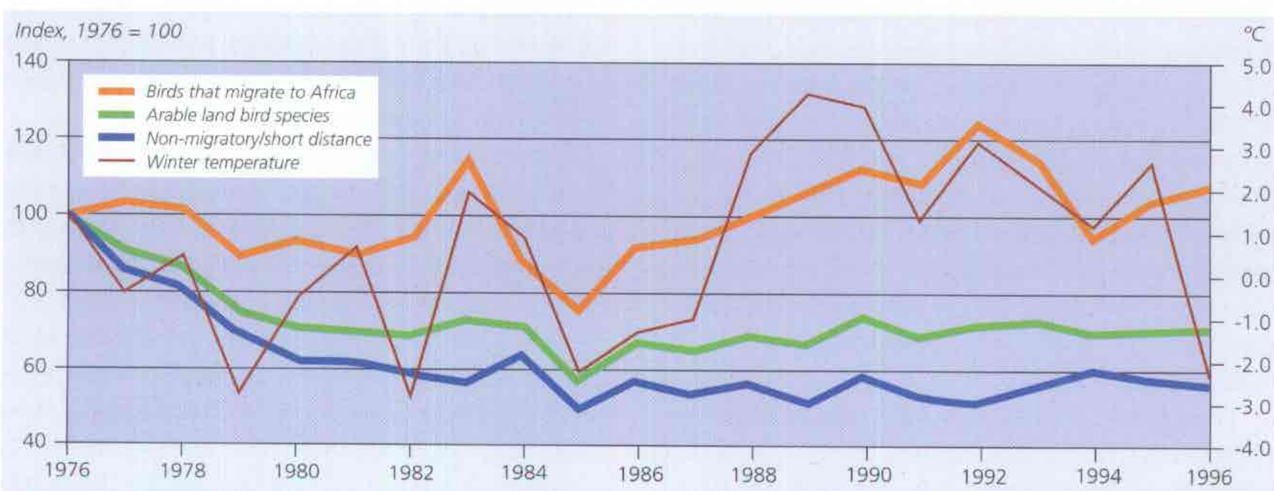


Figure 2.3.9 Bird indices for all arable land species and two types of migratory bird together with the average temperature the preceding winter (Source: Jacobsen, 1996).

nest in the more open areas of towns, e.g. parks and residential districts. It is assumed that this has to do with the development of residential districts since the 1960s, the effect being delayed because the gardens need time to grow and become good breeding sites. In contrast, decline is seen among species such as swift and house sparrow, which have their nesting sites in old buildings with eaves, holes, platforms and cornices. This is presumably attributable to urban renewal and renovation of old houses, but the increased urban pollution may also have contributed.

Forestry, choice of tree species and forest size are of considerable importance with respect to the role of forests as a habitat for wild plants and animals (*Figure 2.3.10*).

Game species

For many game species, bag records can serve as an indicator of the population trend. The percentage of the individual populations constituted by the annual bag records varies from species to species. Moreover, it will usually change over a period of years, for example because of changes in hunting seasons and hunting traditions, as well as in species abundance.

The annual bag for species such as hare and partridge has declined markedly over the past 30 years. In contrast, the roe deer population has increased markedly as reflected in the continuously increasing annual bag, the species apparently having benefited from developments in agriculture, e.g. the increased number of winter-green fields, the establishment of

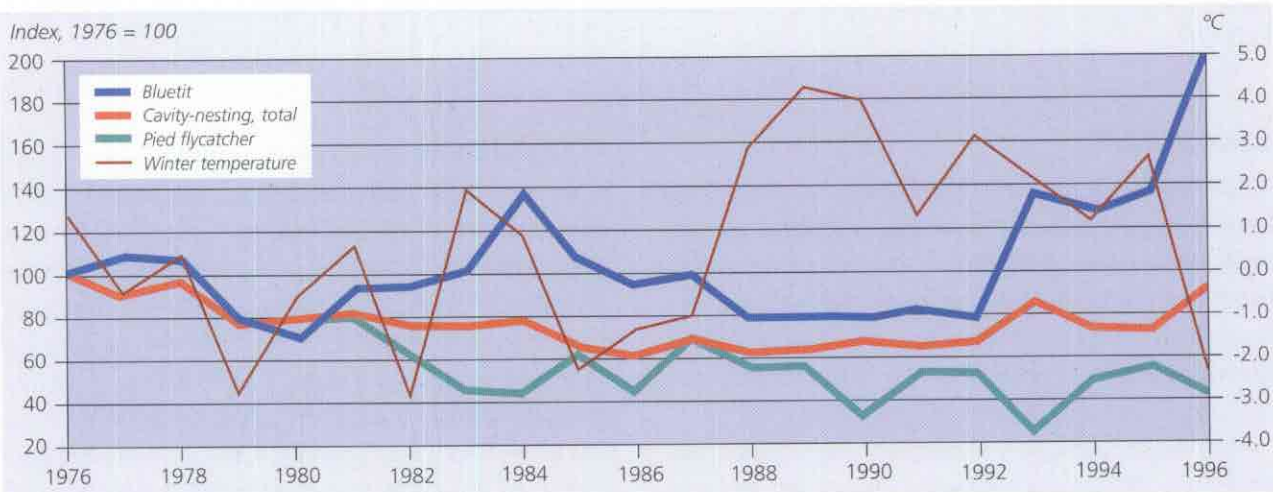


Figure 2.3.10 *Bird indices for selected species and the total population of small cavity-nesting birds in forests together with the average temperature the preceding winter (Source: Jacobsen, 1996).*

For example, the population of small cavity-nesting birds depends on such factors as the number of hollow old trees. The breeding population as a whole has declined over most of the period although this has been almost counterbalanced by a marked population increase in the last few years. With respect to birds such as the pied flycatcher that migrate to Africa, however, conditions in the winter quarters play an important role. In the case of the sedentary birds and short-distance migratory birds such as the bluetit, in contrast, conditions in Denmark such as cold winters and seed availability seem to be of more significance.

The 1992 Natural Forest Strategy aims at preserving sustainable populations and dispersal possibilities for as many of the forest's existing animal and plant species as possible. The strategy is thus expected to gradually improve the situation for the small forest birds.

plantations, etc. (*Figure 2.3.11*). The considerable increase in the roe deer annual bag over the past ten years undoubtedly reflects marked growth in wild populations.

The annual fox bag has decreased in recent years, mainly due to the skin disease mange among foxes in Jutland in the late 1980s and early 1990s. The annual bag for the 1995/96 season indicates an increase in the population, however. As regards the remaining mammalian game species, there have only been minor percentual changes in the annual bags in recent years.

Of the 45 species for which there is presently an open season, 23 have increased in population over the past two decades, 17 have remained stable and 6 have declined. In the case of the remaining 4 species, insufficient data is available to assess population development. There is no sign that hunting has a negative impact on population size, except perhaps in the case of the partridge.

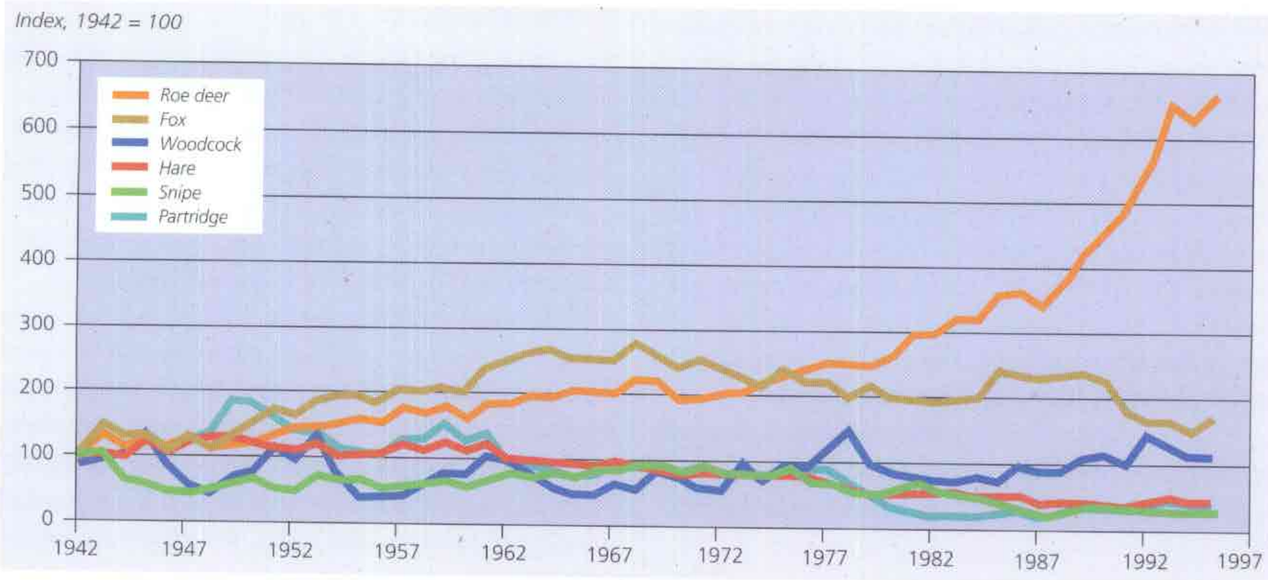


Figure 2.3.11 *Bag record for six selected game species over the period 1942-1995/96 (Source: National Environmental Research Institute).*

Aquatic birds

The most important wintering areas for waterfowl (members of the family *Anatidae*) and other aquatic birds in Northern Europe are located in Denmark. Denmark therefore has a special international responsibility to manage the birds and their habitats. Development in a representative selection of wintering aquatic birds is shown in *Figure 2.3.12*.

Northern European waterfowl populations are generally stable or increasing, however. Among other things, this is attributable to lower hunting pressure or direct preservation orders and the fact that the switch to winter cereals has in many cases ensured these species a stable winter food resource.

The northwest European populations of coot, scaup and red-breasted merganser are believed to be stable. In the mild winters of the early 1990s, the coot population in Danish waters numbered around 200,000, the population having increased markedly since the hard winters of the 1980s. Over the past couple of decades, the scaup has switched wintering grounds and almost half of the population now winters in Holland as compared with a far smaller part earlier. At the same time, the Danish winter population has more than halved from 100,000 around 1970 to 20,000-40,000 around 1990. This is a good example illustrating that population development has to be assessed in an international context.

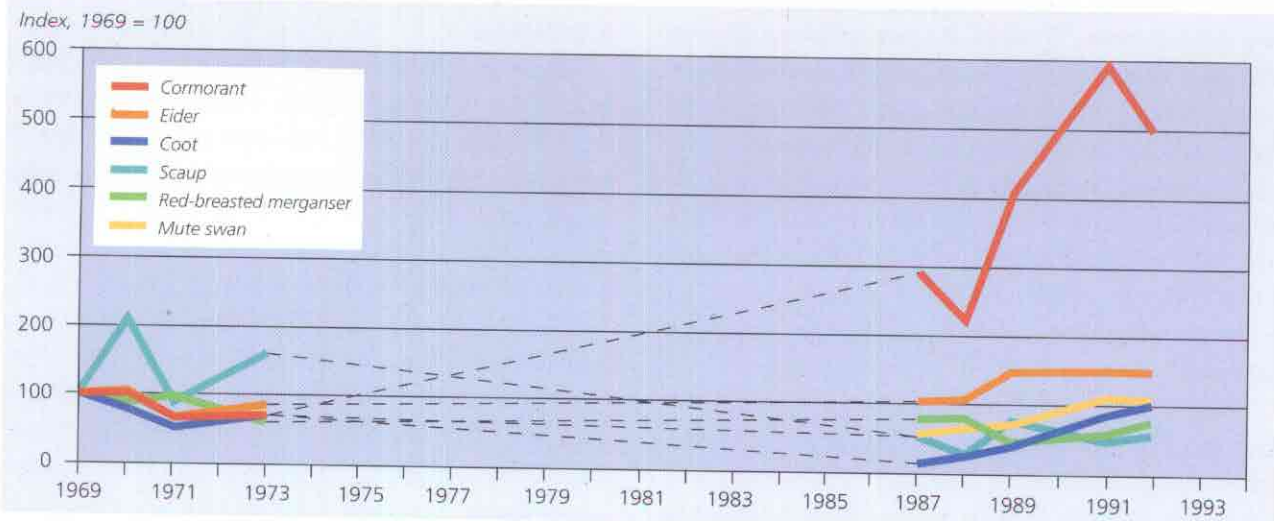


Figure 2.3.12 *Development in the population of wintering aquatic birds over the period 1969-92 (Source: National Environmental Research Institute).*

Threatened plant and animal species

Lists of plant and animal groups that are threatened in Denmark - the so-called Red Data Books *(Box 2.3.1)* - have been published regularly since 1974. Even if a species is listed as threatened in Denmark, this does not necessarily indicate that the existence of the species is threatened globally. It is apparent, though, that Red Data Books from countries that are comparable with respect to landscape, economic structure, etc. are in many ways similar, often including the same groups of species and reflecting the same types of problem. The Red Data Books therefore give an indication as to how nature conservation should be prioritized at the international level if it is also to be effective in relation to the overall distribution of the species.

The trend with respect to some of the threatened species such as the otter, the fire-bellied toad and the pyramidal orchid has been reversed, among other things thanks to the special efforts made to protect and preserve these species.

The list of threatened species is still long, however. A number of the more common species are also undergoing marked and permanent decline, five species having disappeared from Denmark during the 1980s.

Anthropogenic pressures

The most important anthropogenic pressures affecting Denmark's nature and environment are agriculture, forestry, traffic and the pressure on nature caused by outdoor recreational activities.

Agriculture and forestry

Agricultural and forestal production has been considerably intensified and modified over the last century. The trend is towards effectivization and industrialization of the agricultural production with fewer but larger farms, larger fields and larger livestock herds.

This development has markedly enhanced pressure on nature in many ways, including considerably increased use of pesticides and fertilizers, drainage of waterlogged soils, eradication of small biotopes and more recently, to the cessation of grazing of the extensively managed areas.

In the case of forestry, production economy considerations have resulted in priority being given to the development of uniform plantations of conifers. In recent years, greater emphasis has been placed on the establishment of stable forests, e.g. in the form of mixed forests and through afforestation adapted to the locality in question.

Red Data Books

Red Data Books are inventories of plant and animal species at risk of becoming or already extinct in an area. The Red Data Books are subdivided into several internationally agreed categories: Extinct, endangered, vulnerable and rare.

In addition there are two Danish Red Data Book categories for species in special need of protection:

- Species imposing special responsibility: Species where such a large part of the total world population is at some stage present in Denmark that we have a special responsibility towards them.
- Species demanding special attention: Relatively common species of which the populations are so small that they can be expected to become vulnerable in the near future if the negative factors currently affecting them are allowed to continue, as well as common species whose populations are declining markedly in Denmark.

In 1986 and 1991, combined lists were published covering most existing plant and animal groups. The latest Red Data Book from 1991 encompasses 3,176 species in need of protection. This corresponds to 34% of the species in the plant and animal groups in question. Of these, 456 are classified as endangered, 880 as vulnerable and 1,146 as rare. The other species classified as being in need of protection are not at immediate risk of extinction, but are assessed as imposing special responsibility or demanding attention in an international context. A total of 353 species have become extinct in Denmark since 1850.

Box 2.3.1 *Brief description of the Red Data Book concept.*

Traffic

Every year, thousands of large and small animals are killed on the Danish roads and railways. There seems to be a connection between the number of animals killed by traffic and the increasing traffic density and construction of new traffic infrastructure.

In general, the animal species killed on roads are mainly those with a high population density near roads. With certain species, however, traffic deaths seem to be of great significance for population size. This applies for example to the otter and a number of frog and toad species as their ranges often cross roads, etc.

The length of the public road network and the development in road traffic give a good indication of the increasing fragmentation of the landscape. The road network encompassed 65,663 km in 1975 and 71,255 km in 1995, an increase of 9%. During the same period, the motorway network, which comprises the widest roads, increased by 127%.

The length of the railway network has not changed very much, however, but the speed of the trains has increased. Road traffic has undergone a similar development. Over the period 1985-88, road traffic has increased by approx. 5% a year. Since then growth has fallen off somewhat and except in 1993 has been around 3-4%.

Larger roads and railways may constitute direct physical barriers which reduce the population density of the animals and their possibilities to move freely in the landscape to breed and find hiding places. In some cases, traffic infrastructure can isolate local populations completely and prevent contact between the individual animals, especially when they cut through larger, previously coherent areas of countryside.

Outdoor recreation and tourism

Changed patterns of leisure time and improved means of transport, together with an increase in tourism have led to an increased level of outdoor activities. This has in turn increased pressure on wild plants and animals in the form of increased wear on the vegetation and disturbance of the animals.

Membership of the various outdoor and sports organizations is generally increasing, and so too therefore is the use of nature. In contrast, the number of people with hunting licences has stabilized around 170,000-175,000 during the past ten years. Outdoor recreation and tourism are examined more closely in *Section 3.8*.

Objectives and policy measures

International conventions and directives

The 1992 United Nations Conference on Environment and Development in Rio de Janeiro saw the signing of both the Convention on Biological Diversity and the Agenda 21 global action plan. Denmark ratified the Convention on Biological Diversity in December 1993. In order to comply with Article 6 of the Convention and to follow up on Agenda 21, the Government has prepared a status report and strategy for biodiversity in Denmark.

According to the Ramsar Convention on the Protection of Wetlands, 27 areas have been designated in Denmark together encompassing 740,000 ha. Under the EC Bird Directive, the objective of which is to protect a number of threatened or vulnerable bird species, 111 areas have been designated together encompassing approx. 980,000 ha, including the 27 Ramsar areas (*Figure 2.3.13*).

Among other things, the EU Habitat Directive aims at specific protection of habitats for a number of threatened species and sites with threatened habitat types. Member States are committed to designating conservation areas for these, and the Government has put forward a proposal as to which Danish areas should be accorded special protection. This encompasses 175 areas covering a total of approx. 1,100,000

Figure 2.3.13 *Map of Ramsar sites and EC bird protection sites (Source: National Forest and Nature Agency,1996b).*

ha, of which 31% are terrestrial. The Danish areas to be included in the joint European network of nature reserves, NATURA 2000, include all the Ramsar areas and EC Bird Protection areas, as well as the areas to be designated pursuant to the EU Habitat Directive.

In the special preservation areas, the necessary measures have to be implemented to ensure the maintenance of a favourable preservation status for the various habitat types and protected species. If monitoring reveals a negative tendency, management plans have to be drawn up.

Based on a number of criteria, lists have been prepared of the habitat types and species to be protected. While some of these habitat types are threatened or rare, many are habitat types considered to be characteristic and clear examples from the biogeographical region in question. The designated species are either threatened, rare or endemic (i.e. they only occur locally). In many cases they are character species serving as good examples of the biogeographical region in question, and hence are usually good indicators of habitat types worth preserving.

Under the Bern Convention, Denmark is obliged to protect wild plants and animals and their natural habitats. The 1991 Statutory Order on the conservation of reptiles, amphibians, invertebrates and plants is a step in the fulfilment of these obligations.

Through the Washington Convention and associated EU regulations, threatened species are protected in the form of restrictions or bans on trade. The Convention is mainly aimed at trade in tropical species, but encompasses several Danish plant and animal groups, e.g. orchids, tuberous and bulbous plants and birds of prey.

Under the Bonn Convention on Migratory Species, signatory countries are obliged to protect those species most in need of protection. The Convention is based on international agreements, usually dealing with one or a few animal species or groups. Denmark participates in agreements on the protection of seals in the Wadden Sea, of bats in Europe and of small whales in the North Sea and the Baltic Sea. An agreement on the protection of aquatic birds which migrate between Europe/Asia and Africa has been signed and is about to be ratified.

National Acts and regulations

Several national Acts lay down regulatory instruments to regulate exploitation of the country's natural resources. Among others these include:

The Nature Protection Act

Under the Nature Protection Act, a number of habitat types are provided general protection assuming they exceed a certain size, see *Table 2.3.3*. The rules on protected habitat types are administered restrictively and to a high degree have had the intended effect.

Semi-natural habitat types may "grow out of" the general protection provided by the Nature Protection Act if they are left ungrazed or unmowed, thereby allowing them to become overgrown with scrub and later forest. The opposite can also happen. Thus uncultivated agricultural areas can "grow into" the general protection of the Act. In such cases, intervention in the form of resumed extensive management or nature management may be imposed.

The Nature Protection Act also includes the necessary instruments to protect nature in the open countryside and in the forests through the protection of specific areas. In this connection, regulations can

Development in regulatory protection of habitat types

Habitat type	1972	1978	1984	1992
Lakes	All natural	All >0.10 ha	All >0.05 ha	All >0.01 ha
Watercourses	Public	Public + private	Public + private	Pu. + pr. + 2 m borders
Bogs	-	>0.50 ha	>0.50 ha	>0.25 ha
Salt marshes and swamps	-		>3 ha	>0.25 ha
Heaths	-		>5 ha	>0.25 ha
Meadows and dry grasslands	-			>0.25 ha
Stone and earth dykes	-		-	All

Table 2.3.3 *Development in regulatory protection of habitat types and small biotopes from 1972 to 1992 under the Nature Conservation Act (now the Nature Protection Act) (Hedgerows, field boundaries, ditches, thickets and small plantations are not protected).*

be imposed regarding administration of the area in question with the aim of preserving or improving the qualities on which the protection decision was based. In 1996 alone, 2,990 ha of land were designated as protected areas bringing the total protected area up to 197,345 ha, or approx. 4.5% of the country.

The provisions of the Nature Protection Act regarding the beach protection zone and the sand dune protection zone (along most of the Jutland west coast) entail a general ban on altering the state of coastal stretches in the form of building, planting, establishment of hedges, etc. The actual protection zone encompasses the land area up to 300 metres inland from the start of congruent land vegetation. The Town and Country Planning Act includes regulations concerning a 3 km wide coastal protection zone to provide general protection against the establishment of new areas for urban, holiday and recreational purposes and for technical facilities and to reduce the need for coastal protection and the reclamation of land from the sea.

Denmark has approx. 40,000 kilometres of watercourse, of which approx. 28,000 kilometres fall under the general protection of the Nature Protection Act following designation by the county authorities and approval by the Minister for Environment and Energy. In addition, lakes larger than 3 ha are protected by a 150 m wide lake protection zone reaching inland from the lake bank. Within this zone, building and alteration of the terrain is prohibited without the express permission of the county council.

The Game Act

The management of wild mammals and birds is primarily undertaken pursuant to the Game Act. The purpose of this Act is to ensure diverse and numerous game populations and to provide the basis for sustainable administration of the populations. Among other things, this takes place through special protection of game in the breeding season, through regulation of hunting and through the establishment of game reserves.

In Denmark, 92 reserves have been established with a combined total area of 276,000 ha. Of this, almost 248,000 ha are located in Danish marine waters and 28,000 ha on land. In 1993, it was decided to designate approx. 50 Danish game reserves as hunting- and disturbance-free areas before the year 2000. Those will mainly be located in Danish coastal EC Bird Protection areas in order to provide the aquatic birds with better possibilities to rest and forage (see *Figure 2.3.13*).

Figure 2.3.14 *Summary of wetlands restored over the period 1989-96 (Source: National Forest and Nature Agency).*

Town and Country Planning Act

Since the mid 1970s, town and country planning has been an important instrument with which to safeguard not only the aesthetic qualities of the landscape, but also the conditions of life for the plants and animals inhabiting the countryside. Land use is partly regulated through the Town and Country Planning Act and town and country planning - in particular building and construction activities and to some extent afforestation.

Biological interests are incorporated into town and country planning at two levels: generally, in the form of regulations and guidelines for the subsequent planning and administration, and specifically, in the form of local plans and zoning permits in connection with projects or authorizations issued under other legislation, and which are required to harmonize with town and country planning, e.g. inland extraction of minerals. As an instrument of nature protection, the value of town and country planning derives from its broad geographical coverage and the possibilities to incorporate nature interests at an early stage in decisions on building and construction, etc.

Under the Town and Country Planning Act, county councils have to designate quality objectives for watercourses in the Regional Plans. Quality objectives have been designated for approx. 24,000 km of watercourse, of which 1,500 km are designated as areas of special scientific interest and 17,000 km have been designated as fish waters. Eased quality objectives have been designated for the remaining 5,500 km of watercourse.

Watercourse Act

A 1992 amendment of the Watercourse Act prohibits cultivation and physical changes in a two-metre wide border zone alongside rural lakes and watercourses of natural origin and those designated with the highest quality objectives (fish waters and areas of special scientific interest) in the Regional Plans.

Forestry Act

The Forestry Act ensures that areas protected as forest are to remain as forest. The Ministry of Environment and Energy estimates that approx. 90% of the forest area in Denmark is protected forest. The Act also contains provisions on the protection of other types of habitat. Thus lakes, watercourses, bogs, meadows, salt marshes and swamps, heaths and dry grasslands situated in protected forest must not be cultivated, drained, planted or changed in any other way irrespective of their size. There are also regulations on the preservation of oak coppices and forest edges of broadleaved trees and bushes. In addition, the Forestry Act provides for the subsidy of afforestation and "good, diversified forestry".

Inland Fisheries and Marine Fisheries Acts

Regulation of fishery and the protection of fish populations, crustaceans and molluscs takes place through the Inland Fisheries Act, the Marine Fisheries Act and the EU fisheries regulations. For each fish species, minimum sizes, fishing seasons and quotas are stipulated. Among other things, catches are limited through regulations on ships and the nature and use of fishing equipment.

In particular to protect migratory fish such as salmon and trout, restrictions have been imposed on the use of nets in streams and in front of stream mouths, along the coast, and on trawling in coastal waters and certain sections of the open marine waters. Similarly, crustacean fishery is regulated in the Wadden Sea and Limfjorden.

Natural Forest Strategy

The short-term objective of the Natural Forest Strategy is to ensure the existence of at least 5,000 ha of virgin forest by the year 2000, of which 1,500 ha are privately owned. In addition, traditional forestry management are to be ensured on at least 4,000 ha (coppice forest, grazing forest and selective felling).

Research is to be initiated specifically aimed at the preservation of forest biodiversity and the provision of more fundamental knowledge on forest ecosystems and their dynamics and development.

In the longer term, the aim is to ensure the existence by the year 2040 of at least 40,000 ha of virgin forest and forest managed using traditional forestry practices, to designate areas that can be left to become overgrown naturally and thereby help enhance the area of natural forest, and to establish better possibilities for the dispersal of threatened forest plants and animals.

Nature restoration and nature management

Over the period 1989-95, state nature management funds have provided for the re-establishment and maintenance of more than 11,000 ha of lakes, heaths, meadows, forests and recreational areas. Between 1989 and 1996, the State acquired 12,542 ha, of which 6,634 ha are for nature purposes, especially the restoration of lakes, watercourses, bogs and meadows, and 5,459 ha are for afforestation.

The natural areas under the jurisdiction of the Ministry of Environment and Energy (the protected habitat types watercourses, lakes, heaths, bogs, meadows, salt marshes, dry grasslands and dykes) amounted to 50,260 ha in 1996. An analysis from 1993 shows that about 2/3 of this total was regularly maintained and that by far the majority of the sensitive habitat types such as meadows and dry grasslands were managed.

By far the majority of the protected habitats are privately owned, however, and their preservation is in many cases dependent on the owner continuing to operate them.

2.3.3 The terrestrial environment

Introduction

As described above, the land in Denmark is very intensively exploited. A number of valuable functions and properties are associated with the terrestrial environment in that the soil:

- Is a habitat for numerous animals and plants
- Is the basis for much of our food and raw materials production.
- Is the physical basis for many of our activities and contains many cultural relics.
- Functions as a natural filter and transport medium for many substances.
- Possesses a natural buffering capacity (i.e. ability to counteract chemical changes).
- Forms the framework for a number of important storage and transformation processes.

Sustainable exploitation of the soil as a resource is therefore extremely important in order to be able to maintain the quality of the soil in both the short and long terms. In assessing the quality of the soil it is important to bear in mind the context in which the assessment is made. Thus the characteristics that are important with respect to the soil's suitability as a building site or as a source of raw materials are not necessarily those that render it suitable as a habitat for animals and plants.

Similarly, it is important to emphasize that high environmental quality is not necessarily synonymous with great biodiversity since nutrient-poor areas with a low biodiversity, e.g. heaths, can justifiably be characterized as environmentally and culturally valuable.

Numerous factors currently affect the quality of the soil. These encompass both natural processes and processes directly or indirectly related to human activities in the countryside and in towns. Irrespective of what criteria are focused on in connection with soil quality it is often difficult to define and quantify a change in the quality of the soil.

Some of the anthropogenic factors that influence the soil's properties and quality are described below focusing on the soil as a suitable cultivation medium for crops and as a habitat for animals and plants.

Environmentally hazardous substances

Some of the chemical substances used in Denmark and elsewhere in Europe will end up in the terrestrial environment, e.g. through atmospheric deposition or the application of pesticides, fertilizers and waste products to agricultural areas. As a result of the binding properties of the soil, the substances may accumulate over the years. Even though binding to the soil means that the substances do not pose any appreciable immediate risk to the environment, a shift in soil conditions - for example as a result of land use changes - could eventually change the availability and toxicity of these substances. By way of example, the set-aside and subsequent afforestation of arable land formerly treated with lime will eventually affect the chemical condition of the soil. General acidification of the terrestrial environment, for instance as a result of the above mentioned change in land use, could lead to enhanced release of accumulated heavy metals, as for example has been seen for mercury in Sweden.

Soil quality criteria

Heavy metals and other environmentally hazardous substances may exist in concentrations that are toxic to plants, animals and man, and affect processes important for the turnover and mineralization of nutrients and organic matter in the soil. The environmental authorities have therefore stipulated various soil quality criteria for soil media in order to protect the environment. These criteria have different objectives and hence are administered differently. Thus the human toxicological soil quality criteria have been drawn up with a view to protecting man, with children generally being viewed as being the most vulnerable. Direct exposure to the chemical substances may occur through skin contact or the consumption of contaminated soil or groundwater or crops cultivated in the soil. The criteria are primarily used in risk assessment in connection with remediation of contaminated sites.

The corresponding ecotoxicological soil quality criteria have been drawn up with a view to protecting the most sensitive species in an ecosystem from adverse effects of chemical substances. Hence they are an expression of the highest concentrations in the terrestrial environment at which no adverse effects can be expected on microorganisms, plants and invertebrates, even in the most sensitive ecosystems. The quality criteria do not take land use into account and hence cannot immediately be used to assess remediation needs and preventative measures. The criteria stipulated in the Statutory Order on sewage sludge ensure that sludge is not applied to soils where the metals could pose a long-term risk to crops or to human beings via the crops.

The existing soil quality criteria for heavy metals are summarized in *Table 2.3.4*. In addition to these criteria, there are also toxicological and ecotoxicological soil quality criteria for a number of organic substances, e.g. chlorophenols, chlorobenzenes, detergents, PAHs, phthalates, etc.

Heavy metals in Danish soils

In 1996, the National Environmental Research Institute published the results of the first major Danish gridnet survey of the heavy metals content of Danish soils. Soil samples from approx. 400 Danish natural, forest and agricultural soils were collected and analysed over the period 1993-95 in order to map the background level of heavy metals in Denmark. Urban areas and contaminated sites are not included in the survey as these areas constitute a completely different problem. The primary results are presented in *Table 2.3.5*.

In general, there is very great geographic variation in the heavy metals content, with the highest concentrations being found in the clayey and humic soils. Thus for most heavy metals, the clay content and heavy metals content are strongly related. The reason for the lower heavy metals content found in soils from natural ecosystems is partly that as agriculture and forestry are very intensive in Denmark, natural ecosystems such as heath, marsh etc. are primarily found in the sandy and less fertile soils. An example of the geographic distribution of heavy metals in Denmark is given for chromium in *Figure 2.3.15*.

The study did not reveal any increased level of heavy metals in arable fields treated with sewage sludge. Similarly, there was no correlation between heavy metals content and the use of commercial fertilizer and livestock manure, population density or atmospheric deposition.

Soil quality criteria for heavy metals

Metal	Toxicological soil quality criteria (mg/kg)	Sewage sludge soil quality criteria (mg/kg)	Ecotoxicological soil quality criteria (mg/kg)
Arsenic	20	20	10
Cadmium	0.5	0.5	0.3
Copper	500	40	30
Chromium (III)	500	30	50
Chromium (VI)	20	-	2
Lead	40	40	50
Mercury	1	0.5	0.1
Molybdenum	5	-	2
Nickel	30	15	10
Selenium	-	-	1
Silver	-	-	0.5
Thallium	-	-	0.5
Tin (inorganic)	-	-	20
Zinc	500	100	100

Table 2.3.4 *Soil quality criteria for heavy metals in Denmark. The criteria for sewage are those stipulated in the Statutory Order on the application of waste products for agricultural purposes. "-" indicates that no limit value has been stipulated (Source: Nielsen et al., 1995; Jensen and Folker-Hansen, 1995; Jensen et al., 1997; Ministry of Environment and Energy, 1996).*

Heavy metals content of Danish soils								
	Arsenic	Cad-mium	Chromium	Copper	Lead	Mer-cury	Nickel	Zinc
5 % fractile	0.9	0.036	2.7	0.8	4.5	< 0.01	0.9	5.8
Median (*n*=393)	**3.3**	**0.16**	**9.9**	**7.0**	**11.3**	**0.04**	**5.0**	**26.8**
95 % fractile	8.4	0.45	30.4	15.9	19.2	0.12	15.1	59.7
Sandy soils (*n*= 226)	2.6	0.13	6.4	5.6	10.5	0.03	2.9	18.4
Clayey soils (*n*=167)	4.1	0.22	17.1	9.0	12.1	0.05	9.6	43.3
Arable soils (*n*=311)	3.6	0.18	10.7	7.8	11.3	0.04	5.7	29.1
Forest soils (*n*=68)	2.3	0.09	7.0	2.8	12.1	0.04	2.9	18.9
Natural soils (*n*=14)	1.3	0.07	3.8	0.9	8.7	0.01	1.5	7.7
% soils with conc.>SQC								
Sandy soils	-	3.1	0	0	0.4	4.0	1.3	0
Clayey soils	-	25.0	1.8	1.2	1.8	16.0	42.0	1.2

Table 2.3.5 *Heavy metals content in Danish natural, forest and arable soils together with the percentage of soils having a heavy metals content exceeding the Danish ecotoxicological soil quality criteria (SQC). The content is expressed as the median values (i.e. the concentration that 50% of the samples lay below) in mg/kg soil, n = number of analysed samples in each soil category. The fractiles indicate the concentrations that 5% and 95%, respectively, of the samples lay below (Source: Jensen et al., 1996; Larsen et al., 1996).*

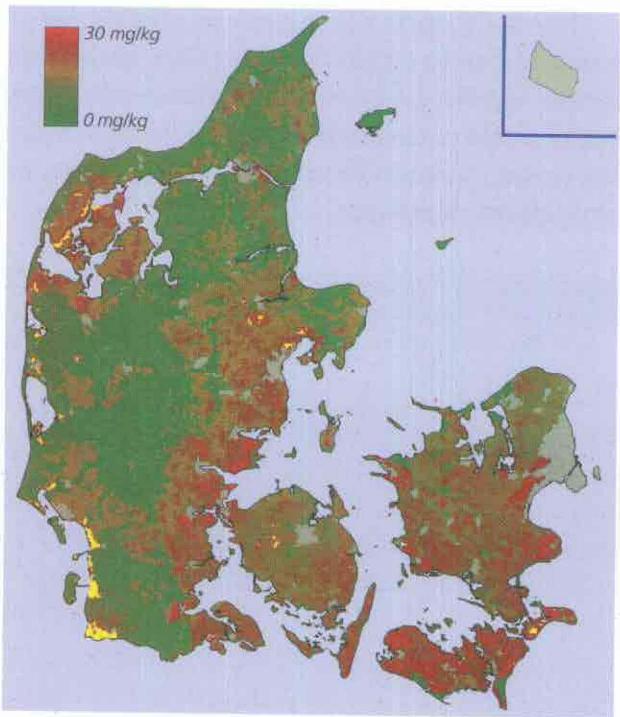


Figure 2.3.15 *Geographic distribution of chromium in Denmark. As the chromium content is highly dependent on soil type, the geographic distribution of chromium follows the soil type distribution in Denmark, with the lowest concentrations in the sandy soils of Jutland. More than 5% of the analysed samples (indicated in yellow) contained more chromium than the limit value of 30 mg/kg stipulated in the Statutory Order on the application of waste products for agricultural purposes. These samples are evenly distributed over the whole country and are mainly the result of naturally high levels of chromium in the soil. Corrected for soil type, the chromium content is thus higher in natural areas than in agricultural soils (Source: Larsen et al., 1996).*

By comparing the concentrations in the individual soil samples with the recommended ecotoxicological soil quality criteria, it is possible (on a very rough basis) to estimate the potential ecological risk caused by heavy metals. However, as the toxicity of the individual heavy metals more depends on the available fraction than on the total amount, as well as on possible adaptation of the organisms to naturally high metal concentrations, such comparisons must be made with reservation.

Major exceedences of the ecotoxicological soil quality criteria and those stipulated in the Statutory Order on sewage sludge have been observed for cadmium, chromium, mercury and nickel. By far the majority of these exceedences occur in clayey soils. Compared to sandy soils, these generally have a greater binding capacity and a higher natural content of heavy metals. Thus the heavy metals will typically be less available for organisms and hence will probably pose a lower risk to animals and plants.

Sources of soil inputs of heavy metals and other environmentally hazardous substances

A number of measures have been implemented in Denmark over the last couple of decades to reduce consumption of and pollution by heavy metals and other environmentally hazardous substances. Despite these efforts, heavy metals and many of the persistent organic pollutants will still end up in the terrestrial environment via a number of different sources. If one excludes the special problems that arise in connection with contaminated industrial sites and landfills, etc., the main sources of pollution of the terrestrial environment are atmospheric deposition and the application of commercial fertilizer, sewage sludge, compost and livestock manure.

The main cause of the enhanced lead concentrations found in many soils is the former use of leaded petrol and lead shot for hunting. Total loading of the soil with lead derived from these sources amounted to 700-800 tonnes per year in 1990.

The main sources of cadmium input to the soil are atmospheric deposition (4.7 tonnes per year) and the application of commercial phosphate fertilizers (2.6 tonnes per year). Total input to the soil amounts to 8.6 tonnes per year (1993). Regulation of cadmium emissions from industry and the cadmium content of commercial fertilizers has reduced the rate at which the cadmium content of the soil is increasing from 0.8% per year to 0.3%.

The main source of mercury input to the soil is long-range transboundary transport (approx. 0.5 tonne per year). Total Danish inputs of mercury to the soil are estimated to be approx. 200-300 kg per year, with sewage sludge being the most important source.

In the majority of cases, present annual inputs of heavy metals to farmland correspond to only a minor fraction of the current heavy metals content of the top soil. Possible exceptions are the input of copper and zinc in sewage and livestock manure. As a result of the use of copper for such purposes as growth promoters in pigs, the average annual input of copper to agricultural soils via livestock manure now corresponds to approx. 3% of the current top soil copper content.

Livestock manure is also the most important source of nickel input to the soil, with commercial fertilizer and agricultural limestone comprising two less important sources.

In general, there is nothing to indicate that the current concentrations of heavy metals in Danish soils comprise a major problem for plants and animals. Nevertheless, there are areas in the vicinity of former landfills and particularly polluting enterprises where there can be reasons for concern, and there can be areas in the countryside where the soil quality criteria for chromium, mercury and nickel are exceeded. The greatest potential risk is associated with those soils in which current input of heavy metals exceeds total removal and where the concentrations therefore increase.

Despite efficient treatment of sewage sludge in modern sewage treatment works, the sludge contains residues of the majority of the chemical substances used by industry and households in a modern society. Of the organic chemicals in sludge, the large amounts of detergents and phthalates are of particular concern. In order to ensure the continued safe use of sewage sludge as fertilizer, limit levels for the application of these substances and PAHs in sewage sludge have therefore been stipulated in the new Statutory Order on the application of waste products for agricultural purposes from 1996.

Preliminary studies indicate that livestock manure may contain low amounts of environmentally hazardous substances. For example, liquid manure has been found to contain organic pollutants such as nonylphenol, LAS and DEHP. However, the concentrations are generally lower than those in compost and sludge from treatment plants receiving mainly household sewage. The concentration of chlorinated and polyaromatic compounds (PCBs, PAHs, dioxins, etc.) is generally very low.

In addition to a number of environmentally hazardous substances, various pharmaceuticals have also been detected in sewage sludge and livestock manure. Pharmaceuticals used in private homes and in hospitals can end up in sewage treatment works via sewage. Depending of the degradation potential, they can then be discharged via effluent or accumulated in the sludge and hence applied to the agricultural land. Little is presently known about the occurrence of pharmaceuticals in sewage effluent and sludge, or the possible environmental effects of these often highly biologically active substances. The same applies to the large amounts of antibiotics used in agriculture as growth promoters or to combat disease in livestock, and which are dispersed into the environment through the application of livestock manure to fields.

Intensive agricultural production

In the long run, the intensive exploitation of the agricultural areas in many industrialized countries will affect the quality of the soil and hence its fertility. This is because the soil treatment methods, choice of crops, cultivation and fertilization etc. can change the basic characteristics of the soil such as its physical structure and chemical properties, among others, its content of carbon and nutrients. Thus both the development of the soil carbon pool and the effects of soil compaction and erosion supposedly constitute a growing problem in many Danish agricultural areas.

For the same reasons, these problems are also relevant in an assessment of the quality of the soil and are therefore included in the present section, even though an exact estimation of the extent of the problems is not possible at the present time.

Organic matter and soil quality

The organic matter in the soil consists of breakdown products from animals, plants and microorganisms. As the organic matter mainly functions as the primary food source for degrading organisms, it has a direct effect on the abundance, composition and activity of the soil's microorganisms and invertebrates. Factors such as the microbial activity and number of earthworms in turn have a direct influence on growth conditions for plants in that the former ensures the release of nutrients and the latter enhance the porosity of the soil. In addition, the organic matter considerably influences the soil's physical and chemical properties - among other things its ability to transport air, water and nutrients, and its buffering and binding capacity.

In ecosystems in natural and semi-natural areas, the majority of the organic matter produced will be turned over within the ecosystems. In agricultural ecosystems, in contrast, harvesting and the removal of crops deplete the ecosystem of both organic matter and nutrients. Without compensation for the removed nutrients through the application of commercial fertilizer and livestock manure the productivity of the agricultural areas would therefore decline markedly.

Compensation for loss from the organic matter pool does not have the same dramatic effect on the agricultural ecosystems, however, and it is not presently possible to determine the optimal organic matter content of the individual soil types. It is nevertheless uncertain whether it would be possible to maintain the fertility of the soil in a long perspective without the input of organic matter.

Experimental studies have thus shown increased yield of both root crops and cereals following many years of application of organic matter (*Table 2.3.6*). The difference was greatest when little or no nitrogen was applied in the form of commercial fertilizer, however.

There is considerable uncertainty as to the trend in the carbon content of Danish agricultural soils, and to what extent a further fall would reduce the fertility of the soil. Long-term experiments at Askov research station indicate that the carbon content of Danish agricultural soils has generally been falling over the last 100 years (*Figure 2.3.16*), among other things as a result of dilution caused by deep ploughing.

If the carbon content is to be increased over a period of a few years, it will be necessary to apply considerable amounts of organic matter. This can be done in many ways.

The application of livestock manure and sewage sludge is an obvious possibility. However, the amount of livestock manure and sewage sludge is insufficient to fertilize all the agricultural land in Denmark. Moreover, as indicated above, there can be other problems associated with for example the application of sewage sludge.

Effect of nitrogen input on crop yield

		Nitrogen input			
Crop	Fertilizer type	0	L	M	H
		Yield tonnes/ha			
Potatoes	LM	24.20	38.40	44.00	44.00
	PK	11.60	21.50	29.90	36.20
Suger beet	LM	27.40	43.50	48.60	49.60
	PK	15.80	27.00	39.00	45.60
Barley	LM	4.18	5.40	5.16	5.08
	PK	1.85	3.74	4.83	4.92
Wheat	LM	2.44	3.73	3.92	3.79
	PK	1.46	2.97	3.53	4.12

Table 2.3.6 *Yield in tonnes per ha for potatoes, sugar beet, barley and wheat following more than 100 years of fertilization with livestock manure (LM) compared to commercial fertilizer (PK). The amounts of nitrogen applied in kg/ha are zero (0), 72 (L), 144 (M) and 216 (H) for potatoes and sugar beet, and zero (0), 48 (L), 96 (M) and 144 (H) for barley and wheat (Source: Christensen and Johnston, 1997).*

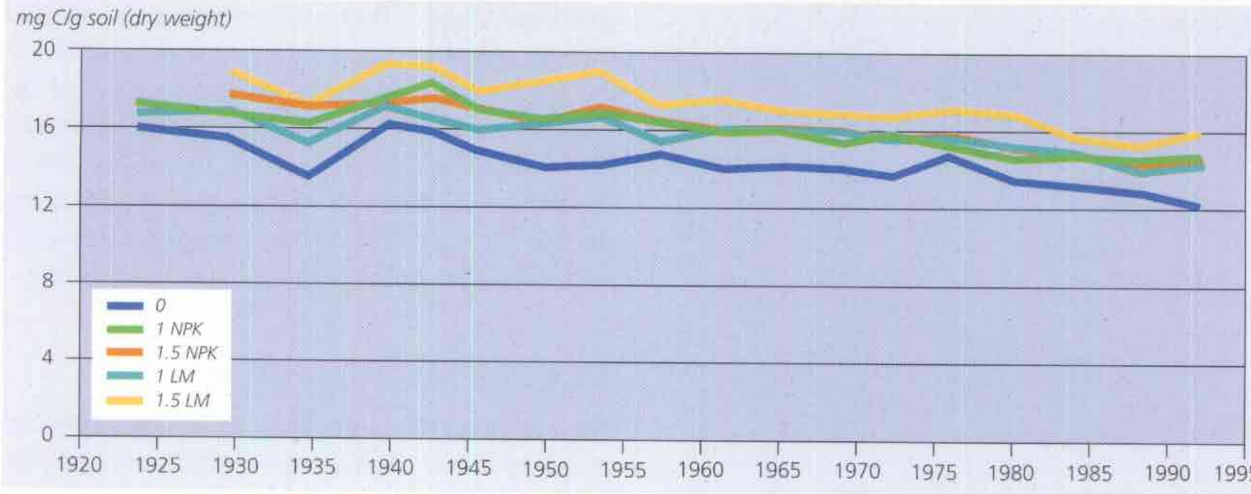


Figure 2.3.16 *Carbon content in clayey soil at Askov research station. The treatments were: No fertilizer (0), and commercial fertilizer (NPK) or livestock manure (LM) in the doses 1 and 1.5 (Source: Christensen and Johnston, 1997).*
Note: The doses have not remained constant over the 70-year period studied. The normal application rates (dose 1) were 41-98 kg N/ha annually, 13-19 kg P/ha annually and 29-87 kg K/ha annually.

It can therefore be prudent to plough down straw in order to hinder further reduction in the carbon content of the soil as this has been shown to increase its carbon content in the long run.

In general, changes in the total carbon content of the soil will first occur after many years of ploughing down the straw. Moreover, the effect will be greatest on clayey soils which already have a low carbon content.

The apparent decline in the carbon pool observed over the last 100 years together with the beneficial effects of the ploughing down of straw on the carbon content of the soil has led to discussion of the desirability of increasing the use of straw for energy purposes. In contrast, the cultivation of biofuel crops such as elephant grass and willow could help enhance the carbon content of the soil and hence its fertility.

Soil compaction, erosion and quality

The structure of the soil develops slowly in the original geological materials under the influence of climatic processes such as drought, rain and frost and through the input of organic matter. A good soil structure is an important precondition for a fertile soil. Compaction of the soil's structural elements and particles reduces its pore volume, which among other things is important for aeration of the soil.

Compaction also reduces the transport of water (the so-called hydraulic conductivity). Moreover, a compacted soil provides poorer living conditions for plants and soil animals. Among other reasons, this is because periods of water saturation and anoxic conditions can considerably prolong the degradation time of pesticides and other environmentally hazardous substances. This does not apply to nitrate, though, where increased degradation through denitrification can be expected to take place under anoxic conditions.

The main cause of soil compaction is the use of increasingly larger agricultural machinery throughout the period of mechanization of agriculture practice.

It has been shown that the soil is compacted 2-3 times annually by the wide back wheels of a tractor. Much of this traffic takes place during periods of the year when the soil is wet, and hence easy to compact. Even though a certain degree of compaction can be necessary after ploughing to optimize growing conditions for the future crops, the driving of heavy machines causes such marked compaction of the topsoil that crop yield is reduced (*Figure 2.3.17*).

Experiments have shown that annual traffic with normal harvesters and transporters can reduce yield by up to 20% depending on the type of soil. The greatest effect is generally seen in clayey soils. Studies have also shown that compaction generally reduces the number of earthworms in the soil.

Very heavy or repeated traffic can compact the soil so much in the deeper, unworked soil strata (30-100 cm) as to result in the formation of a so-called plough-pan - a compact layer immediately below the plough depth.

Such compaction has proven to persist for many years. Thus even in areas with repeated periods of hard frost, compaction effects have been detected up to 10 years after heavy machinery has been driven

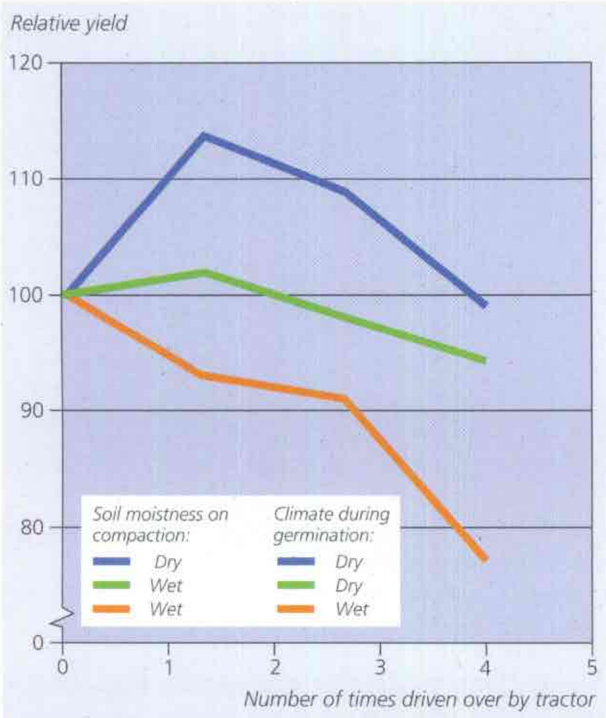


Figure 2.3.17 The significance of soil compaction for yield of spring barley under different soil moistness and climatic conditions. Field experiments on clayey soil (Source: Rasmussen, 1976; Schjønning and Rasmussen, 1994).

over the soil. In addition to the direct effects on crop yield and soil animals, the formation of a plough-pan also enhances the risk of soil erosion. This is because the reduced hydraulic conductivity of the soil increases water runoff from the soil surface itself. Soil particles can thereby be removed in large quantities and create furrows and fissures which can trigger landslides - with considerable resultant loss of organic matter and nutrients.

Wind erosion can also comprise a considerable problem on certain Danish soils. Wind erosion can thus be a significant factor for plant growth conditions on sandy soils with a loose, dry and fine particle composition.

As wind is the driving force, erosion is more widespread in windblown areas that lack or are insufficiently protected by hedgerows, e.g. the sandy soils of western and northern Jutland. The loss of seed grain and the dispersal of pathogenic organisms is another cost of wind erosion. By prolonging the period of plant cover and increasing the carbon content of the soil, the risk of wind erosion can be reduced markedly.

No nationwide data are available that clarify the extent, development and significance of soil compaction and erosion in Denmark. However, the available Danish studies indicate that soil compaction is a real problem in many Danish agricultural soils, and that the use of increasingly larger machines for an increasing number of operations has augmented the problem over the last many years. Greater awareness of the problem and a reduction in the number of operations together with the use of twin wheels, bogie axles or triple axles, and low-pressure tyres could help reduce the extent of the damage in the future.

Objectives and policy measures

For a more general description of the environmental measures aimed at environmentally hazardous substances, the reader is referred to *Section 2.5*. In addition to the above mentioned soil quality criteria (*Table 2.3.4*), the Danish authorities have stipulated limit values for the cadmium content of commercial fertilizers and for the content of cadmium, lead, chromium, copper, mercury, nickel, zinc and certain environmentally hazardous substances in waste products used for agricultural purposes. At both the national and international levels only few initiatives have focused on preventing damage caused by loss of the soil's organic pools or compaction caused by traffic with heavy agricultural machinery. The burning of field stubble is prohibited by Statutory Order. There are no regulations concerning the ploughing down of straw, however.

Internationally, limit values for the sewage sludge content of the seven above mentioned heavy metals have been implemented in the EU through a 1986 Council Directive. Without specifically aiming at the terrestrial environment, the international marine conventions such as OSPARCOM, HELCOM and the forthcoming UN-ECE protocols (on long-range transboundary air pollution) attempt to limit the use and emissions of certain heavy metals and persistent organic pollutants.

2.4 The aquatic environment

2.4.1 Introduction

The water in nature is constantly in circulation. Evaporation takes place from the sea, lakes and the land. The water vapour subsequently forms precipitation and falls as rain or snow. Part of the precipitation that falls on the land evaporates again. The part that does not evaporate is called the net precipitation. The net precipitation either flows to the watercourses as surface runoff, especially through drains, or percolates further down into the ground and forms groundwater. The majority of the groundwater will flow out into the bottom of lakes and watercourses and will flow out to the sea via the watercourses.

Total net precipitation in Denmark amounts to approx. 12,000 million m^3 annually. There is considerable variation in the magnitude of net precipitation from year to year and from region to region. In general, net precipitation is greatest in the western part of the country and least in the eastern part (*Figure 2.4.1*).

Aquatic environment problems

The environmental pressures associated with water can generally be related to three factors:

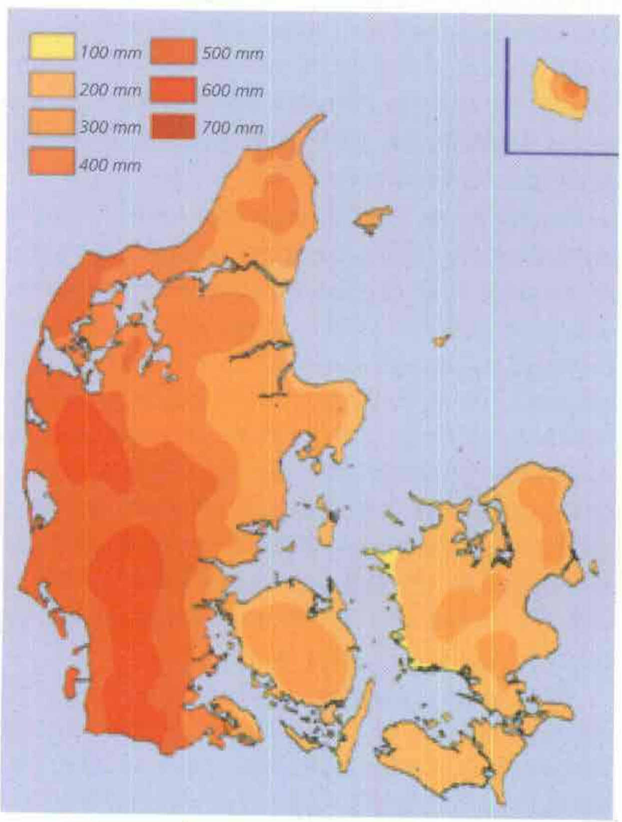


Figure 2.4.1 *Average net precipitation in Denmark during the period 1961-90 (Source: Skop, 1995).*

- High level of water abstraction
- Discharge of pollutants
- Physical destruction of water bodies (e.g. channelization of watercourses and large marine construction projects).

Water abstraction

In areas where large amounts of water are abstracted, the level of abstraction can exceed the natural level of water formation, the groundwater table can sink, and water flow in the watercourses can almost cease, especially during the summer.

In addition, lowering of the groundwater table can lead to the release of harmful substances into the water, and salt water can infiltrate up into and pollute the groundwater resources.

Discharge of pollutants

The aquatic environment can be polluted with substances that render the water unsuitable for use as drinking water or destroy ecological conditions for animals and plants. Many human activities result in the discharge of pollutants to the aquatic environment.

- During the present century, the urban population has increased from around 40% of the population to more than 80%. At the same time, sewerage systems have been constructed and industrial production and household consumption have increased markedly. This has resulted in very large amounts of waste water and hence of pollutants. With our effective sewerage systems, this waste water is now led directly out into the water bodies. In the old days, the amount of waste water was much lower and a large part was discharged to land and retained there. Nowadays, the amount of waste water has increased markedly. Waste water treatment removes much of the pollutants, however.
- The structure of agriculture has also changed and its efficiency has been markedly improved. The most important change in agricultural practice is the markedly increased use of fertilizer and pesticides. In the last 35 years, fertilizer consumption in agriculture has almost doubled, thereby resulting in a marked increase in nutrient leaching.
- Substances are present in our landfills and contaminated sites that might percolate down to the groundwater and render it unsuitable as drinking water.

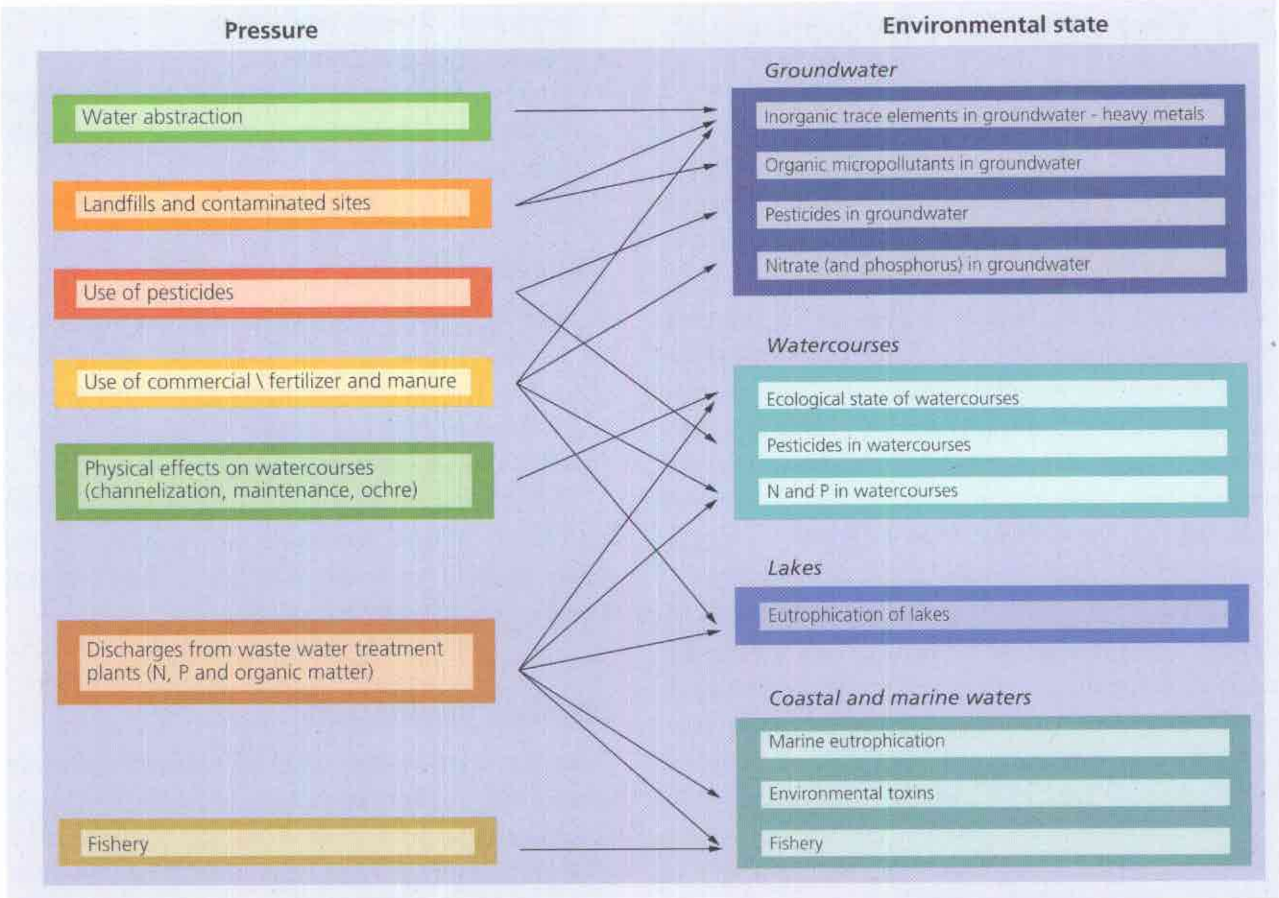


Figure 2.4.2 Pressures affecting the environmental state of the aquatic environment.

Physical destruction of water bodies

Much of the agricultural land is now drained, the majority of the watercourses are channelized and many of our bogs, ponds and lakes have disappeared. All of these are activities that have affected ecological conditions for a number of the animals and plants associated with our watercourses and lakes. In the marine waters, extraction of marine aggregates (e.g. gravel, sand, boulders, etc.) and major construction projects (the fixed links across the Great Belt and Øresund) exert a marked temporary pressure on the environment in limited areas.

The following sections examine the environmental problems facing the groundwater and the environmental state of the watercourses, lakes and coastal and marine areas. The final section describes the quality objectives and the measures taken by society to reduce environmental problems related to the aquatic environment.

2.4.2 **Groundwater**

Until 1950, virtually all the groundwater in Denmark was of a quality suitable for use as drinking water following simple treatment in the waterworks. The quality of groundwater generally depends on the quality of the precipitation, on land use, on the substances input from industry, agriculture, forestry, towns, landfills, etc., and on variation in the movement of the groundwater table.

Groundwater constitutes a main source of water input to watercourses, lakes and coastal waters, and at the same time can itself be formed from watercourses and lakes. Water for the public supply in Denmark is almost solely (99%) abstracted from groundwater at the approx. 3,000 public or private waterworks. The iron and manganese content of the water abstracted for drinking has always posed a problem, but this has been solved by oxygenating and filtering the groundwater. Expansion of water abstraction by the waterworks has led to problems with the infiltration of sea water into the aquifers in coastal areas, e.g. in Køge Bight.

The increasing use of commercial fertilizer and livestock manure in agriculture led to groundwater pollution that started to become apparent at the end of the 1960s. The actual extent of nitrate pollution did not become clear until the groundwater monitoring programme was established at the end of the 1980s, however. Phosphorus leaching to the groundwater from agricultural land is normally negligible. At present, the focus is on charting pesticide pollution of the groundwater.

Nitrate in the groundwater

The major source of groundwater nitrate pollution is leaching from agricultural land.

The concentration of nitrate in the water leaving the root zone varies depending on crop rotation and fertilization practice, as well as soil and weather conditions. When nitrogen fertilization levels are high, nitrate leaching is generally also high. Leaching from crop holdings is less than from livestock holdings, where nitrate leaching increases with livestock density. Beneath the root zone, it is the composition of the soil layers that determines whether the nitrate content of the water is reduced.

Nitrate leaching from agriculture

The nitrate content of the very uppermost part of the groundwater is measured at six agricultural monitoring catchments. As is apparent from *Figure 2.4.3*, the mean nitrate concentration is greater in the sandy areas than in the clayey areas. In the groundwater below the root zone, major climatic and cultivational changes are rapidly reflected as a change in the nitrate content. In 1992, the early part of the summer was very dry and crop growth therefore poor leading to a further nitrogen excess, this probably being the reason for the enhanced nitrate content in 1992 and 1993 (*Figure 2.4.3*).

Whether the positive development in the nitrate level in 1994 and 1995 is due to improved agricultural practice or the high level of precipitation in 1994 cannot be determined at present. A statistical analysis of 111 borehole filters (one borehole can have several filters at different depths) in the agricultural monitoring catchments during the period 1990-95 shows that the nitrate content had fallen significantly in 25 filters, increased in 11 filters and remained stable in 75 filters.

Aquifer nitrate content

Analysis of the primary groundwater aquifers used for water abstraction in the groundwater monitoring areas revealed that the nitrate content exceeded 1 mg/l in 38% of cases. The average content in these samples was approximately 40 mg/l.

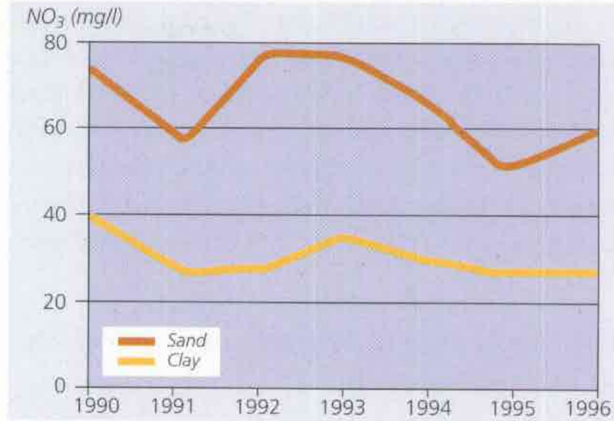


Figure 2.4.3 *Concentration of nitrate in subsurface groundwater (1.5-5 m depth) in clayey and sandy areas in the agricultural monitoring catchments (Source: Geological Survey of Denmark and Greenland, 1997).*

Statistical analysis of the groundwater monitoring areas for the period 1990-96 reveals that the nitrate content had fallen in 52 filters, increased in 83 filters and remained unchanged in 161 filters.

As is apparent from *Figure 2.4.4*, the nitrate content in the primary groundwater aquifers remained roughly constant over the period 1990-96. The figures conceal considerable variation, however.

Location of the nitrate zone

When nitrate percolates down through the soil it becomes reduced. In the deep groundwater, the nitrate content is zero. The location of the nitrate zone in the groundwater aquifers is highly dependent on the composition and rate of nitrate leaching from the cover bed, and of the character of the water table - unconfined or confined. Under moraine clay, the nitrate zone generally reaches from 2-15 m below ground level.

Figure 2.4.4 *Development in the concentration of nitrate in the primary groundwater aquifers with concentrations exceeding 1 mg/l, showing the median values and variation in nitrate content in mg/l. It is the primary aquifers that are used for water abstraction by the water works (Source: Geological Survey of Denmark and Greenland, 1997).*

In areas with a sandy cover bed (e.g. western Jutland), the nitrate zone generally reaches down to a depth of 20-30 m below ground level. In some places under both clayey and sandy cover beds, however, increased nitrate content has been detected down to 50-60 m below ground level. On Bornholm, the nitrate zone reaches down to 30 m below ground level.

Development in the nitrate content of newly formed groundwater

The groundwater content of nitrate on the way down to the primary groundwater aquifers is determined by leaching of nitrate from the root zone and by the precipitation. The development in the nitrate content of the groundwater in the nitrate zone is shown for the period 1990-96 in *Figure 2.4.5*.

The nitrate concentration is lowest and at the same level on the island part of Denmark (Funen, Zealand, etc.) and in western Jutland, but the number of filters affected by nitrate is much greater in western Jutland than on the islands. The volume of water affected by nitrate is therefore considerably greater in sandy western Jutland than in the more clayey bedrock on the island part of Denmark. On the islands, the nitrate-contaminated groundwater is mainly found in small, secondary groundwater aquifers. The nitrate level is markedly higher in eastern Jutland than in the other two parts of Denmark. Nitrate loading in eastern Jutland and on the island part of Denmark is high, but the water volume represented is considerably smaller than in western Jutland.

If the filters below the nitrate zone were also included, the average for the island part of Denmark would be very low, i.e. the majority of the groundwater does not contain nitrate. In contrast, the average nitrate concentration would be 15-20 mg/l in western Jutland and 20-30 mg/l in eastern Jutland. The nitrate content of the groundwater is estimated to have increased markedly in line with agricultural intensification since the 1950s. With adoption of the Action Plan on the Aquatic Environment in 1987, nitrate pollution from agricultural sources should slowly fall again, first in the young, newly formed groundwater. Groundwater formation takes a long time, however, and at the national level the expected decrease in the nitrate content of the relatively young groundwater cannot yet be demonstrated. With the recent adoption of the Action Plan on the Aquatic Environment II, nitrate pollution will be further curtailed up to the year 2003. The new Action Plan is not expected to lead to a demonstrable decrease in the groundwater nitrate content until a decade has passed, however.

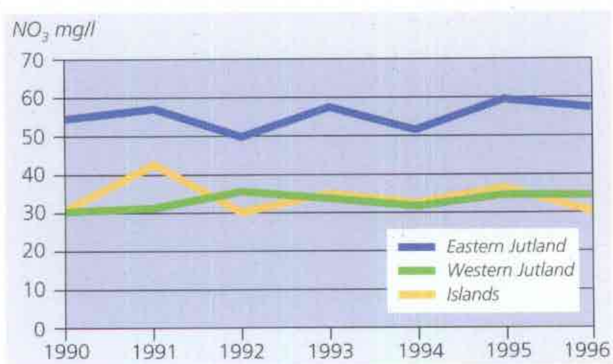


***Figure 2.4.5** Development in the concentration of nitrate in newly formed groundwater. Only the 84 point-monitoring filters located in the Nitrate Belt and analysed annually are included here. No. of filters: Eastern Jutland 16, Island part of Denmark 14 and western Jutland 54 (Source: Geological Survey of Denmark and Greenland, 1997).*

Nitrate in untreated waterworks water

Up to 1997, the waterworks had reported a total of 7,873 abstraction boreholes containing nitrate. In the majority of these boreholes, the nitrate concentration is low (*Table 2.4.1*). Boreholes with a high nitrate concentration, i.e. over 25 mg/l, are mainly found in the so-called "Nitrate Belt" in Jutland (*Figure 2.4.6*). High nitrate concentrations are particularly common in the northern part of Viborg and Aarhus counties, as well as in areas with thin clay cover, such as at Aalborg and on Stevns. In western Jutland, where the uppermost unconfined aquifers are extremely nitrate-contaminated, the majority of the groundwater is abstracted from deeper-lying confined aquifers that do not contain nitrate, and nitrate consequently does not yet constitute a threat to the water supply.

Inorganic trace elements

Marked lowering of the groundwater table (e.g. in connection with water abstraction) can result in the influx of oxygen-rich groundwater or atmospheric air. The oxygen causes the pyrite in the soil to dissolve, whereupon the nickel and other possible trace elements it contains such as arsenic and selenium are released to the groundwater. Leaching and percolation of nitrate from overlying agricultural land can dissolve pyrite, causing the release of nickel and other inorganic trace elements. Waterworks abstraction boreholes with a nickel concentration exceeding 10 and 20 µg/l, respectively, are shown in *Figure 2.4.7*. The limit level for nickel in drinking water is 20 µg/l

Water abstraction boreholes		
Nitrate content (median)	No. of boreholes	Percent distribution
>50 mg/l NO_3	239	3.0%
25-50 mg/l NO_3	502	6.4%
1-25 mg/l NO_3	2,070	26.3%
<1 mg/l NO_3	5,062	64.3%

***Table 2.4.1** Distribution of drinking water abstraction boreholes according to nitrate content for the period 1990-96 (Source: Geological Survey of Denmark and Greenland, 1997).*

ex waterworks. In the majority of cases, the high level of nickel is probably due to oxygenation of pyrite caused by lowering of the groundwater table.

After nickel, zinc is the trace element that most often exceeds the limit level for drinking water of 0.1 mg/l. High concentrations of zinc often occur in relatively high-lying filters, and the concentration is generally far higher under agricultural land than under natural countryside. The zinc content is relatively high in slurry and in sewage sludge, which constitute a major source of the enhanced zinc content in subsurface groundwater.

The cadmium content sometimes exceeds the limit level for drinking water. In this case, too, the high concentrations are assumed to be mainly attributable to atmospheric deposition, point sources (landfills, fly ash depositories) and surface sources (application of phosphorus fertilizers and sludge).

Organic micropollutants

The organic micropollutants can be subdivided into four groups:

- Chlorinated aliphatic hydrocarbons
- Aromatic hydrocarbons
- Phenols and alkylphenols
- Pesticides

The chlorinated aliphatic hydrocarbons mainly derive from industrial use of organic solvents. The aromatic hydrocarbons mainly derive from oil products and organic solvents, while phenols and alkylphenols derive from gasworks and the tar industry. The organic micropollutants in the groundwater are thus chiefly (although not solely) associated with point sources in urban areas and waste deposits in rural areas (*Figure 2.4.8*).

The most frequently detected micropollutants are trichloromethane (chloroform), trichloroethylene, benzene, toluene, xylene and phenol. In general, the micropollutant concentrations hitherto detected have been low, although the data material is still too weak to provide a representative picture of the level and extent of such pollution on a national scale.

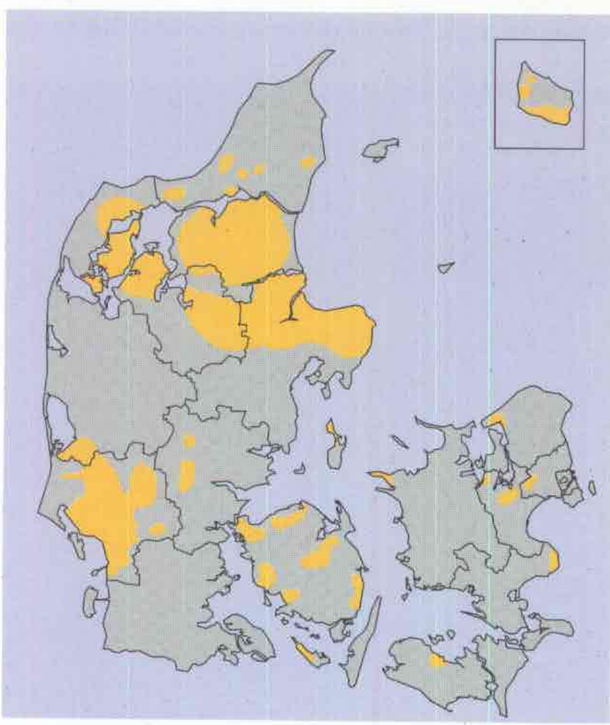


***Figure 2.4.6** Areas where county authorities consider the nitrate content of the groundwater to be a current or future problem for the drinking water supply (Source: Geological Survey of Denmark and Greenland, 1995).*

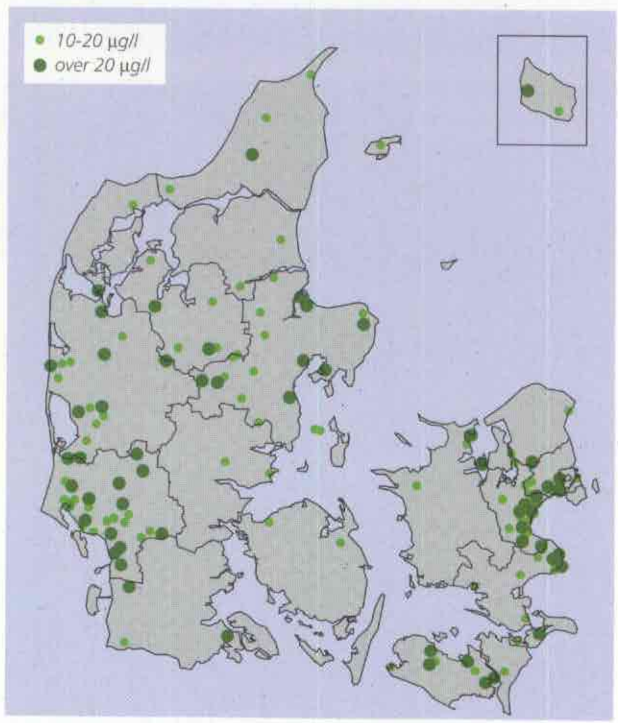


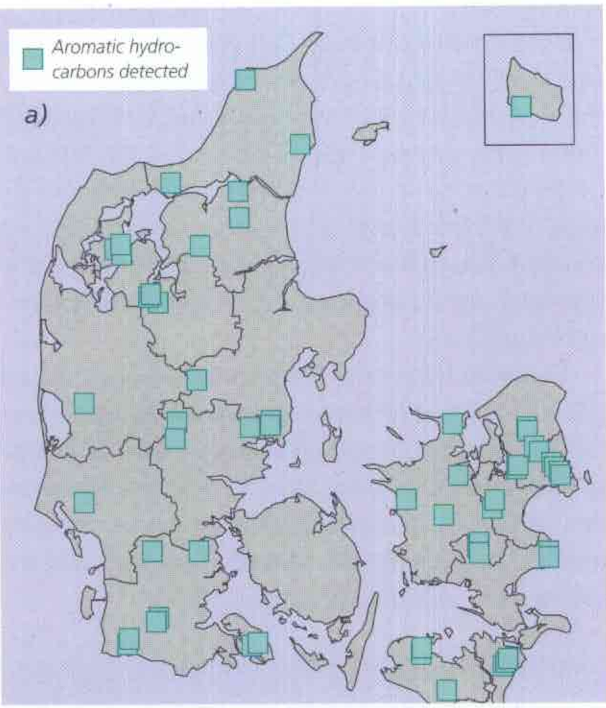
***Figure 2.4.7** Water abstraction boreholes where the nickel content exceeds 10 and 20 µg/l, respectively. The quality standard for nickel in drinking water is 20 µg/l ex waterworks (Source: Geological Survey of Denmark and Greenland, 1997).*

Pesticides

Systematic monitoring of the pesticide content of groundwater was initiated in 1990. Under the groundwater monitoring programme, 1,006 filters have been tested during the last 5-6 years. Water samples from the filters have been analysed for eight pesticides, and a total of 3,873 water samples have hitherto been tested. To date, pesticides have been detected in just over 12% of the borehole filters. In just under 4% of the filters, the concentration is so high as to exceed the limit level for drinking water (0.1 mg/l).

The waterworks analyses for the same eight pesticides during the period 1990-95 revealed one or more pesticides in 388 boreholes corresponding to just under 12% of the 3,382 boreholes tested. The limit level for drinking water was exceeded in water samples from 168 boreholes, corresponding to 5% of the boreholes tested. Some Counties and waterworks have analysed the groundwater for additional pesticides other than the eight included in the general moni-toring programme. Analysis data are thus available for 83 pesticides and pesticide residues, of which 35 were detected. While detection frequency varies, the pesticide residues detected with the greatest frequency are the degradation products desethylatrazine, desisopropylatrazine and hydroxyatrazine from atrazine and 2,6-dichlorobenzamide (BAM) from dichlobenil (*Figure 2.4.9*). Bentazone is also frequently detected, but rarely in concentrations exceeding the limit level. The use of atrazine and dichlobenil is now prohibited, and that of bentazone is subject to severe restrictions.

In the very young groundwater located at depths from 0-10 m below ground level, pesticide residues have been detected in just under 40% of the boreholes tested (*Figure 2.4.10*). In the older deeper lying groundwater down to about 50 m below ground level, pesticide residues have been detected in approx. 20% of the boreholes tested. As many of the studies undertaken encompassed selected boreholes in areas particularly at risk of groundwater pesticide contamination, the



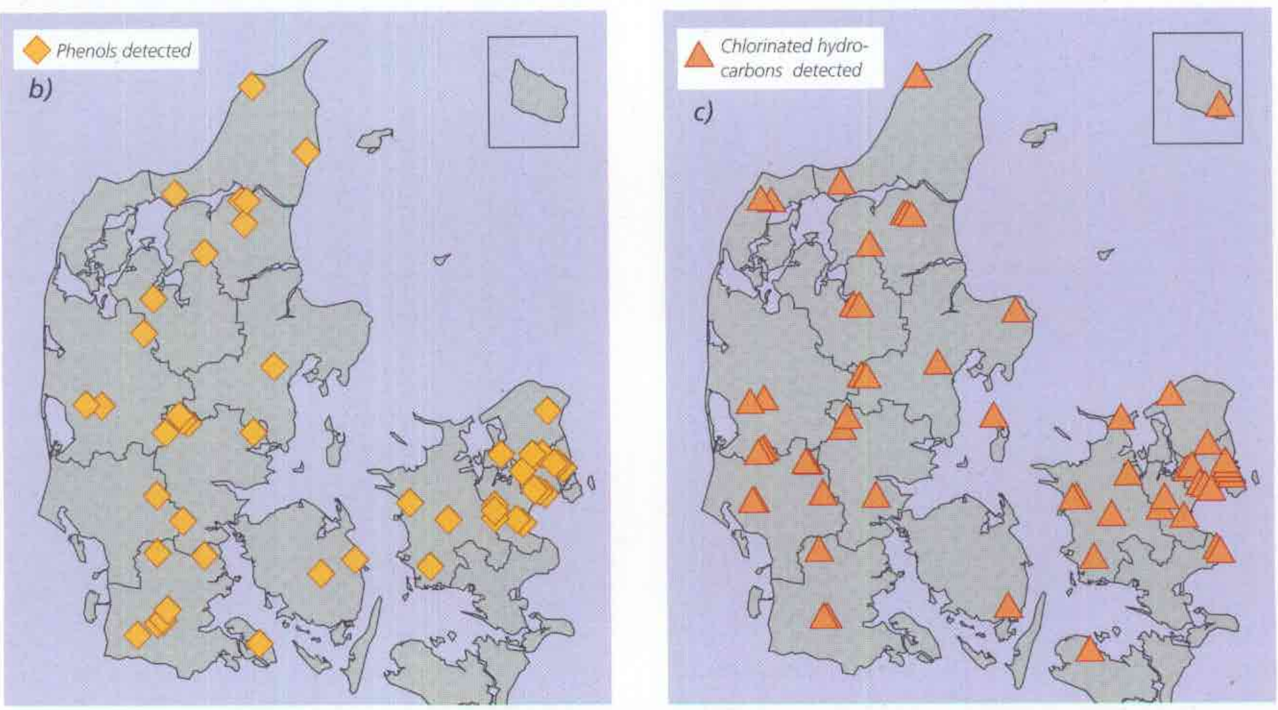


Figure 2.4.8 *Sites where organic micropollutants have been detected in Danish groundwater. a) Aromatic hydrocarbons. b) Phenols. c) Chlorinated hydrocarbons (Source: Geological Survey of Denmark and Greenland).*

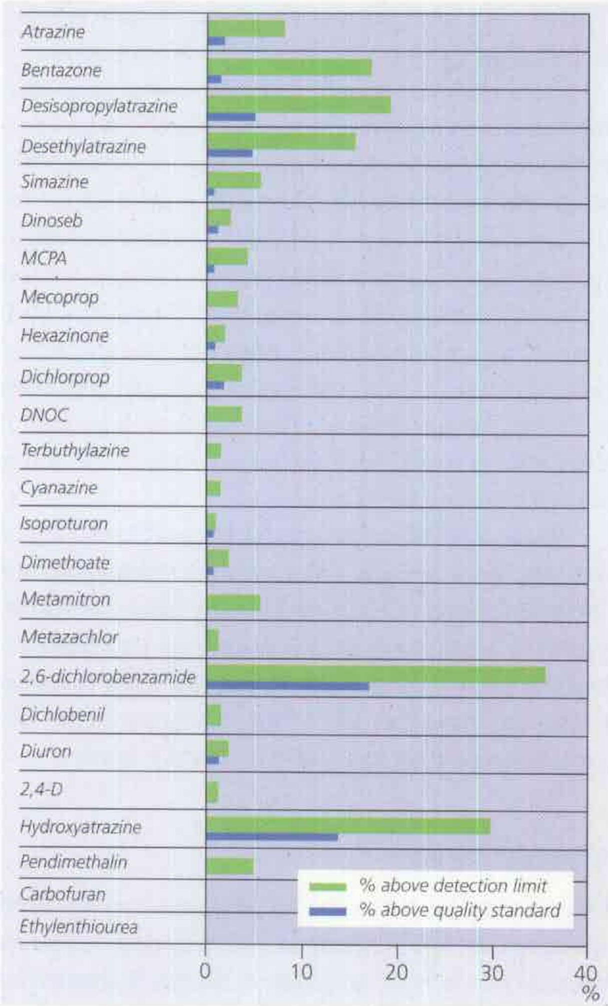


Figure 2.4.9 *Percentage of tested groundwater boreholes in which pesticides and pesticide residues have been detected. The substances are ranked according to the number of boreholes investigated, atrazine thus being the most frequently investigated substance. Carbofuran and ethylenthiourea have been found in a couple of cases by the National Environmental Research Institute during analysis of younger groundwater (Source:Geological Survey of Denmark and Greenland, 1996).*

number of positive finds for the individual substances probably reflects an overestimation in relation to the groundwater as a whole. BAM is found in many monitoring programme and waterworks boreholes and is particularly frequent in boreholes near or under urban areas (*Figure 2.4.10*). As approx. 50% of the 3,000 waterworks are located in the vicinity of towns or major roads, it can be assumed that many waterworks will detect BAM, not least because the compound has often been used on uncultivated and paved areas. For example, Hvidovre Waterworks has found BAM in more than 90% of its water supply boreholes and has consequently built a carbon filtration plant. Copenhagen Waterworks has ceased abstraction of water at four larger abstraction sites due to BAM contamination of the groundwater.

During the period 1956-94, at least 411 pesticides (active substances) were used in Denmark. To this should be added at least 100 degradation products. As many of these substances have only been used in limited quantities, they will probably only be detectable in the groundwater locally. Today approx. 180 pesticides are in use in Denmark. Of the 254 pesticides and resultant degradation products that have been or still are in use in Denmark, 151 have been detected in the groundwater of other countries at markedly varying frequency. A number of these substances can be expected to be present in Danish groundwater.

Due to the marked increase in acreage of fields with catch crops and winter-green fields since the end of the 1980s, the pesticide application period has been extended to also include the autumn and the early spring. This is unfortunate from the groundwater point of view as it is during the winter season that the majority of the groundwater is formed.

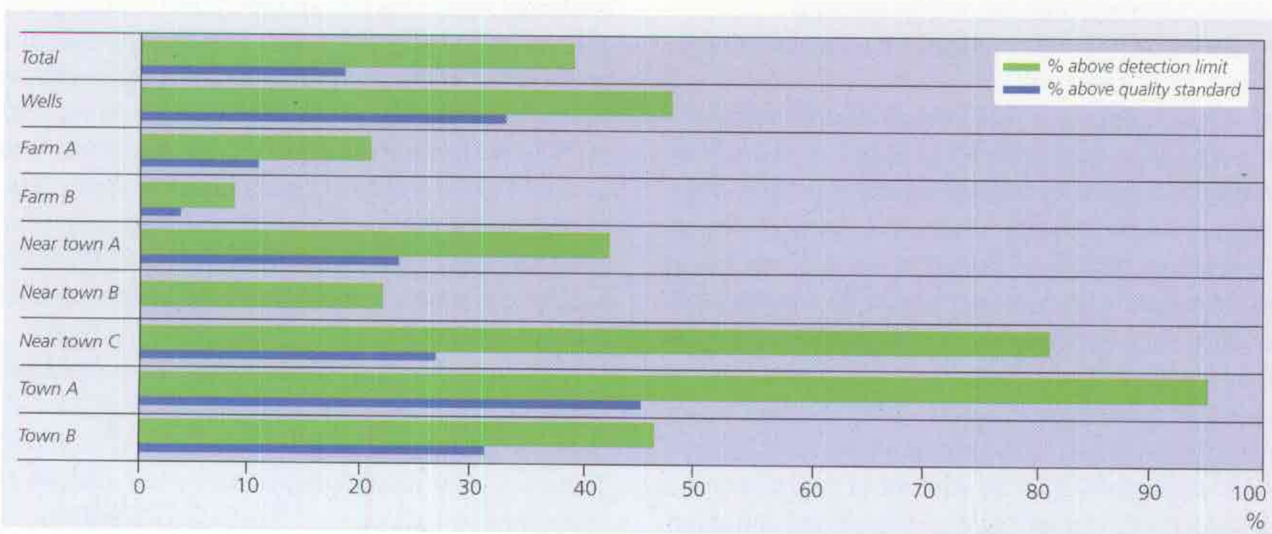


Figure 2.4.10 *Occurrence of 2,6-dichlorobenzamide (BAM) in various Danish analysis programmes undertaken by the Counties and the waterworks (Source: Geological Survey of Denmark and Greenland, 1996).*

The water we drink today was typically formed during the period 1950-70. Since then the use of pesticides has increased considerably. The degree to which the groundwater is affected can thus be expected to increase in the future. For this and other reasons, the groundwater monitoring programme has now been extended and from 1998 will encompass approx. 50 pesticides and pesticide degradation products. A detailed assessment of the consequences of the expected increase is needed, especially for small waterworks and individual water supplies, including wells.

An international expert panel has concluded that the Danish approval procedure for pesticides is one of the most stringent in northern Europe. Nevertheless, the procedure cannot completely prevent the percolation of pesticides down to the groundwater. Thus with a view to regular adjustment of the approval procedure for pesticides, the fate of the pesticides will be monitored more closely from the time they leave the root zone until they reach the uppermost groundwater under various soil conditions.

Exploitation of the groundwater resources

Size of the groundwater resources

On a national scale, the total renewable ground-water resource is greater than the total amount of water abstracted. The latest estimate of the renewable groundwater resource is 1,800 million m^3/yr, which is greater than the current water consumption of about 1,000 million m^3/yr. Due to considerable regional variation there is a shortage of water in certain parts of the country, however. In assessing the magnitude of the groundwater resources, two significant factors have not been taken into account:

- Pollution by environmentally hazardous substances (pesticides, etc.)
- The significance of longer-term climatic variations

If a correction was made for pollution with environmentally hazardous substances and the significance of longer-term climatic variations (especially the occurrence of periods of drought), the estimated total exploitable water resource would be considerably smaller. An exact figure cannot be given based on the information available, however. In the latest national estimate, the total exploitable water resource under conditions of reduced precipitation was approx. 1,500 million m^3/yr. The amount of precipitation is obviously of great significance for groundwa-ter formation. Precipitation has generally been plentiful over the last 30 years, especially during the period 1980-94. The level of groundwater formation was extremely low during the period 1995-96, however.

Groundwater formation mainly takes place during the winter season (October to March), when precipitation is greater than evaporation. In winter 1995/96, precipitation was less than half of the average for the latest 30-year period. Records of the variation in the height of the groundwater table provide a good picture of changes in groundwater formation, both from year to year and with respect to seasonal variation and enable the size of the groundwater resources to be regularly estimated. The variation in precipitation, and groundwater table at selected stations is shown in *Figure 2.4.11*.

The general fall in the groundwater table and hence the size of the groundwater resources from the mid 1960s to the mid 1970s is particularly clear. Thereafter followed a very wet period with high precipitation and a resultant increase in the groundwater table up to the beginning of the 1980s. In recent years the groundwater table has fallen markedly again.

Climate changes

Over the last 125 years, marked fluctuations have been measured in the amount of precipitation. This has been shown to have an effect on the groundwater resources. For example, there was a period of very low precipitation just before the turn of the century. There has also been a period of low precipitation during the last 25 years from the beginning and especially the middle of the 1970s. In contrast, precipitation has been relatively high over the period 1980-95.

The last couple of years have been unusually dry, with limited precipitation in the winter as well as relatively warm and dry summers and a consequent great need for crop irrigation. This has resulted in a marked fall in the groundwater table, especially in southern, western and northern Jutland. At the end of 1996, the groundwater table in these regions was around the level of its former minimum from 1976. In the eastern part of the country, the groundwater table has not generally reached the low 1976 level because groundwater formation is delayed due to the clay cover.

The groundwater table in the eastern part of Jutland and on the island part of Denmark can also be expected to continue to fall due to the delayed response. There is a close relationship between the amount of groundwater formed (i. e. the level of the groundwater table) and the amount of summer runoff. Climatic variation is currently only taken into account to

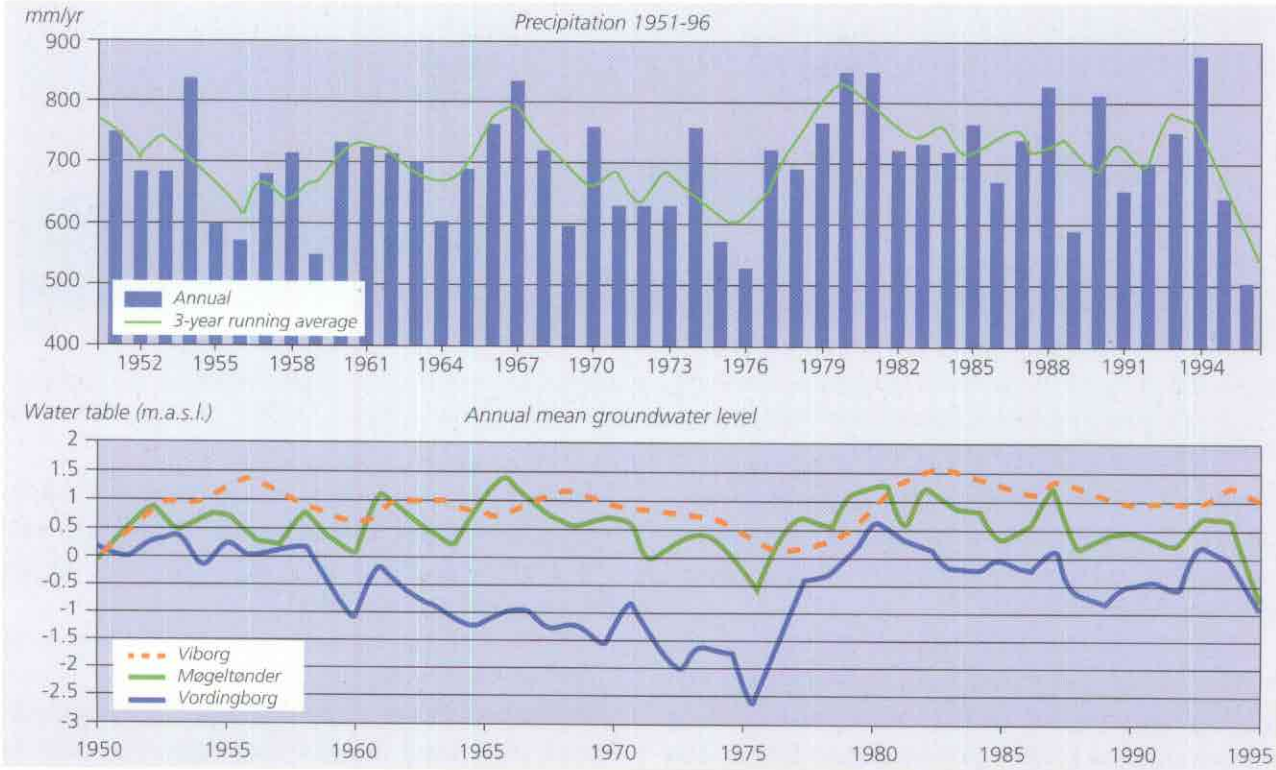


Figure 2.4.11 *Changes in annual precipitation and the groundwater table in Jutland and Zealand during the period 1950-96 (running average for 1996 is based on figures for the 2 years 1995-96 (Source: Geological Survey of Denmark and Greenland, 1997).*

a limited extent when estimating the exploitable water resource. Greater water supply security could be assured in future land and water resource planning if climatic variation was incorporated in the forecast balance between demand and the available water resource.

Development in water consumption

Abstraction and consumption of fresh water has been increasing through the 1970s, was static during the 1980s, and has been falling since 1989 (*Figure 2.4.12*). The categories used in the figure are not completely unambiguous as many industries are supplied by public waterworks and total industrial consumption is therefore greater than shown.

The category "Agriculture" covers all agricultural uses, including crop irrigation etc., as well as use in freshwater fish farms. The considerable focus on water savings and increasing water levies in the preceding years has had a visible effect, especially on household and industrial water consumption.

2.4.3 Watercourses

General characteristics of Danish watercourses

By European standards, all Danish watercourses are small. The catchment areas of the two largest watercourses, the rivers Skjern and Gudenå, are each about 2,500 km^2. Together they cover 11% of the area of Denmark. There are approx. 35,000 km of natural watercourse in Denmark, as well as approx. 25,000 km of man-made ditches and canals. With more than 1 km watercourse per km^2 land, the watercourses are an important element in the Danish landscape.

The Danish watercourses have undergone considerable change due to human activities, particularly in the agricultural sector. In order to drain agricultural land, extensive drainage systems have been established and watercourses have been culverted and channelized. In order to facilitate drainage, weed clearance and sediment excavation are undertaken. As a result, physical conditions are extremely poor in approx. 31,000 km of the natural watercourses (85-90%).

Environmental state of the watercourses

The environmental state of the watercourses can be illustrated on the basis of the composition of the macroinvertebrate fauna as different species react differently to pressures. Based on the faunal composition, an index can be calculated that provides an integrated impression of the environmental state of watercourses. In a watercourse with a poor environmental state, the number of species will be low and indicator species for a poor environmental state will

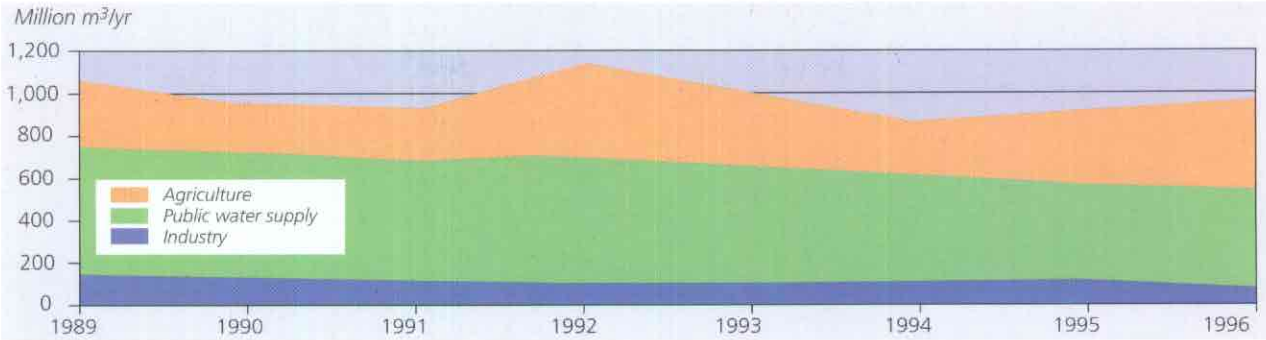


Figure 2.4.12 Water abstraction in Denmark apportioned by abstraction category based on figures reported to the Geological Survey of Denmark and Greenland and information from the Counties in the monitoring reports for 1989-96 (Source: Geological Survey of Denmark and Greenland, 1997).

be present, e.g. species adapted to poor oxygen conditions. An index value of I indicates a completely unaffected state while an index of IV indicates a very poor environmental state.

The 1996 results for the approx. 200 watercourse stations included in the Nationwide Monitoring Programme indicate that the state of the majority of the watercourses is II-III or poorer (*Figure 2.4.13*). The county authorities undertake regional monitoring at a far greater number of stations. Comparison of county monitoring data from 18,000 km of watercourse for the period 1993-96 showed roughly the same distribution as for the Nationwide Monitoring Programme stations. Since 1989, the environmental state of the Danish watercourses seems to have improved slightly. An analysis of the regional data showed that the state was slightly better in large watercourses (>2 m wide) than in small watercourses.

No information on the longer-term development in the environmental state of the watercourses exists at the national level. As an example of the long-term trend, data from major watercourses in Aarhus county for the periods 1972-75 and 1990-93 show that the percentage of watercourses with poor environmental state (III to IV) has decreased from 16% to 5% as a consequence of the measures implemented to improve the environmental state of our watercourses (*Figure 2.4.14*).

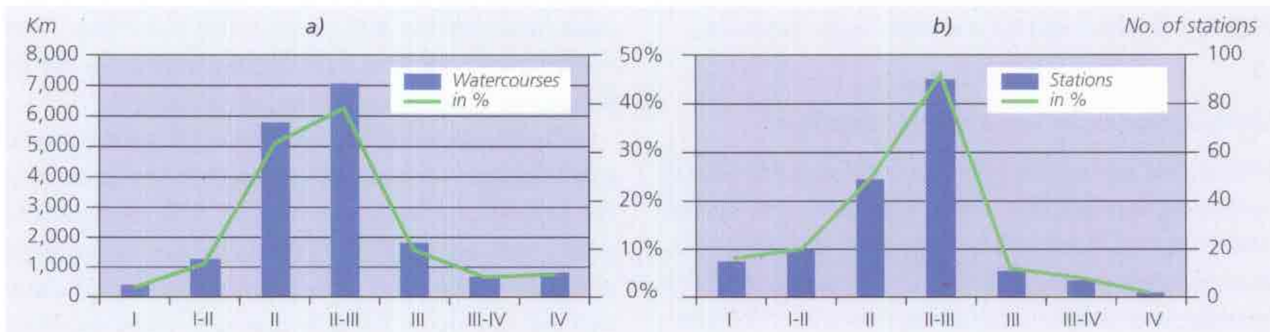


Figure 2.4.13 Watercourse quality (biological). a) Data from the Counties' regional monitoring 1993-96. b) Danish Fauna Index on 194 stations under the Nationwide Monitoring Programme (Source: Windolf et al., 1997).

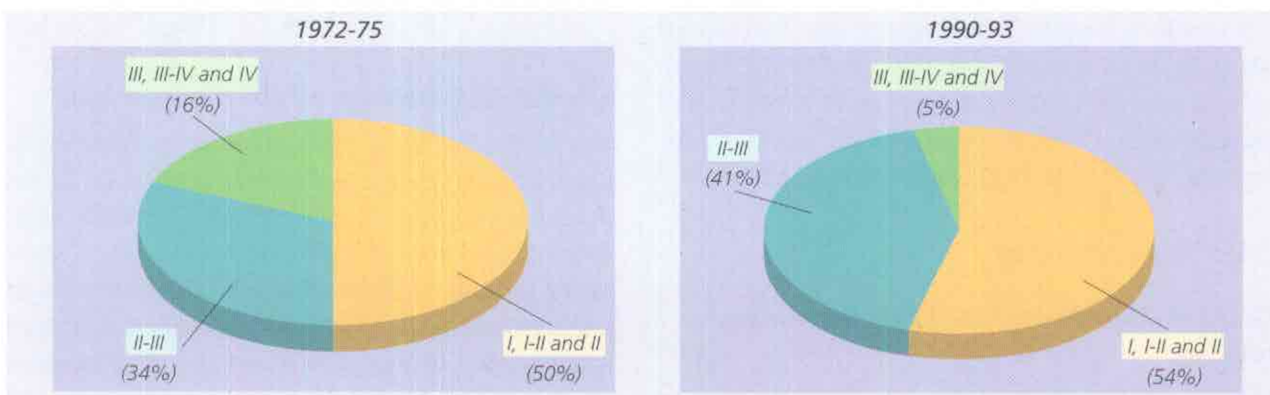


Figure 2.4.14 Development in the biological quality of 700 km of major watercourse in Aarhus county (Source: Aarhus County, 1994).

Pressures on the environmental state of watercourses

The environmental state of watercourses is affected by a number of anthropogenic factors, of which the most important are waste water discharges, deterioration of watercourse physical state, and discharge of ochre and environmentally hazardous substances.

Discharge of organic matter

Untreated waste water contains large amounts of easily degradable organic matter that affects the environmental state of watercourses into which it is discharged. The organic matter is degraded by microorganisms, thereby reducing the oxygen content of the water. This deteriorates ecological conditions for the watercourse fish and macroinvertebrates.

Just 20 years ago, several examples still existed of highly polluting discharges of untreated or poorly treated waste water, and discharges from livestock manure stores. These discharges have now been reduced through the implementation of improved treatment at waste water treatment plants and through efforts to curb unlawful agricultural discharges.

Analysis of the sources of waste water organic matter discharges to inland waters in 1995 revealed that discharges from scattered dwellings (small villages and isolated houses) are now the most significant (36%), exceeding discharges of treated waste water from treatment plants (21%) (*Figure 2.1.15*). Discharges from freshwater fish farms and stormwater outfalls (overspills from treatment plants and stormwater from paved areas) comprise the remainder – 29% and 13%, respectively.

Physical condition of watercourses

The naturally meandering watercourse alternates between riffles with a strong current and deep pools

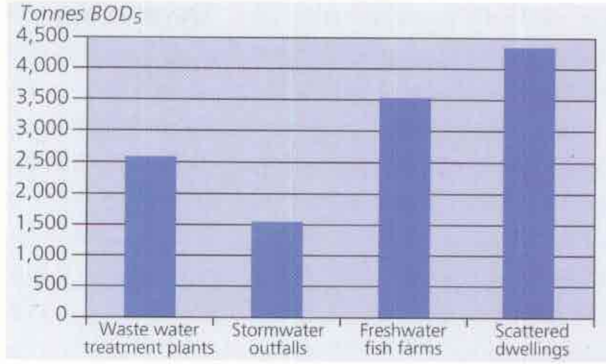


Figure 2.4.15 *Sources of organic matter input to inland waters from point-source discharges in 1995 (Source: Danish Environmental Protection Agency, 1996).*

with low flow and hence has a varied bottom. In highly channelized watercourses, current speed and bottom conditions are more homogenous. This deteriorates ecological conditions for the watercourse fauna, and watercourse environmental state is therefore worse than in physically unaffected watercourses. In recent years, a number of measures have been introduced to improve physical watercourse conditions, e.g. gentle watercourse maintenance and watercourse restoration.

Watercourse maintenance (weed clearance and excavation of sediment) in the major watercourses has changed markedly since 1985 (*Table 2.4.2*). In 1985, only 26% of watercourses were subjected to no or gentle maintenance, while this was the case in 52% of watercourses in 1996.

Since 1982, more than 900 restoration projects have been undertaken in larger Danish watercourses (*Table 2.4.3*). A number of projects have aimed to improve physical conditions locally in a single watercourse reach (Type 1), for example in order to establish spawning grounds and habitats for trout. However, the majority have aimed to restore continuity between different watercourse reaches (Type 2) in order to facilitate the natural upstream and downstream migration of fish such as salmon, trout and

Watercourse maintenance			
Maintenance type	**1985**	**1990**	**1996**
Harsh	50	14	7
Ordinary	24	35	41
Gentle	21	45	45
None	5	6	7

Maintenance types:

Harsh: *Maintained according to the profile principle by removing the bed and bank vegetation*
Ordinary: *Maintained according to the current channel principle by removing a considerable part of the bed and bank vegetation*
Gentle: *Maintained according to the current channel principle by removing a minor part of the bed and bank vegetation*
None: *Watercourses where (regular) weed clearance is not undertaken*

Table 2.4.2 *Development in maintenance practice in major watercourses (county watercourses) (Source: Windolf et al., 1997).*

eel, and of macroinvertebrates. The third type is more holistic and encompasses restoration of both the watercourse and part of the river valley (Type 3).

In addition to the projects shown in *Table 2.4.3*, a number of projects have been undertaken by the Municipalities. It is estimated that since 1982, Type 2 projects have resulted in the re-establishment of continuity between 5-10,000 km of watercourse, while 200 km of watercourse has been remeandered. Watercourse flow can be affected by water abstraction in the catchment area. Low flow causes deterioration of the physical conditions in the watercourse and enhances the impact of waste water discharges on the environmental state of the watercourse due to poorer dilution of the discharged waste water. This effect is naturally regional and related to the magnitude of water abstraction. Thus water flow in many watercourses in the eastern part of the country is highly affected, with unacceptably low or no summer flow.

Figure 2.4.16 illustrates how water flow in the river Aarhus has fallen since 1920 as a result of increasing water abstraction (household water supply and crop irrigation). In contrast, water flow in the rivers Gudenå and Skjern, where groundwater abstraction is less intensive, has generally been increasing.

Ochre and pesticide loading

Watercourses affected by ochre have an impoverished macroinvertebrate fauna with a highly reduced number of species and individuals. In Denmark, ochre loading is a major environmental problem in Sønderjylland, Ribe and Ringkjøbing counties. No national assessment of the significance of pesticides in watercourses is available, but Funen County has estimated that approx. 20% of the watercourses investigated during the period 1988-96 have been subjected to acute pesticide pollution with resultant death of macroinvertebrates. It is estimated that 10% more of the major watercourses in the county would have a satisfactory biological watercourse quality if they had not been subjected to pesticide pollution. Pesticides in watercourses are examined in more detail in *Section 2.5*.

Watercourse quality objectives

The county Regional Plans stipulate the desired environmental quality objectives for the county watercourses. There are three main categories of quality objective:

- Stringent (A): Natural state, no impact permitted.
- Basic (B): Only slight impact permitted
- Eased (C, D, E, F): Significant impact permitted.

Watercourse restoration projects undertaken

		No. of projects
Type 1	Improvement of the physical conditions in shorter watercourse reaches	181
Type 2	Re-establishment of continuity between watercourse reaches	740
Type 3	Integrated restoration of watercourses and river valleys	15
Total		*936*

Table 2.4.3 *Number of restoration projects undertaken in major Danish watercourses during the period 1982-96 (Source: Windolf et al., 1997).*

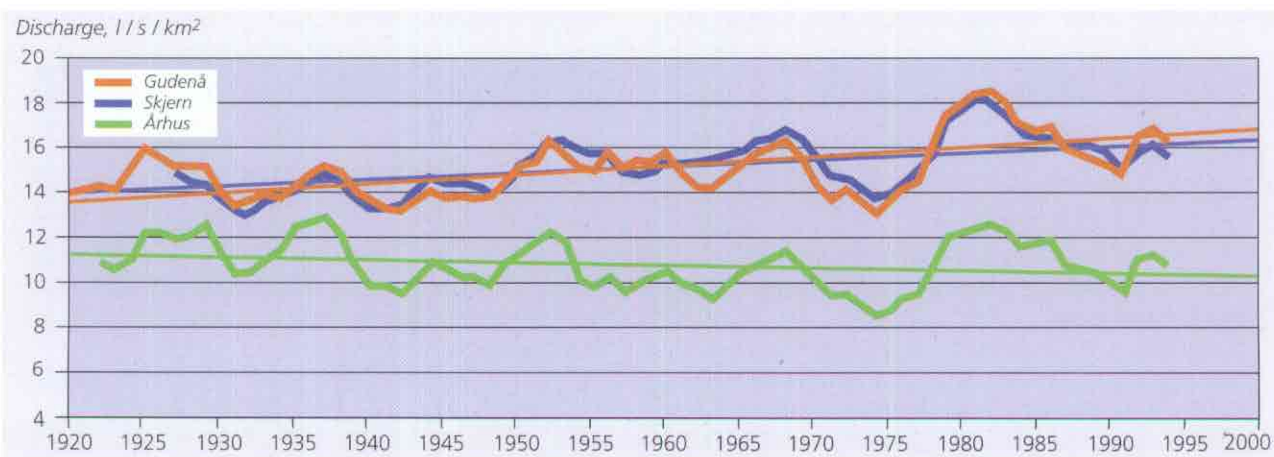


Figure 2.4.16 *Development in discharge in the rivers Skjern, Gudenå and Aarhus (area-specific runoff) (Source: Windolf et al., 1997).*

Of the total of 25,000 km of watercourse for which a quality objective has been stipulated, only approx. 5% falls under category A, the percentage being slightly higher in Jutland than on the island part of Denmark (*Figure 2.4.17a*). The natural conditions for high watercourse quality are best in western Denmark, where there is generally less anthropogenic influence. This fits well with the fact that 80% of the watercourses in Jutland have been assigned quality objective B as compared to only 51% on the island part of Denmark.

The quality objectives are only met in 44% of Danish watercourses (*Figure 2.4.17b*). While the objective has been met in half of the watercourses in Jutland, the figure for the island part of Denmark is only 30%. The main reasons for the lack of quality objective compliance are thought to be waste water discharges (49%) and poor physical conditions (27%) (*Figure 2.4.14c*). Waste water from houses with septic tanks also affects watercourse quality.

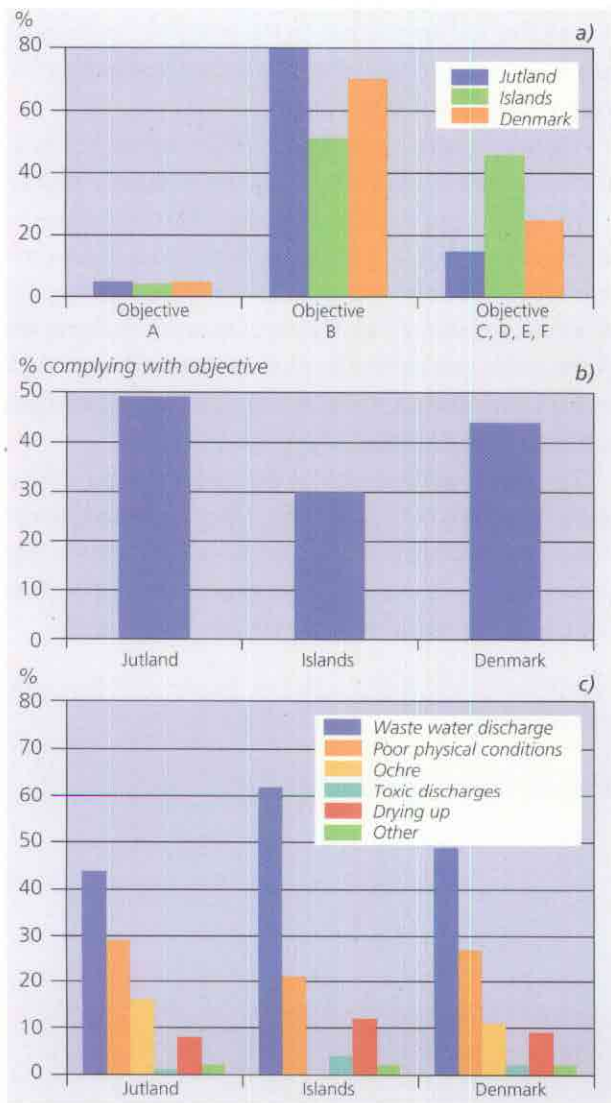


Figure 2.4.17 a) *Quality objectives for the environmental state of Danish watercourses.* ***b)*** *Compliance with quality objectives for Danish watercourses, as assessed by the Counties.* ***c)*** *Main reasons for lack of quality objective fulfilment, as assessed by the Counties (Source: Windolf et al., 1997). Note: All data are calculated on a reach basis for the period 1992-96. Results calculated in this way can deviate slightly from former analyses, which were made solely at the station level.*

Untreated waste water from a few scattered dwellings can have just as great an impact on a small watercourse as the effect of treated waste water from a whole town on a major watercourse. In Jutland, ochre loading of the watercourses accounts for the failure of 16% of the watercourses to meet their quality objective. Most of these lie in the most western counties of Jutland. Hence in Ribe county, 20-30% of the watercourses fail to meet their quality objective because of ochre loading. The main reasons why the watercourses fail to meet their quality objective are thus the impact of local waste water discharges, ochre loading and watercourse physical conditions.

Watercourses as a transport medium for nutrients

Watercourses transport a major part of the nutrients that are fed into the lakes and coastal marine waters (see the following sections on lakes and marine waters).

The nutrients do not have any significant negative environmental effects on the watercourses themselves. Nutrient concentrations in the watercourses are a function of man's various activities in the catchment. In watercourses that drain uncultivated natural catchments, nutrient concentrations are markedly lower than in watercourses draining cultivated catchments or in watercourses receiving point-source discharges (*Figure 2.4.18*).

Watercourses that drain uncultivated countryside typically have a phosphorus content of 0.05 mg P/l, while the concentration is about 0.12 mg P/l in watercourses where most of the catchment is cultivated and 0.2 mg P/l in watercourses receiving waste water discharges. From 1991 to 1996, the phosphorus level fell in these waste water polluted watercourses, mainly due to improvements in waste water treatment. The nitrogen concentration in watercourses draining uncultivated catchments is typically 1 mg N/l, while that in the cultivated catchments and point-source catchments typically lies between 4 and 10 mg N/l.

The nitrogen concentration and catchment loss of nitrogen are chiefly determined by the degree of cultivation in the catchment and of the amount of nitrogen inputs in the form of fertilizer applied to agricultural land (*Figures 2.4.18 and 2.4.19*). The level of nitrogen is generally lower in watercourses that drain sandy catch-

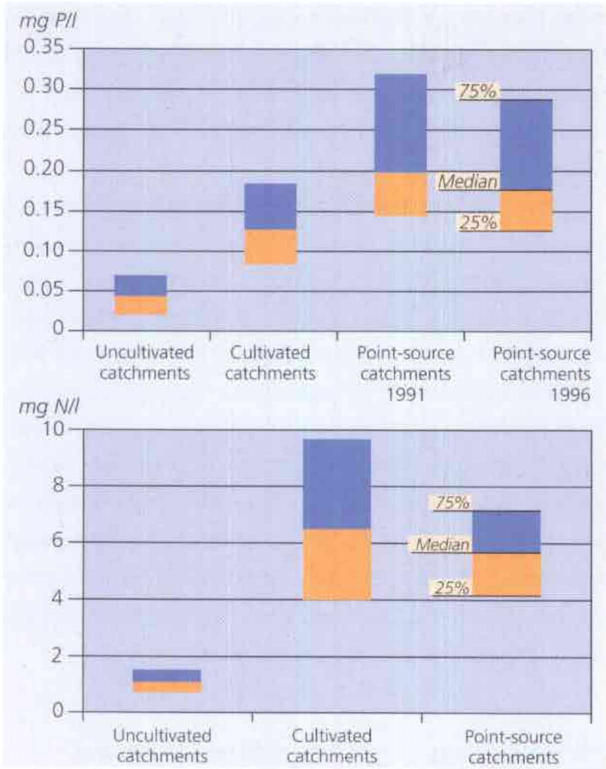


Figure 2.4.18 Concentration of phosphorus and nitrogen in watercourses in uncultivated catchments, cultivated catchments without significant point-source discharges of treated municipal waste water, and catchments with significant point-source discharges of treated municipal waste water. The watercourses are classified according to loading in 1991 (Source: Windolf et al., 1997).

ments than in those that drain clayey catchments receiving the same nitrogen input (*Figure 2.4.19*).

The nitrogen balances for agricultural land in predominantly sandy and clayey catchments are shown in *Figure 2.4.20* (see also *Section 3.4*). In both cases, the

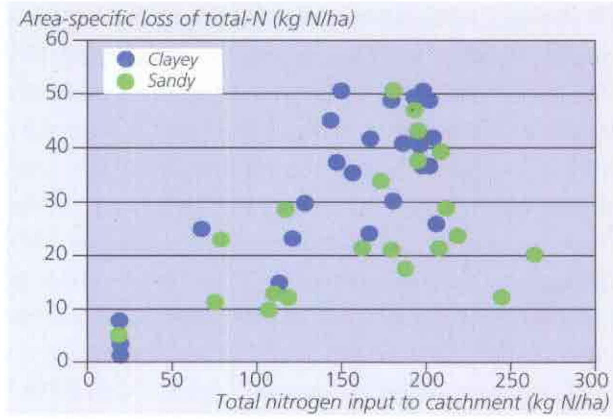


Figure 2.4.19 Relationship between the amount of nitrogen input via fertilization and catchment loss of nitrogen (Source: Windolf, 1996).

amount of nitrogen input in the form of commercial fertilizer and livestock manure is far greater than the amount removed in the crops.

On sandy soils, a relatively greater amount of livestock manure is applied due to the relatively higher livestock density on the sandy soils. Part of the excess nitrogen is released to the air in the form of free nitrogen and ammonia, and part accumulates in the soil, while the remainder leaches out. On sandy soils, much of the water percolates down to the groundwater and hence to the watercourses. A large part of the nitrogen is removed during this transport, however.

On clayey soils, much of the water flows rapidly to the watercourses via drains. Thus nitrate contamination of groundwater is mainly a problem on the sandy soils, while nitrate contamination of watercourses is mainly a problem on the clayey soils.

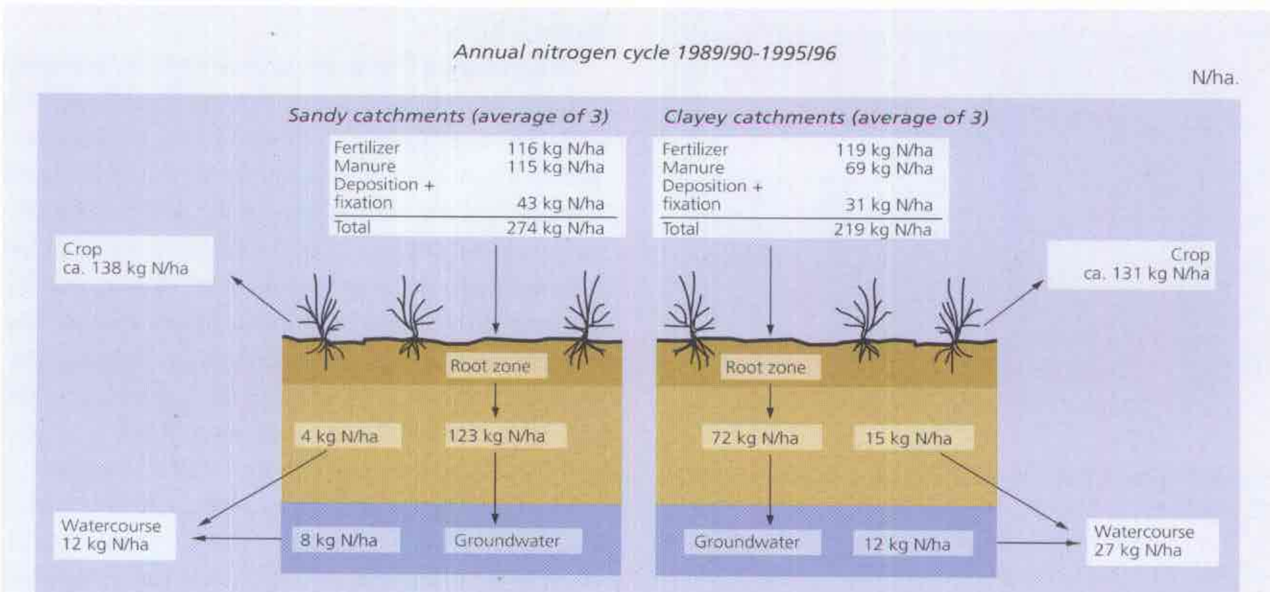


Figure 2.4.20 Nitrogen cycle for catchments with predominantly sandy or clayey soils. (Deposition + fixation = Atmospheric deposition and nitrogen fixation by plants) (Source: Grant et al., 1997).

Model calculations based on data for the development in fertilizer application, choice of crop etc., show that adjusted to normal climatic conditions, nitrogen leaching from agricultural land has fallen approx. 17% during the period 1989-96.

Measurements of nitrogen transport are available back to the end of the 1970s for 18 watercourses draining cultivated clayey catchments. The actual nitrogen transport varied considerably from year to year in line with the variation in precipitation and runoff. Analysis of the development corrected for this natural year-to-year variation revealed that the normalized nitrogen transport in the years 1993-97 was less than during the preceding 15-year period (*Figure 2.4.21*). This is in concert with the fact that an effect of a general reduction in nitrogen leaching from agricultural land will first be detectable in the watercourses in clayey catchments with a relatively high level of subsurface runoff. Hence the results from these watercourses are not at variance with the model calculations of a 17% reduction in nitrogen leaching.

Watercourse nutrient concentrations and runoff have been monitored over the last 30 years. In the period from the mid 1960s to the mid 1970s, there was a trend towards an increasing concentration of both phosphorus and nitrogen. Total annual Danish runoff of water, nitrogen and phosphorus via watercourses in the 1980s (prior to the Action Plan on the Aquatic Environment) and annually from 1989 to 1996 is shown in *Figure 2.4.22*.

The nitrogen and phosphorus loads are shown apportioned by source.

Total runoff of nitrogen has varied between 40,000 and 120,000 tonnes, with the majority deriving from diffuse sources (agricultural land). In dry years such

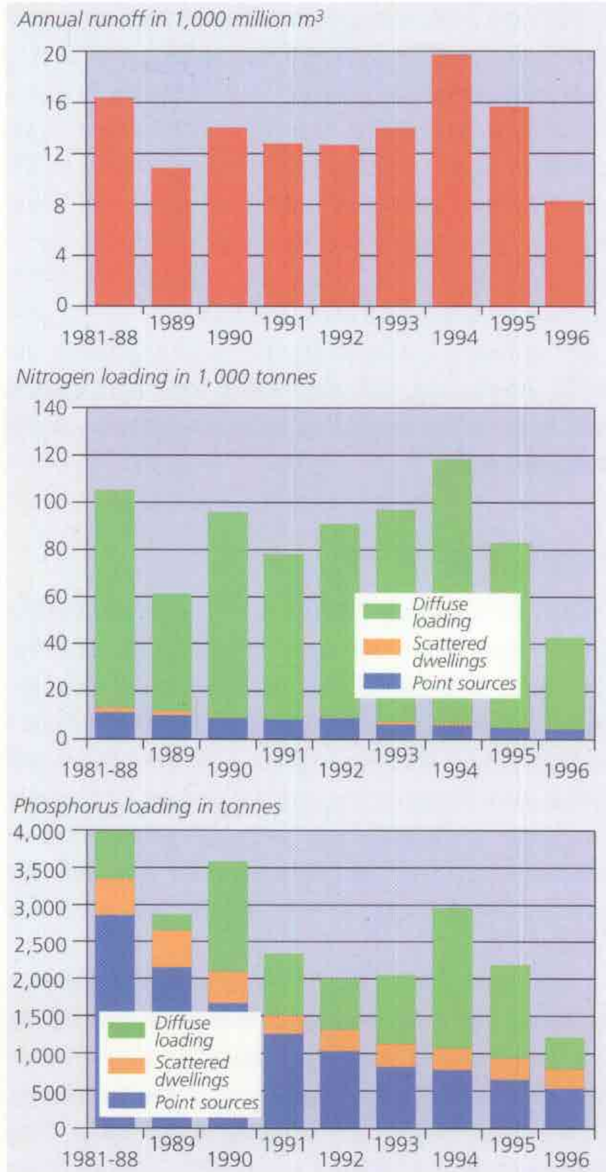


Figure 2.4.22 *Development in annual runoff of water, nitrogen and phosphorus via inland surface waters with the loads shown apportioned by source. (Source: Windolf et al., 1997).*

Figure 2.4.21 *Normalized nitrate transport in 18 watercourses in clayey catchments in hydrological years (June-May). Percentage deviation from the average for the period 1978-87 (Source: Windolf et al., 1997).*

as 1989 and 1996, nitrogen runoff was relatively small. In wet years such as 1994, in contrast, it was relatively high. Improvements in waste water treatment have reduced nitrogen loading of fresh waters by over 5,000 tonnes nitrogen, corresponding to approx. 5% of the total nitrogen transport in the period 1981-88. Total runoff of phosphorus has been reduced markedly as a result of improved waste water treatment. In 1995, point-source loading thus amounted to just under 1,000 tonnes as compared with 3,300 tonnes in the 1980s. At present, diffuse loading from agricultural land is the main single source of phosphorus in the watercourses.

2.4.4 Lakes

There are more than 100,000 standing water bodies greater than 100 m² in Denmark. By far the majority are ponds and small lakes, however, and there are only 2,762 true lakes, i.e. with an area greater than 1 ha (10,000 m²). As a consequence of agricultural and urban development, many lakes and especially ponds have disappeared through reclamation or drainage. In Aarhus municipality, for example, the number decreased by 70% during the period 1900-80 (*Table 2.4.4*).

During the 1980s and 1990s, regulations were introduced that ensure much better protection of the smaller lakes and ponds. A number of new lakes of various sizes have even appeared in the landscape. Thus over 20 larger lakes ranging in size up to 70 ha have been re-established since 1990, among other things due to public subsidies for nature restoration projects. Numerous small lakes and ponds have also been created or re-established.

Environmental state of lakes

No national assessment is available of the environmental or ecological state or development in the very small lakes and ponds. County monitoring of the environmental quality of lakes has focused on the slightly larger lakes. In some cases, data is available right back to the 1970s. Since 1989, the environmental state of lakes has been monitored systematically and intensively in the 37 representative major lakes included in the Nationwide Monitoring Programme.

The majority of Danish lakes are shallow with a mean depth of less than 3 m. In an unaffected state, these clear water lakes are characterized by extensive benthic vegetation as sunlight can reach large parts of the bed. The fish stock is dominated by the piscivorous species perch and pike, while the abundance of roach and bream is low.

At present, the environmental state of many of the Danish lakes is poor. They are generally very eutrophic with high concentrations of phosphorus and nitrogen, large amounts of phytoplankton and turbid water. The majority of the lakes currently contain more than 0.1 mg P/l and more than 2 mg N/l. The Secchi depth (transparency of the water) during the summer period is low (less than 1 m). Out of 182 lakes monitored by the county authorities over the last 5-6 years, approx. 60% had a summer Secchi depth of less than 1 m, around 25% had a Secchi depth between 1 and 2 m, and only 15% of the lakes had reasonably clear water with a Secchi depth greater than 2 m (*Figure 2.4.23*). Only few of the lakes have widespread submerged macrophyte vegetation and in most cases the fish stock is dominated by roach and bream. In many of the lakes, undesirable blooms of blue-green algae occur during the summer season.

Secchi depth is primarily determined by the amount of phytoplankton in the lake water. At the same time, Secchi depth can generally be related to the lake water phosphorus concentration, thus indicating that phosphorus is the limiting factor for phytoplankton in Danish lakes (*Figure 2.4.24a*). Moreover, the clarity of the water (Secchi depth) determines the depth to which the benthic macrophytes can colonize (*Figure 2.4.24b*).

A number of other biological conditions can also be related to the lake water phosphorus concentration. This applies to the fish stock, for example. In hy-

Lakes and ponds in Aarhus municipality					
Period	<1,000 m²	1,000-10,000 m²	1-10 ha	>10 ha	Total
1900-1907	2,246	405	81	20	2,752
1951-1952	996	182	43	8	1,229
1980	626	173	29	7	835
Decrease	72%	57%	64%	65%	70%

***Table 2.4.4** Development in the number of lakes and ponds in Aarhus municipality (Source: Skriver, 1981).*

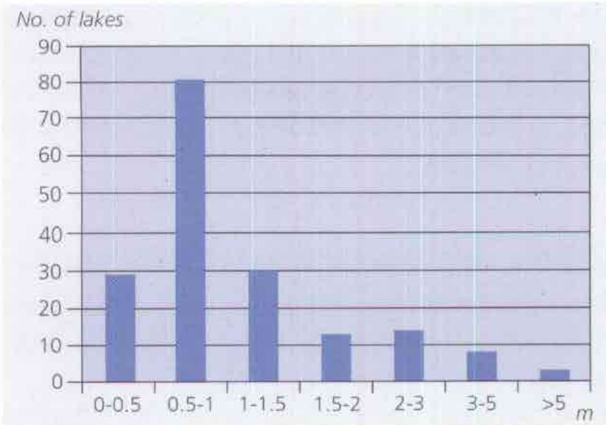


Figure 2.4.23 Secchi depth in Danish lakes in the 1990s (Source: Jensen et al., 1997).

pertrophic lakes (with abundant phosphorus), zooplanktivorous fish such as roach and bream comprise the main part of the fish stock. In clean lakes, in contrast, there is a greater percentage of piscivorous species such as pike and perch (*Figure 2.4.24d*). In the eutrophic lakes, the many zooplanktivorous fish will reduce the zooplankton to low numbers (*Figure 2.4.24c*), thereby further increasing the amount of phytoplankton.

A general interpretation of the relationships in *Figure 2.2.24* is that in order to ensure a clear lake with a good Secchi depth, a widespread vegetation of submerged macrophytes, possibilities for zooplankton to reduce the phytoplankton, and a reasonable percentage of piscivorous fish, the total phosphorus concentration in the lake water has to be less than approx. 0.1 mg P/l.

At the beginning of this century, the Danish lakes had clear water and extensive submerged vegetation. The deterioration in environmental state has occurred gradually since the turn of the century, but accelerated from the beginning of the 1950s to the mid 1970s in line with the introduction of phosphate detergents and the concomitant steep increase in the amount of waste water as a result of expansion of the sewerage system.

In the 1970s and 1980s, phosphorus loading of many lakes was reduced through either diversion of waste water discharges or through the introduction of phosphorus precipitation in the waste water treatment plants. An analysis of the development in 142 lakes from the 1970s until the present time revealed a marked general reduction in the phosphorus concentration (*Figure 2.4.25*).

The number of lakes with low phosphorus concentrations (< 0.025 mg P/l) has remained largely static. The number of lakes with a phosphorus concentration lower than 0.1 mg P/l has increased from 33 to 47, while the number with very high phosphorus concentrations (>0.25 mg P/l) has fallen from 63 to 41.

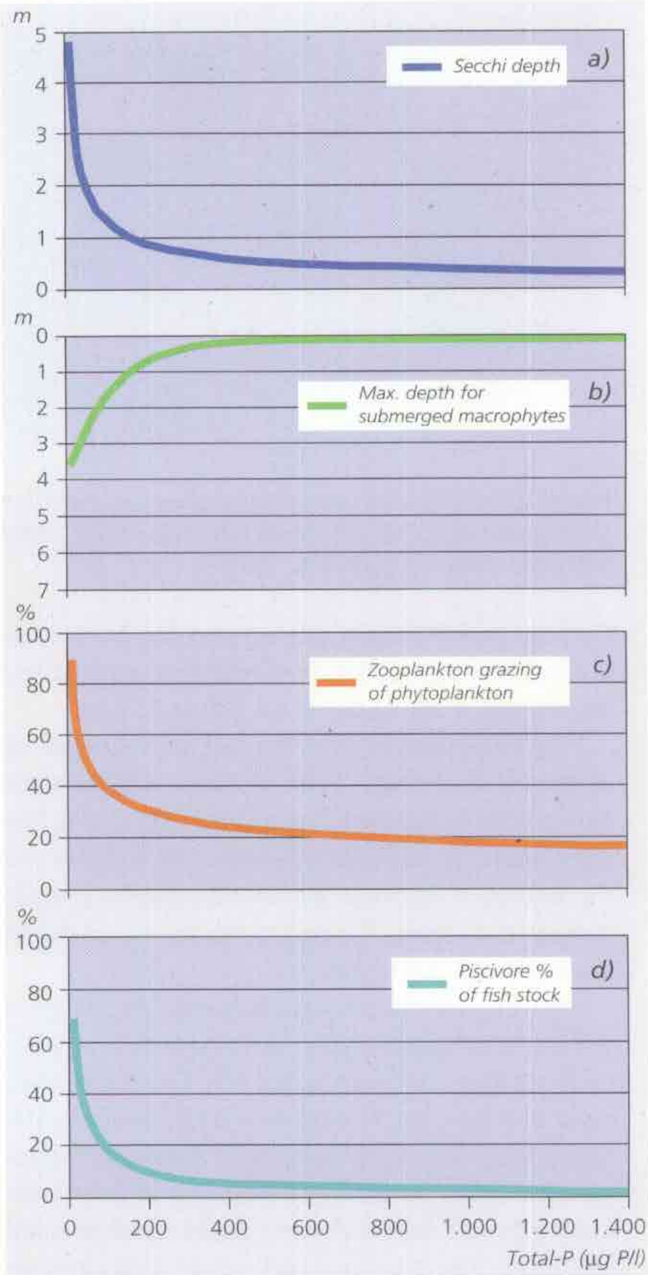


Figure 2.4.24 *Typical relationships in Danish lakes between phosphorus concentration and:*
a) *Secchi depth,*
b) *Depth distribution of submerged macrophytes,*
c) *Zooplankton grazing of phytoplankton,*
d) *Piscivore percentage of the fish stock.*
(Source: National Environmental Research Institute).

There has not been any corresponding marked improvement in Secchi depth, during the same period , however, even though there has been a tendency towards less turbid water, especially in the 1990s. The explanation is primarily that the fall in phosphorus concentration has mainly occurred in

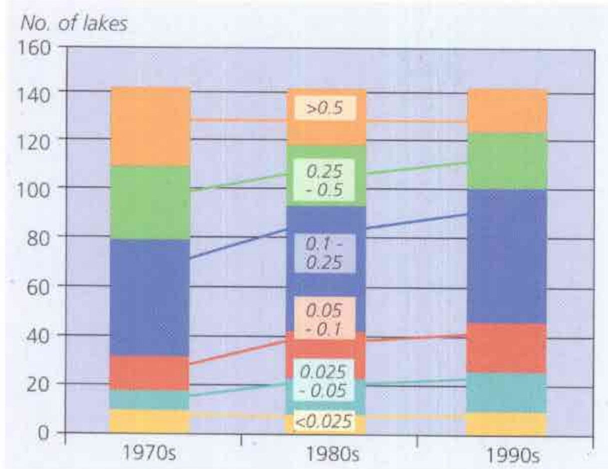


Figure 2.4.25 Distribution of phosphorus concentration (measured in mg P/l) in 142 Danish lakes in the 1970s, 1980s and 1990s (Source: Jensen et al., 1997).

the most polluted lakes, where the concentration has not yet become so low as to enable a marked improvement in Secchi depth (cf. *Figure 2.2.24a*).

The development over the last six years can be illustrated on the basis of the 37 lakes included in the Nationwide Monitoring Programme (*Table 2.4.5*). The phosphorus concentration has fallen in 18 lakes and the amount of phytoplankton (chlorophyll *a* concentration) in 14 lakes. Correspondingly, Secchi depth has increased in 12 lakes.

The amount of blue-green algae has decreased in 9 lakes. Blue-green algae are undesirable in lakes because they can form water blooms (a greenish, paint-like layer on the water) and because they can sometimes be toxic. Among other things, the toxins can cause skin problems in bathers and have been known to kill dogs that have drunk contaminated lake water. The municipal and county authorities are aware of the problem and if necessary erect warning signs and prohibit bathing.

In five of the lakes, however, the amount of blue-green algae has increased. This is attributable to the fact that the amount of blue-green algae is not very high at the highest phosphorus concentrations. When the phosphorus concentration is reduced in these lakes, the abundance of blue-green algae increases. With a further reduction in phosphorus concentration, however, the significance of the blue-green algae will decline.

Quality objectives and current lake quality

The Counties have established environmental quality objectives for the larger Danish lakes. The quality objectives fall in three categories:

- A: Stringent: In lakes with this quality objective, the flora and fauna has to be unaffected by anthropogenic activity, including the effects of agricultural production.
- B: Basic: General quality objective. In lakes with this quality objective, the natural flora and fauna may only be slightly affected by anthropogenic activity.
- C: Eased: Lakes in this category are allowed to be affected by anthropogenic activity such as waste water and agricultural production.

The objectives are often expressed in terms of lake Secchi depth. For lakes with quality objective A, the requirement is typically that the Secchi depth has to be greater than 3 m, as compared to greater than 1-2 m for lakes with quality objective B.

Of the 698 lakes for which quality objectives have been stipulated, 94% fall into categories A or B (*Figure 2.4.26a*). Anthropogenic pressures on these lakes are therefore strictly regulated and their environmental quality is only allowed to be slightly affected by man's activities.

Of the lakes in category A, 46% meet their quality objective (*Figure 2.4.26b*), while only 26% of those in category B meet their quality objective. There are a total of 37 lakes in category C and of these, only 6 meet their quality objective. In total, only 34% of the 698 lakes meet their quality objective, mainly because phosphorus loading has not been adequately reduced.

Development in environmental state		
Indicator	No. of lakes with improved state	No. of lakes with deteriorated state
Lake concentration of total-P	18	1
Chlorophyll *a* concentration	14	1
Secchi depth	12	3
Amount of blue-green algae	9	6

Table 2.4.5 Development in the environmental state of the 37 lakes included in the Nationwide Monitoring Programme during the period 1989-96 (Source: National Environmental Research Institute).

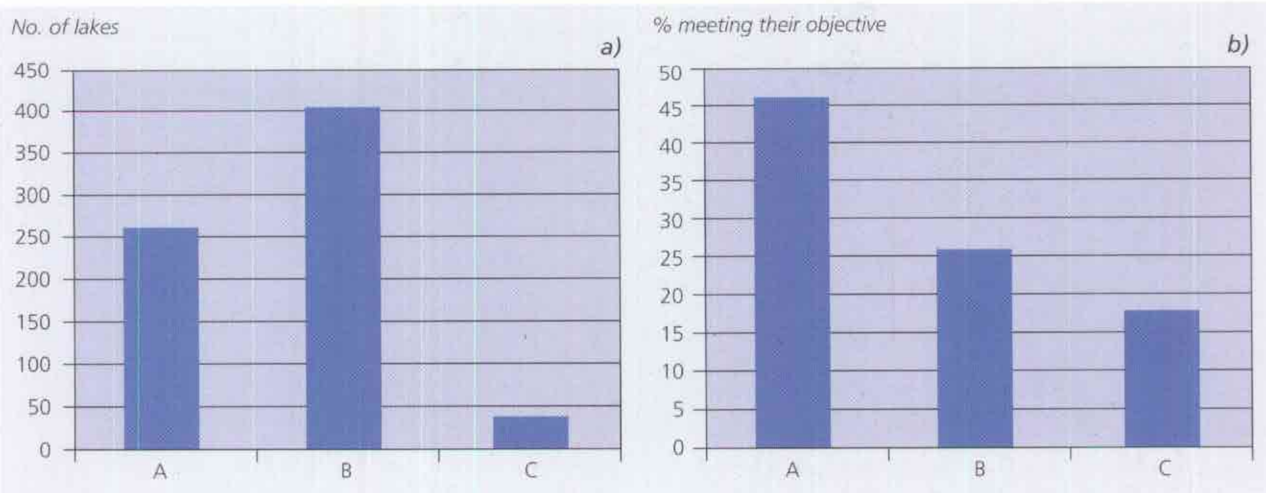


***Figure 2.4.26** Quality objectives of Danish lakes. a) Number of lakes with quality objective A, B or C. b) Percentage of these lakes meeting their quality objective (Source: Jensen et al., 1997).*

Factors affecting environmental state

The environmental state of lakes is determined by a number of natural and anthropogenic factors. In shallow lakes, for example, submerged macrophytes are able to colonize the whole lake bed. In contrast, very deep lakes lack submerged macrophytes in their deep parts even in a natural state.

Soil conditions in the lake catchments also affect the lakes' natural state. By far the majority of lakes in Denmark are alkaline (high pH) due to the high level of calcium carbonate in the inflowing water. In sandy catchments, the soil can be very low in lime, and the lakes in these areas have a poorer buffering capacity and will be more susceptible to acid precipitation (see also *Section 2.1*).

The main factor affecting lake environmental state is anthropogenic nutrient loading from waste water discharges and agricultural production. Only very few, if any, Danish lakes can presently be characterized as completely unaffected by this.

Over the last 20-30 years, considerable efforts have been made to reduce nutrient loading of lakes, especially with regard to phosphorus from waste water. Considerably improved treatment or the removal of waste water discharges from the lake catchments have markedly reduced phosphorus loading of a number of lakes. With many lakes these efforts have been inadequate, however, as their environmental state still does not meet the quality objective.

Most phosphorus loading of lakes currently derives from diffuse sources (56% of total loading), with the majority of this being phosphorus loss from agricultural land (*Figure 2.4.27*).

Loading from scattered dwellings is also an important source, accounting for 14% of the total load.

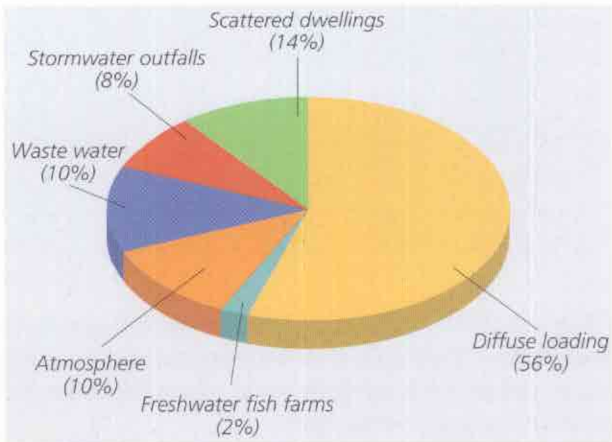


***Figure 2.4.27** Source apportionment of phosphorus input to the monitoring programme lakes for the period 1992-96 (Source: National Environmental Research Institute).*

The effects of the various measures to reduce phosphorus loading on lake environmental state can be calculated on the basis of the 37 lakes included in the Nationwide Monitoring Programme (*Figure 2.4.28*). The following calculations have been made:

A: Current situation.

B: Unchanged external loading combined with cessation of internal loading. Some of the lakes have accumulated considerable amounts of phosphorus in the lake sediment. This is now being released, thereby increasing the lake water phosphorus concentration. The accumulated phosphorus is slowly flushed out of the lakes and the phosphorus concentration will fall to an equilibrium determined by the external loading.

C: B plus 50% reduction in point-source loading.

D: C plus 50% reduction in diffuse loading.

In example B, the environmental state of the lakes improves and only one lake has a phosphorus concentration greater than 0.2 mg P/l as compared with

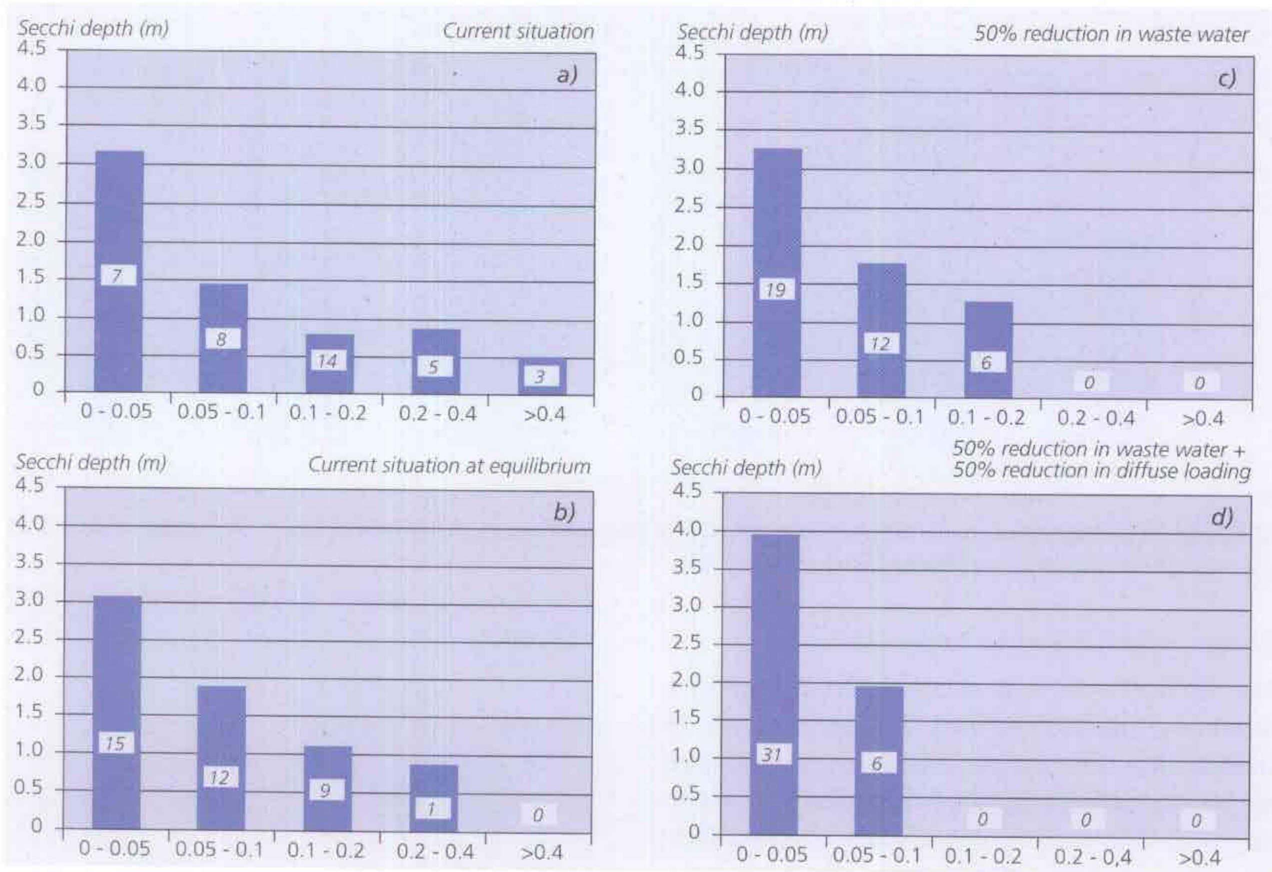


Figure 2.4.28 *Environmental state under different phosphorus loading situations. The lakes are grouped according to phosphorus concentration. The height of the columns indicates the average Secchi depth for the lakes in the individual phosphorus concentration groups, while the figure on the columns indicates the number of lakes.*

a) *Current situation in the lakes.*

b) *The situation when phosphorus release from the sediment stops (i.e. the lakes are in equilibrium).*

c) *The situation if loading by waste water effluent is halved.*

d) *The situation if diffuse loading is also halved. (Source: National Environmental Research Institute).*

8 lakes at present. At the same time, 15 lakes have a Secchi depth of about 3 m as compared with only 7 at present. Additional halving of point-source input to the lakes (example C) increases the number of relatively clear water lakes to 19 while 18 still have a Secchi depth of less than 2 m. In order to obtain marked improvement of the environmental state of all the lakes it is necessary to also halve phosphorus loading from diffuse sources (example D). Thereafter, 31 of the 37 lakes will have a phosphorus concentration below 0.05 mg P/l and a Secchi depth of around 4 m. The remaining 6 lakes will have a phosphorus concentration between 0.05 and 0.1 mg P/l and a Secchi depth around 2 m. The conclusion of these calculations is that lake environmental quality will improve considerably if waste water inputs and loading from diffuse sources are reduced.

In addition to the above mentioned delay in the reaction of the lakes to reduced external phosphorus loading due to internal release of phosphorus from the lake sediment, many lakes are also subject to biological resilience which hinders an immediate effect of reduced nutrient loading. The reason is that for several years following a reduction in nutrient loading the fish population will continue to be dominated by zooplanktivorous species. The amount of zooplankton is therefore held down at a low level, which makes it difficult for the zooplankton to control the amount of phytoplankton. The result is turbid water despite reduced nutrient loading.

If nutrient loading has been reduced sufficiently, however, it is possible to overcome this biological resilience. This can be done by removing the majority of the zooplanktivorous fish and/or stocking with piscivorous fish such as pike and perch, a measure termed biomanipulation. This promotes the zoo-plankton population and reduces the phytoplankton population. This method is being employed in numerous locations in Denmark with varying degrees of success. The possibility for success seems to increase the more nutrient loading is reduced and the greater the percentage of zooplanktivorous fish removed.

2.4.5 The marine environment

General characteristics

The Danish marine waters cover an area 2.5 times that of the Danish land mass. Of these marine waters, approx. half are accounted for by the Danish part of the North Sea, while the Kattegat and the Belt Sea (including Øresund) each account for 15%, and the Skagerrak and the Baltic Sea each account for 10%. With approx. 7,300 km of coastline the marine environment is an important part of the Danish nature. The marine waters exhibit great variation with respect to physical, chemical and biological conditions. The physical conditions range from small shallow coves, to closed estuarine fjords with poor water exchange, to open estuarine fjords, to sounds such as the Øresund and the Belt Sea, to open marine waters such as the Baltic Sea, the Kattegat, the Skagerrak and the North Sea. The salinity varies from virtually fresh water near the mouths of major rivers to around 8‰ in the Baltic Sea near Bornholm to approx. 35‰ in the deep waters of the Skagerrak, which sometimes penetrate far in along the bottom of the northeastern Kattegat. Salinity affects the ecological conditions. Thus there are far more species of animals and plants at the high salinities in the northern Kattegat than in the low salinities of the southern Belt Sea and the Baltic Sea.

The environmental state of the estuarine fjords is dominated by local inputs of pollutants and water, while the open marine waters are affected over long distances via water exchange and deposition from the atmosphere. There are considerable differences in the structure and function of the ecosystems moving from the estuarine fjords out into the open marine waters, with production and biomass of phytoplankton, benthic vegetation and benthic macroinvertebrates generally being higher in the fjords.

The main differences between ecosystem structure in the fjords and open marine waters are due to differences in water depth and stratification of the water column. In shallow areas, the wind can more easily break down the stratification and mix the water mass right down to the bottom. In the deep waters, in contrast, the water column can remain stratified for long periods.

Apart from nutrients, the environmental state of the marine waters is also affected by discharges of heavy metals, oil and environmentally hazardous substances via point sources, watercourses and the atmosphere, as well as by man's activities in the marine waters such as ship traffic, off-shore industries, extraction of marine aggregates (sand, gravel and stones), construction projects, marine fish farms and fishery. Fishery and the environmental problems associated with it are more closely examined in *Section 3.4.4*.

Eutrophication

The most important environmental problem in the Danish marine waters is eutrophication, i.e. the effect of enhanced nutrient loading leading to increased abundance of phytoplankton and annual filamentous algae and consequent negative impacts such as blooms of toxic phytoplankton and oxygen deficit.

For much of the year, the growth of phytoplankton and other plants in marine areas is limited by nitrogen availability. In estuarine fjords, however, phosphorus can be limiting for algal growth during short periods. Under natural conditions, both nutrient input and phytoplankton growth are relatively poor, and there are varied and stable plant and animal communities in the different marine waters.

When nutrient loading increases, these communities are destabilized. In many parts of the coastal waters, enhanced nutrient loading leads to an increase in the growth of annual filamentous algae, often accompanied by blooms of filamentous algae and sea lettuce. Filamentous algal blooms destroy ecological conditions for benthic invertebrates as well as spawning and nursery possibilities for fish. At even higher nutrient loading, the amount of phytoplankton increases dramatically and the water becomes turbid such that sunlight is unable to penetrate down to the benthic macrophytes, which therefore disappear. When the phytoplankton die, considerable oxygen is consumed, possibly resulting in fish mortality and destruction of larger water bodies such as seen in Mariager Fjord and other estuarine fjords in summer 1997.

Nutrient concentrations

Nitrogen and phosphorus loading leads to enhanced nutrient levels in the fjords and open marine waters, especially in the shallow and medium-depth fjords (*Figure 2.4.29*).

There is a clear relationship between the concentration level and land-based loading in both the fjords and open marine waters, the coupling being closest in the winter season, when fresh water input via watercourses is greatest.

The highest winter concentrations of nitrogen are mainly observed in estuarine fjords that are relatively closed, shallow and receive large amounts of fresh water from large watercourses. Examples are Nissum Fjord, Randers Fjord, Odense Fjord, Ringkjøbing Fjord, Mariager Fjord, and Roskilde Fjord, all of which receive large fresh water inputs from, respectively, the rivers Storå, Gudenå, Odense, Skjern, Kastbjerg and Villestrup, as well as a number of watercourses discharging into Roskilde Fjord. The highest winter concentrations of phosphorus are seen in Roskilde Fjord, Mariager Fjord, Odense Fjord and Flensborg Fjord.

In the summer season, the phosphorus concentration level is partly determined by land-based loading. In many fjords, however, the phosphorus level in the summer period is mainly determined by the release of phosphate from the fjord sediment. This release is attributable to the accumulation of large amounts of phosphorus in the fjord sediment during preceding years which is released during periods of high temperature and low oxygen conditions (*Figure 2.4.30*). In the majority of the Danish estuarine fjords, reductions in phosphorus loading over the period 1989-96, especially from waste water discharges, have led to a significant fall in the phosphorus concentration. During the same period, there has not been any demonstrable decrease in the nitrogen concentration, which is in accordance with the fact that nitrogen loading has remained at the same high level. In the open marine waters, there was also a tendency (although not statistically significant) towards falling winter phosphate concentrations over the period from the beginning of the 1980s to the 1990s, whereas the concentration of nitrogen (nitrate) has remained unchanged.

Plankton

In the fjords, the concentration of phytoplankton decreases with increasing mean depth, increases with increasing nitrogen loading and is limited by filter-feeding mussels (*Figure 2.4.31*). Thus the highest concentrations of phytoplankton are found in shallow fjords with a high level of nitrogen loading such as Ringkjøbing Fjord, Nissum Fjord and Randers Fjord.

For the period 1989-96, no general development in phytoplankton biomass and production has been demonstrated in the fjords. In the case of the open marine waters, however, phytoplankton biomass and maximal production have fallen over the period 1979-93. Zooplankton density and biomass also fell during the same period, except in the southern Belt Sea. This corresponds to the runoff-dependent variation in nitrogen loading, with high runoff in the 1980s and relatively low runoff during the period 1989-93. The high runoff in 1994 and 1995 increased

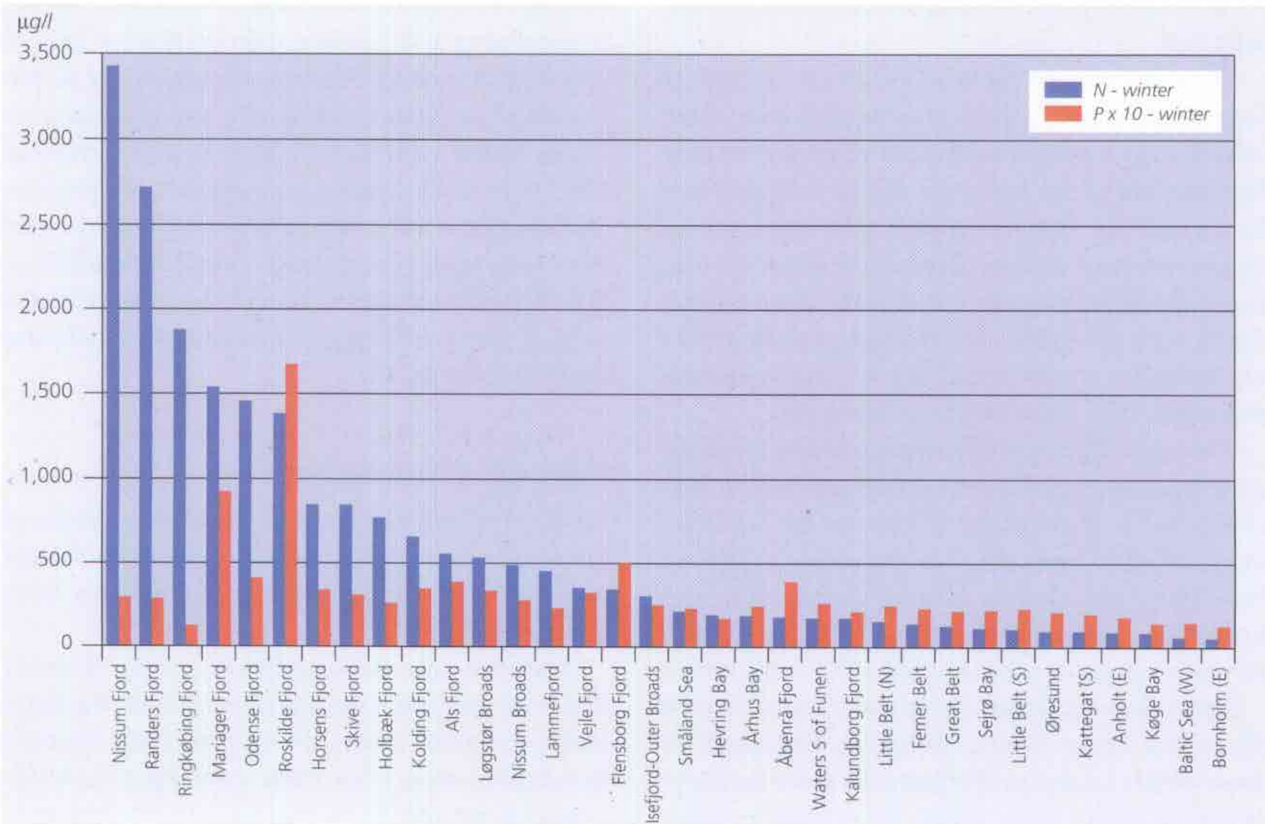


Figure 2.4.29 *Winter mean concentrations (January-February) of nitrate+nitrite (N) and phosphate (P) in 1995 in Danish marine waters from closed estuarine fjords to open marine waters, ranked according to decreasing nitrate+nitrite concentration. Not all Danish fjords are shown in the figure (Source: Data from the Counties and the National Environmental Research Institute).*

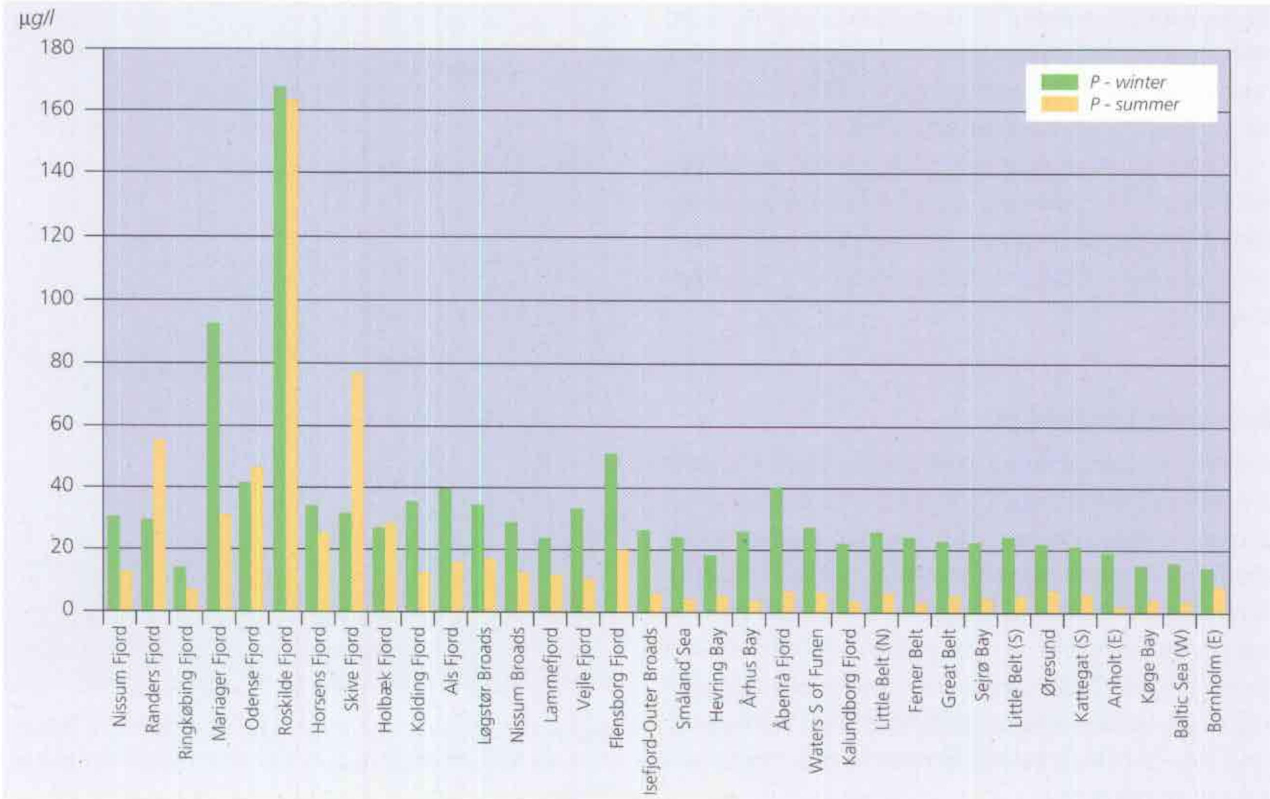


Figure 2.4.30 *Winter (January-February) and summer (May-September) mean concentration of phosphate (P) in 1995 in Danish marine waters from closed estuarine fjords to open marine waters, ranked according to decreasing nitrate/nitrite concentration. Release from the sediment during summer is apparent as markedly higher summer concentrations than winter concentrations in a number of the fjords (Source: Data from the Counties and the National Environmental Research Institute).*

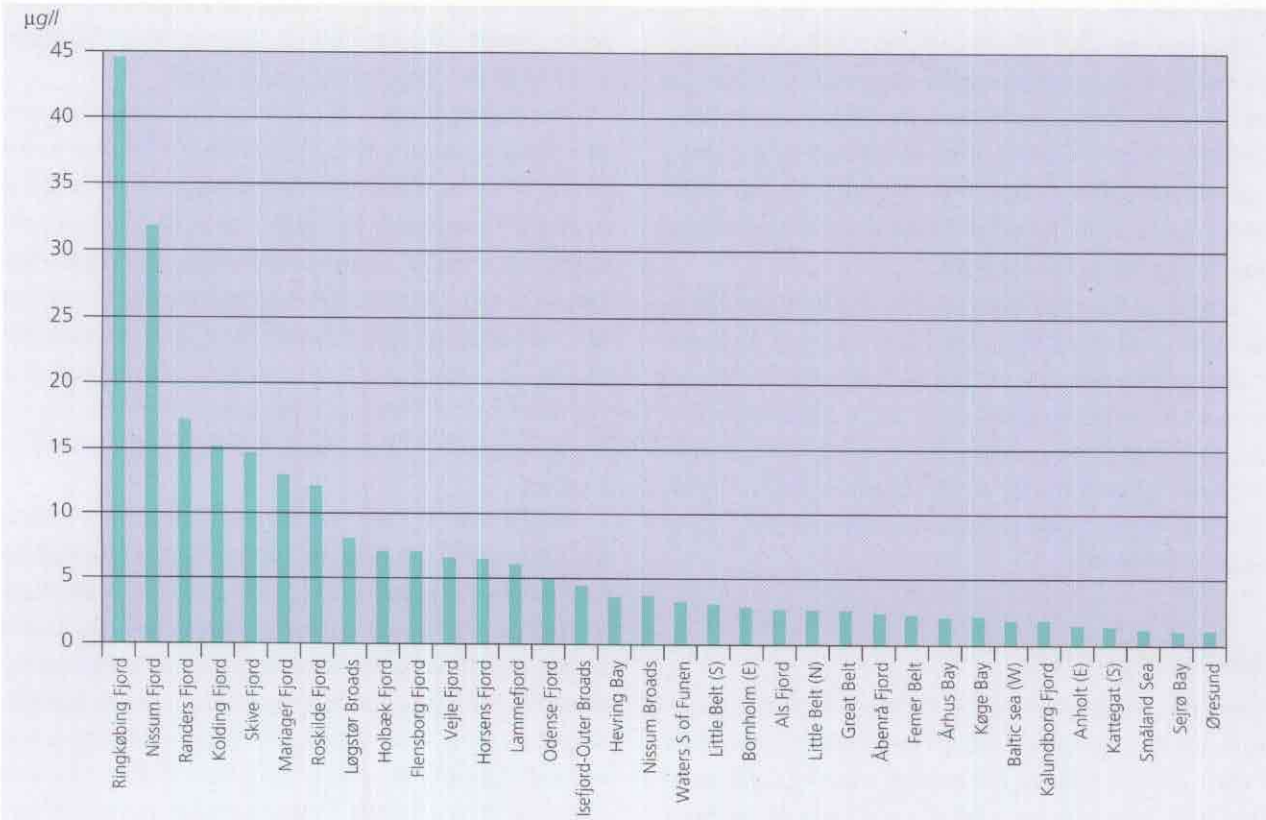


Figure 2.4.31 *Summer (May-September) mean concentration of phytoplankton biomass expressed as chlorophyll a concentration in 1995 in Danish marine waters from closed estuarine fjords to open marine waters, ranked according to decreasing concentration (Source: Data from the Counties and the National Environmental Research Institute).*

phytoplankton biomass and production again in the open marine waters. In 1996, a very low freshwater runoff and nutrient loading caused low primary production and more transparent water.

Based on the models established it can be predicted that a 50% reduction in nutrient loading of the Danish fjords will lead to a 25% average reduction in phytoplankton biomass during summer (May-September).

Toxic phytoplankton

Potentially toxic phytoplankton are found in low concentrations throughout most of the year in all marine waters. During the summer in areas with good growth conditions, including a plentiful supply of nutrients, toxic algae can bloom. Toxic algal blooms have been known to cause mortality among fish and benthic invertebrates, as well as deaths among cattle and dogs. In the 1980s in particular, there were many episodes of fish mortality in marine fish farms and fishing equipment.

Even when present in low concentrations, phytoplankton can accumulate in shellfish (mussels) and cause shellfish poisoning. Thus during the 1980s, it was often necessary to stop shellfish fishery in restricted areas.

In summer 1997, blooms of potentially toxic blue-green algae occurred along the coasts of the Øresund and the Belt Seas, and it was necessary to prohibit bathing for periods. In addition, blooms of the same algal species that caused fish mortality in the 1980s were observed in the western Kattegat and northern Belt Sea in the early autumn.

Based on the studies available, it is not possible to determine whether there has been any development in the occurrence of potentially toxic species. However, as toxin-producing algae are a natural part of the phytoplankton community, a reduction in nutrient loading and hence a reduction in total phytoplankton abundance will reduce the risk that these algae will bloom.

Benthic vegetation

From the beginning of the century to the present time, the eelgrass population has declined markedly (*Figure 2.4.32*), first as a result of wasting disease in the 1930s and later as a result of increased nutrient loading. Within the last few years, the most marked development in the eelgrass populations has been a number of local reductions in 1992 and 1994, probably due to a combination of high water temperature and oxygen deficit with the release of hydrogen sulphide. In 1996, the eelgrass populations declined in some of the shallow waters and especially in the more closed estuarine fjords, among other things as a result of the long period of ice cover.

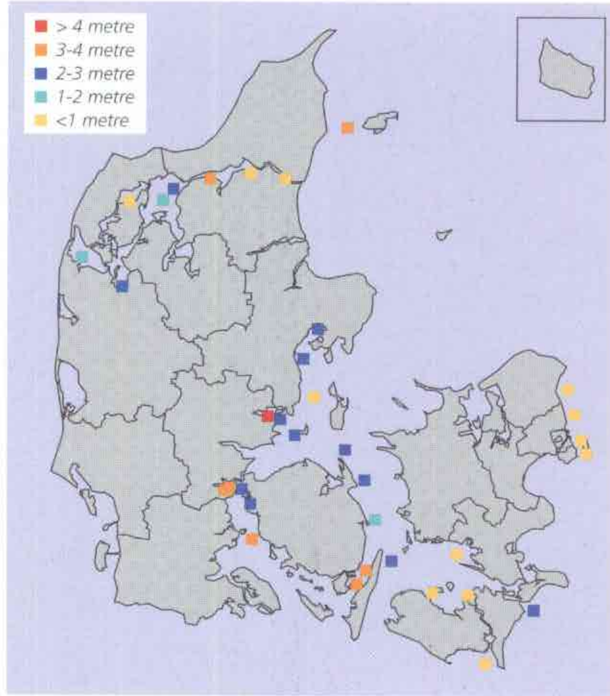


Figure 2.4.32 *Reduction in the depth distribution of eelgrass between the turn of the century and 1995 (Source: Kaas et al., 1996).*

In several places, re-establishment of these populations is underway and should be complete in the next few years. The depth distribution of the eelgrass is largely regulated by light and will therefore increase as a result of improved light conditions following a reduction in nutrient loading. This will entail a significant improvement in eelgrass areal distribution. In addition, it is expected that the eelgrass populations will become more stable if the risk of oxygen deficit is reduced following a reduction in loading.

In the case of the macroalgae (green, brown and red algae, etc.), a reduction in loading will entail an increase in the number of species, a reduced biomass of species associated with eutrophic conditions and a change in the species' relative dominance from communities with large numbers of a few species to communities with several species. In general, improved light conditions in connection with falling nutrient concentrations result in the benthic macrophytes gaining in importance relative to phytoplankton. Examples of such shifts in dominance between phytoplankton and benthic macrophytes are seen in

Norsminde Fjord and at Seden Beach in the innermost part of Odense Fjord in connection with the marked reduction in phosphorus loading and a reduction in summer nitrogen loading.

Oxygen conditions

Considerable parts of the Danish inner marine waters and fjords are regularly affected by poor oxygen conditions with negative effects on the benthic invertebrates and fish. The oxygen concentration normally reaches its minimum during the late summer and early autumn. How far the oxygen concentration falls in the late summer to some extent depends on the magnitude of phytoplankton production in the spring and summer, which in turn depends on the nutrient content of the water. Wind and water temperatures are also of great significance in connection with oxygen deficit. During periods with little wind, the water masses are not mixed and no new oxygen is supplied to the bottom water. During periods of high temperature, organic matter degradation proceeds rapidly with a high level of oxygen consumption.

In many Danish fjords, episodes of oxygen deficit occur every summer (*Table 2.4.6*). The situation is worst in Mariager Fjord and Flensborg Fjord, where more than half of the measurements made in July-September revealed severe oxygen deficit during the period 1989-94.

Frequent episodes of oxygen deficit also occur in other fjords, especially the deep fjords and coastal waters or medium-depth fjords with poor water exchange with the more open marine waters. In late summer 1997, oxygen deficit was detected in many Danish fjords (*Figure 2.4.33*). The situation was particularly bad in Mariager Fjord, where an area of 20 km^2 was devoid of oxygen throughout the whole of the water column, and there was very high mortality among fish and benthic invertebrates. Around one third of the Limfjorden was also struck by severe oxygen deficit, as was the outermost part of Vejle Fjord and the fjords of southern Jutland. Severe oxygen deficit also occurred in the marine waters south of Funen, and two thirds of Isefjord was affected by oxygen deficit or severe oxygen deficit.

Studies in Skive Fjord and Roskilde Fjord showed that oxygen conditions in the bottom water could be explained by the length of the period with stratification of the water column and nitrogen loading in the period prior to stratification. Under conditions of nitrogen loading like the average for the period 1984-94, oxygen deficit will typically occur in these two fjords after 6 days of stratification, and severe oxygen deficit will occur after 14 days of stratification. If nitrogen loading is halved as assumed in the Action Plan on the Aquatic Environment, oxygen deficit and severe oxygen deficit will typically occur after 12 and 28 days of stratification, respectively. The number of days with severe oxygen deficit will thus be markedly reduced. In the open, permanently summer stratified marine waters, a significant fall in the bottom water oxygen concentration has been demonstrated in July-October over the period 1970-96 in the Kattegat, Øresund, Great Belt and Femer Belt.

In the Danish part of the North Sea, oxygen deficit or indicators of oxygen deficit have been recorded in 1982-83, 1989 and 1994-96. As in the fjords, the most serious episodes of oxygen deficit in the open marine waters have occurred in years with high nitrogen loading and little or late bottom water mixing and exchange. Model computations of the effect on oxygen conditions in the inner Danish marine waters have been conducted for a number of scenarios involving reductions in nitrogen loading from Denmark, the countries around the Baltic Sea and North Sea, and from the atmosphere. The computations show that assuming the adopted reductions are fully implemented, oxygen conditions will improve considerably, especially in the southern Belt Sea, although without reaching right up to the level in the 1950s. The reduction in nitrogen loading to the North Sea will have little effect on the inner marine waters.

Benthic fauna

The benthic fauna (measured as biomass) in Danish estuarine fjords is highly dominated by annelids and especially by filter-feeding mussels. These can be considered as key organisms with regard to the state of the fjords as they affect the amount of phytoplankton. A cross-cutting analysis reveals a positive relationship between benthic invertebrate biomass, nitrogen loading and water depth. The positive relationship between nitrogen loading and benthic invertebrate biomass shows that the enhanced phytoplankton production as a result of eutrophication increases the food resource for the benthic invertebrates, while the negative effects of deteriorated oxygen conditions are generally limited. However, it has been shown that the benthic fauna in the majority of the fjords has changed since the beginning of the century such that it is presently dominated by species more tolerant to pollution and oxygen deficit. In several areas, the low runoff in

Classification of estuarine fjords and coastal waters

<4 mg O_2/l	Oxygen deficit	<2 mg O_2/l	Severe oxygen deficit
>50%	Mariager Fjord Flensborg Fjord Aabenraa Fjord	*>50%*	Mariager Fjord Flensborg Fjord
50-25%	Genner Fjord Waters S of Funen Skive Fjord Vejle Fjord Lammefjord Århus Bay	*50-25%*	Aabenraa Fjord
25-10%	Kalundborg Fjord Isefjord - Outer Broads Bjørnholm Bay/Risgårde Broads Limfjorden NW of Mors Helnæs Bay Isefjord Horsens Fjord	*25-10%*	Waters S of Funen Skive Fjord Genner Fjord Lammefjord Bjørnholm Bay/Risgårde Broads
10-5%	Roskilde Fjord Randers Fjord Holckenhavn Fjord Dybsø Fjord Kolding Fjord	*10-5%*	Limfjorden NW of Mors Vejle Fjord Roskilde Fjord Dybsø Fjord Århus Bay
0-5%	Isefjord - Inner Broads Løgstør Broads Kertinge Cove/Kerteminde Fjord Haderslev Fjord Odense Fjord Ringkøbing Fjord Little Belt Broads Skælskør Fjord Nakkebølle Fjord Nissum Fjord Stege Bay Limfjorden S of Mors	*0-5%*	Helnæs Bay Isefjord Isefjord - Inner Broads Haderslev Fjord Kalundborg Fjord Holckenhavn Fjord Skælskør Fjord Nakkebølle Fjord Kolding Fjord Horsens Fjord Isefjord - Outer Broads Stege Bay Løstør Broads Limfjorden S of Mors
0%	Præstø Fjord Grådyb tidal flats Lindelse Cove Holsteinborg Cove Korsør Cove Holbæk Fjord Augustenborg Fjord Nibe-Gjøl Broads	*0%*	Præstø Fjord Nissum Fjord Ringkøbing Fjord Grådyb tidal flats Randers Fjord Odense Fjord Kertinge Cove/Kerteminde Fjord Lindelse Cove Little Belt Broads Holsteinborg Cove Korsør Cove Holbæk Fjord Augustenborg Fjord Nibe-Gjøl Broads

Table 2.4.6 *Classification of estuarine fjords and coastal waters according to the relative frequency (in %) of oxygen deficit (<4 mg O_2/l) and severe oxygen deficit (<2 mg O_2/l) in the late summer (July-September) during the period 1989-94. >50% indicates that more than half of the measurements in a fjord yielded bottom water oxygen concentrations below the limit for oxygen deficit (Source: Kaas et al., 1996).*

winter 1995-96 resulted in improvement of the state of the benthic fauna as the occurrence of oxygen deficit in 1996 was relatively limited.

Retention of nutrients in fjords

Estuarine fjords are often considered as filters for nutrients on their way from land to the open sea. As a large part of the Danish nutrient discharges take place to fjords, quantification of this filtering effect is particularly important when Danish inputs to marine waters such as the Kattegat are to be determined and compared to inputs from adjoining open marine waters, the atmosphere and neighbouring countries. In ten fjords for which data is available on nutrient inputs to the fjords and exchange across their open boundary, nitrogen was found to be retained in nine. The average loss in the fjords was 31% of the input, and was attributable to a combination of denitrification and accumulation in the fjord sediments. The percentage of nitrogen removed increases with the residence time of the water in the fjords. In the case of phosphorus, retention only occurred in two of the nine fjords while there was net release of phosphorus in the other seven fjords. The export of phosphorus from the fjords to the open marine waters is due to the release of phosphorus that has accumulated in the sediment in the earlier years of higher phosphorus loading.

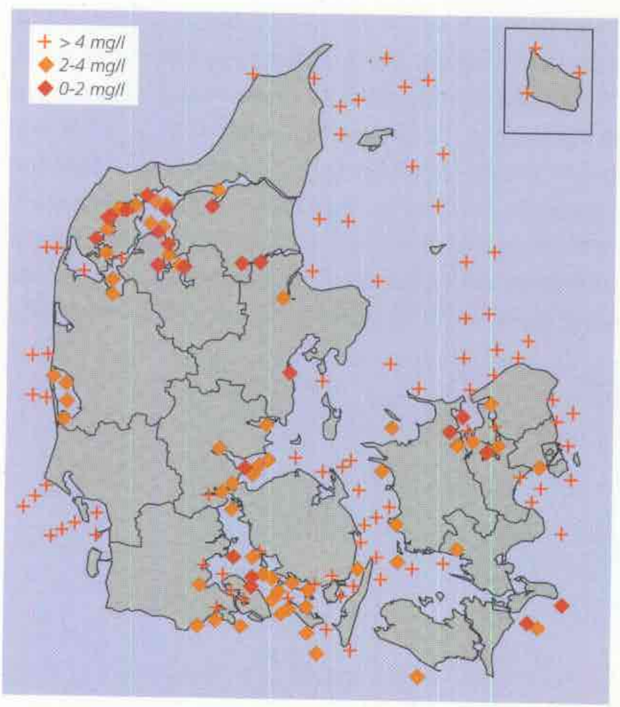


Figure 2.4.33 *Oxygen deficit and severe oxygen deficit in August 1997 (Source: National Environmental Research Institute).*

Nutrient loading

The marine waters receive nutrients via watercourses, from direct point sources, by atmospheric deposition and by exchange with adjoining marine waters. *Figure 2.4.34* provides an overview of annual inputs of fresh water, nitrogen and phosphorus to the marine waters from Denmark over the years 1989-96 compared with the mean value for the period 1981-88 (prior to the Action Plan on the Aquatic Environment).

Nitrogen loading in the individual years has generally followed the variation in freshwater runoff.

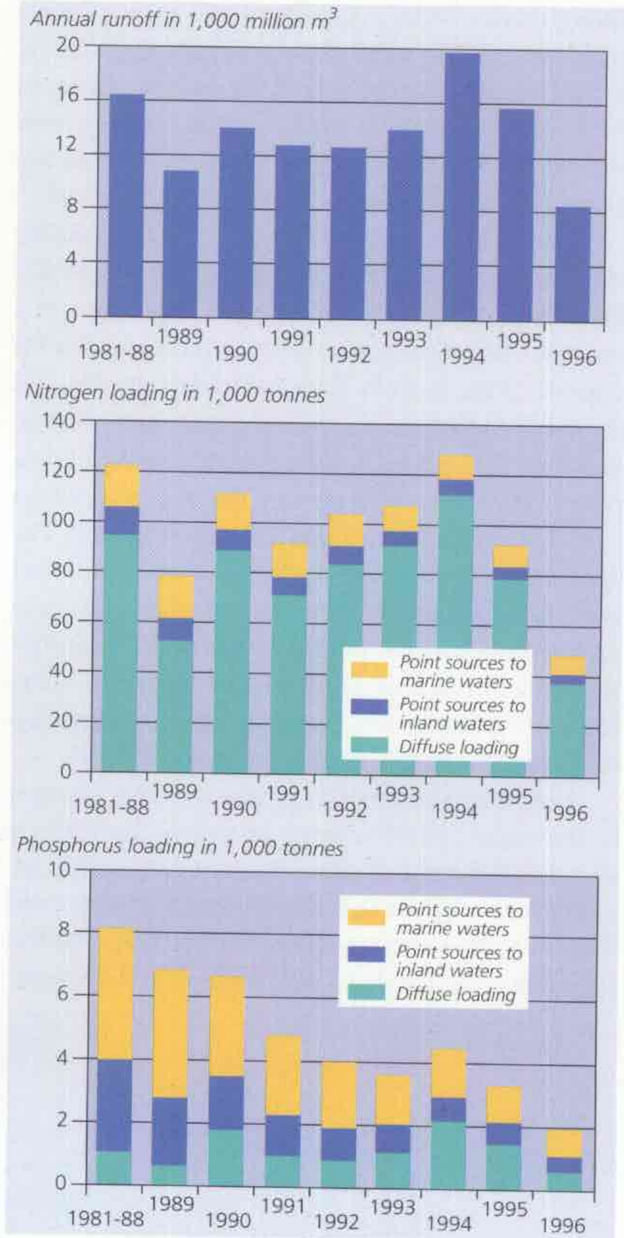


Figure 2.4.34 *Development in annual runoff of water and nitrogen and phosphorus loading of marine waters via point-source inputs to inland waters, diffuse sources (including scattered dwellings), and Danish direct point-source discharges to the sea for the period 1981-88 (mean) and each year since the start of the Nationwide Monitoring Programme (1989-96) (Source: Kaas et al., 1997).*

Nitrogen loading was therefore least in the dry years 1989 and 1996, and greatest in 1994, when runoff was among the highest ever measured. Point-source discharges account for a relatively smaller part (15%) of total nitrogen loading, and the 50% reduction in nitrogen loading from point sources thus has not had any major impact on total nitrogen loading.

Phosphorus loading is dominated by the point-source discharges, and the marked reduction in these has resulted in a general reduction in phosphorus loading. The most marked reduction is seen in the fjords that were formerly the most polluted. In 1996, though, point-source discharges still accounted for more than 50% of total phosphorus loading. On average, phosphorus loading of the marine waters in 1996 was approx. 1/3 of that in 1989. Loading from our neighbours Sweden and Germany follows the same developmental trend as that from Denmark.

In addition to the land-based inputs from watercourses and point sources, nitrogen is also supplied to the marine waters via atmospheric deposition. In a normal year, atmospheric deposition accounts for approx. 1/3 of the total load and of this, approx. 1/3 derives from Danish sources, with ammonia volatilization from agriculture as an important source. Atmospheric deposition of nitrogen on the marine waters in 1996 varied between 0.7 and 1.4 tonnes N/km^2. The deposition per unit area is greatest in the fjords and coastal waters, due to their close proximity to areas with livestock herds and hence ammonia volatilization on land, and least in parts of the North Sea. There has been no significant change in nitrogen deposition on the marine waters during the period 1989-96.

A mass balance for biologically available nitrogen in the inner Danish marine waters in the 1980s is shown in *Figure 2.4.35*. Since the start of the 1950s, input from land (Denmark, Sweden and Germany) and the atmosphere and net input from the Baltic Sea has approximately doubled. Gross input from the Skagerrak has remained largely unchanged except in a few years, when the Kattegat received extra nitrogen with the Jutland Coastal Current via European rivers (Elbe, Weser, etc.) that flow into the German Bight. The most important increase has thus been in the direct point-source discharges from land and the atmosphere, and to a lesser extent from the Baltic Sea.

The concentration level is generally low in the Baltic Sea, higher in the Skagerrak, relatively higher in the inner marine waters, even higher in the coastal waters and estuarine fjords, and highest at the mouths of the watercourses. Thus even though in quantitative terms there is a large transport between the Baltic Sea and the Skagerrak through the inner marine waters, it is the high concentrations in the inputs from land that are the cause of the high concentrations in the inner marine waters.

Environmentally hazardous substances in the marine environment

Environmentally hazardous substances that are not readily degraded in the environment will often end up in the sea. The substances are supplied to the marine environment from the atmosphere, watercourses and point-source discharges, as well as from activities such as ship traffic, the offshore industry and marine dumping of polluted harbour sediments. Metals and a number of persistent organic compounds are generally rather insoluble in water and they will therefore often adsorb to particles or sediment out on the sea floor, where they can be taken up by living organisms and possibly accumulate up the food chain. Long after the use and discharge of compounds such as PCB, DDT and heavy metals such as mercury, cadmium and lead has been reduced, they are still found in the environment and can cause undesirable effects. The highest concentrations of environmentally hazardous substances are often found in the coastal areas close to human activity.

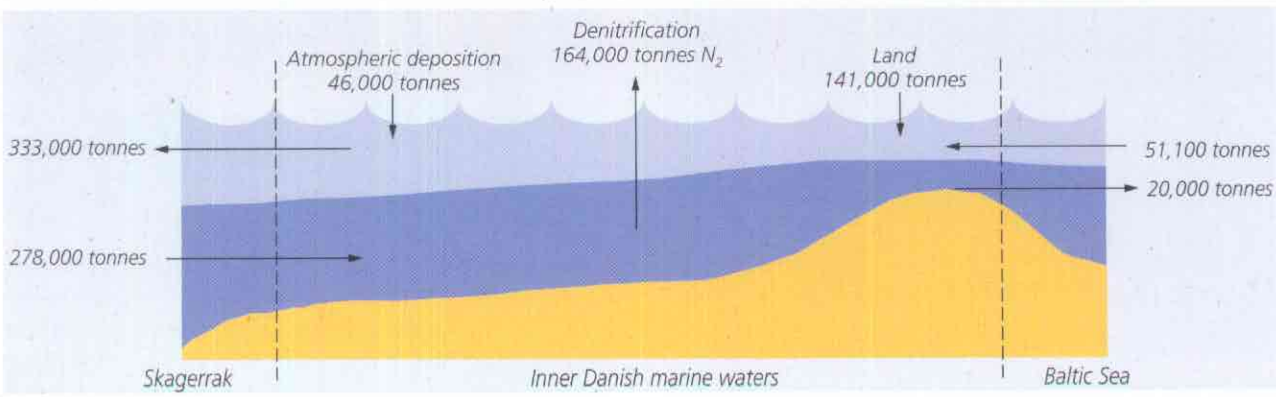


***Figure 2.4.35** Annual balance for biologically available nitrogen in the inner Danish marine waters calculated as the mean for the 1980s (Source: Hansen et al., 1994).*

Because of the high number of environmentally hazardous substances and the very complex physical-chemical and biological processes in which they are involved, our knowledge of the subject is very fragmentary. In the present section, reference is made to a few individual studies concerning the sources of and the occurrence and impact of environmentally hazardous substances in the marine environment. A broader examination of environmentally hazardous substances is given in *Section 2.5*.

Sources

Environmentally hazardous substances are input to the sea via point sources and diffuse loading via the air and watercourses. Our knowledge of diffuse loading is very sparse. With regard to the point sources, these encompass both industries with direct discharges and discharges from municipal waste water treatment plants, as well as discharges from marine activities such as marine transport and off-shore activities. The discharges from industry have been reduced considerably, as have discharges of the more insoluble substances from treatment plants, which instead now largely end up in the sewage sludge. In contrast, the more soluble substances such as phthalates, PAHs (polyaromatic hydrocarbons), chloroform, trichloroethane, nonylphenols, LASs (linear alkylbenzene sulphonates) are found in relatively high concentrations in the discharged waste water. A number of these substances are acutely toxic, and some are suspected of having oestrogen-like effects (see *Section 2.5*). Other sources include antifouling paints for ships and discharges from oil platforms.

Occurrence

No systematic monitoring is undertaken of environmentally hazardous substances in the marine environment, but only a number of dispersed studies.

Heavy metals concentrations in nonmigratory fish are investigated in an international monitoring programme for the North Sea and Baltic Sea. *Figure 2.4.36* shows the cadmium and mercury content of flounder from Nivå Bay in Øresund and plaice from Hvide Sande in the North Sea. It is apparent that the inter-annual variation can be very great and that the levels are considerably higher in the Øresund than in

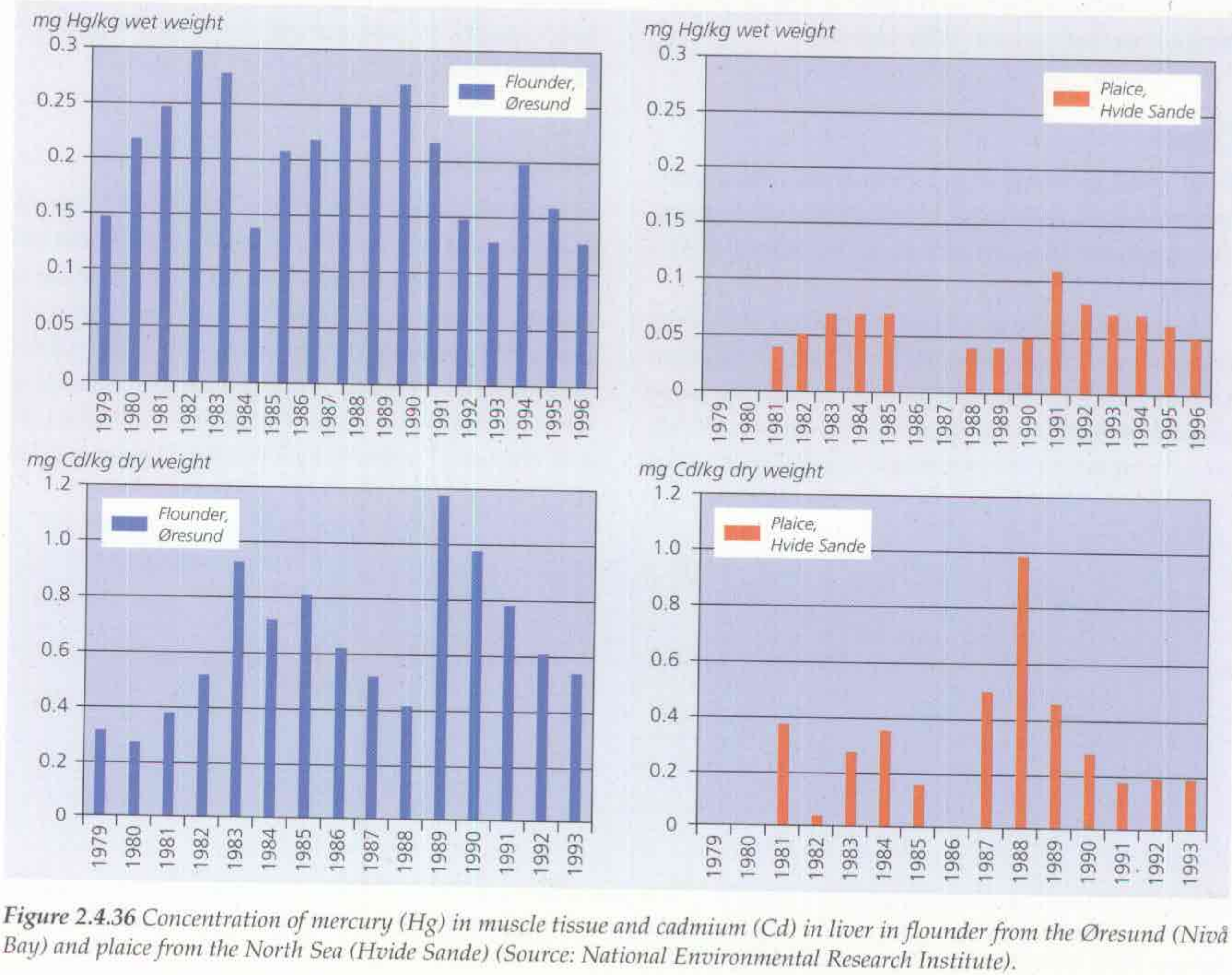


Figure 2.4.36 *Concentration of mercury (Hg) in muscle tissue and cadmium (Cd) in liver in flounder from the Øresund (Nivå Bay) and plaice from the North Sea (Hvide Sande) (Source: National Environmental Research Institute).*

the North Sea. Moreover, there is no clear tendency for the concentration of either metal to decrease. These substances have been strongly regulated over the last 10 years, and their continued presence is probably due to the fact that they have accumulated in the marine sediments, from where they continue to be released in considerable amounts. Persistent organic micropollutants such as PCB, DDT and chlorinated pesticides still frequently occur in the marine environment, despite the fact that they have been prohibited for some or many years.

A number of the substances that are discharged with waste water are also found in marine sediments, e.g. phthalates and PAHs. The antifouling agent TBT (tributyl tin) occurs in the highest concentrations in and around harbours, but can also be detected along busy shipping lanes. *Figure 2.4.37* shows measured concentration levels in Danish marine waters and the German Bight. In several places, the level is considerably above the lowest hazardous concentration, despite the fact that it is forbidden to use TBT on ships of less than 25 m in the EU, although it can still be used on larger ships until the year 2006. In antifouling paint for smaller boats, TBT has been replaced by other active components whose impact on the environment are not fully known.

Effects

Even small amounts of environmentally hazardous substances can have marked environmental impacts. The oestrogen-like substances are examined in *Section 2.5.*

In the case of the persistent substances, the worry is that they accumulate in the food chain. Thus regulation of the heavy metals focuses on their negative impacts on health when present in foods such as fish, etc. A number of the persistent organic substances are suspected of affecting fecundity capacity, especially in the higher fauna. In very low concentrations (<1 ng/l), TBT can render snails sterile and enhance shell thickness in oysters. Among other things, TBT has been found to affect mussels and algal communities in the North Sea.

Other marine environment problems

Bathing water quality

Out of the approx. 7,300 km of Danish coast, some 5,000 km are well suited for bathing. The quality of the bathing water is controlled at approx. 1,300 monitoring stations. In 1997, bathing was prohibited at 17 monitoring stations as compared with 19 in 1996.

Bathing water quality was doubtful at 18 beaches in 1997as compared with 57 beaches in 1996. In the mid 1980s, water quality was only acceptable for bathing at about 80% of the monitoring stations. By 1997, the figure has risen to 97%. In general, it can be concluded that bathing water quality has improved. The decline in the number of bathing prohibitions in recent years is attributable to efforts by the Municipalities to trace sources of pollution responsible for the poor bathing water quality, as well as measures to stop waste water discharges.

Oil pollution

During the period 1988-95, the Danish EPA has received an average of 350 reports of oil pollution annually. Up to 1991, there was a tendency towards a steady increase in the number of oil pollution reports, this probably being attributable to increased awareness of pollution at sea. By far the majority of these reports concern minor pollution incidents, and over the last 15 years there have only been a few ac-

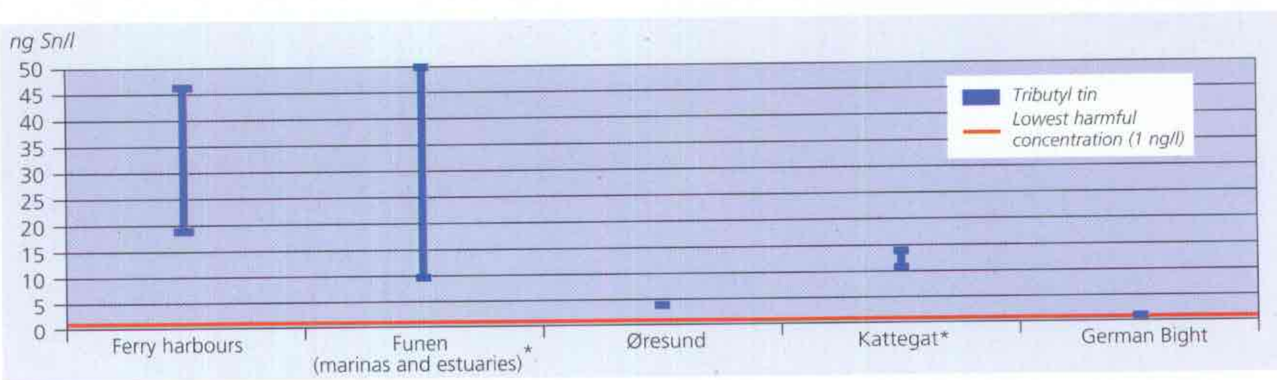


Figure 2.4.37 *Concentration of tributyl tin and organic tin in Danish marine waters and the German Bight (calculated as ng Sn/l sea water). *Measured as organic tin (Source: Copenhagen Environmental Control Unit, 1996, Danish Environmental Protection Agency, 1993, Kure, 1990, and Harvey and Cleary, 1992).*

cidents within the Danish area of jurisdiction that have caused major pollution. By far the majority of the reported incidents of oil pollution are thought to be caused by unlawful operational oil discharges from ships in transit through Danish marine waters and the North Sea.

The Danish EPA and the Danish Ornithological Society have together undertaken a project concerning the percentage of oil-polluted birds among stranded sea birds along the Danish coasts during the period 1984-95. The study showed that the percentage of polluted sea birds has fallen by 4-6% per year in the Baltic Sea and Belt Sea since 1985 (*Figure 2.4.38a*). In the Kattegat, the corresponding effect is less pronounced in that the decline in the number of oil-polluted birds did not start until after 1989 (*Figure 2.4.38b*), which indicates that the aerial surveillance which started in 1990 has had a preventative effect in the Kattegat. No corresponding fall has been demonstrated along the Jutland North Sea and Skagerrak coasts, where the percentage of oil-polluted sea birds has remained at an unchanged high level (*Figure 2.4.38c*). In other parts of the North Sea, however, in-cluding the Danish Wadden Sea, there has been a measurable fall in the percentage of oil-polluted sea birds (*Figure 2.4.38d*).

Offshore raw materials extraction and construction projects

Offshore industry

Oil exploration and extraction have both temporary and permanent effects on the marine environment. The environmental effects of offshore facilities include both the effect on the benthic flora and fauna, especially in connection with the construction of fixed installations and the placement of movable installations, and the effects on the marine environment caused by the discharge and spill of drilling fluids during oil well drilling. Routine production leads to the discharge of oil and production chemicals with the extracted formation water as well as chemicals used to stimulate the reservoir and other operations in connection with maintenance of the wells. Since 1991, an agreement has been in force with operators that they do not use oil-based drilling fluids in Denmark.

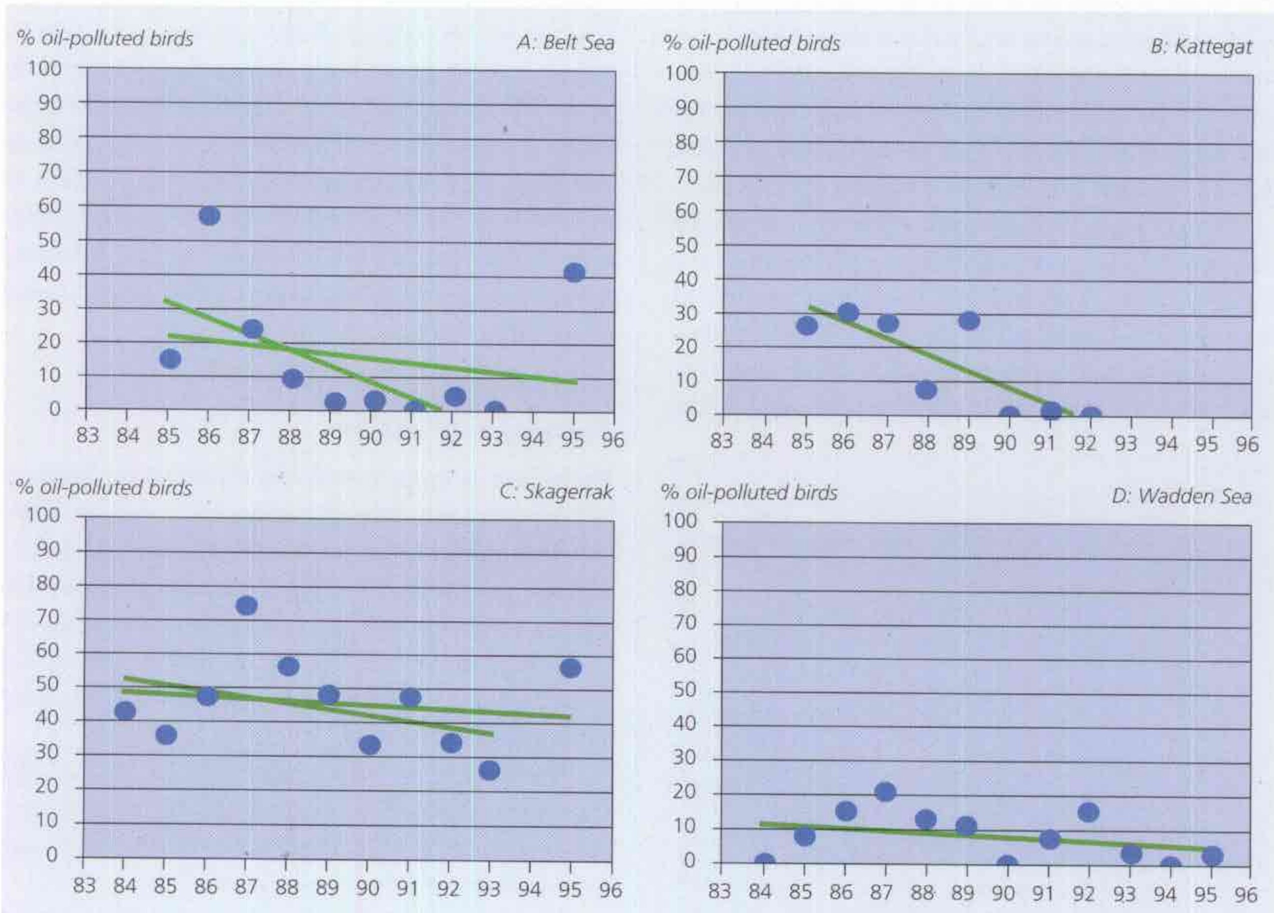


Figure 2.4.38 *Development in the percentage of oil-polluted birds among stranded sea birds along the Danish coasts illustrated for gulls in A: Belt Sea; B: Kattegat; C: Skagerrak and D: Wadden Sea. The fitted lines indicate linear trends for A, B, C and D calculated for the periods 1: 1984/85-1995 and 2: 1984/85-1994 (Source: Danish Environmental Protection Agency, 1997).*

Discharges of oil in formation water have amounted to around 100 tonnes annually, with an increasing tendency due to increased production and oil field aging. Chemicals are also used on the fixed installations to process the gas (before it is transported to land), the formation water (before it is discharged to the sea) and the sea water (before it is injected into the formation to improve recovery). These processes result in some discharge of the chemicals to the sea.

Gravel and sand pumping

Extraction of marine aggregates can considerably affect bottom conditions, depth conditions and the composition of the surface sediments, and will cause the dispersal of resuspended material in and beyond the area of operations.

Similarly, construction projects at sea involve appropriation of part of the sea bed for the actual installation, have negative effects on areas where excavation is undertaken and cause sediment to disperse into the water. The benthic flora and fauna are affected by the actual pumping or dredging activity as well as by the fine-grained particles in the water column, which reduce light penetration and which subsequently sediment out on the sea bed. Extraction of marine aggregates can be subdivided into gravel and sand pumping, extraction of stones, shell dredging and exploitation of sand and gravel from dredging operations.

Extraction of the high-quality materials sand, gravel and pebbles has been relatively constant for a number of years. In contrast, extraction of sand fill has varied markedly, primarily due to large construction projects such as the Great Belt Fixed Link (*Figure 2.4.39*). The amount of sandy waste from dredging operations that is exploited as a raw material and hence not dumped at sea is increasing slightly. The large amounts of moraine clay and lime excavated in connection with the construction of the fixed links across the Great Belt and Øresund has been fully utilized in the projects themselves.

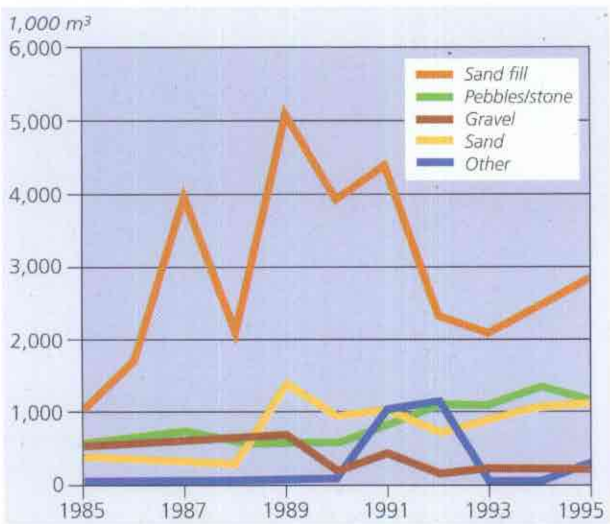


Figure 2.4.39 *Raw materials extraction in Denmark in 1,000 m³ per year (Source: National Forest and Nature Agency).*

It has previously been possible to extract marine aggregates anywhere unless specifically prohibited. In January 1997, a new Raw Materials Act entered into force and all extraction of marine aggregates now has to be undertaken in designated areas where the commercial and environmental interests have been weighed against each other. The total area presently designated for the extraction of sand, gravel and pebbles currently amounts to approx. 930 km^2. It is estimated that at the present level of activity, the area of sea bed directly affected by marine aggregate extraction will be 1-3 km^2 annually.

The largest amounts are extracted in areas where the sea bed predominantly consists of sand, and where the long-term environmental effects are considered to be limited. In contrast, sand and gravel pumping in deposits where the sea bed consists of coarse gravel or pebbles can be problematic as there is a risk that the sea bed will gradually change to one permanently consisting of a more fine-grained surface sediment. The change will mean that the original flora and fauna communities will not be able to re-establish in the areas. In conjunction with former restriction of extraction in the EC Bird Protection Areas, the limitations in the new Raw Materials Act will considerably reduce pressure on the environment in a large number of sensitive areas.

Extraction of stones

Extraction of large stones and boulders for harbour breakwaters, etc. currently amounts to approx. 7,000 m^3. The amount extracted annually is expected to decline up to 1999, when the extraction of stones will cease except in a few specially designated areas. Extraction of stones has previously had a very radical impact on the stone reef ecosystems, which are areas with great biodiversity.

The operations affect both the species that live directly on the hard sea bed, as well as the many species associated with the protected environment under and between the dense vegetation.

Based on the findings of detailed studies, the extraction of stones was stopped on the most valuable stone reefs. However, it was assessed that limited extraction of stones could continue in 29 areas until

1999 without having any permanent hazardous effects. After 1999, the number of areas will be reduced to 18 specially designated areas.

For a number of years, considerable quantities of mussel shells have been extracted in Roskilde Fjord. This will cease at the end of 1997, however.

Construction projects

In recent years, a number of major construction works have been undertaken in Danish marine waters in connection with the establishment of fixed links across the Great Belt and Øresund. The greatest permanent changes occur in those areas of the sea bed that have been appropriated by artificial islands and bridge piers, and in those areas permanently deepened by compensatory excavation. The excavation work is usually planned so as to minimize the character and duration of the environmental effects.

The dispersal of fine-grained sediment in the water as a result of marine excavation work can shadow or cover the benthic flora and fauna in very large areas. However, the permanent effects can be limited through the correct choice of equipment and detailed management of the excavation work. Thus in the case of the Øresund Fixed Link, requirements have been imposed limiting average spillage to 5% of the excavated material.

The main environmental impacts of construction of the Great Belt Fixed Link were caused by the major excavation work between April 1989 and February 1991. A total of 4.5 million tonnes marine sediment was spilt, and 20% of this was still present one year later as a 10 cm to more than 50 cm thick layer in three main areas in particular. Of these, a 4 km^2 area of sea bed southeast of Sprogø was the largest and most severely affected.

The common mussel population at Sprogø was reduced by up to 90% in the period 1989-92, and the overwintering eider duck population that lives off the mussels moved to other areas. The eelgrass and macroalgae vegetation around Sprogø and the inner part of Halskov Reef also declined, among other reasons because of reduced light penetration and blanketing with sediment. In contrast, the spring spawning herring in the Great Belt did not seem to be affected by the activities.

In 1994, the natural conditions investigated had virtually re-established around Sprogø. At Halskov Reef, however, mussel beds had taken over the areas formerly occupied by the macroalgae.

2.4.6 **Objectives and policy measures**

As described above, the aquatic environment does not really consist of one single entity, but rather a cycle that encompasses a number of subsystems, namely:

- Groundwater
- Watercourses and lakes
- Coastal and open marine waters

As elements in a unified cycle, these subsystems are inter-related. Thus changes and pressures in one part of the cycle often propagate further through the cycle,

Legislation on the aquatic environment

International:	National:	Local:
• Oslo and Paris Conventions • North Sea Convention • Helsinki Conventions **EC Directives:** • Freshwater Fish Directive • Water Directive - forthcoming • Bathing Water Directive • Shellfish Waters Directive • Nitrates Directive • Drinking Water Directive • Birds Directive • Habitats Directive	• Environmental Protection Act • Nature Protection Act • Marine Environment Act • Watercourse Act • Hunting and Game Management Act • Water Supply Act • Ochre Act • Raw Materials Act • Inland Waters Fishery Act • Action Plan on the Aquatic Environment • Action Plan for Sustainable Agricultural Development • Pesticides Action Plan • 10-point programme for protection of the groundwater and drinking water	• Regional planning • Recipient quality planning • Designation of environmentally vulnerable areas • Environmental supervision

Box 2.4.1 *Summary of legislation etc. pertaining to the aquatic environment.*

as for example is the case with nutrient loading from agriculture, which affects the whole cycle through a large number of transport and turnover processes. Conversely, the individual elements of the cycle each comprise an independent ecological system each with its own special characteristics such that the effects of pressures differ from subsystem to subsystem. Environmental policy measures in this area reflect the dual character of the aquatic environment i.e. a unified cycle on one hand and a number of subsystems each with its own characteristics on the other. Thus on one hand there are a number of laws and regulations directed at the individual subsystems e.g. the Watercourse Act, while the 10-point programme for protection of groundwater and drinking water and the Marine Environment Act,while on the other hand there are a number of plans and endeavours directed at the whole cycle e.g. the Action Plan on the Aquatic Environment.

Because of the complex character of the aquatic environment, the relevant administrative body ranges from the local/regional level to the national level to the international level.

A number of international marine conventions and a large number of EU Directives thus provide part of the frameworks for the efforts to improve the state of the aquatic environment. These supplement the national environmental legislation as well as a number of national action plans. Within the framework of these international and national regulations, it is up to the individual Counties and Municipalities to implement the overall environmental protection efforts in practice through their local planning powers and environmental supervision duties.

Anthropogenic pressures on the aquatic environment can be divided into two main types:

Discharges of polluting substances such as nutrients, organic matter, environmentally hazardous substances etc., and physical pressures such as water abstraction, drainage and watercourse channelization, construction activities such as roads and bridges, etc.

The environmental endeavours directed at each of the three aquatic subsystems, i.e. groundwater, watercourses and lakes, and coastal and open marine waters are examined below. The endeavours are di-vided into those directed at pollutant discharges and those directed at physical pressures on the environment

Groundwater

Pollution

As is apparent from *Section 2.4.2*, the main problems facing the groundwater are pollution with nitrate, pesticides and a number of organic and inorganic micropollutants. The source of nitrate is agriculture, while that of pesticides is both agriculture and other users of pesticides. The other environmentally hazardous substances mainly derive from landfills and contaminated sites. The efforts encompass a broad range of measures directed at the various sources. The majority of these are summarized in the 10-point programme for protection of groundwater and drinking water put forward by the Government in December 1994 (see *Table 2.4.7*).

The 10-point programme contains two main types of endeavour: Endeavours directed towards reducing general loading of the groundwater with the undesirable substances, and endeavours directed towards protecting areas of special importance for the drinking water supply. The efforts directed towards general nitrate loading follow the objectives and initiatives stipulated in the Action Plan on the Aquatic Environment and subsequently followed up by a number of action plans for the agricultural sector. These are examined in detail in *Section 3.4.2* as well

Government's 10-point programme

1. Particularly environmentally harmful pesticides removed from the market.
2. Pesticide levy - consumption of other pesticides to be halved.
3. Nitrate pollution to be halved by the year 2000.
4. Organic farming to be promoted.
5. Protection of particularly vulnerable water abstraction areas.
6. New Contaminated Sites Act - contaminated sites to be remediated.
7. Enhanced afforestation and nature restoration to protect the groundwater.
8. Enhanced efforts in the EU.
9. Improved monitoring of groundwater and drinking water.
10. Dialogue with the agricultural sector.

Table 2.4.7 *The Government's 10-point programme to protect the groundwater and drinking water.*

as later in this section. As is apparent from *Section 2.4.2*, the effects of these measures are not yet detectable in the concentration of nitrate in the groundwater. The endeavours directed towards areas of special importance for the drinking water supply aim to change land use in these areas in the direction of less intensive use, for example afforestation, conversion to organic farming or other forms of extensive agricultural production. Thus in connection with the preparation of their Regional Plans in 1997, the Government asked the Counties to identify groundwater resources in special need of protection. Large-scale conversion of land use in these sensitive agricultural areas has not yet been undertaken, but the Government Budget for 1998 includes appropriations for strengthening endeavours on this front.

The endeavours to curb pesticide pollution follow the Government's general efforts on the pesticide front. These comprise the phase-out of the most environmentally hazardous pesticides and a general reduction in pesticide consumption. The pesticides previously approved have been reevaluated and over the period 1994-97, more than 150 products containing 28 different active substances have been prohibited. The pesticide levy was raised in 1995 and again in 1998. Endeavours on this front are examined in more detail in *Section 2.5*. From 1 January 1998, the Nationwide Monitoring Programme has been expanded to also include analysis for a considerably greater number of pesticides and pesticide residues than before.

Because of the complex nature of pesticide pollution, many years will pass before a clear effect on the groundwater will be detectable. Protection of areas of special interest for the drinking water supply follows the same principles as mentioned above concerning nitrate. Endeavours on this front will be strengthen-ed by the 1998 Government Budget. The objective is that clean-up of landfills and contaminated sites that threaten the groundwater in future areas of special interest for the drinking water supply should be completed within 10 years. Clean-up will also be undertaken outside these areas if this is worthwhile with regard to a well-functioning existing water supply. Responsibility for the clean-up of landfills will lie with the Counties. Finally, it should be mentioned that on 10 June 1997, Parliament prohibited the use of quarries for depositing soil.

Physical pressures

The physical pressures on the groundwater are associated with groundwater abstraction. During certain periods in certain parts of the country, abstraction can exceed groundwater formation, thereby causing the groundwater table to fall. This can result in the release of substances such as nickel, arsenic and selenium to the groundwater (cf. *Section 2.4.2*), as well as to the drying out of watercourses and lakes in the summer months. The endeavours on this front have primarily consisted of various water-saving campaigns supplemented with a water levy, and have resulted in a clear general reduction in water consumption (cf. *Section 2.4.2*). The problems mentioned can still arise in certain parts of the country, however.

Watercourses and lakes

Pollution

As is apparent from *Sections 2.4.3* and *2.4.4*, interest concerning pollution of watercourses and lakes has mainly centred around ochre pollution of the watercourses in western Jutland, and phosphorus pollution of the lakes. Discharges of organic matter and environmentally hazardous substances from certain industries used to be a problem but upgrading of the waste water treatment plants and endeavours to curb unlawful point-source discharges from agriculture have solved these problems in most areas. An emerging problem may be pesticide pollution of watercourses.

With regard to phosphorus pollution, this has also been reduced considerably as a result of phosphorus precipitation in municipal waste water treatment plants and in individual industrial outfalls. The Action Plan on the Aquatic Environment's goal of an 80% reduction in these discharges has largely been met (cf. *Section 3.9*). Nevertheless, phosphorus loading of our lakes continues to be too high to meet the environmental quality objectives that the Counties have stipulated for the lakes (cf. *Section 2.4.4*). This is mainly attributable to diffuse phosphorus loading from the countryside, including scattered dwellings. As regards ochre pollution, the Ochre Act empowers the Danish EPA to subsidize special measures. A number of successful ochre removal projects have thus been undertaken in recent years.

Physical pressures

The environmental quality of the watercourses and to a certain extent that of the lakes is very much affected by physical conditions such as water abstraction, lowering of the groundwater table, drainage, obstructions, culverting, channelization, weed clearance, etc. In 1995, Parliament amended the Watercourse Act and the Water Supply Act with the aim of accelerating the recreation of an ecologically well-functioning watercourse system.

In addition, the 1992 Nature Protection Act introduced protection provisions for lakes and watercourses, and established the possibility to subsidize nature restoration projects. As a result of these initiatives, far more environmentally sound water-course maintenance has been introduced and more than 900 restoration projects have been undertaken that have improved the environmental quality of many watercourse reaches. In addition, about 20 formerly reclaimed lakes have been re-established since 1989.

The Danish watercourse systems are nevertheless still affected by physical intervention as a result of human activities. 85-90% of the watercourses are estimated to have impoverished physical conditions and hence improvement of their quality remains a major challenge. In connection with the recent discussion on nutrient loading of watercourses, lakes and marine waters, attention has focused on watercourses, riparian areas and lakes as possible natural filters for nutrients. This aspect also entails a major challenge for the future.

Coastal and open marine waters

Pollution

The dominant pollution problem facing the Danish marine waters is nitrogen loading, as described in *Section 2.4.5*. According to the 1987 Action Plan on the Aquatic Environment, nitrogen loading from agriculture, waste water treatment plants and industry was to be halved over a 5-year period from 290,000 to 145,000 tonnes per year (agricultural sources 127,000 tonnes, waste water treatment plants 15,000 tonnes and industry 3,000 tonnes). The correspond-ing reduction target for phosphorus loading was 80%, primarily from waste water treatment plants and industry. In 1991, the Government followed up on the Action Plan on the Aquatic Environment with the Action Plan for Sustainable Agricultural Development. The targets were maintained, but the time frame for reducing nitrogen loading was postponed to the year 2000. In recent years, monitoring of the aquatic environment has not demonstrated any marked changes in the level of nitrogen. There is a tendency towards a slightly lower nitrogen concentration in watercourses from clayey soil areas, but there has not been any demonstrable fall in the nitrogen concentration in the estuarine fjords and inner marine waters. However, models of leaching from agricultural land based on information of fertilization levels, crop grown, livestock density, weather conditions etc., show that leaching from agricultural land has been reduced by 17% (cf. *Section 3.4.2*). In connection with the 1998 Government Budget, a framework agreement was entered into aimed at realizing the Action Plan on the Aquatic Environment's goal of halving nitrogen loading from agricultural sources.

The instruments under consideration include enhanced afforestation and nature restoration, more stringent livestock density requirements, improved utilization of the nitrogen content of livestock manure, and a reduction in fertilization norms combined with a fertilization quota exceedence levy.

In addition to nitrogen loading, interest is also directed towards discharges of a number of environmentally hazardous substances to the marine environment since the sea often serves as the final recipient for these. The Helsinki Declaration adopted a 50% reduction in discharges of heavy metals and other persistent environmentally hazardous substances from 1989 to 1995. It is estimated that Denmark has achieved this reduction, mainly as a result of improved treatment capacity in the municipal and industrial waste water treatment plants. In the 1995 North Sea Declaration, it was decided that discharges of these substances were to be phased out completely within the next generation (25 years). Pollution from ship antifouling agents has been partly curtailed by prohibition of the use of tributyl tin (TBT) on ships less than 25 m. In the case of ships longer than 25 m, the prohibition enters into force from the year 2006.

Physical pressures

The physical pressures on the marine environment are considerable (cf. *Section 2.4.5*). These include marine construction works in connection with offshore activities and major bridge-building projects, gravel and sand pumping, extraction of stones, etc. The Raw Materials Act, the Nature Protection Act, the Marine Environment Act and the Environmental Impact Assessment Directive contain provisions that regulate these conditions. Pursuant to these provisions, restrictions have been imposed on gravel and sand pumping, extraction of stones and major construction projects, which are subject to major environmental studies. The impact of fishery is examined in *Section 3.4.4*.

2.5 Environmentally hazardous substances

2.5.1 Introduction

It is believed that about 100,000 chemical substances are on the market worldwide, of which approx. 1,500 account for more than 95% of total world production of chemicals by weight. In Denmark, up to 20,000 chemical substances are estimated to be on the market in about 100,000 different chemical products used in the production of over 200,000 industrial products.

Chemical substances are thus present throughout society, and circulate from the chemicals industry via other production sectors to a myriad of products that feed into consumption and finally end up in society's waste streams. Some degree of loss to the surroundings will occur during each step in this cycle through society, in general via emissions to the air or water, and in some cases directly to the soil, with resultant dispersal and turnover of the substances in the environment. Some of the substances are degraded to harmless end products, some are transformed to hazardous breakdown products, and others are persistent and accumulate in various parts of the environment depending on their physical and chemical properties. Here they enter into nature's biological cycle and are taken up in greater or lesser amounts by plants and animals, whereby they can migrate up the food chain, possibly accumulating from step to step.

Certain of the substances thus return to man in trace amounts in plant or animal foodstuffs. In the biological cycle the substances can cause a multitude of toxicological and ecotoxicological effects ranging from acute toxicity and allergic reactions to more long-term effects such as an increased risk of cancer and effects on animal and human reproduction.

It is an extremely complicated matter to regulate such a complex and manifold problem. Just the task of procuring knowledge on the use, turnover and effects of the substances is enormous. Moreover, since many of the substances are components of products that have become firmly rooted in the whole of society's complex production and consumption structure, regulation of their use is a very demanding task.

As a result of this complexity, the regulation of environmentally hazardous substances has followed different lines of approach, including media-oriented, source-oriented, product-oriented and substance-oriented regulatory approaches.

Existing knowledge on the occurrence of environmentally hazardous substances in the individual media is examined in the preceding media-oriented sections of this report. The present section instead focuses on some of the more broad problems associated with these substances. First comes a general introduction to our knowledge about their production, use and emissions, then an examination of certain selected groups of substances - heavy metals, pesticides and oestrogen-like substances, and a summary of what is known about the occurrence of environmentally hazardous substances in foodstuffs. Thereafter follows a description of how risk assessment of environmentally hazardous substances is undertaken and finally, of current efforts to regulate them.

2.5.2 Production, use and emissions

The chemicals industry is one of industrial society's important branches. In Denmark, industrial turnover amounts to just over DKK 30,000 million, corresponding to just under 10% of total industrial turnover. At the global level, the chemicals industry markets about 100,000 substances, although the majority are marketed in small amounts. In the EU, high-volume substances are defined as substances that are marketed in amounts exceeding 1,000 tonnes per producer per year. Substances falling into this category number approx. 2,700. It is estimated that between 10,000 and 20,000 substances are produced in the EU in amounts exceeding 10 tonnes per producer per year.

On the basis of information in the Danish Product Register, it is estimated that up to 20,000 different chemical substances are marketed in Denmark in about 100,000 different chemical products. The total consumption of chemical products recorded in the Product Register is estimated at about 8 million tonnes. These products are shown apportioned by area of use and branch in *Figures 2.5.1* and *2.5.2*. As can be seen, the majority of chemical products are used in cleaning agents and paints/varnishes, with the main branches being the iron and metals industry followed by the chemicals industry and repair and service sector.

The chemical substances are discharged into the environment from all steps in their life cycle from production to use to disposal. Discharges from industrial point sources have been regulated for many years under the provisions of the Environmental Protection Act, and have therefore been reduced considerably. As a consequence, discharges from the more diffuse sources associated with commercial and private consumption have gained in importance and have come more into focus.

Part of these diffuse discharges end up in sewage sludge from sewage works and in residues from waste incineration. The substances detected in sewage sludge are primarily a number of environmentally hazardous organic compounds, especially PAHs, phthalates and detergents. These have caused problems with respect to the use of the sludge in agriculture. The residues from waste incineration (slag, fly ash, flue gas abatement residues, etc.) contain a wide range of heavy metals (lead, cadmium, arsenic, nickel, mercury, zinc), inorganic salts (especially chlorides), and smaller amounts of organic compounds, especially chlorinated compounds. The concentration of these substances is often so great as to present problems as regards the use of the residues as filling material or depositing them in an environmentally safe manner.

The 20,000 chemical substances used in Denmark differ markedly in chemical composition and with respect to their effects on man and the environment. A large number of the substances do not present any problems if handled correctly.

Some of the substances present problems due to their persistence and accumulation in the environment, and the consequent long-term effects on nature and man. This is particularly the case with the heavy metals. Others present problems because of their immediate toxicity, e.g. pesticides. In recent years, attention has been brought to bear on a group of substances resembling hormones (endocrine disruptors) which are suspected of causing hormonal imbalance in animals and man. These groups of substances are examined more closely below.

2.5.3 Heavy metals

Heavy metals are elements that are naturally occurring in the environment in small concentrations. Through man's activities, heavy metals accumulate in the environment, for example in the food chains, where the last stage, including man, is particularly exposed to their harmful effects.

Use/consumption

Total Danish consumption of a number of heavy metals is summarized in *Table 2.5.1*. As is apparent,

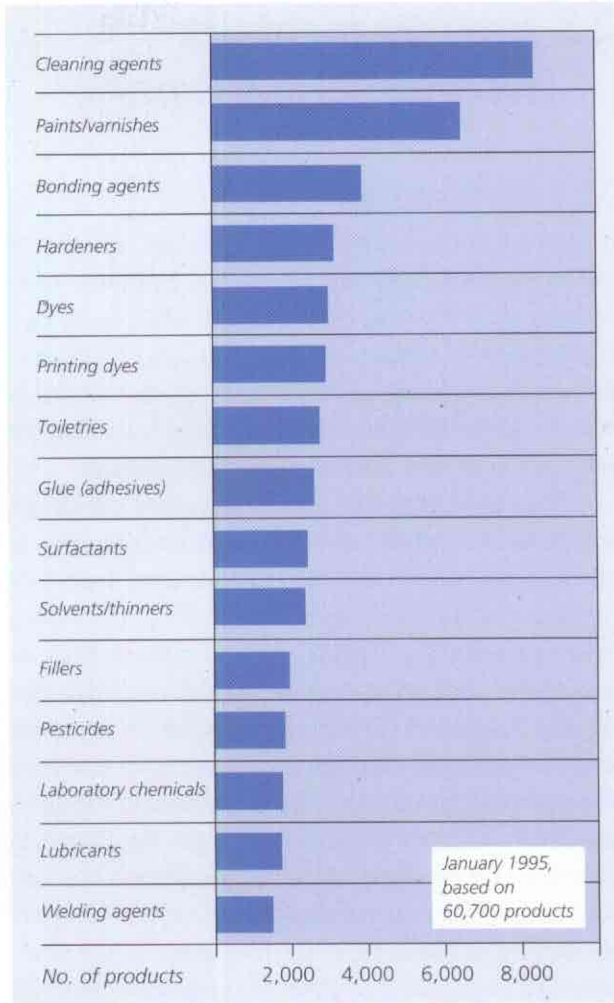


Figure 2.5.1 *Chemical products in use in Denmark apportioned by area of use (Source: the Danish Product Register, 1995).*

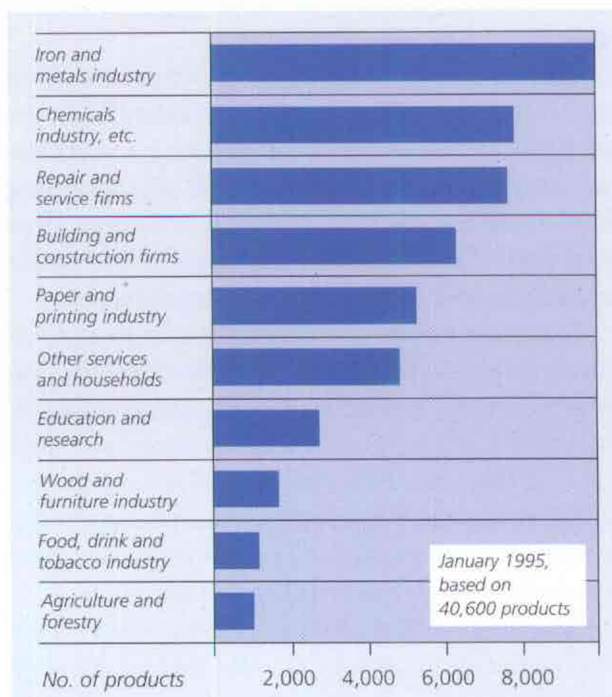


Figure 2.5.2 *Chemical products in use in Denmark apportioned by branch (Source: the Danish Product Register, 1995).*

Heavy metals consumption				
Year	Lead	Cadmium	Mercury	Nickel
1977	-	-	31	-
1980	-	110	-	-
1982-83	-	-	17-20	1,900-4,000
1985	21,000-25,000	-	-	-
1990	20,800-24,600	49	10-13	-
1992-93	-	51	6.4-9.5	5,400-7,800
1994	15,500-19,800	-	-	-

Table 2.5.1 *Total consumption of selected heavy metals over the period 1977-94 in tonnes/yr. (Source: Danish EPA).*

consumption of lead has decreased by approx. 20% in Denmark over the last 10 years. Because of legislative regulation, the consumption of lead for use as petrol additives and in lead shot has almost ceased. In certain areas, lead consumption has increased, however, for example in the manufacture of cathode-ray tubes for computer and TV screens.

By 1990, consumption of cadmium had fallen to half the level in 1980. In the case of most of the former major uses of cadmium, consumption has now been reduced considerably or has ceased completely. This applies to its use as pigment, stabilizer in PVC, surface coating for iron and steel, cable sheathing and as an impurity in coal and fertilizer. The reduction is attributable to legislative restrictions introduced for cadmium in both Denmark and internationally. In contrast, consumption of rechargeable nickel-cadmium batteries has increased, and their consumption is expected to increase approx. 20% annually.

In the case of mercury, consumption is also falling off. Between 1982/83 and 1992/93, total consumption in Denmark was more than halved. This is due to a marked reduction in consumption of batteries, dental fillings, mercury thermometers, etc. and the complete cessation of certain other uses (e.g. fungicidal treatment of seed corn). Consumption is expected to be reduced further in the coming years, in particular as a result of a 1994 Statutory Order prohibiting certain uses of mercury.

Nickel consumption in Denmark in 1992/93 was markedly higher than in 1982/83, largely due to a marked increase in the use of nickel in alloys (including stainless steel) and a minor increase in the use of nickel in accumulators, dyes and catalytic convertors. The figures should be viewed with a certain degree of reservation, however, as consumption has been estimated differently in the various studies.

Emissions

Air

Calculated total annual emissions of selected heavy metals to the air are summarized in *Table 2.5.2*.

Traffic was formerly the main source of lead emissions to the air (approx. 1,000 tonnes/yr), but as a result of the phase-out of lead additives in petrol, total emissions of lead to the air has been reduced considerably in recent years (see *Figure 2.2.6*).

Total annual emissions				
	Lead tonnes/yr (1994)	Cadmium tonnes/yr (1990)	Mercury tonnes/yr (1992/93)	Nickel tonnes/yr (1992/93)
Waste incineration	3.4-5.4	0.9	1.6	1.5-2.5
Power stations	0.8-2.4	0.9	0.2 - 0.6	0.2-1
Petrol and oil	2-12	-	-	21-49
Other sources	3-12	0.15	0.1 - 0.3	0.6-1.2

Table 2.5.2 *Annual emissions to the air apportioned by main sources. The table should be interpreted with a certain degree of caution as the figures stem from different years (Source: Danish EPA, 1996a and 1996d).*

Improved flue gas abatement at certain major incineration plants has also contributed to the reduction in lead emissions. At present, the main sources of lead emissions are steel manufacture and waste incineration. Lead casting is also estimated to be a not unimportant source, though. The main source of cadmium emissions is incineration of combustible waste because of cadmium-containing waste such as PVC and, to an increasing extent, nickel-cadmium batteries.

The actual emission depends on the quality of flue gas abatement at the incineration plants. In this respect, considerable improvement has been made during the last 10-15 years due to more stringent regulations. All waste incineration plants in Denmark now have to be equipped with flue gas abatement systems for heavy metals, etc.

The main sources of mercury emissions to the air are waste incineration, coal-fired power stations and the manufacture of cement. With the introduction of improved flue gas abatement at the waste incineration plants, emissions of mercury to the air are expected to be reduced further in the coming years. However, complete cessation of mercury emissions can only be achieved by avoiding the use of mercury in products. In the case of nickel, the most significant source of emissions to the air is the combustion of oil products - especially heavy oil products such as fuel oil - which accounted for about 90% of total nickel emissions to the air in 1992. Waste incineration accounted for 5% and isestimated to be the second most important source.

Air quality monitoring in Danish town

The air quality in Danish towns is monitored regularly under the Nationwide Air Quality Monitoring Programme established in 1982. Measurements are made in Copenhagen, Odense and Aalborg. The background measurements are conducted in LilleValby, approx. 25 km west of Copenhagen. Among the pollutants measured are lead, cadmium and nickel.

The lead concentration of Danish town air has decreased 20-fold since 1982. The mean concentrations measured in the three towns in 1995 ranged from 26-31 ng/m^3, which is 50-fold lower than the limit level stipulated by the EU in 1982 (2 µg/m^3).

The cadmium concentration of Danish town air has remained at roughly the same low level since 1982. The concentration measured in 1995 ranged from 0.7-0.8 ng/m^3, which is 10-fold lower than the WHO's guide level for the cadmium content of air.

From *Figure 2.5.3*, it can be seen that the nickel concentration of town air has also decreased since 1982, the average concentration in 1995 ranging from 2.7-4.4 ng/m^3 as compared to approx. 7 ng/m^3 in 1982. The town air concentration of nickel is now approaching the background level, which indicates that the majority of nickel pollution in Denmark is attributable to long-range transboundary transport.

Atmospheric deposition

Atmospheric deposition of heavy metals over the Danish land mass and the Danish marine waters is far greater than total Danish emissions to the air.

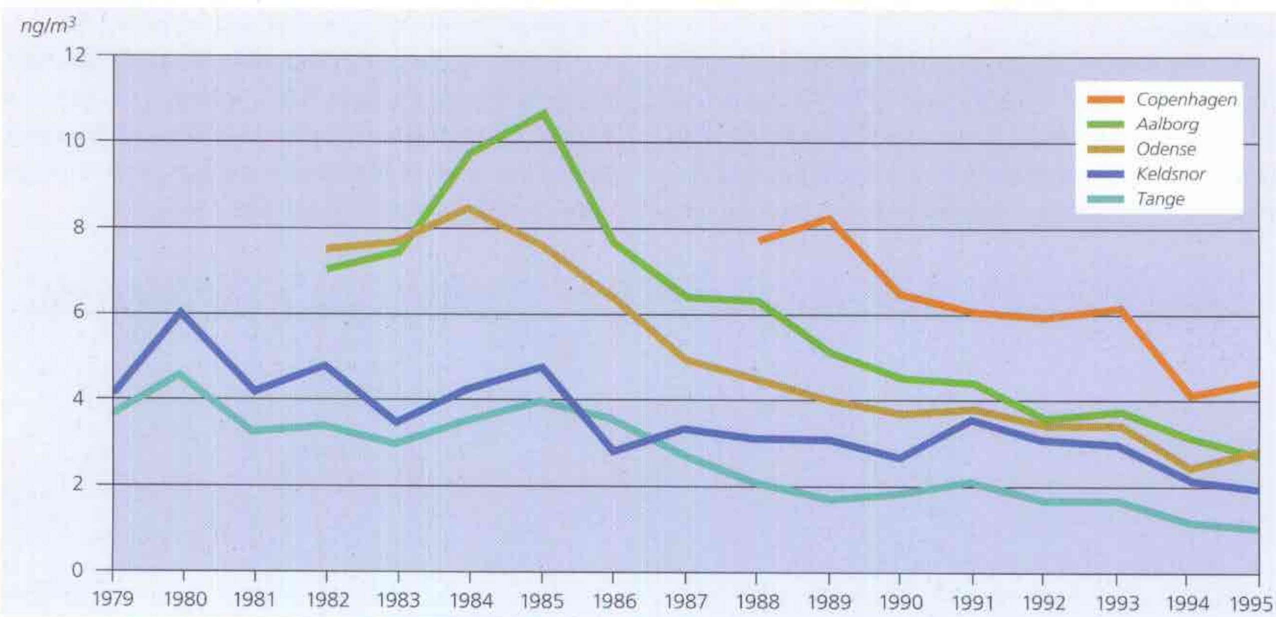


Figure 2.5.3 *Nickel concentration of town air (Copenhagen, Aalborg and Odense) compared with that at two background stations (Keldsnor and Tange) (Source. Kemp et al., 1996).*

This is explicable by a certain amount of long-range transboundary transport of heavy metals via the air, especially from the rest of Europe. Little is known about the magnitude of long-range transboundary transport, and it is therefore not possible to determine how great a part of Danish emissions contribute to loading of the environment in Denmark.

The aquatic environment

Heavy metals are mainly input to the aquatic environment via atmospheric deposition, sewage and storm water. Estimates are available for annual Danish discharges of various heavy metals to the aquatic environment apportioned by main source.

The figures are summarized in *Table 2.5.3*. In the case of lead, "Other sources" account for most of the discharge. These encompass fishing equipment, ammunition, lead-sheathed telecommunication cables and rust protection paint for ships (red lead).

Discharges of heavy metals in sewage effluent are less prominent in recent years, among other reasons as a result of improved sewage treatment brought about by the Danish government's Action Plan on the Aquatic Environment.

Atmospheric deposition on water bodies has also decreased in step with measures such as the phase-out of lead in petrol and the introduction of improved treatment measures in commercial enterprises. The discharges are expected to decrease further in the future, partly as a result of even better treatment measures, and partly as a result of the introduction of cleaner technology in commercial enterprises. In the case of lead in particular, the contribution of discharges from "Other sources" is expected to diminish in future due to legislative regulation of the use of lead, among other things prohibition of the use of lead shot and other lead products.

The terrestrial environment

Various heavy metals have been input to the soil via atmospheric deposition and the use of commercial fertilizers and waste products for agricultural purposes. In addition, large amounts of heavy metals are deposited in the form of residual products from the incineration of waste. What is involved here, though, is controlled deposition, and not diffuse dispersal.

The main causes of the enhanced lead concentration in the soil at certain locations are former use of leaded petrol and lead shot in hunting. Total loading of the terrestrial environment from these two sources was 700-800 tonnes/yr in 1990 and 1,500-1,600 tonnes/yr in the period 1970-75.

The total amount of lead input to the soil (excluding that in deposited materials) was 630-2,400 tonnes in 1994. Of this, 400-2,000 tonnes derived from buried electric cable sheathing, thus representing the main source of lead pollution of the soil. The figures are subject to some uncertainty, however.

It is estimated that between 100,000 and 200,000 tonnes lead are present in the soil in the form of sheathing around electric cables still in use. Some of this lead will eventually be dissolved by corrosion.

The cadmium input to the terrestrial environment largely derives from atmospheric deposition (4.7 tonnes/yr), although fertilization with commercial phosphate fertilizers is also a significant source (2.6 tonnes/yr). The total amount of cadmium (excluding that in deposited materials) input to the soil is estimated to be approx. 8.6 tonnes/yr based on figures for 1990 and 1993.

It has previously been calculated that the cadmium concentration in Danish agricultural land is increasing at the rate of 5-6 g cadmium/ha/yr, corresponding to an increase of 0.8%/yr, largely as a result of fertilization with phosphate fertilizers and deposition from the air. Due to regulation of cadmi-

Total annual discharge				
	Lead tonnes/yr (1994)	Cadmium tonnes/yr (1990)	Mercury tonnes/yr (1992/93)	Nickel tonnes/yr (1992/93)
Atmospheric deposition	76 - 94	4.8	0.5	15
Sewage/storm water	5.4 - 7.9	0.9	0.3	13 - 14
Other sources	156 - 580	0.12	-	-

Table 2.5.3 *Annual discharges of selected heavy metals to the aquatic environment apportioned by main sources. The table should be interpreted with caution as the figures are from different years as shown in parentheses (Source: Danish EPA).*

um emissions from industry and the cadmium content of fertilizers, net input of cadmium in 1990 has decreased to approx. 1.5 g/ha/yr, the rate of increase in soil cadmium concentration consequently having fallen to 0.3%/yr. The input of mercury to the soil is largely attributable to atmospheric deposition, the majority of which is believed to be imported from other European countries (0.5 tonnes/yr). Total Danish discharges of mercury to the soil (excluding that in deposited materials) is estimated to be approx. 200-300 kg/yr, of which the main source is sewage sludge (140 kg/yr).

The use of commercial fertilizers, fodder (which is input to the soil in the form of animal fertilizer) and agricultural lime are the main sources of nickel input to the soil. Nickel input to agricultural land from these sources amounted to 38-111 tonnes/yr, with input via fodder being the most important of the three sources. Since mid 1995, the nickel content of fodder has been regulated.

In 1991, a comprehensive investigation was initiated of the heavy metals content of Danish soils with a view to drawing up a proposal for a monitoring programme for heavy metals in Danish soils. The background was that earlier studies indicated that the heavy metals content of Danish soils was increasing. In the investigation, soils have been subdivided according to soil type and land use (arable land, broadleaved, conifer and mixed forest, and natural ecosystems). In addition, the investigation encompassed a number of specially selected agricultural soils that have been treated with sewage sludge for a number of years. The measurements were completed in January 1993. The results of the investigation are described in *Section 2.3.3*. The main conclusion was that enhanced heavy metals concentrations do not present a general problem in the open countryside, although there are localities in the vicinity of former landfills, particularly polluting enterprises, heavily trafficked roads, etc., that deserve attention. The investigation did not encompass urban areas, where point sources and heavy traffic in particular have caused problems of quite another magnitude. These are examined in *Section 2.2*.

Soil quality criteria

The use of sewage sludge as fertilizer on agricultural land is subject to restrictions if the heavy metals content of the sludge exceeds stipulated levels - the so-called soil quality criteria.

In 1995 in connection with risk assessment of contaminated sites, the Danish EPA established other types of soil quality criteria, namely the human and ecotoxicological soil quality criteria. The human toxicological criteria are intended to be used in environmental evaluation in connection with the clean-up and remediation of contaminated sites. They are therefore not directly relevant with regard to soil quality in general. In addition to appearance and odour criteria, they are based on a health risk assessment of heavy metals taken up through human activities on the soil. Compliance with the human and ecotoxicological criteria does not represent the ideal, which is restoration of the original natural state, but rather the minimum requirement necessary to ensure protection of health and the environment. The soil quality criteria are examined more closely in *Section 2.3.3.*

2.5.4 **Pesticides**

Pesticides are chiefly used in rural production (agriculture, horticulture and forestry) to combat weeds, diseases and insect pests. While the majority of pesticides are applied to rural land used for these purposes, a considerable amount is also applied to certain other types of land such as sports fields, railways, residential gardens, parks, etc.

The consumption of pesticides increased sharply at the beginning of the 1980s. In order to reduce the impact of pesticides on health and the environment, the then Minister for the Environment drew up an action plan in 1986 aimed at reducing pesticide consumption and substituting those most harmful to the environment and health with less harmful pesticides.

During and following spraying, pesticides can be dispersed to other parts of the environment by wind drift, long-range transboundary transport and leaching. In Denmark and abroad, pesticide residues have thus been detected in groundwater, surface water and rainwater.

Pesticides in watercourses

The majority of Danish Counties have begun to collect samples from selected watercourses for analysis of pesticides. The results from Funen County and Ringkjøbing County indicate that pesticides can be present almost anywhere, even in spring water.

Ringkjøbing County has tested 12 watercourses in different types of catchment area: Agricultural, urban and natural countryside. The analyses encompassed 28 pesticides and pesticide residues, of which 22 were detected in one or more watercourses.

Funen County has tested the pesticide content of 6 watercourses and 4 springs. The analyses encompassed 99 pesticides and pesticide residues, of which 30 were detected in the watercourses. Eighteen pesticides/residues were detected in both Funen county and Ringkjøbing county. Which particular pesticides are found in a watercourse depends on a number of factors, including which pesticides are sprayed in the area, when they are sprayed, the dose applied, whether or not they bind to soil particles or can be leached out with the precipitation, and how quickly they are degraded by soil microorganisms. Moreover, the weather (wind, temperature, precipitation) during and following crop spraying significantly affects wind dispersal, degradation rate and leaching.

As is apparent from *Figures 2.5.4* and *2.5.5*, the occurrence of pesticides in watercourses is most frequent in agricultural areas on rich soils. It is also there that the highest concentrations have been found. This is in accordance with previous studies of two watercourses in Sønderjylland county and on Lolland. This pattern particularly reflects the fact that cultivation is more intensive on rich soils and pesticide consumption higher.

In forest watercourses only few pesticides are found, but those herbicides that are used are very frequently found in the watercourses. It is also noteworthy that so many pesticides are found in watercourses in urban areas. No general limit values for pesticides have been established for surface waters, but the limit level for tap water is 0.1 µg/l for individual pesticides and 0.5 µg/l for the total pesticide content. The concentration in watercourses in many cases exceeds these limit levels.

The significance of these occurrences of pesticides for the flora and fauna is little understood and deserves closer study. With some pesticides, limit levels have been established for watercourse quality. Three of these pesticides were included in the above mentioned studies. *Table 2.5.4* shows the limit levels and the highest concentrations measured in the watercourses. It is apparent from the table that the watercourse quality objective for simazine has been exceeded.

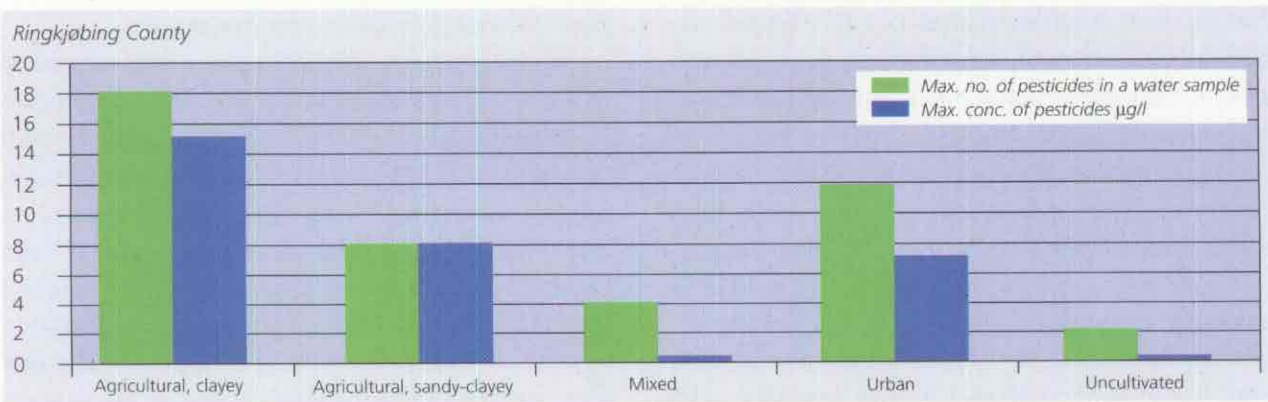


Figure 2.5.4 *Pesticides in watercourses in Ringkjøbing County. The values represent the highest total pesticide concentrations and highest number of pesticides found in individual samples from the various types of catchment area (Source: Ringkjøbing County, 1997).*

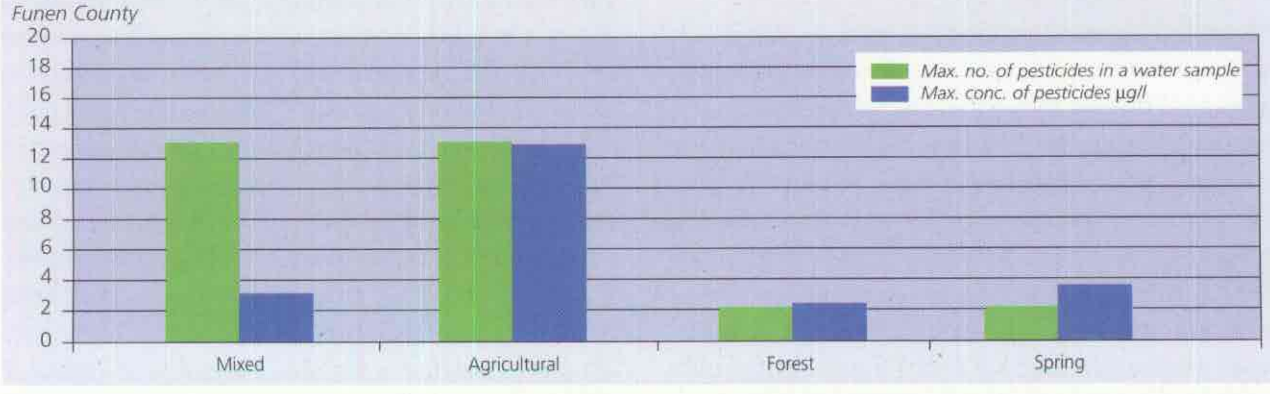


Figure 2.5.5 *Pesticides in watercourses in Funen County. The values represent the highest total pesticide concentrations and highest number of pesticides found in individual samples from the various types of catchment area (Source: Funen County, 1997).*

Limit levels for pesticides in watercourses			
Substance	Limit level (µg/l)	Highest concentration Funen County	Highest concentration Ringkjøbing County
Dimethoate	1	0.2	0.6
Linuron	1	0.6	-
Simazine	1	0.3	3.7

***Table 2.5.4** Limit levels for pesticides in watercourses and the highest concentrations found in watercourses in Funen County and Ringkjøbing County (Source: National Environmental Research Institute).*

Pesticides in rainwater

In the beginning of the 1990s, the pesticide content of rainwater was measured in Scandinavia and Germany. While the results are not fully comparable due to differences in the location of the monitoring stations and in the measurement programme, there are nevertheless some common features: Pesticides can be present in rainwater, also in areas far from agricultural land. The insecticide lindane, which is prohibited in Scandinavia, is found in rainwater in all the Scandinavian countries throughout the year, although in different concentrations (highest in the crop spraying season). In addition, most of the highest pesticide concentrations in rainwater are accounted for by herbicides. The phenoxy acid herbicides (2,4-D, dichlorprop, MCPA and mecoprop) are particularly frequently present in rainwater in Scandinavia, although bentazone is also found. It seems that in addition to local pesticide consumption, the presence of pesticides in rainwater is to some extent attributable to long-range transboundary transport, an example being lindane.

There are no general limit levels for pesticides in rainwater and their impact on flora and fauna is uncertain. In many cases, the concentration of pesticides in rainwater exceeds the limit levels for pesticides in tap water.

Pesticides in groundwater

Pesticides in groundwater are examined more closely in *Section 2.4.2* on groundwater. As stated there, pesticides are present in approx. 12% of the borehole filters included in the groundwater monitoring programme, which includes analysis for 8 pesticides. The tap water limit level of 0.1 µg/l is exceeded in approx. 4% of the filters. Similar figures are obtained by the waterworks in their analyses for the same 8 pesticides in abstraction boreholes. In some counties, the groundwater has been tested for more than the 8 pesticides encompassed by the Nationwide Monitoring Programme.

The general tendency is that the greater the number of pesticides tested for, the greater the number detected and the greater the frequency of samples containing pesticides or pesticide residues.

Pesticide Action Plan

The Minister for the Environment's 1986 action plan for reducing pesticide consumption aimed to reduce consumption 50% by 1997 relative to 1981-85. A further objective was to promote the switch to pesticides that were less harmful to the environment and health. Advice and research were two important means of attaining these goals, although the action plan also encompassed other initiatives.

Development in pesticide consumption expressed in terms of pesticide sales for agricultural purposes is shown together with the reduction target for 1997 in *Figure 2.5.6*. Consumption approached the 50% reduction target in 1994. However, there was a marked increase in pesticide consumption in 1995, possibly due to hoarding in connection with planned levy increases per 1 January 1996. A general fall in sales in 1996 confirms this. To compensate for this non consumption-dependent variation, the average sales figures for 1995 and 1996 are used in *Figures 2.5.6-2.5.9*.

The fall in consumption expressed in terms of amount of active substance is partly attributable to the fact that many of the newer pesticides are used in much lower doses than the earlier pesticides to obtain the same effect. This is reflected in *Figure 2.5.7*, which shows the corresponding development in application frequency (the number of times per year that each individual field could be sprayed if the recommended dose was used). The application frequency is calculated from information on pesticide sales, crop distribution and normal doses. The figure is used as a measure of the environmental impact of pesticides. According to the Action Plan on Pesticides the application frequency was also to be reduced 50%

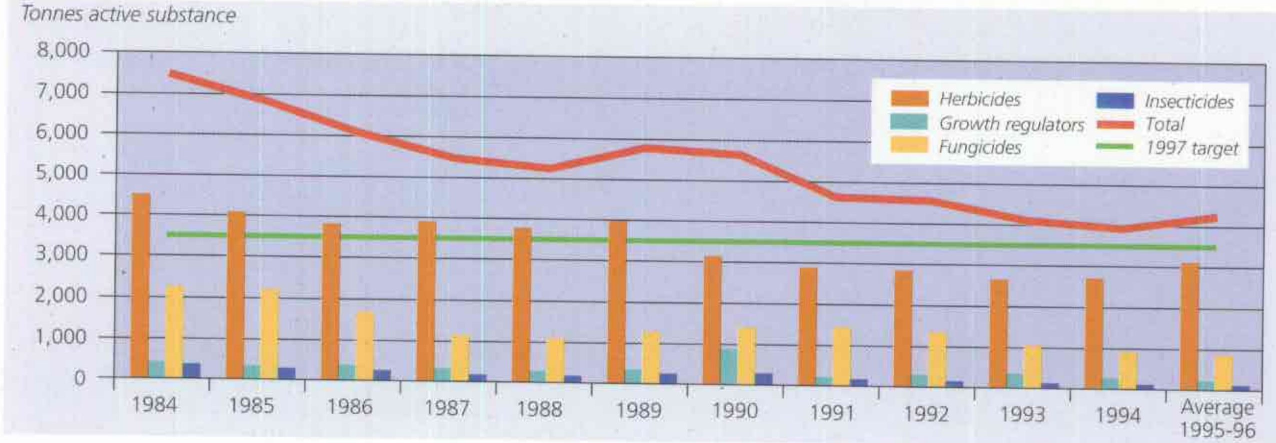


Figure 2.5.6 Pesticide consumption in Denmark over the period 1984-96 expressed in terms of amount of active substance shown together with the 1997 target level stipulated in the Action Plan on Pesticides (Source: Pesticide consumption statistics 1984-96).

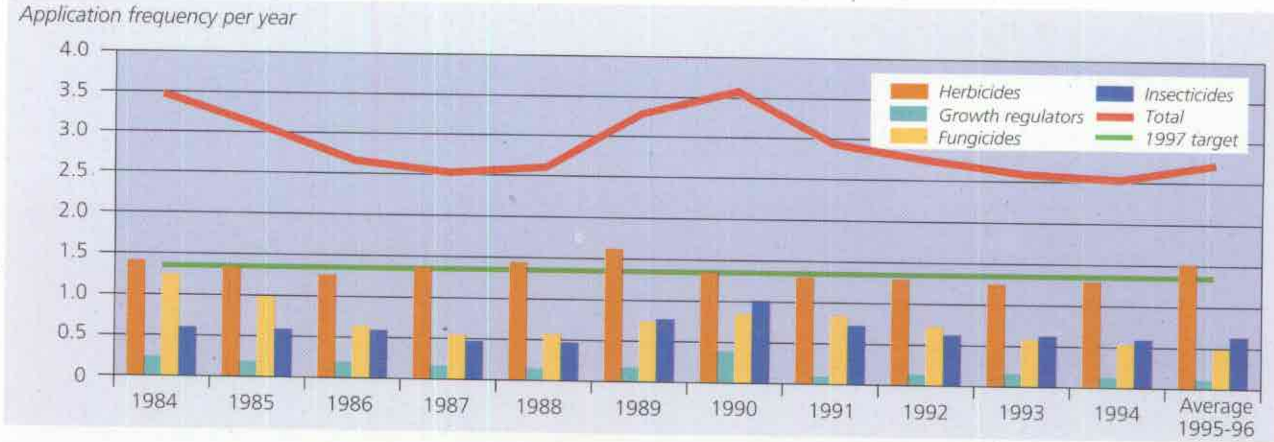


Figure 2.5.7 Pesticide consumption in Denmark over the period 1984-96 expressed in terms of application frequency shown together with the 1997 target level stipulated in the Action Plan on Pesticides (Source: Pesticide consumption statistics 1984-96).

by 1997. As is apparent from the figure, however, the reduction in application frequency hitherto achieved is far from the 50% target.

Development in pesticide consumption is exemplified in *Figures 2.5.8-2.5.9*. *Figure 2.5.8* shows development in the consumption of phenoxy acid herbicides, which previously accounted for 75% of total herbicide consumption. These substances have now been found in the groundwater in many areas (cf. *Section 2.4.2*), and their use is now subject to stringent regulation. *Figure 2.5.9* shows that there has been a corresponding increase in the consumption of sulphonyl urea herbicides during the same period. These belong to the above mentioned group of newer pesticides effective at very low doses.

Several of the initiatives included in the Action Plan on Pesticides aimed at safeguarding the environment and health have been implemented. Enhanced research efforts have resulted in new knowledge about the behaviour and effects of pesticides in the environment, and this has been utilized in assessing the environmental harmfulness of the substances. The Danish EPA has re-evaluated all pesticides approved before 1980. In this connection, approx. 20 products containing 7 different active substances were prohibited in 1994. A further 110 or so products containing 12 active substances were prohibited in 1996, while 40 products containing 9 active substances were prohibited in 1997. Concomitantly with this, restrictions were placed on the use of other products. Finally, a further 100 or so products are no longer approved, either because renewal of approval was not sought or because the applications were rejected on the grounds of insufficient documentation.

Obligatory training of all commercial users of pesticides has been undertaken. Moreover, all farmers have to keep crop spraying records, and inspection requirements have been imposed on crop spraying equipment. Efforts have been made to strengthen research and information on more environmentally sound methods of cultivation. A status report on the Ministry of Environment and Energy's action plan to reduce pesticide consumption was

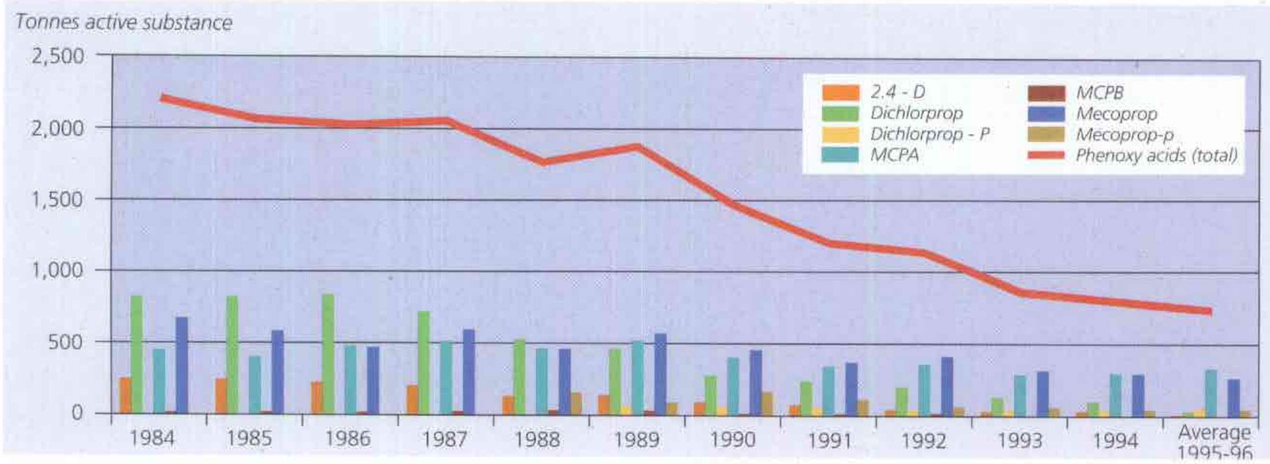


Figure 2.5.8 Development in consumption of phenoxy acid herbicides in Denmark over the period 1984-96 (Source: Pesticide consumption statistics 1984-96).

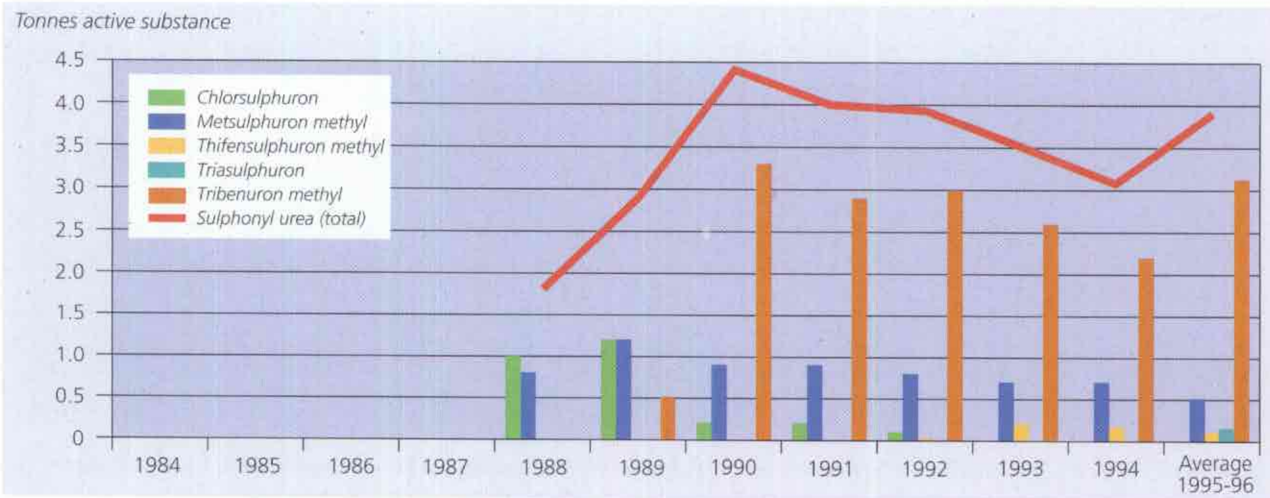


Figure 2.5.9 Development in consumption of sulphonyl urea herbicides in Denmark over the period 1984-96 (Source: Pesticide consumption statistics 1984-96).

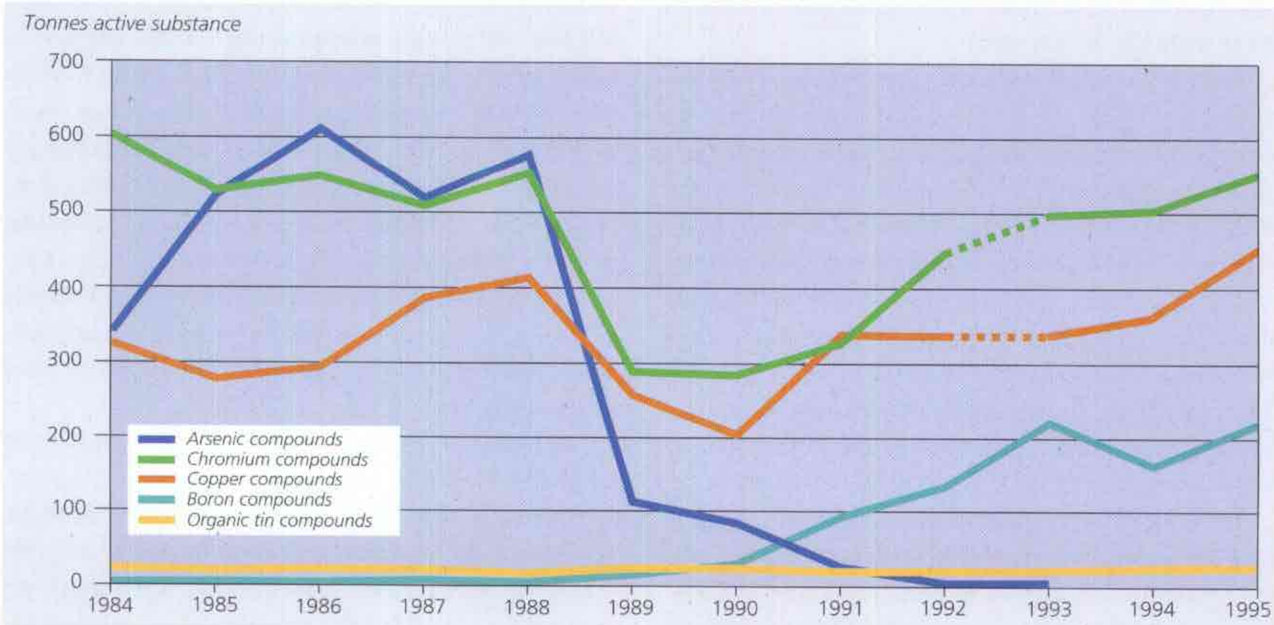


Figure 2.5.10 Development in consumption of active substances in wood preservatives used for pressure and vacuum impregnation. The method of calculating chromium and copper compounds differs from 1993 onwards (see text) (Source: Chemical consumption statistics 1984-96).

submitted to Parliament in autumn 1997. In connection with the adoption of the 1998 Government Budget, it was decided to intensify efforts so far made on this front by doubling pesticide levies, by making the approval scheme more stringent, by phasing out the use of pesticides on public land and in residential gardens, and by enabling restrictions to be imposed on the cultivation of environmentally vulnerable areas.

Wood preservatives

In Denmark, large amounts of wood are impregnated to protect it against fungal and insect attack. Constructions in which the wood is in close contact with water or soil are particularly in need of a high degree of protection.

Standardized requirements (DS 2122) govern both the wood preservatives and the impregnation processes so as to ensure the durability of the impregnated wood. The substances used have to be approved by the Danish EPA (Chemical Substances and Products Act), which assesses their environmental and health characteristics. Agents for pressure impregnation account for the majority of wood preservative consumption. Consumption was previously dominated by the toxic and carcinogenic substances chromium VI and arsenic compounds, but these have now been phased out. Arsenic compounds have not been marketed in Denmark since 1994. With few exceptions, the use of chromium compounds ceased at the end of 1996. Boric acid compounds are increasingly being used as a substitute for arsenic. Development in consumption of the active substances in wood preservatives is shown in *Figure 2.5.10.*

Prior to 1993, the consumption of arsenic, chromium and copper was expressed in terms of the amount of the chemical compounds of which they were a part. From 1993 onwards, consumption is expressed in terms of pure chromium and copper. Consumption of organic tin compounds which are used for vacuum impregnation of window frames, etc., has varied only slightly over the period.

2.5.5 Chemical substances with oestrogen-like effects

In recent years, it has become apparent that a number of environmentally hazardous chemical substances can affect animals and probably also man in the same way as the female sex hormone oestrogen. In a number of animal species in nature, such chemical substances have been shown to induce genital malformation, disturb sexual differentiation and cause changes in sexual behaviour.

According to the "oestrogen hypothesis", these substances are also suspected of being a possible cause of falling sperm quality and increased frequency of testicular cancer and genital malformation in men. In addition, these substances seem in some way to be connected to the increasing frequency of breast and ovarian cancer in women and to disturbances in development of the nervous system in children.

Oestrogen-like effects are not only found in substances that are chemically similar to oestrogen and which act directly through so-called oestrogen receptors, however, as oestrogen-like effects can be induced in a large number of principally different ways. The problem of identifying the substances that can induce oestrogen-like effects is therefore comprehensive and complicated.

In Denmark, several comprehensive research programmes have been initiated or are planned with a view to developing test methods and animal models for identifying and evaluating the oestrogen-like effects of chemical substances and studying the human and animal population exposure to these substances and the effects of that exposure.

The majority of the chemical substances presently suspected of having oestrogen-like effects are either prohibited in Denmark, are being phased out, or are in focus for some other reason. This is because in addition to their oestrogen-like effects, the substances have other serious environmental and/or health effects.

The substances involved are chlorinated pesticides such as DDT, polychlorinated biphenyls (PCB), alkylphenolic compounds, phthalates, biphenol A, dioxins and furans.

Oestrogens are only one example of a number of hormones involved in a complicated physiological interplay in both man and animals. It has become increasingly clear that disturbances of the hormonal systems will become the subject of increasing attention in the future.

The main groups of substances suspected of having oestrogen-like effects are summarized in *Figure 2.5.5* together with information on their uses and occurrence. In the coming years, our knowledge on this subject can be expected to increase considerably when the results of the research initiated become available.

Chemical substance groups with oestrogen-like effects					
Substance group	**Area of use**	**Consumption in Denmark**	**Occurrence**	**Effects**	**Regulation**
Chlorinated pesticides	Mainly used as insecticides. No longer approved in Denmark	0	Fish, meat, eggs, dairy products. Concentration in fish fell markedly in the 1970s. Presently at a more stable, low level	Affects the reproductive capacity of seals and birds	These substances are either prohibited or withdrawn from the market in Denmark. Still used in many developing countries
PCBs	Various industrial uses. Since 1986 only used in closed systems	0	Found everywhere in the environment due to slow degradation, but the level has fallen markedly during the 1970s and 1980s. Concentration in fish has stabilized	209 substances, of which some have oestrogen-like effects or other hormone-like effects	Since 1986, PCB has only been permitted in closed systems. Since 1995, all use has been prohibited in Denmark
Alkyl phenols/ ethoxylates	Cleaning and degreasing agents. Ancillary substances in pesticides, paints/ varnishes, polyurethane foam	Approx. 600 tonnes (1994)	Alkyl phenols: Sewage and sewage sludge. Many places in the environment	Oestrogen-like effects seen *in vitro*, reduced sperm quality in rat experiments	Voluntary agreement on phase-out of soap, perfume and cleaning agents. Declaration of intent from the Minister for Environment and Energy on complete phase-out by 2000
Phthalates	Mainly as plasticizers in PVC (90%). Glue, sealants, paints/ varnishes	9,000-14,000 tonnes (1992). Especially DEHP	Sewage and sewage sludge: 15-25 tonnes/yr. Emissions to the air: 1-20 tonnes/yr	Sparsely investigated. Oestrogen-like effects shown for BBP and DBP	Action plan for the reduction of phthalates in soft plastics
Dioxins/ furans	Not used, but is formed as a byproduct in the manufacture of chlorinated hydrocarbons, incineration of waste, etc.		Flue gas from waste incineration: Approx. 0.1 $\mu g/m^3$ (1994)	Affects the reproductive system in male foetuses	Dioxin Action Plan (1985) imposed more stringent requirements on waste incineration
Bisphenol A	Component of paints and varnishes, and especially of hard plastic products such as polycarbonate and epoxy	100-115 tonnes/yr	In water from epoxy-treated water tanks and foodstuffs in varnish-coated tins. Up to 9 $\mu g/l$ in river water. Up to 4.8 $\mu g/l$ in industrial waste water	Oestrogen-like effects *in vivo* and *in vitro*, in the latter case down to 2.3 $\mu g/l$.	Special working environment rules for epoxy products

Table 2.5.5 *Summary of the main groups of substances known to have oestrogen-like effects (Source: Danish EPA 1995a and 1995e).*

2.5.6 Occurrence of environmentally hazardous substances in foodstuffs

In 1983, the Food Agency of Denmark established a system for monitoring the concentration of selected pollutants in fruit, vegetables and animal products sold in Denmark. These include the heavy metals cadmium, mercury, lead and nickel, and a number of persistent chlorinated pesticides (DDT and its residues DDD and DDE, dieldrin, HCB (hexachlorobenzene), lindane, α-HCH, β-HCH and heptachloroepoxide) and PCB, which encompasses a group of persistent substances previously much used in industry.

The monitoring runs over 5-year periods and the first two periods (1983-87 and 1988-92) have so far been reported. The third period of monitoring ends at the end of 1997. The results for the period 1988-92 indicate that the average concentrations of the above mentioned heavy metals were generally lower than during the period 1983-87. In the case of nickel, relatively high concentrations were found in certain categories of foods, including beans, offal and high-roughage content grains and bread, and the nickel concentration in the different foodstuffs differed considerably during the two periods.

The persistent chlorinated organic compounds (pesticides and PCB) are mainly present in fatty foods such as fat fish and diary products. The average concentration of these compounds in the foodstuffs is generally lower in the period 1988-92 than in the period 1983-87. As an example, *Figure 2.5.11* illustrates variation in the nickel content of rye bread over the period 1984 to 1992. In order to be able to assess

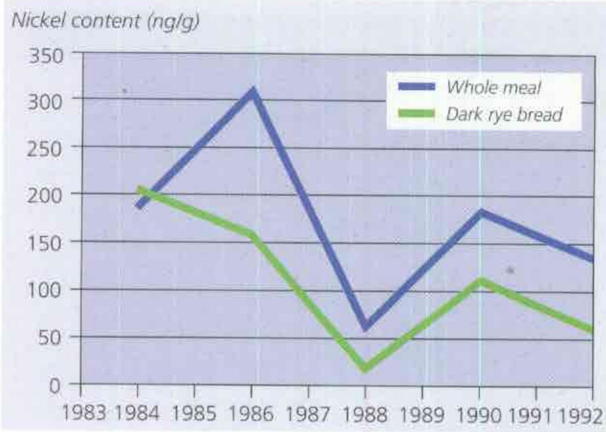


Figure 2.5.11 *Average nickel concentration of wholemeal bread and dark rye bread over the period 1984-92 (Source: Food Agency of Denmark, 1995).*

the significance to health of changes in the heavy metals content of foodstuffs, the actual concentrations in the foodstuffs are compared with the food habits of Danes. This enables the variation in the intake of the individual heavy metals to be determined and hence potential risk groups to be identified.

Figure 2.5.12 illustrates the changes in nickel intake from the first to the second monitoring period. It is apparent that there has been a general slight fall, albeit that there is some variation between the individual foodstuffs. Corresponding studies show that the intake of lead and mercury has fallen markedly from the first to the second monitoring period, whereas that of cadmium has only fallen slightly. For selected pollutants found in foodstuffs, sources of pollution, sources of intake, intake limit levels and normal intake in Denmark are summarized in *Table 2.5.6.*

2.5.7 **Risk assessment**

Current regulation of chemical substances and products is based on the concept that these can be freely marketed unless it can be rendered probable that they comprise a risk to man or the environment.

To facilitate risk assessment by the authorities, companies are required under a 1981 EU Directive to submit certain basic information on new substances prior to placing them on the market. In the case of those substances already on the market before 1981, companies are required to submit available information on substances produced in amounts exceeding 1,000 tonnes per manufacturer per year. On this basis, the substances will be prioritized with respect to closer assessment of risks.

To facilitate official assessment of the risks that chemical substances and products pose to man and the environment, a scientifically based risk assessment procedure has been developed. In principle this consists of three steps:

1. The first step is assessment of the substances' inherent dangerousness, from which one can establish a threshold level for the concentration or dose below which the substances are not anticipated to cause any harmful effect. The more toxic the substance is, the lower this threshold level will be.
2. The next step in the risk assessment consists of assessing what actual concentrations or doses one can expect man and the environment to be exposed to taking into consideration the use of the substance, the amount used and its physical/chemical properties.

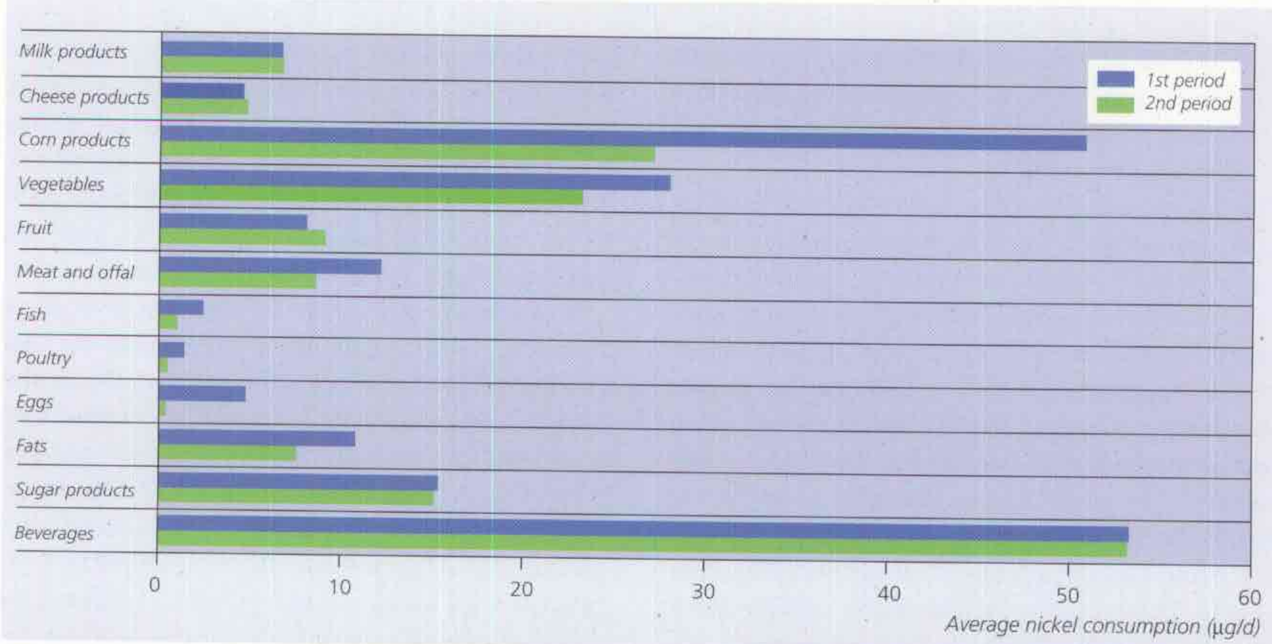


Figure 2.5.12 *Average nickel intake in foodstuffs in the 1st and 2nd monitoring periods (Source: Food Agency of Denmark, 1995).*

Sources, limit values and normal intake of selected substances				
Substance	**Source of pollution**	**Source of intake**	**Limit levels for intake (PTWI)**	**Normal intake in Denmark**
Lead (Pb)	Atmospheric deposition	Cereal products, fruit and vegetables (especially leaf vegetables), beverages (wine and coffee). Other: Respired air and soil (small children)	25 µg/kg/week (WHO), corresponding to a weekly intake of 1,750 µg for an adult (70 kg) and 250 µg for infants (10 kg)	189 µg/week 11% of PTWI
Cadmium (Cd)	Fertilizer, sewage sludge, atmospheric deposition	Cereal products, vegetables, meat and offal, beverages. Other: respired air	7 µg/kg/week (WHO), corresponding to a weekly intake of 490 µg for an adult (70 kg)	119 µg/week 24 % of PTWI
Mercury (Hg)	Atmospheric deposition, fertilizer	Fish, cereal products, meat and offal	5 µg/kg/week, with a maximum of 3.3 µg as organically bound mercury (WHO/FAO), corresponding to a weekly intake of 350 µg Hg (maximum 230 µg as organically bound Hg) for an adult (70 kg)	35 µg/week 10 % af PTWI
Nickel (Ni)	Atmospheric deposition, fertilizer, sewage sludge	Beverages (tea and coffee), cereal products, vegetables, meat and offal	Recommended daily maximum intake of nickel for persons with nickel allergy: 250 µg/kg (National Food Agency of Denmark). Tap water limit level: 0.2 µg/l (WHO)	157µg/day 63% of the recommended maximum intake for persons with nickel allergy
Pesticides	Agriculture, market gardening, fruit farming, forestry	Vegetables, fruit, cereal products	Varies from substance to substance. Limit level in tap water is 0.1 µg/l for individual substances and 0.5 µg/l for total pesticide content	
PCB	Emissions from industrial plants	Meat, fish, eggs, dairy products		<7.9 µg/day
DDT	Imported foods, use of the substance in other countries	Meat, fish, eggs, dairy products	1,200 µg/person/day	<2 µg/day
Other chlorinated pesticides *	Imported foods, use of the substances in other countries	Meat, fish, eggs, dairy products	6-480 µg/person/day	<0.8 µg/day

* "Other chlorinated pesticides" encompasses HCB, lindane, α-HCH, β-HCH, dieldrin and heptachloroepoxide

Table 2.5.6 *Summary of sources of pollution and intake, intake limit levels (PTWI) and normal intake in Denmark for selected pollutants. PTWI: Provisional Tolerable Weekly Intake (Source: Food Agency of Denmark, 1995 and Danish EPA).*

3. The third step consists of comparing the results of steps 1 and 2. If the anticipated actual concentrations or doses exceed the threshold levels, the substance poses a risk.

This assessment procedure has been made as stringent and simple as possible, but in practice it is not surprisingly extremely complicated, and the assessments are therefore subject to some degree of uncertainty. Assessment of the substances' dangerousness has to include assessment of their effects on man (human toxicological effects), the organisms in nature (ecotoxicological effects) and the chemical processes in the environment. The effects on human health that have to be assessed include the substances' acute toxicity, allergenic effects and long-term effects. The ecotoxicological effects include acute and chronic toxic effects on fish and daphnia, microorganisms and soil-dwelling organisms. The effects can be assessed on the basis of a number of standardized laboratory experiments. In addition, there are other effects such as hormonal effects whose causal mechanisms are not yet fully understood. Some of these effects will probably be difficult to document in laboratory experiments, and will therefore require comprehensive research.

Even in the case of the standardized tests, large amounts of data are required considering the vast number of chemical substances currently on the market. In the case of the 2,700 substances produced in amounts exceeding 1,000 tonnes per year per manufacturer (high-volume substances), risk assessment has been initiated in the EU. The availability of effect data for these substances in the EU's joint database (IUCLID) is shown in *Table 2.5.7*. It can be seen that even for these high-volume substances, much of the effect data is lacking.

The other part of the risk assessment procedure comprising assessment of the actual concentrations or doses that man and the environment are exposed to is in practice just as complicated and data-heavy. For this purpose, information is required on the substances' production, use and disposal, as well as on the transport and turnover of the substances in the environment and the possible resultant exposure of man and the environment. Thus reasonably comprehensive information on the life cycle of hazardous substances in society is currently only available for a few substances, mainly heavy metals and pesticides.

The degree of exposure is determined partly with the aid of specific measurement data and partly with the aid of models that use basic information on the substances' properties and uses. Even though such model calculations are subject to uncertainty, they can provide valuable information that would otherwise be difficult to obtain because of the limited extent of the monitoring and because the data collected are subject to uncertainty. The risk assessment procedure, where information on the substances' dangerousness and exposure is combined, is thus complicated and data-heavy in practice, and will often contain a number of estimates.

In May 1997, the Minister for Environment and Energy presented a report to the Danish Parliament on future initiatives in the chemicals area. Among other things, this contained proposals for how to improve the future risk assessment procedure in the EU. The report accords priority to making the risk assessment procedure more flexible. It should be possible to make use of previously implemented, internationally recognized risk assessments instead of starting from scratch each time as at present. In addition, it should be possible to substitute full risk assessment with partial assessments if the problem in question is already known.

Other methods proposed to simplify or improve the current risk assessment procedure include:

- Undertaking risk assessment for groups of substances or types of substances rather than individual substances.
- Graduation of the risk assessment procedure according to simple criteria, e.g. such that substances produced or used in larger amounts or with a high probability of being released into the environment are subjected to more stringent assessment and control.
- Certain special criteria for dangerousness, e.g. persistence of the substances in the environment, could evoke particularly strict precautions.

These principles are already in practice to a certain extent in the risk assessment undertaken in Denmark and the EU and are being considered in several other countries.

2.5.8 Objectives and policy measures

The Environmental Protection Act and the Chemical Substances and Products Act form the legislative framework for efforts on the chemicals front in Denmark. Since chemical substances move across national borders - both as commodities and as air and water pollution - Danish regulation of chemicals is to a large extent based on international agreements, including EU legislation.

As mentioned in the introduction, regulation of environmentally hazardous substances in Denmark has followed four different approaches:

- A media-oriented approach, whereby requirements are imposed on total loading of the individual recipients - soil, water and air - based on limit levels for the concentration of the pollutant in these recipients.
- A source-oriented approach, whereby requirements are imposed on individual sources such as sewage works, waste incineration plants and particularly polluting enterprises.
- A product-oriented approach, whereby requirements are imposed on product content of environmentally hazardous substances.
- A substance-oriented approach, whereby requirements are imposed on the classification, labelling and possibly also limitation of use of the individual substance.

The media- and source-oriented approaches are conducted pursuant to the Environmental Protection Act, while the product- and substance-oriented approaches are conducted pursuant to the Chemical Substances and Products Act. As the product- and substance-oriented approaches impinge upon the free movement of goods, they are largely EU regulated, whereas the media- and source-oriented approaches are largely nationally regulated. The media- and source-oriented approaches can be used to reduce discharges from well-defined sources by imposing requirements as to treatment measures or conversion to cleaner production processes.

The efforts directed towards enterprises, incineration plants, sewage works, etc. in the 1970s and 1980s have markedly reduced discharges of a number of environmentally hazardous substances. The efforts directed at more diffuse loading, which cannot usually be reduced via treatment measures etc. require regulation of the use of the substances in question, including possibly the prohibition of their use. Among other things, these efforts have resulted in the prohibition of the use of a number of pesticides during the 1980s.

Moreover, as a result of the reevaluation of pesticides, a further 28 active substances were prohibited during the period 1994-97. The use of heavy metals has also been considerably reduced, as described earlier in this section. The CFCs have been prohibited and phased out, as discussed in *Section 2.1.3.*

In addition, a number of individual substances have been prohibited or restriction have been imposed on their use because of documented effects on man or the environment. Examples are PCB, PCP, nickel, creosote, brominated flame retardants, and formaldehyde. Finally, the procedure for the approval of new substances to be placed on the market has slowed down the introduction of new hazardous substances. Since 1981, approval has been sought for approx. 2,000 new substances in the EU. Of these, two have been prohibited from being placed on the market.

The overall picture is that the regulatory efforts have been effective with regard to reducing environmental loading from well-defined point sources and phasing out or restricting the use of individual substances for which risk assessment has been relatively simple and unambiguous. However, when it comes to the more diffuse environmental loading from the extensive spectrum of chemical substances included in the products of modern society, the regulatory efforts have been less visible.

In the coming years, greater attention will be focused on this area, however. Thus the Ministerial Declaration of the 4th International Conference on the Protection of the North Sea held in Esbjerg in 1995 includes a commitment to cease diffuse discharges of environmentally hazardous substances within the space of one generation.

Moreover, in connection with its 1996 discussion paper "Chemicals - Status and Perspectives", the Danish EPA has published an inventory of approx. 100 unwanted chemical substances or groups of substances that it considers unwanted and whose use should be limited. In a subsequent report to Parliament, the Minister for Environment and Energy has stipulated that the inventory will be published as an official inventory, and that special initiatives will be initiated with regard to a number of substances accorded priority.

Finally, through its 1996 discussion paper "Intensified Product-Oriented Environmental Action", the Danish EPA has signalled a broader approach to dealing with the problems of diffuse pollution throughout a product's life cycle.

Effect data

Data type	Availability in IUCLID 1996
Acute toxicity*	71%
Long-term toxicity (including carcinogenicity)*	53%
Harmful effects on reproductive capacity*	20-30%
Acute toxicity to fish and daphnia	51% (fish) 44% (daphnia)
Acute toxicity to algae	30%
Toxicity to microorganisms	21%
Long-term toxicity to fish	6%
Toxicity to soil-dwelling organisms	3%

* *In nearly all cases, established on the basis of animal experiments with rodents*

Table 2.5.7 *Effect data available in the EU's joint database on the 2,700 substances marketed in amounts exceeding 1,000 tonnes per manufacturer per year (Source: Hansen, 1996).*

2.6 Genetically modified organisms

2.6.1 Introduction

From its very beginning, the use of genetically modified organisms (GMOs) has been the subject of intense debate, both among the public and among scientists. The debate blossomed in Denmark in 1985, when the companies Novo and Nordisk Gentofte (now merged as NovoNordisk) sought approval for the use of genetically modified microorganisms in production. As a result, Denmark was the first country in the world to pass a genetic engineering law in 1986. Among other things, the law introduced an approval procedure for industrial production involving GMOs. The basis for approving such productions is assessment of the risks posed to human health and the environment. This has since been followed up through the common EU legislation currently in force that also introduced a corresponding scheme for approval of the deliberate release of GMOs to the environment.

Today, much of the enzyme and pharmaceuticals production at NovoNordisk is based on genetically modified microorganisms. The company is among the leaders with respect to the industrial exploitation of genetically modified bacteria and fungi. The company's research is conducted in contained laboratories, while production takes place in closed tanks with approval of limited discharge of genetically modified production organisms into the environment. Since the organisms are adapted to the production environment, they generally have poor chances of survival in the external environment.

All the first approvals for production with genetically modified microorganisms were appealed by the environmental organizations and/or dissatisfied members of the public. This seldom occurs today, however. The public debate now primarily revolves around agricultural use of genetically modified plants and the application of genetic engineering to animals and man.

The first field release of a genetically modified plant for research purposes in Denmark took place in 1991. Since then, many others have followed and the first EU approvals have been given for the placing on the market of genetically modified seeds of tobacco, rape, chicory, soya bean and maize. With the approval of soya beans, food products were placed on the market that can contain products from the genetically modified soya bean.

The common EU legislation encompasses organisms that have had their genetic material modified in a manner that does not occur naturally. Organisms made by mutagenesis, natural gene transfer and other traditional methods of breeding are not encompassed by the legislation.

As a rule, genetically modified organisms have been given new traits. In a few cases, however, genes have been removed or the formation of selected substances has been blocked. The latter applies in the case of the Flavr Savr tomato, which is unable to form the enzyme polygalacturonase, thereby slowing down the rate at which the tomato ripens. In the laboratory it is now possible to genetically modify the majority of organisms, e.g. viruses, bacteria, fungi, algae, plants, insects, fish, mammals and man. In the present section, the discussion focuses on microorganisms and agricultural plants, these being the only groups so far of environmental relevance in Denmark. There is no doubt, though, that other groups of genetically modified organisms will make their appearance in Denmark in the next decade.

2.6.2 Genetic engineering in the biotechnology industry

It was obvious for the biotechnology industry to attempt to exploit the possibilities posed by genetic engineering at an early stage in its development. The industry already mastered the use of bacteria and fungi to produce enzymes, amino acids, antibiotics, etc., and it was exactly bacteria and fungi that were the first organisms to be modified through genetic engineering. Genetic engineering made it possible to render processes more efficient, as well as to produce completely new products. A good example of the latter is the lipid-cleaving enzymes (lipases), which can now be produced industrially with the aid of a genetically modified fungus. Lipases are widely used in modern detergents.

To date, approval has been given for industrial productions involving five different types of organism:

- Coliform bacteria (*Escherichia coli*).
- Various bacteria of the genus *Bacillus*.
- The unicellular fungus *Saccharomyces cerevisiae* (better known as baker's yeast).
- The multicellular fungus *Aspergillus oryzae*.
- Mammalian (hamster) cells in culture.

These GMOs are used for the production of pharmaceuticals and enzymes. About 50 products have so far been approved. The main products are summarized in *Table 2.6.1*.

Genetically modified microorganisms		
Production organism	**Product**	**Use**
Yeast *(Saccharomyces cerevisiae)*	Insulin	Pharmaceutical, against diabetes
Yeast	Glucagon	Pharmaceutical
Yeast	Aprotinin	Pharmaceutical
Yeast	PDGF	Pharmaceutical
Aspergillus oryzae	Amylases	Enzymes for degrading starch
Aspergillus oryzae	Carbohydrase	Enzyme for treatment of animal feed
Aspergillus oryzae	Carboxyhydrase	Enzyme for setting fruit gels
Aspergillus oryzae	Cellulases	Enzymes for degrading cellulose.
		Used in detergents, etc.
Aspergillus oryzae	Hydrolase	Enzyme for treatment of animal feed
Aspergillus oryzae	Lipases	Fat-degrading enzymes.
		Used in detergents, etc.
Aspergillus oryzae	Oxidases	Enzymes used for bleaching textiles, etc.
Aspergillus oryzae	Oxidoreduktases	Enzymes for removing hydrogen peroxide, e.g. after bleaching
		of textiles
Aspergillus oryzae	Xylanase	Enzyme for degrading hemicelluloses
Bacillus amyloliquefaciens	Amylase	Enzyme for degrading starch
Bacillus lentus	Proteases	Enzyme for degrading proteins
		Used in detergents, etc.
Bacillus licheniformis	Amylases	Enzymes for degrading starch
Bacillus licheniformis	Xylanase	Enzyme for degrading hemicellulose
Bacillus subtilis	Amylase	Enzyme for degrading starch
Bacillus subtilis	Decarboxylase	Enzyme used for ripening of various foods
Eschericia coli	Growth hormone	Pharmaceutical for growth stimulation
Eschericia coli	Nuclease	Enzyme for degrading DNA
Eschericia coli	Vaccine component	Veterinary vaccine against swine influenza
Cell culture	Factor VII	Pharmaceutical, coagulation factor for hæmophiliacs

***Table 2.6.1** Genetically modified microorganisms approved for production use in the biotechnology industry (Source: Danish EPA).*

The majority of GMO-based production in Denmark is undertaken by the biotechnology company NovoNordisk, and is thus restricted to a few geographical locations. In contrast, research activities are much more widespread, over 300 laboratories having been approved to work with GMOs.

Risk assessment

As mentioned in the introduction, prior assessment of GMO-based production is a key principle in the legislation. Risk assessment ensures that production can be carried out without risk to human health or the environment. The factors on which the risk assessment is based are summarized in *Table 2.6.2*.

In the case of production based on yeast (*Saccharomyces cerevisiae*), *Aspergillus oryzae* and *Bacillus* spp., the Danish EPA has approved restricted discharge of the organisms to the environment. This has been done because the risk assessments concluded that these organisms do not comprise a risk to human health and the environment. The justifications for these conclusions are summarized in *Table 2.6.3*.

The approved discharge levels are determined by weighing up the technological and economic possibilities to limit their discharge against the precautionary principle, which dictates that discharge should be limited as much as possible. The maximal allowable concentrations of GMOs in waste water, air, solid waste and sewage sludge are summarized in *Figure 2.6.1*. The quantitatively predominant source is sewage sludge. The number of microbes actually discharged is more difficult to judge as the analysis of small numbers of production organisms is involved.

Approval criteria
Human health
Possible effects on human health are assessed from a knowledge of the microorganism's:
• Infectious properties
• Toxic properties
• Carcinogenic effects
• Allergenic effects
Environmental impact
Possible effects on the environment are assessed from a knowledge of the microorganism's:
• Natural habitats in the environment
• Survival strategy
• Spread
• Possibilities for establishment in the environment
• Possible effects in the environment

Table 2.6.2 *Main factors assessed in connection with the approval of genetically modified microorganisms for contained use (Source: Danish EPA).*

The production approvals also attempt to take the possibility of accidents into account in that unintended discharges of organisms to the environment have to be reported to the authorities.

While a few accidental discharges have resulted in significant release of production organisms to the surroundings, subsequent analyses of samples have not demonstrated their establishment in the environment.

NovoNordisk has found the same negative results upon analysis of various sample materials that could have received genetically modified production organisms. These results show that the genetically modified production organisms have not established themselves in the environment.

As the analysis method can only analyse concentrations of production organisms above a certain detection level, it cannot be excluded that smaller quantities of production organisms could exist in the environment.

Conclusion and perspectives

Hitherto industrial use of GMOs in Denmark has not been shown to have had any effects on the environment.

The future is expected to bring new products, new production organisms and new companies. Development in this area is expected to focus on pharmaceuticals and the food industry.

Justification for restricted discharge of production organisms
Yeast *(Saccharomyces cerevisiae)*
• Do not cause disease in man, animals and plants
• Due to temperature and carbon limitations, will not grow in the natural environment
• Has been used for hundreds of years for baking, brewing, etc.
• Has been discharged to the environment for hundreds of years by bakeries, breweries, etc. without any observable direct effects
Aspergillus oryzae
• Risk of infection is extremely low
• Production strains do not form harmful secondary metabolites (i.e. metabolic products)
• Due to temperature requirements, will not grow in the natural environment
• Production strains do not form more spores or grow more rapidly than the host organism, which means that their possibilities for survival in the environment are like those of the host organism or poorer
• Has been used for fermentation of foods (e.g. soy sauce) for hundreds of years
Bacillus spp.
• No infection risk for healthy humans
• Are widespread in the natural environment
• Production strains are asporogenic, which means that their chances of survival in the environment are markedly reduced

Table 2.6.3 *Summary of the justification for allowing the discharge of certain production organisms to the environment (Source: Danish EPA).*

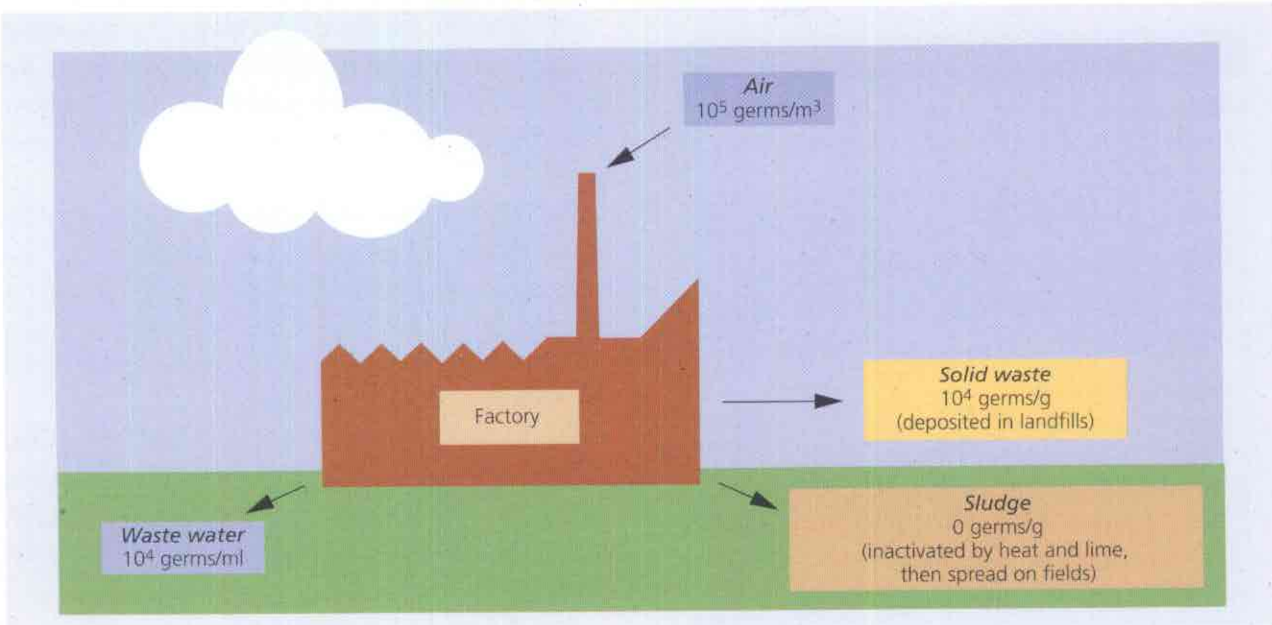


Figure 2.6.1 Limit levels for the maximum concentration of genetically modified organisms in waste water, air, solid waste and sludge from a given production plant. By sludge is understood inactivated sludge, which must not contain germ in measurable concentrations (<1 germ per gramme) (Source: Danish EPA).

2.6.3 Genetically modified plants in agriculture

Man has been breeding and refining plants for thousands of years. In nature and through traditional plant breeding, physical or biological barriers hinder the crossing of distantly related species. By employing genetic engineering in plant breeding, it is now possible to transfer genetic material between different species such as between plants and bacteria or animals.

The first genetically modified plant - a tobacco plant with a model gene - was produced in the USA in 1980. The first field release for research purposes in Denmark took place in 1991, when the sugar company Danisco tested a Roundup-resistant sugar beet.

Here in Denmark, genetically modified plants have so far only been released on small experimental fields. It can hardly be long before the first genetically modified varieties are ready for cultivating in the fields, however. Thus the first genetically modified varieties have been approved for placing on the market in the EU, and the number of notifications for the placing on the market of such plants is increasing year by year. The number of field releases where plant breeding firms test the genetically modified plants before they are placed on the market is also increasing.

The first Danish notification of the placing on the market of a genetically modified plant is currently being examined. This is a Roundup-resistant fodder beet developed by DLF Trifolium in collaboration with Danisco and Monsanto.

How is genetic engineering of plants undertaken?

The development of genetically modified plants starts in the laboratory, where the transfer of genes takes place (*Box 2.6.1*). The majority of the plants so far developed belong to the dicotyledons, which are the easiest to genetically modify. Good progress is being made with the monocotyledons, however, and there is enormous potential to be exploited once the technique has been perfected since the group encompasses the cereals and grass. Genetically modified grass species are particularly likely to cause environmental problems. Their pollen and seeds are easily spread, thereby enhancing the risk of genes spreading to wild plants. Attempts are therefore being made to develop non-flowering grasses.

What traits are introduced?

Genetic engineering is used to endow the plants with new traits. Three types of trait are in focus:

1. Resistance to herbicides, insects, viruses or fungal infections (*Box 2.6.2*).
2. Tolerance to such factors as drought, cold, salt or low soil nutrient levels.
3. Changes in the plant's quality traits, e.g. the plant metabolites, keeping qualities or flower colour.

Genetic modification of plants

Normally, at least two different genes are introduced into the plants. First and foremost the desired trait, e.g. resistance to herbicides, insect attack or drought.

Thereafter a so-called selective marker is introduced to differentiate the genetically modified plant cells from the nonmodified cells. The marker typically used hitherto has been antibiotic resistance.

The use of genes for antibiotic resistance has been the subject of discussion, however, and efforts are therefore being made to develop alternatives. In Denmark, for example, Danisco has patented a system based on the sugar mannose.

Actual introduction of the new genes in the plants is undertaken slightly differently depending on the individual plant. The dicotyledonous plants are easiest to genetically modify. Plants such as beans, peas, beet, rape and potatoes can be genetically modified using the bacteria *Agrobacterium tumefaciens*. It has a plasmid (circular chromosome) that enables it to insert new genes in the host plant.

Agrobacterium tumefaciens does not infect the monocotyledonous plants, which encompass all our cereal and grass species. With these, genetic modification is undertaken by shooting microscopic gold particles coated with DNA directly into the plant cells.

Box 2.6.1 *Genetic modification of plants.*

The first generation of genetically modified plants is dominated by herbicide- and insect-resistant plants. That herbicide and insect resistance dominates is primarily because single gene resistance is best understood and technically the most simple to transfer to other species. Disease resistance typically involves a number of genes.

Future perspectives

The second generation of plants is already on the way. These are plants that in addition to having herbicide and insect resistance, can also be resistant to viruses and fungi. Such crops are expected to be placed on the market within the next five years, and the future is expected to bring many of these "package solutions", where a number of genes are inserted into the same plant. Danisco, for example, is working on a sugar beet that is resistant to both the herbicide Basta and a virus. In addition, intensive research is being undertaken into the so-called quality traits such as plant metabolites and keeping quality. In 1997, Danisco thus undertook field testing of potatoes in which an enzyme had been modified so that the potato cannot convert starch to sugar. This modification should ensure that the potato does not contain sugar, which caramelizes during the manufacture of potato crisps.

With the third generation of genetically modified plants, development is expected to accelerate. Plants will be developed with tolerance to environmental factors such as drought, cold, salt or heavy metals. The development of plants with such traits will have to be assessed very carefully. The crops that we cultivate today have been developed for a field environment in which they are fertilized, sprayed and watered. If their tolerance to drought is modified, for example, the plants might be able to compete outside the field environment, and will therefore spread in nature.

Finally, one can expect to see the development of more precise promoters, which are gene sequences that switch genes on and off. An example could be promoters that are tissue- or development-specific, or which are only activated during attack by pests. There is no reason, for example, for roots to produce insecticide (*Bt* toxin) if the insects only eat the leaves.

From laboratory to field to consumer

According to the Environment and Genetic Engineering Act, the release of genetically modified plants has to be undertaken stepwise. This means that each individual step has to be assessed separately: From the laboratory until the farmer can purchase the seeds

Plant resistance

Plant resistance to pests is controlled by either a single gene (discrete character) or several genes (quantitative character). An example of a discrete character is barley's resistance to the fungus mildew, where a single gene determines whether or not the plant can "recognize" the fungus. If the fungus is recognized, the plant activates a number of other genes, which initiate hypersensitive cell death just around the point of fungal penetration, whereafter the fungus dies. Quantitative resistance is more complicated in that many genes control the defense of the plant.

Unfortunately, however, pests (insects, fungi, viruses) relatively rapidly become tolerant to the plant's defences. As the typical pest occurs in large numbers and has a short life cycle, many mutations will occur in every growing season. Moreover, as selection for tolerance in plant monocultures such as our fields is great, not long usually passes before a population of pests develops tolerance. An example is single gene resistance to mildew. This has been introduced into barley many times by traditional breeding, but new mildew strains always develop against which the plants are unable to defend themselves. New resistant mildew strains have thereafter been rapidly spread throughout the country. In a number of cases, tolerance has been observed to develop more rapidly towards single gene resistance than towards quantitative resistance. Thus in future, greater attention is likely to be focused on genetically modified plants with quantitative resistance towards pests.

Herbicide resistance

Plants that are herbicide-resistant are not affected by a given herbicide. In plants that have been given herbicide resistance through genetic engineering, a gene has been introduced that codes for the resistance. The farmer can consequently spray his crop with the herbicide without affecting the crop. When one sprays with herbicides one exploits a difference in the resistance of weeds and crops. Some herbicides kill grasses whereas the dicotyledonous plants (e.g. beet) survive. Other herbicides, termed "total herbicides", kill all plants. If a gene is found that renders crop plants resistant to a total herbicide, the farmer can apply the herbicide and thereby combat all weeds with one herbicide, without damaging the crop.

The genetic engineering work primarily focuses on resistance towards two agents: Basta and Roundup, which are trade names for ammonium gluphosinate and glyphosate, respectively. Great faith is currently accorded to Roundup as one of the more environmentally sound herbicides for the future. This is because the substance and its degradation products have little direct effect on the environment. Advocates of Roundup thus emphasize that a Roundup-resistant beet can save the environment for tonnes of herbicide compared with traditional beet cultivation. On the basis of this example, however, it is difficult to say anything more general of future consumption of herbicides. Model simulations have thus shown that genetically modified beet can probably be sprayed less, but that this is hardly likely to be the case with a Roundup-resistant rape.

The use of herbicides can lead to herbicide-resistant weeds. This is known from other areas, where spraying has been undertaken using the same herbicide for many years in a row. So far only one case of resistance to Roundup has been reported, even though it has now been in worldwide use for more than 20 years.

Insect resistance

Insect-resistant plants are plants that are not eaten by insects. Insect resistance can be attained in many ways, for example by the formation of a hard surface, through the release of substances that deter insects, or by containing substances that are toxic to insects. The resistance spectrum can vary from narrow to broad, i.e. the plant can be resistant towards a single or a number of insects. Through genetic engineering, one or more genes can be introduced into the plants that code for the trait in question.

The best known example is plants able to form a toxin from the bacterium *Bacillus thuringiensis (Bt)*. The bacterium forms different toxins that are secreted in crystal form during spore formation. The crystals in the bacteria are toxic to certain insects when ingested following activation in the insect's alimentary canal. It is the gene for the activated toxin that is introduced into the plants through genetic engineering. When the insect eats from the genetically modified plant, it dies. The bacteria have genes for different toxins that are each toxic for a group of insects and other invertebrates, e.g. butterfly larvae, beetles or springtails.

As with herbicides, insects are known to have developed resistance to *Bt* toxin. Resistance has thus been demonstrated both through the use of *Bt* bacteria and through the cultivation of genetically modified Bt plants.

Box 2.6.2 *Plant resistance.*

and cultivate the plants in his fields, and finally until the consumer can purchase genetically modified foods. The first studies are conducted in pollen-tight climate chambers and greenhouses. Thereafter follows field testing, initially in small experimental plots. Later the plants are tested under more realistic conditions.

The idea of stepwise release is to "slowly unpack" the plant. One of the important moments is when the time comes for the plant to leave the greenhouse. At that point approval has to be obtained for experimental field release.

Approval processing and risk assessment

It is the Danish authorities who approve the field release of genetically modified plants in Denmark. The EU Commission and the other Member States are notified in advance so that they have the opportunity to submit their observations before the decision is taken. If and when approval is given for an experimental field release, the approval specifies a number of conditions that must be complied with before the field release can take place. Supervision of Danish field releases lies with the county authorities. If the conditions are not complied with, the county authorities have to immediately inform the Danish EPA.

Field releases of genetically modified plants

Species	Number	Species	Number
Cotton	8	Aubergine	2
Barley	2	Cauliflower	5
Wheat	9	Chicory	35
Lucerne	2	Carrot	2
Maize	245	Arabidopsis (model plant)	1
Oil-seed rape	206	Strawberry	1
Beet	152	Potato	117
Brassica rapa spp. oleifera	11	Melon	8
Sunflower	6	Lettuce	4
Soya bean	8	Squash	6
Tobacco	38	Tomato	62
Vine	2	**Vegetables - total**	**243**
Field crops - total	**689**	African violet	1
Orange	1	Chrysanthemum	1
Plum	1	Marigold	8
Eucalyptus	3	Carnation	3
Poplar	7	Petunia	2
Scotch pine	2	**Ornamental plants - total**	**15**
Norway spruce	2		
Silver birch	2		
Apple	1	***No. of species***	***36***
Trees - total	**19**	***No. of releases***	***966***

Table 2.6.4 *Summary of field releases of genetically modified plants notified to the EU in the period 21 October 1991 to 21 June 1997 (Source: National Forest and Nature Agency).*

In 1996, 233 field releases were notified in the EU as compared with only 71 in 1992. *Table 2.6.4* shows the number of field releases that have hitherto been undertaken in the EU with various crops.

At present, work is being conducted on 36 different species, although by far the majority of field releases have been with maize, rape, sugar beet and potato. In 1997, there were six field releases in Denmark: Three with sugar beet, two with potato and one with rape. Since 1991 there have been 31 field releases in Denmark, thus placing Denmark eighth as regards field releases in the EU.

The processing of notifications for the placing on the market of genetically modified plants involves all EU Member States. This is because approval concomitantly entails approval for the plant to be placed on the market in all Member States. A notification for approval has to be submitted to one Member State, which following thorough risk assessment can either deny approval or forward the notification to the EU Commission with a positive recommendation. Hereafter the notification and recommendation are submitted to the other Member States for their comments. If none of the other Member States raise objections, the genetically modified plant can be immediately approved. If just one of the Member States raises objections, the case has to be decided by a vote among the Member States in accordance with a specified procedure.

When such notifications are submitted for approval in Denmark, the Danish EPA prepares a memorandum to the Minister for Environment and Energy, who takes the final decision. The memorandum is drawn up on the basis of an ecological risk assessment by the National Forest and Nature Agency, an agricultural risk assessment by the Plant Directorate and a health risk assessment by the Institute of Food Safety and Toxicology (see *Box 2.6.3*). These institutions assess the consequences of placing the genetically modified plant on the market on the basis of the information and studies included in the notification. If necessary, they can require further studies or more documentation. A short summary of the notification is sent for hearing in more than 45 institutions and organizations, and their comments are incorporated in the memorandum to the Minister.

Notified genetically modified plants			
Species	**No. of cases**	**Traits introduced**	**Approval status**
Tobacco	1	Herbicide resistance	1 approved
Maize	5	Insect and/or herbicide resistance	1 approved 4 under examination
Rape	6	Herbicide resistance and/or male sterility	3 approved 3 under examination
Soya bean	1	Herbicide resistance	1 approved
Chicory	2	Male sterility and herbicide resistance	1 approved 1 under examination
Potato	1	Modified starch content	1 under examination
Carnation	1	Modified colour	1 under examination

***Table 2.6.5** Notifications for the placing on the market of genetically modified plants in the EU up to September 1997. The summary encompasses the cases that the EU Commission had then (September 1997) circulated to Member States for commenting. The first Danish notification (for a fodder beet) had not been forwarded to the EU Commission at that time (Source: Danish EPA).*

As per 15 September 1997, 17 notifications for the placing on the market of genetically modified plants had been submitted for approval in the EU. These are being examined under Directive 90/220/EEC on the deliberate release of genetically modified organisms to the environment. Of the 17 notifications, 7 have been approved and 10 are still being examined (*Table 2.6.5*).

Denmark has hitherto raised objections in respect of 6 notifications, all concerning herbicide-resistant oil-seed rape, on the grounds of inadequate knowledge of what effects such plants will have on herbicide consumption in the longer term.

Moreover, in virtually all cases the Government has indicated that Denmark will not be able to support approval. The reason is that the notifications for approval do not specify that the product will be labelled with information to the fact that it is genetically modified, a 1994 parliamentary decision having committed the Government to work for the compulsory labelling of food products based on GMOs.

Risk assessment

The release of genetically modified plants entails the possibility that the plant or its genes can spread to the surrounding nature or that the genetically modified plants cross with members of the same species or closely related species, thereby giving rise to resistant weeds. An ecological assessment is made to determine the risk that they might spread and establish themselves. At the same time the ecological effects of

Risk assessment of genetically modified plants

When undertaking risk assessment the genetically modified plants are compared with the corresponding nonmodified plant with respect to:

Ecological risks

- Whether the plant itself or its genes spread to natural ecosystems and affect these systems
- The effects on nontarget organisms
- The impact on the ecosystem, biodiversity or locally adapted genetic variations

Agricultural risks

- Whether the plant itself or closely related species that receive genes by hybridization develop resistance traits

Health risks

- The content of toxic or allergenic substances
- Changed nutritional value

***Box 2.6.3** Risk assessment of genetically modified plants.*

the release are assessed. For example, both pests and non-target organisms can be affected by the release of insect-resistant plants.

Another problem is whether genetically modified plants will be able to transfer the modified traits to wild plants. Studies undertaken at Risø National Laboratory have shown for example that oil-seed rape (*Brassica napus*) can form fertile crosses with the closely related weed *Brassica campestris.* A genetically modified rape will therefore be able to transfer its genes to plants in the environment. To what extent such a transfer will have an effect in the fields or in nature will depend on both the plant and the genes inserted.

The total acreage cultivated with genetically modified plants is still very limited. It must be expected that genetically modified plants will be cultivated on a much larger area in future, however. In the longer term, it will therefore be necessary to come to a decision on both the direct and indirect environmental effects.

The indirect effects include the effects on arable bird species, whose food resource can be lost if the insect fauna changes or disappears. The effect on arable land biodiversity is thus important.

Another central question is the development of resistant weeds. What will happen when weeds become resistant to the "environmentally sound" herbicides? Will the farmer have to return to the old herbicides or to mechanical weeding?

The use of marker genes that code for antibiotic resistance can cause problems if the resistance can be transferred to the gut flora of man, for example. Attempts are therefore being made to avoid marker genes. The above mentioned fodder beet being developed by DLF Trifolium is the world's first beet lacking marker genes as only the gene for Roundup resistance has been inserted.

Revision of the GMO release Directive

In 1997, work was begun on revising the EU Directive on the deliberate release of genetically modified organisms to the environment. In this connection, Denmark will work for improved labelling of GMOs and a more holistic approach to risk assessment that among other things incorporates the long-term and secondary effects, as well as a change in the current committee procedure to a procedure in which decisions are taken by simple majority.

2.6.4. Conclusion

To date, no environmental problems have arisen that can be attributed to genetic engineering. To what extent this is due to the legislation implemented is obviously difficult to assess.

There is no doubt, however, that the activity in certain areas has been curtailed by the legislation. Thus the legislation has resulted in better conditions in the laboratories with respect to both their physical organization and the procedures used, and has made industry and agriculture think twice before starting production involving genetic engineering as alone the costs of providing the necessary documentation for approval are enormous, especially if the release of GMOs is involved.

In Denmark, the authorities have not yet rejected a single notification of industrial production or field release, although in a number of cases more stringent conditions have been imposed than those requested by the applicants.

In contrast to chemicals, which in the worst case are non-degradable, living organisms have the property of being able to reproduce in nature.

As already mentioned, it must be expected that development on the plant side will result in constructions that are considerably more difficult to assess than those previously known. Notifications of the field release and marketing of genetically modified microorganisms and possibly also genetically modified fish and insects will probably appear during the next decade. In this context, it will be important to ensure that the overall environmental consequences of development within the genetic engineering area are assessed.

2.7 The cultural environment

2.7.1 Introduction

The cultural environment encompasses all the physical elements of cultural history that man creates and leaves behind in the towns, in the country and in the sea. As such it comprises an important part of man's surroundings. The Ministry of the Environment and Energy's November 1995 environmental policy paper thus emphasized the cultural environment as environmental policy's third dimension - alongside pollution control and the protection of plants and animals.

Protection of the country's ancient monuments has deep roots, although it was based solely on voluntary preservation until the 1937 Nature Conservation Act. As a result, only approx. 1/4 of the ancient monuments that existed just 150 years ago have been preserved, interest having primarily centred around the most significant monuments. Over the years, however, the term ancient monument has been widened and more precisely defined.

With the 1992 Nature Protection Act, the term has thus been widened from one solely encompassing actual structures to one also encompassing other traces in the landscape such as sunken roads, fields/ selions, settlements, etc.

Adoption of the first Building Preservation Act in 1918 created the foundation for the preservation of the best of our building heritage. The basic principles espoused in this law have been maintained up to the present time, although the provisions have been expanded and made more stringent on several occasions. Apart from actual listing, the preservation work is currently supplemented by the identification and registration of buildings and urban environments considered particularly worthy of preservation.

Societal development over the last 100 years has helped to draw stronger attention to the cultural environment in a broader sense. This development has been brought about by the major conversions of our landscape and our urban structures in the form of industrial districts, a fine-meshed network of railways and motorways, large infrastructural installations, electricity pylons and wind turbines, expansion of holiday and tourist facilities along the coast, the establishment of large chalk and gravel quarries, intensive large-scale agricultural production, etc. This has not only exerted marked pressure on Danish nature, but has also totally changed our settlement pattern, the conditions for life in the local communities, and the historical features in the landscape as a whole. The consequence is loss of character and identity at both the general and local levels. However, this development has also helped enhance interest in the cultural environment and cultural history. Thus local history societies have arisen throughout the country, and interest among the population in local planning is considerable.

In its widest sense, cultural environment thus concerns preservation of the landscape's historical dimensions and structures, and not just the safeguarding of individual elements. This section approaches the theme through the specific legislative efforts to preserve ancient monuments and buildings, although threads are also drawn to the broader landscape and urban environment context against which these efforts must be viewed.

The development of the modern Danish landscape is summarized in *Box 2.7.1* as a basis for understanding the present efforts.

2.7.2 Listed ancient monuments

The preservation of particularly valuable elements in the modern landscape has centred around the so-called ancient monuments. Under the Nature Protection Act, a number of specified categories of monuments, ruins and other traces of the past have thus been protected as ancient monuments.

There are a total (1997) of about 33,000 listed ancient monuments in Denmark, as summarized in *Table 2.7.1*.

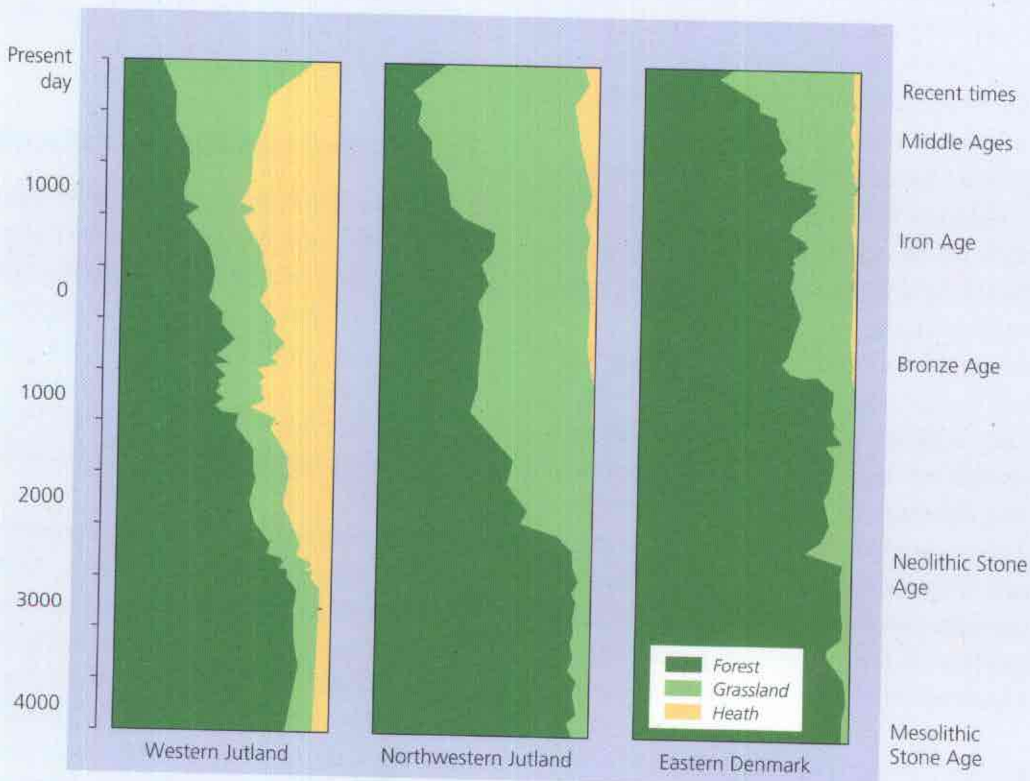
The number of listed ancient monuments has increased year by year from approx. 7,000 in 1925 to over 33,000 in 1997. The increase in the number of listed ancient monuments is primarily attributable to the fact that the term ancient monument has been widened several times. In the 1992 Nature Protection Act, the term encompasses not only actual edifices, but also traces of former field systems, road remains such as sunken roads, wheel tracks and fords, as well as stone and earth dykes.

The geographic distribution of ancient monuments is shown in *Figures 2.7.1-2.7.4*. The uneven distribution of the listed ancient monuments partly reflects the fact that the land in parts of the country has been subjected to very intensive exploitation in recent times, partly the fact that the buildings of antiquity have actually been less concentrated in certain areas and that this has changed throughout the ages.

Development of the modern landscape

The first faint cultural traces in the landscape stem right back from the Mesolithic Stone Age in the form of kitchen middens of shellfish along the coasts. Cultivation of the land started in the Neolithic Stone Age nearly 6,000 years ago, and the settlements began to spread inland from the coasts. From that time stem the great burial mounds, dolmens and passage graves that were raised throughout present-day Denmark over half a millennium.

Forest clearance continued during the Bronze Age and thousands of burial mounds were erected that sometimes contain rich grave gifts of gold and bronze bearing witness to a hierarchical, class society. The transition to the Iron Age is characterized by expansion of society, where large new areas were placed under the plough and where large stone roadworks near bogs and water-courses bear witness to marked growth in traffic. It is in the Iron Age that the present settlement pattern has its origins, this being the time when the settlements were collected into small towns, each with its own owners association. Major ramparts (e.g. the Dannevirke) and ship barriers bear witness to the fact that the Iron Age and the Viking Age were periods characterized by conflict and war. The state began to take form and an independent crown unified the realm in the Viking Age, which forms the transition to historical times.



Landscape development through 6,000 years in western Jutland, northwestern Jutland and the eastern part of Denmark assessed on the basis of pollen analyses. No distinction is drawn between natural forest/cultivated forest or between grassland/arable land (Source: Geological Survey of Denmark and Greenland).

In the Middle Ages (approx. 1000-1550 A.D.), the foundation was created for the whole of the present-day settlement structure. The villages were accorded permanent locations within the new parish boundaries and a new wave of expansion led to the formation of new villages with names typically ending in -rup, -strup or -torp. Around 2,000 village churches from that time bear witness to Christianity's great significance for the whole structure of society. Sharp boundaries were established between the social classes: Nobility, clergy, commoners and peasants. This had a considerable impact on exploitation of the landscape. Castles were erected throughout the country by the untaxed nobility, and the crown established large state castles in strategic locations, e.g. Nyborg, Kalundborg, Vordingborg and Sønderborg. The market towns were typically located by the water, where they were awarded monopoly on trade and craft. They functioned as autonomous units with their own jurisdiction.

The landscape had no sharp boundaries between forest and land because the peasants had the right to use the forest undergrowth for grazing. Pressure on the forests finally became so great that there was a shift to building half-timbered houses with mud walls to save on timber. During the 17th Century, farm buildings developed into 3- or 4-winged complexes built around a farm-yard, a type of farm that in many places has survived to the present day. The enormous economic success of the nobility in the 1500s-1600s is reflected in the many impressive manor houses from that period. The infrastructure was developed, new roads were established and milestones erected.

With the land reforms implemented over a longer period from the end of the 18th Century to some way into the 19th Century, the old collective farming was abandoned and the farms were moved from the village out onto their own land. The new fields were marked out using fences, boundary ditches and hedgerows.

An attempt was made to counteract the catastrophic lack of wood through the introduction of the Forest Preservation Act in 1805. Since the end of the 17th Century, forest acreage had fallen from 20% of the country to only 3%. To reverse this development, the peasants were forbidden to use the forest undergrowth for grazing. Stone walls were erected around the forests, afforestation was commenced, among other things with new tree species such as Norway spruce, larch and Scotch pine, and a large number of lakes and bogs were drained and reclaimed.

In the middle of the last century, industrialization won forward in the towns. When the right to ply a trade was set free in 1853, the sharp trade boundaries between town and country were abolished. The establishment of thousands of smallholdings followed in the heals of the new land laws, and the small, uniform houses became easily recognizable throughout the country. The structure of the landscape as we know it today was taking form.

In the present century, massive population growth and industrial development has inverted the balance of strength between the towns and countryside. The majority of the population now lives in the towns, and rationalization in the agricultural sector has led many farms to be merged. Electricity pylons and factory smokestacks are characteristic features of the landscape's "air space", and large areas with light industry and modern residential districts have shot up on the outskirts of the towns. Outstretched summer cottage districts form a closely built-up area along the attractive coasts, while the old fishing villages die out.

The infrastructure has developed explosively and the country is covered by a fine-meshed network of roads, railways, bridges and motorways. Arable land is receding to the benefit of urban development. On the threshold of the 21st Century we are about to enter a new era where the landscape's development will be affected by man on a scale and rate not previously seen.

Box 2.7.1 *Development of the modern landscape.*

Listed ancient monuments					
Antiquity		Middle Ages and historical times		Recent times	
Mounds/stone mounds	25,700	Castle mounds	705	Milestones, etc.	256
Dolmens, etc.	2,067	Fortifications*	222	Mills/dams	48
Stone ships	45	Abandoned graveyards	70	Bridges/roads*	255
Rune stones, etc.	749	Ruins, etc.	1,072	Canals*	14
Rock carvings	315	Holy springs	57	Memorials	78
Settlements*	32	Fields*	35	Other*	50

*There is a certain degree of overlap to proceeding and/or following period

Table 2.7.1 *Distribution of listed ancient monuments (Source: National Forest and Nature Agency).*

Numerous categories of ancient monument display local variations. In the western Jutland, there are small Stone Age and Iron Age barrows that are not found elsewhere. Similarly, a special group of small Bronze Age barrows is found on the southern islands. Dolmens and passage graves are particularly abundant on Zealand, while the historical ancient monuments are relatively rare in western and northern Jutland. Certain areas such as Himmerland and Thy are particularly rich in burial mounds. In general, though, listed ancient monuments are to be found throughout the country.

Ancient monuments are not just to be found on the land, however, and the Danish sea bed is rich in cultural relics from virtually all periods of our history.

More than 8,000 marine localities or objects of historical interest are presently recorded. These include both finds from before historical times (up to 1000 A.D.) such as Stone Age settlements, and finds from the Middle Ages and recent times, especially in the form of shipwrecks, ship barriers, fortifications, etc.

In the early Stone Age - 7,000 years ago - the sea level was 15 metres below that at present, and many settlements are therefore found on the sea floor. They comprise more than 90% of the ancient monuments from before historical times, numbering more than 1,000 in all.

In addition, there are a number of finds of former harbours from the Iron Age to recent times, ship barriers from two periods in particular - 200-400 A.D. and 1100-1300 A.D. - and a large number of shipwrecks that are listed in accordance with the Nature Protection Act.

It is thus estimated that the Danish marine waters contain approx. 25,000 wrecks from the Viking Age up to recent times in very different states of preservation.

The preservation efforts require not only listing of the monument, but also control of the listing regulations as well as restoration and maintenance work. In general, the listing regulations are complied with, although there are examples of more or less gross violations. The most common violation is ploughing and planting within the protected zone around ancient monuments. Maintenance of ancient monuments is primarily undertaken by the county authorities, while actual restoration work, especially of ruins and passage graves, is undertaken by the National Forest and Nature Agency.

Since 1986, quite a lot of the ruins from the Middle Ages have undergone extensive repair work. Thus out of 250 selected ruins, restoration of 104 has been completed and the remainder are expected to be restored before 2001. In addition, approximately 30 passage graves have been restored.

Throughout the country the soil layer where archaeological finds are made is threatened by spreading deep ploughing in connection with afforestation, planting of windbreaks and in many cases also by ordinary agricultural production. Ploughing has reached a depth of 70 cm resulting in the total annihilation of many settlements from antiquity as well as a large

Visitors to ancient monuments	
Number of visitors	Average 1995/96
Hammershus	297,000
Aggersborg	32,000
Kalø	100,000
Gåsetårnet	28,000

Table 2.7.2 *Number of visitors to selected ancient monuments (Source: National Forest and Nature Agency).*

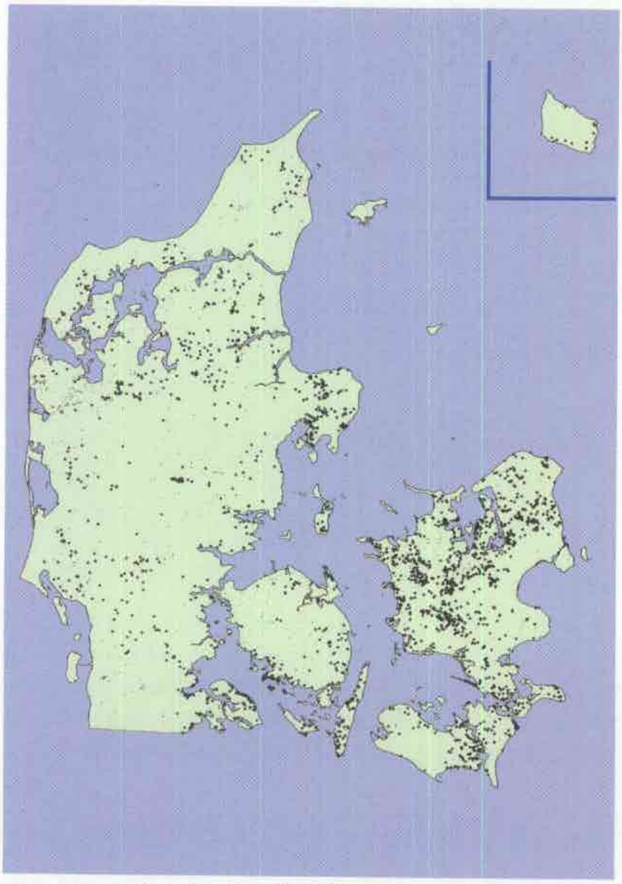


Figure 2.7.1 *Distribution of listed dolmens and passage graves (Source: National Forest and Nature Agency).*

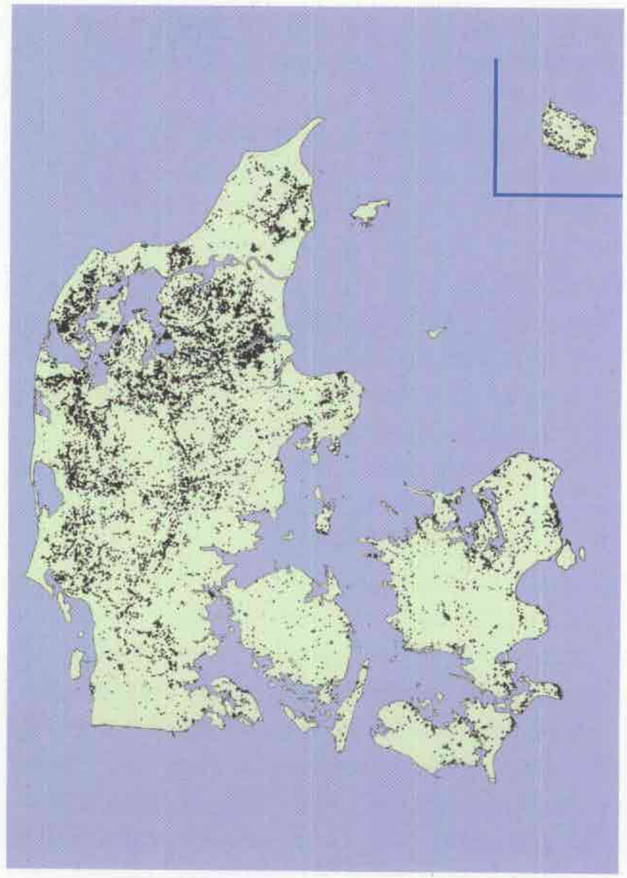


Figure 2.7.2 *Distribution of listed burial mounds (Source: National Forest and Nature Agency).*

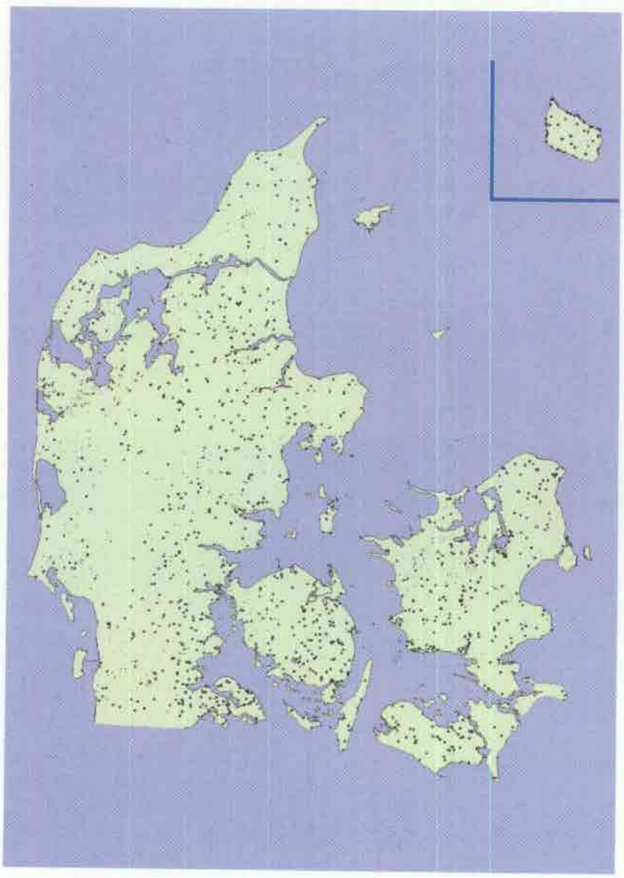


Figure 2.7.3 *Distribution of ancient monuments from historical times (Source: National Forest and Nature Agency).*

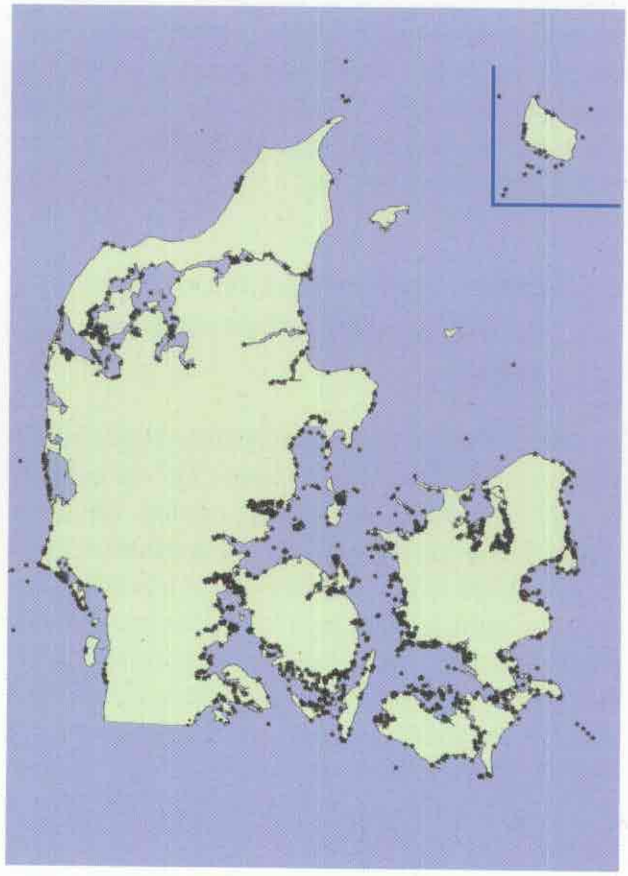


Figure 2.7.4 *Distribution of registered Stone Age settlements in Danish marine waters (Source: National Forest and Nature Agency).*

number of ramparts, etc. The situation today is very different from that when the Museum Act was revised in 1989.

The large kitchen middens from the Mesolithic Stone Age are also being destroyed, among other reasons because of increasingly heavy mechanization of agriculture. A study of 22 kitchen middens has shown that 15 of these were totally destroyed. It is estimated that around 75% of the country's shell middens have been destroyed. Ancient monuments are a popular tourist attraction and the most well-known attract large numbers of visitors (*Table 2.7.2*).

Preservation efforts have previously focused on safeguarding individual ancient monuments. However, in acknowledgement of the fact that many irreplaceable culture-historical entities have been lost during recent decades, it has now been decided to focus more on the protection of the broader culture-historical relationships and values in the landscape.

As examples of the unfortunate development, one can mention the destruction of many fine coastal environments, among other things as a result of unplanned development of tourism, the wiping out of old village structures and original roadways, unsightly construction near village churches, etc. Among the cultural environments in the landscape currently in focus in relation to regional and municipal planning are villages and their surroundings, fishing villages with accompanying drying grounds etc., manor house landscapes, smallholding districts, rivers with water mills, etc.

2.7.3 Listed and preservation-worthy buildings and urban environments

At present there are approx. 9,200 listed buildings in Denmark (*Figure 2.7.5*). Of these, 1,100 are publicly owned while 8,100 are privately owned. The listed buildings represent the best of our architectural heritage. In order to be worthy of listing, a building has to have significant culture-historical or architectural value, and as a general rule must be more than 50 years old. The owner of a listed building is bound to maintain the building in accordance with its original construction and state, and has to obtain prior approval for building work other than routine maintenance.

The Building Preservation Act originated in 1918 and has subsequently been revised several times, although it is still founded on the same principles.

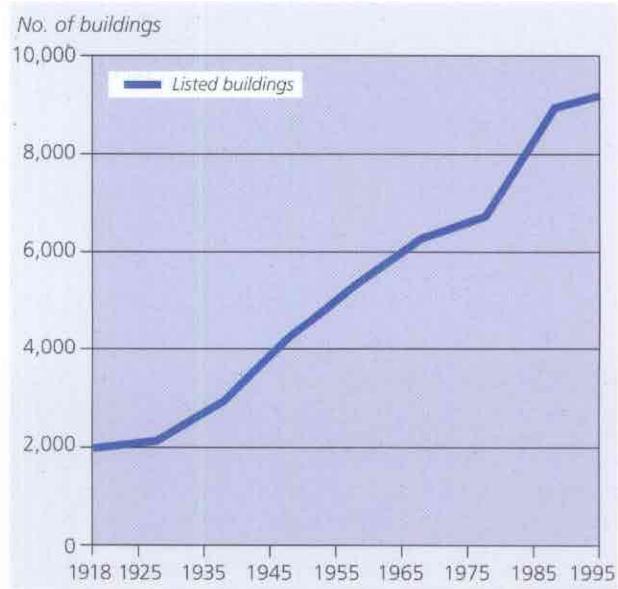


Figure 2.7.5 *Development in the number of listed buildings during the period 1918-95. The increase partly reflects enhanced awareness among the population concerning building preservation rules, and partly the greater efforts being made to register buildings (Source: National Forest and Nature Agency).*

Since about 1990, approximately 50 buildings have been listed annually. The listed buildings are not evenly distributed throughout the country. Greater Copenhagen, including Copenhagen and Frederiksberg municipalities, have a high concentration - approx. 2,600 listed buildings - while five of the 14 Danish counties each have under 300 privately-owned listed buildings.

Four categories of listed building are used : "Urban buildings", "Country buildings", "Manor houses" and "Other buildings". The latter encompasses industrial buildings, production buildings, water mills, wind mills, light houses and water towers (*Figure 2.7.6*).

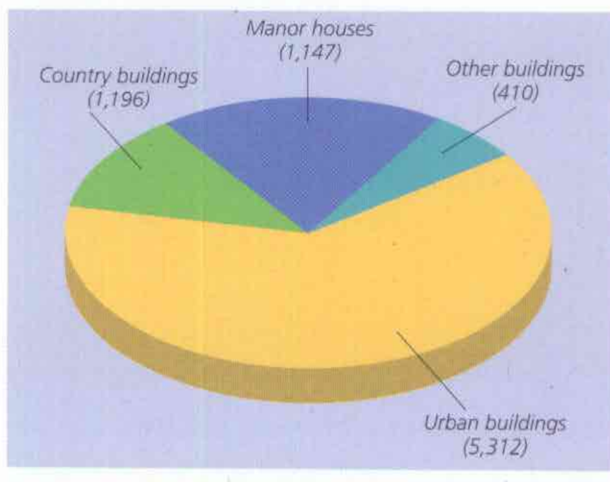


Figure 2.7.6 *Listed buildings apportioned by building category (Source: National Forest and Nature Agency, 1996a).*

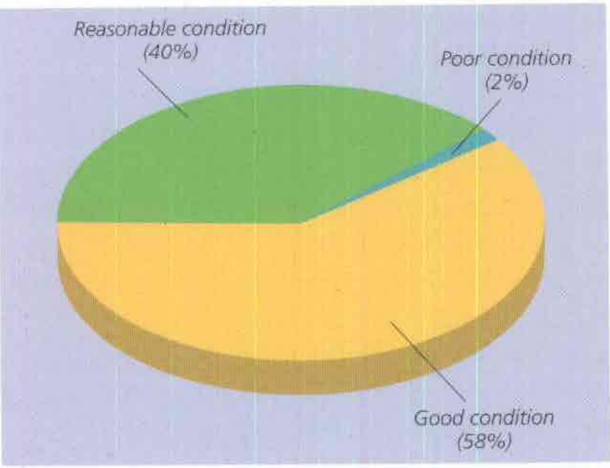


Figure 2.7.7 Listed buildings apportioned according to their state of preservation (Source: National Forest and Nature Agency, 1996a).

The condition of the listed buildings is generally good. This applies both to the listed urban buildings and the listed country buildings. In the latter case, the picture is not so unambiguous, however, as some of these are in poor condition. The listed manor houses are also generally in good condition, but a small part of them are in poor condition. The other listed buildings are generally in a poorer condition.

The developmental trend within the different categories of building differs. The state of the listed urban buildings seems generally to be improving. The country buildings are also generally improving, although this is not always the case. In the case of the manor houses, in contrast, their state is generally deteriorating. It has not been possible to assess the trend for the category "Other buildings".

It is estimated that the exterior of listed buildings would require renovation work totalling DKK 1,700 million if the buildings were to be renovated right now. This includes the costs of repairing the deficiencies in the listed buildings that are in poor condition.

It is estimated that the annual exterior maintenance requirements for the listed buildings is approx. DKK 273 million. *Table 2.7.3* shows the maintenance

Building maintenance

Annual external maintenance costs, DKK million	
Urban buildings	185
Country buildings	27
Manor houses	51
Others	10
Total	273

Table 2.7.3 Annual external maintenance costs apportioned by building category (Source: National Forest and Nature Agency).

costs for the individual categories of building. If one also takes into account the total need for interior maintenance of listed buildings, the estimated total maintenance requirement is around DKK 590 million. Annual state subsidies (both direct and indirect) for listed buildings amount to approx. DKK 180 million plus possible loans of approximately DKK 7 million. The possibilities for financial support encompass both internal and external repair and maintenance of listed buildings. It is estimated that within a five-year period, it should be possible to undertake the necessary work on the buildings that are in poor condition for an annual subsidy of approx. DKK 32 million more than the subsidies, etc. that are provided today.

The cultural and architectural heritage that buildings constitute is not just associated with individual exceptional buildings. It is just as well manifested in the more anonymous mass of buildings and in the characteristic local building tradition that forms the recognizable relationships and urban environments with their own identity.

Since 1990, the Ministry of Environment and Energy has developed a close cooperation with the municipalities on the so-called Municipal Atlases, the aim of which is to evaluate and chart the preservational value of each individual municipality's buildings (*Figure 2.7.8*).

The atlases form part of the foundation for municipal planning and building administration. Up to the present day, approx. 1,600 urban environments have been charted and approx. 220,000 buildings evaluated. Under current legislation, legal protection of buildings worthy of preservation enters into force when a Local Plan containing preservation orders is finally adopted by the Municipality. Approx. 50,000 buildings have been designated by Municipalities as being worthy of preservation in this way and under former town planning regulations. Experience indicates that local preservation efforts have been accorded higher priority in the individual municipalities.

During 1996, a national assessment was made of preservation conditions and the technical state of the preservation-worthy buildings.

Figure 2.7.9 shows the estimated distribution of the preservational value of all the buildings in the country considered worthy of preserving on a scale from 1 to 9, where buildings in group 1 have the highest preservational value and those in group 9 have low preservational value. As mentioned earlier, local preservation efforts have increased in recent

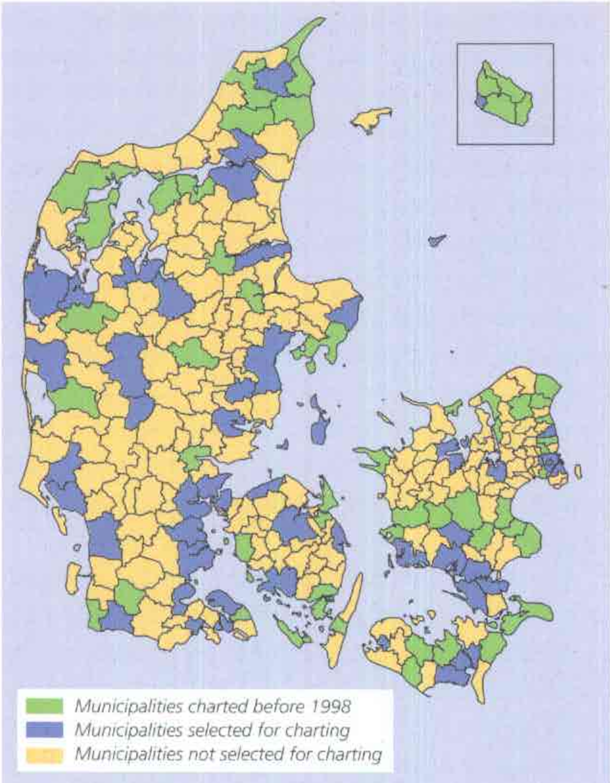


Figure 2.7.8 Summary of progress in the preparation of Municipal Atlases of preservation-worthy buildings. Up to the end of 1997, 61 municipal and urban district atlases had been drawn up in 48 of Denmark's 275 municipalities (Source: National Forest and Nature Agency).

years. This is reflected in the introduction of more stringent preservation regulations for buildings, but only to a lesser extent to a more broad planning approach directed at preservation of the overall urban environment.

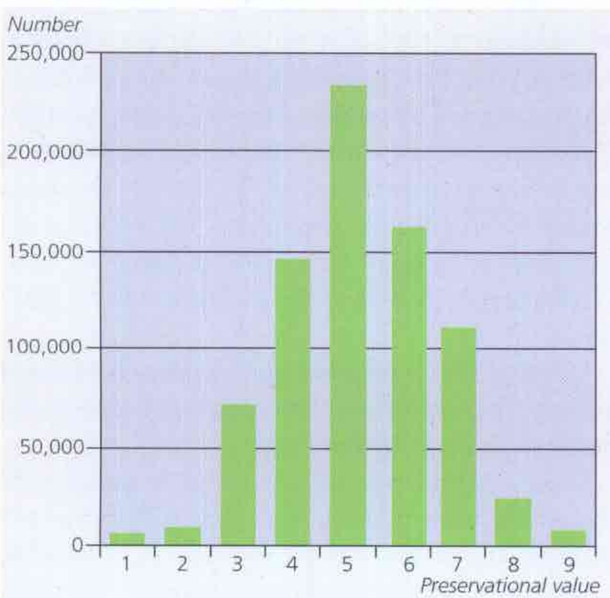


Figure 2.7.9 Estimated distribution of the preservational value (scale 1 to 9) of buildings considered to be worth preserving (Source: National Forest and Nature Agency).

2.7.4 Conclusions and trends

In general, it can be concluded that the specific efforts being made to safeguard ancient monuments and valuable buildings are well underway. The listed ancient monuments and buildings are generally in good condition, even though a small part of them require some additional work. In addition, new buildings and ancient monuments are regularly being added to the existing inventory of listed buildings and monuments. In recent years, the term cultural environment has been widened such that it now encompasses not only individual monuments and buildings, but also other cultural traces in the landscape, buildings worthy of preservation in the broader sense, and large entities in both the landscape and the urban environment. This broader understanding of the term is reflected in the 1992 Nature Protection Act as well as in the preservation work on the landscape and urban environment undertaken by the Municipalities and Counties.

Thus apart from the actual preservation work, local planning now pays greater consideration to the conservation aspects of culture-historical values.

In contrast, however, it must also be concluded that the general growth of society and the resultant tremendous changes in population distribution, the landscape and the urban environment impose considerable pressure on the cultural environment. Apart from threatening the individual traces of cultural history in the landscape and urban environment, this also changes the overall relationships and entities in the cultural environment. Contiguous industrial districts in the old towns fall into disuse as industries move out, town centres are under pressure from new shopping centres, fishing villages disappear, village environments are changed in step with the continued migration from agriculture, and the characteristics of the open countryside change with the associated industrialization and concentration of farms.

To counteract these developmental tendencies a broader effort is needed than that possible within the framework of current preservation regulations. Safeguarding of the cultural environment thus needs to be better incorporated into the planning of our society - as with environmental policy endeavours in general.

3. Environmental impact of society

3.1 General development of society

3.1.1 Introduction

The environment and the economy are an integral part of societal development and mutually influence each other. Economic activity consumes resources and causes pollution and other effects of significance for the quality of the environment. The overall environmental impact of society's activities is thus a product of the size of the population and the sum of the environmentally detrimental activities that accompany a given standard of living. At the same time, though, it is the environment and the natural resource base that determine the conditions for economic activity since they are the foundation for man's production and consumption. The economic system has thus to be considered within the framework of the global network of ecosystems and the resource base upon which these rest.

However, the close correlation between the level of overall economic activity and the state of the environment are not unambiguous. In general, increasing economic activity results in increased production and consumption of goods and hence enhanced resource consumption and pollution. However, much depends on the composition of the enhanced activity and the technologies used in production.

The enhanced activity and the concomitant increase in gross domestic product thus also result in a shift in the composition of production and consumption. Moreover, replacement of capital equipment could lead to the introduction of cleaner and less resource-intensive technologies. Furthermore, the state of the environment does not necessarily deteriorate in step with economic growth and through conscious efforts on the environmental front it will be possible, at least in the short term, to partly or completely neutralize some of the negative environmental consequences of continued economic growth.

The present section examines the elements of the general societal and economic development, i.e. development in the size and composition of the population, the general economic development and development in the structure of production and consumption. These elements are of decisive significance for the magnitude of the pressures on the environment. Development in the environmentally most important sectors is examined in more detail in *Sections 3.2 to 3.9*.

3.1.2 Demographic conditions

On 1 January 1996, the Danish population totalled 5.251 million. In the period 1980 to 1990, the population remained relatively constant (an increase of just over 13,000) while the age composition of the population changed. The share of children and youths in the age group 0-19 years fell from 29% to 24%, while the share of persons of working age (20-66 years) increased from 59% to 62% (corresponding to just over 170,000 persons) and the share of elderly persons (67 years and older) increased from 12% to 14%, see *Figure 3.1.1*.

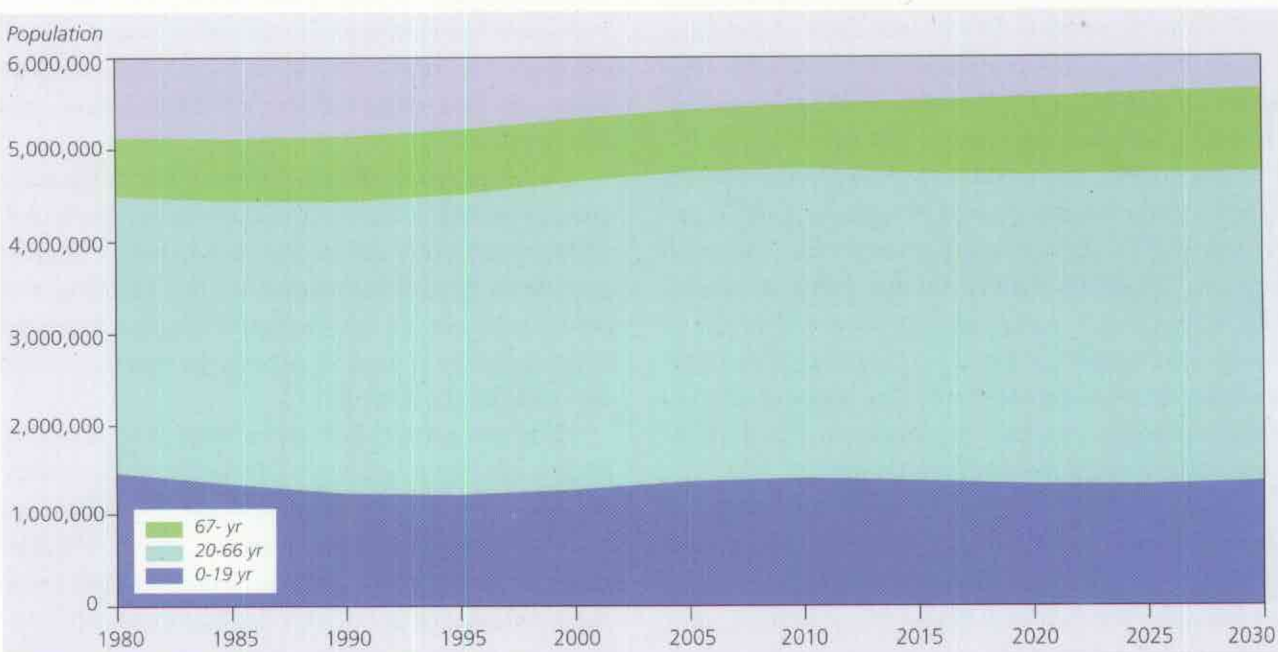


Figure 3.1.1 *Development in the size and age composition of the Danish population (Source: Statistics Denmark, 1997).*

The birth rate reached its hitherto lowest level in 1983 at just over 50,000. Since 1990, the population has grown by just over 115,000, the number of people of working age has increased by just over 123,000 and the birth rate has increased to approx. 70,000 per year. For the period 1980-96 as a whole, the total population has thus grown by just under 130,000 while the number of people of working age has concomitantly grown by just over 290,000.

Up to the year 2010, the birth rate is expected to continue to remain at just under 70,000 per year and the total population is expected to grow by just under 245,000 persons or an average of 0.33% per year. This means that the share of children and youths will increase while the share of persons of working age will fall and the share of elderly persons will remain roughly constant.

After the year 2010, the picture changes in that the share of youths falls while the share of elderly persons increases considerably. The share of persons of working age remains roughly constant. From the year 2010 to 2020, the number of elderly persons is expected to increase by just under 150,000.

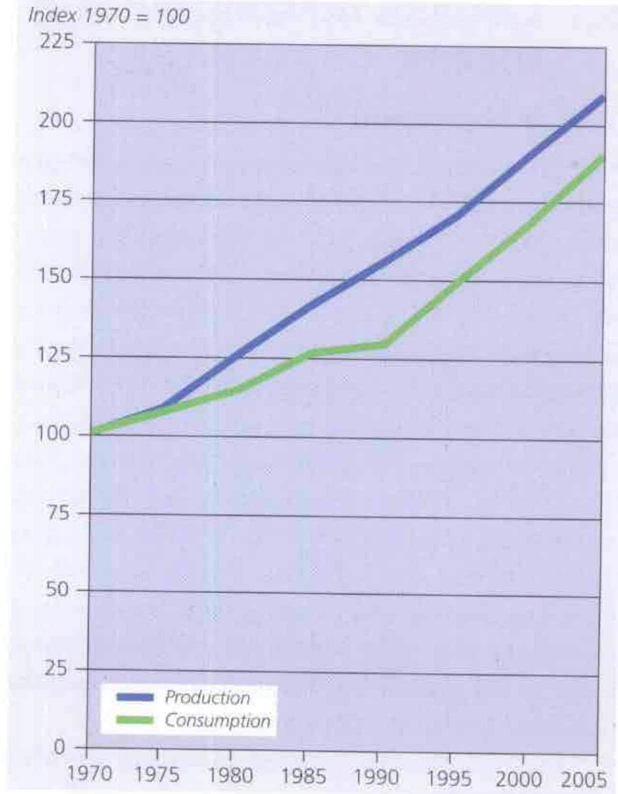


Figure 3.1.2 Development in production and consumption in real terms (1980 prices) (Source: Statistics Denmark, 1997, Ministry of Finance, 1996).

3.1.3 Economic development

In the 1970s and 1980s, economic development was characterized by oil crises, increasing unemployment and balance of payments deficit, but also by a growing labour force (among other things, as a result of increasing participation in the labour market) and economic growth averaging just over 2% per year or a total of 50% over the period 1970-90. Private consumption grew by approx. 30% in real terms during the same period. As the population concomitantly only grew by just under 5%, private consumption per inhabitant thus grew by approx. 25% in real terms.

Since 1990, the trend has changed on several points. After having peaked at approx. 350,000 unemployed in 1993, unemployment has fallen to approx. 250,000 in 1996. This is due partly to increasing employment in the last few years and partly to extended possibilities for leave, for example for educational or personal reasons. The balance of payments is positive and the rate of increase in production and private consumption has grown.

The hitherto development in production and consumption is shown in *Figure 3.1.2*. The figure also shows the expected development up to the year 2005 as forecast in the Ministry of Finance's Medium Term Economic Survey. As is apparent from the *Figure 3.1.2*, the trend seen in recent years is expected to continue. Production and consumption are thus expected to increase by just over 2% per year or a total of approx. 25% between 1996 and 2005, unemployment is expected to fall to approx. 160,000, and the balance of payments is expected to remain positive.

An indication of the extent to which the environmental impact of total production and total consumption has increased/decreased or will increase/decrease can be obtained from the overall development in the composition of production and consumption.

Development in the production value of the commercial sectors is shown in real terms in *Figure 3.1.3*. So far all the main commercial sectors have exhibited growth in production except for the building and construction sector, where production has stagnated (Very recently, however, activity in this sector has also increased markedly).

Production has grown most in the private service sector, but has also grown markedly in the public service sector and industry. Agricultural production has only increased slightly over the period. The Medium Term Economic Survey forecasts that these main tendencies in societal development will continue up to the year 2005. However, it is expected that energy extraction, which has been growing evenly since oil and gas production started in the North Sea at the beginning of the 1980s, will peak around the turn of the century.

Figure 3.1.4 shows the development in private consumption in real terms for the various categories. With respect to the hitherto development in patterns of private consumption, the most marked changes have been a fall in energy consumption for home heating and a marked increase in consumption of services and tourist journeys.

The more traditional consumption of material products (foods, clothes, durable goods) has also increased during the period. The Medium Term Economic Survey forecasts that this trend will continue, i.e. that energy consumption for home heating is expected to continue to decrease and the share of total consumption accounted for by services is expected to continue to increase.

The trends in both production and private consumption both show a clear general tendency for more rapid growth in the service-oriented elements than in the goods-oriented elements. The magnitude and significance for the state of the environment of this general trend, now and in the future, is one of the factors that will be examined more closely in the sections to follow.

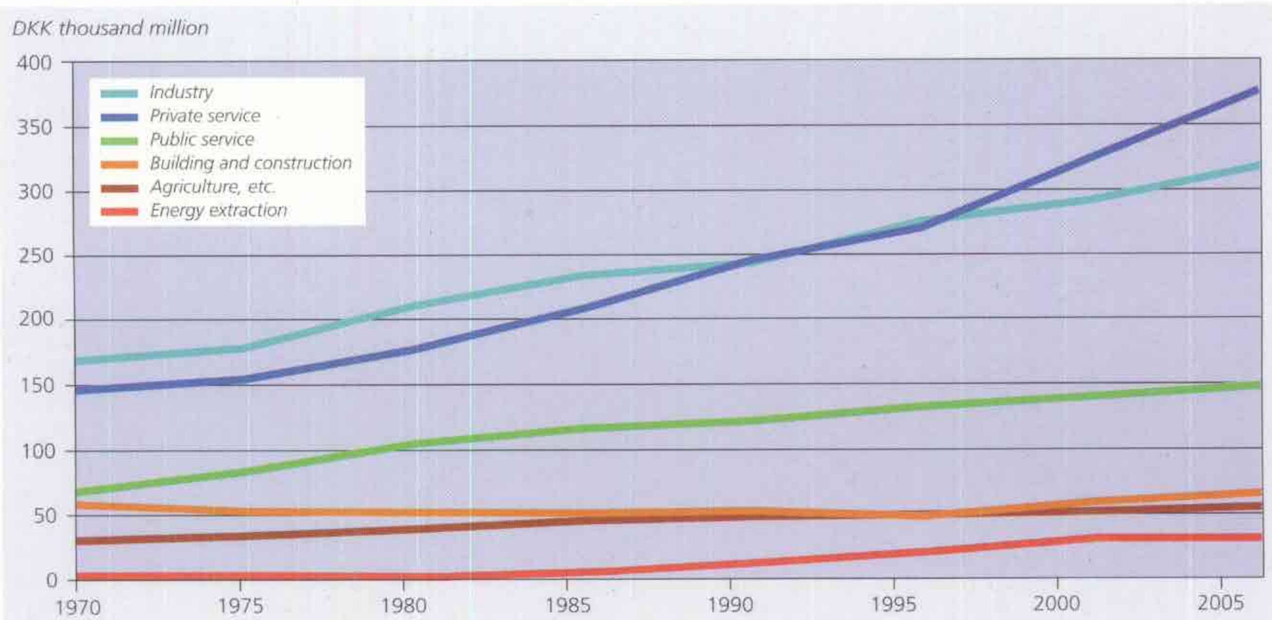


***Figure 3.1.3** Development in production value of the commercial sectors in real terms (1980 prices) (Source: Statistics Denmark, 1996; Ministry of Finance, 1996).*

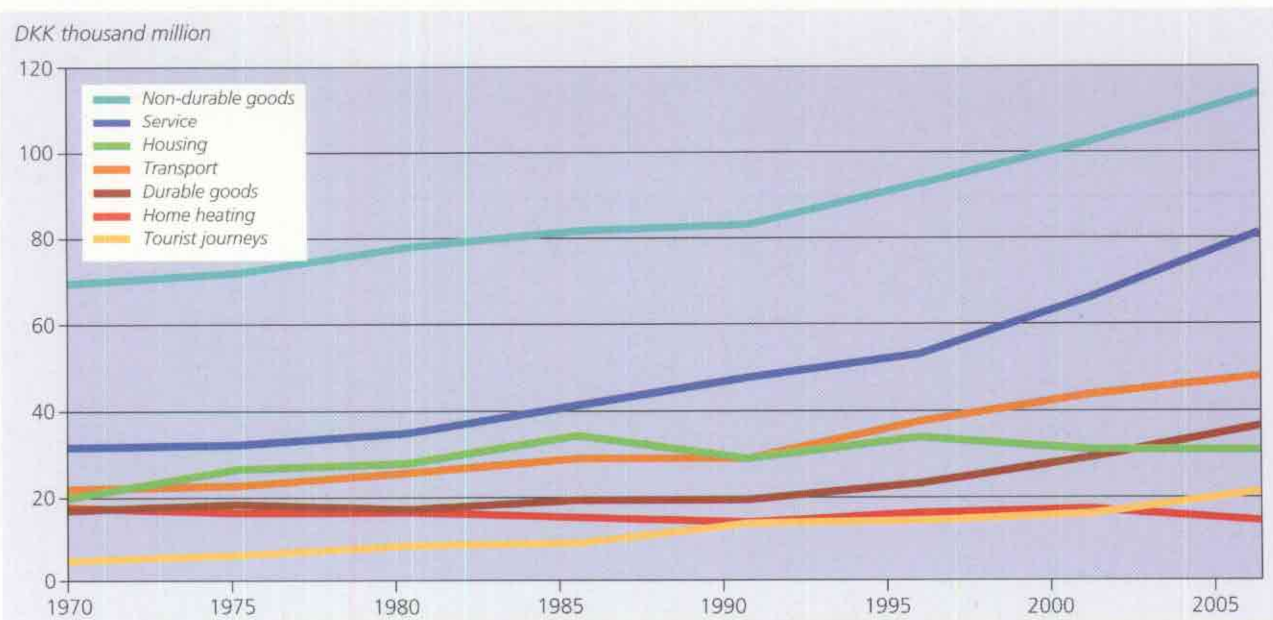


***Figure 3.1.4** Development in private consumption in real terms (1980 prices) (Source: Statistics Denmark, 1996; Ministry of Finance, 1996).*

3.2 Energy

3.2.1 Introduction

The present section examines a number of environmental problems associated with the use and production of energy. A cross-cutting approach to energy use by the various economic sectors is employed in order to provide an overall description of energy use in society and the resultant pressures on the environment.

The development in energy consumption is determined by the development in society's need for energy services (cooling, heating, lighting, transport, etc.). Only little of the environmental impact of the use of energy is directly related to the consumption of these energy services, however. The majority of the environmental impact is attributable to the production of energy for these services, i.e. the conversion of fuels to useful forms of energy (electricity, heat, kinetic energy), although a considerable part is attributable to the extraction of energy resources, transport of fuels, etc.

The section begins with a brief review of the hitherto development in the use and supply of energy in society and of the underlying regulatory factors. Thereafter follows a description of the environmental impact of energy production and consumption. The section closes with a review of some of the developmental perspectives of future energy consumption seen in relation to existing objectives and action plans to reduce its environmental impact.

3.2.2 Development in energy consumption, supply and production in Denmark

Final energy consumption

The development in final energy consumption, i.e. energy use associated with the consumption of society's energy services, is shown for the last 25 years in *Figure 3.2.1*. It can be seen that the total final energy consumption tended to decrease until the beginning of the 1980s, since when it has been increasing. Since 1990, it has increased by an average of 0.9% annually.

As is apparent from the figure, energy consumption for transport has increased most during the period and consequently has comprised an increasing share of the total final energy consumption. From *Figure 3.2.2* it can be seen that this increase is almost solely attributable to road transport.

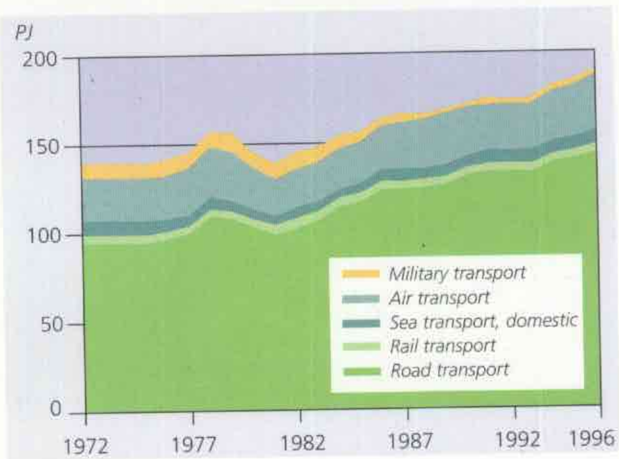


Figure 3.2.2 *Energy consumption in the transport sector apportioned by means of transport (Source: Energy Agency, 1997).*

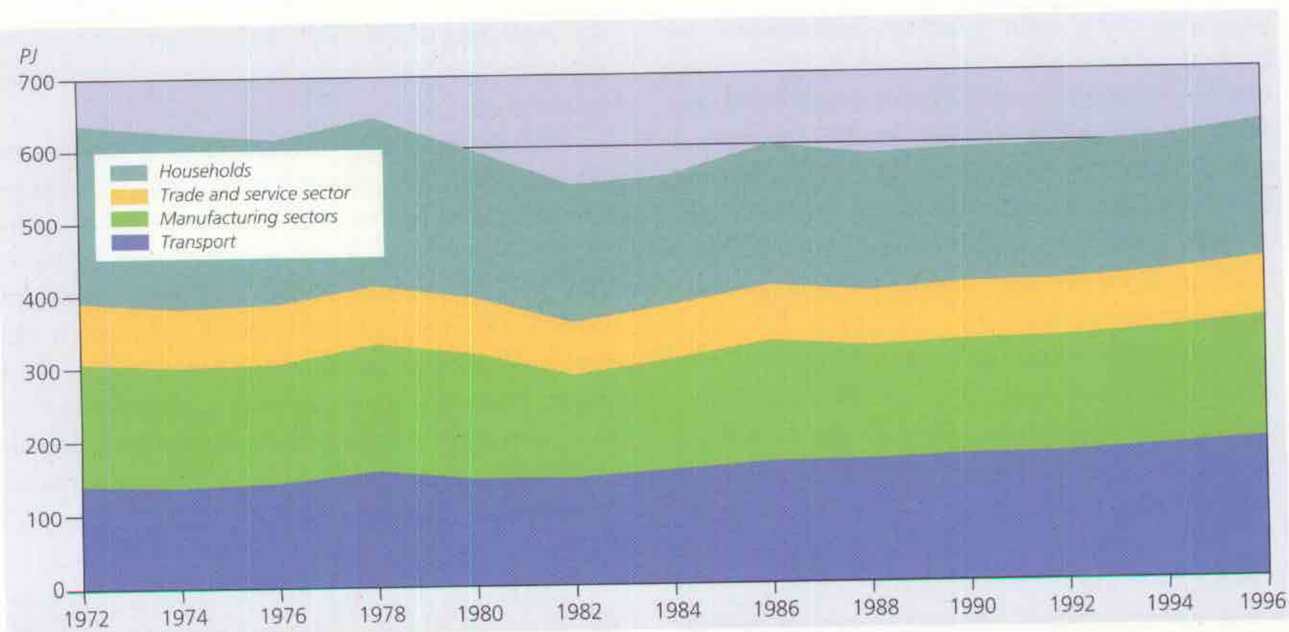


Figure 3.2.1 *Final energy consumption apportioned by sector (Source: Energy Agency, 1997).*

The development in the final energy consumption for space heating is an exception to the general tendency in that it has fallen markedly throughout the whole period. From *Figure 3.2.3* it is apparent that this fall has taken place despite an increase in heated floor space. The efficiency of energy use for space heating has therefore increased considerably, primarily through improved regulation and insulation of buildings and through behavioural changes such as a lower indoor temperature, turning off heating at night, etc.

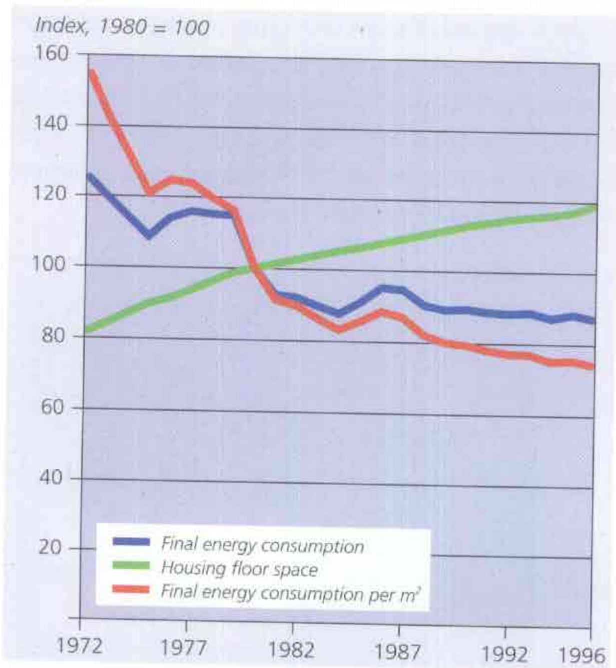


Figure 3.2.3 *Energy consumption for room heating (climate corrected) (Source: Energy Agency, 1997).*

The marked fall in consumption of heat up to the beginning of the 1980s is mainly attributable to the marked increase in the real price of energy for space heating during that period. Since the mid 1980s, consumption of heat has remained roughly constant, although with a tendency towards a slight decrease. This decrease is probably attributable to the subsidy schemes for housing improvements, more stringent building regulations and possibly also to enhanced environmental awareness.

Final energy consumption in the manufacturing sector is shown in *Figure 3.2.4*. Of this, industry accounts for approximately 2/3 while agriculture, forestry, market gardening, fishery and the building and construction sector account for the remaining 1/3.

In the beginning of the 1980s, increases in real energy prices led to a fall in energy consumption by industrial enterprises, although a special subsidy scheme for energy savings also had an effect.

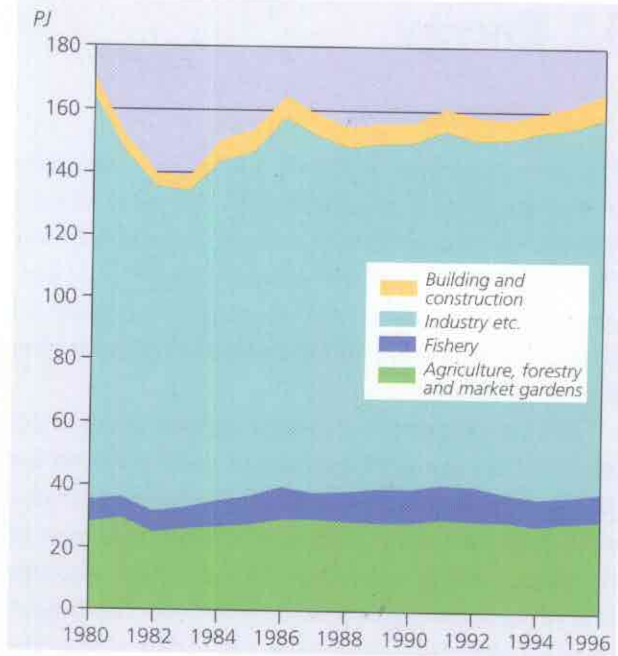


Figure 3.2.4 *Energy consumption in the manufacturing sector (Source: Energy Agency, 1997).*

Energy consumption by industry is still less than in 1980, but has been increasing since the mid 1980s. This is most certainly due to the fact that industry's energy costs have been halved since the beginning of the 1980s due the refund of the energy levy to industry, which has allowed falling import prices for energy to affect energy consumption in industry directly.

In industry, there has been a marked shift between energy types. Thus electricity consumption has increased steadily, primarily as a result of conversion to new production equipment based on electricity. Moreover, since the introduction of natural gas at the beginning of the 1980s there has been considerable growth in its consumption, especially at the expense of oil.

Even though energy consumption for space heating has been falling, overall final energy consumption in both the service and household sectors nevertheless follows the general developmental trend in energy consumption. This is because as with the manufacturing sector, consumption of electricity has increased throughout the whole period. *Figure 3.2.5* shows that while electricity only accounted for 17% of final energy consumption in the service sector in 1972 and 10% in the household sector, the corresponding figures today are 40% and 20%, respectively.

Residential electricity consumption is primarily for electric appliances (refrigerators, freezers, washing machines, etc.). Approx. 20% is used for lighting.

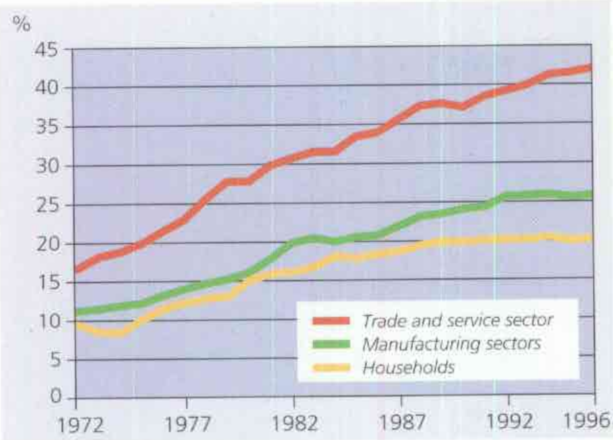


Figure 3.2.5 Percentage of final energy consumption accounted for by electricity (Source: Energy Agency, 1997).

Even though electricity consumption in the household sector seems to have stagnated in the last couple of years, the number of electric appliances has continued to grow. In other words, the electric appliances and lighting have become more effective. Electricity consumption in the service sector is primarily used for lighting, cooling and ventilation.

The development in total consumption of electricity apportioned by sector is shown in *Figure 3.2.6*. Since 1980, electricity consumption has increased by over 40% and the increase appears to be continuing. Up to the end of the 1980s, electricity consumption in-creased in all sectors, whereafter it primarily continued to increase in the service and manufacturing sectors.

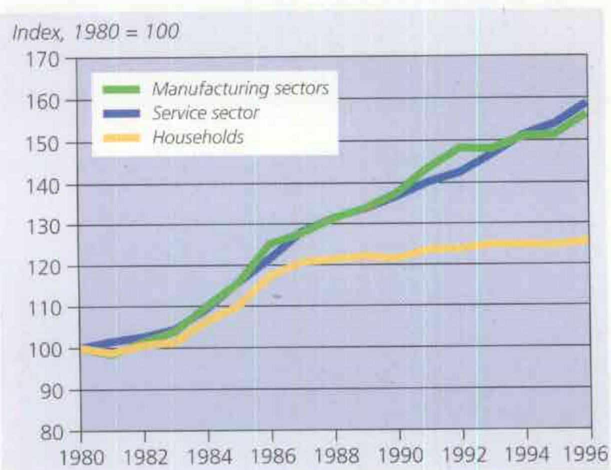


Figure 3.2.6 Electricity consumption apportioned by sector (Source: Energy Agency, 1997).

Energy supply

The final energy consumption is met by a number of collective and individual energy supply plants. The collective plants include power stations, district heating plants, combined heat and power plants (CHP), wind turbines, etc., while the individual plants include oil and natural gas furnaces in detached houses, central heating plants in blocks of flats, etc.

The supply plants are thus either conversion plants, where fuels are converted to electricity and/or heat, or actual production plants. The amount of fuel that is converted in the conversion plants and the amount of energy produced in the production plants for domestic use comprises the gross inland energy consumption. The development in this is shown in *Figure 3.2.7*.

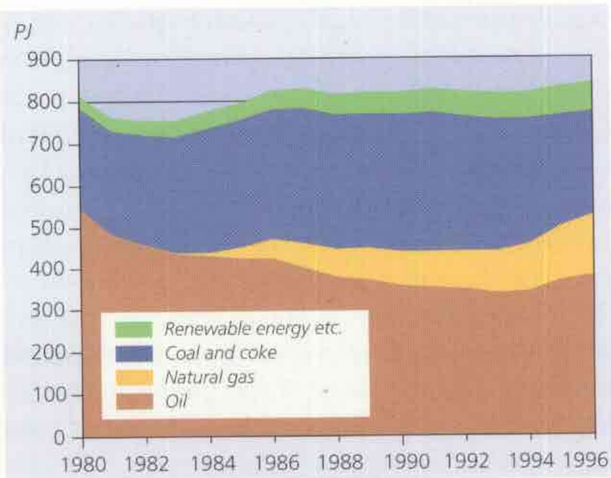


Figure 3.2.7 Development in gross inland energy consumption apportioned by fuel type (corrected for climate and net import of electricity) (Source: Energy Agency, 1997).

Since 1980, Denmark's gross inland energy consumption has remained at a more or less constant level, while there has been a concomitant switch in fuel mix. One of the most important energy policy objectives has been to reduce the oil dependence of the energy supply. The percentage of the energy supply accounted for by oil has now fallen to approx. 45%. Up to the beginning of the 1980s the fall in oil consumption was primarily due to conversion from oil-fired to coal-fired power stations. Thereafter, however, the fall in oil consumption is primarily attributable to expansion of the district heating network and enhanced use of natural gas in homes, industry and district heating plants. Coal consumption has also remained fairly constant since the mid 1980s, although there has been a tendency towards a slight decrease in the 1990s. Among other things, this is due to increasing use of renewable energy and natural gas for power production and district heating. Since the introduction of natural gas in the beginning of the 1980s, its use has increased markedly. In recent years, the use of natural gas for power production in particular has increased both in the decentral and industrial combined heat and power plants, as well as at some central power stations.

Development in the consumption of renewable energy is shown in *Figure 3.2.8*. This has been increasing steadily and now accounts for just over 8% of gross inland energy consumption if one counts waste as a renewable energy source. Apart from waste it is wind power and straw that are the dominant renewable energy sources, while the contribution to the total energy supply made by sources such as wood, biogas and solar energy is still minor.

That it has been possible to keep gross inland energy consumption roughly constant since the beginning of the 1980s despite the concomitant increase in final energy consumption is largely attributable to effectivization of the power and heat supply that took place during that period. Co-production of electricity and heat has increased markedly. There has been a marked expansion of the district heating supply network around the major power stations in order to utilize the heat produced herefrom, and conversion from local district heating plants to decentral combined heat and power (CHP) production has really started to gain momentum in recent years. Of the total district heating production approx. 70% currently derives from combined heat and power production. The percentage of electricity generation accounted for by CHP has also increased markedly over the period. Similarly, the use of wind energy for electricity generation has increased from almost nothing at the beginning of the 1980s to 3.7% in 1996 (*Figure 3.2.9*). The development in the efficiency of the energy supply system is depicted in *Figure 3.2.10* as the development in the relationship between final and gross inland energy consumption since 1980.

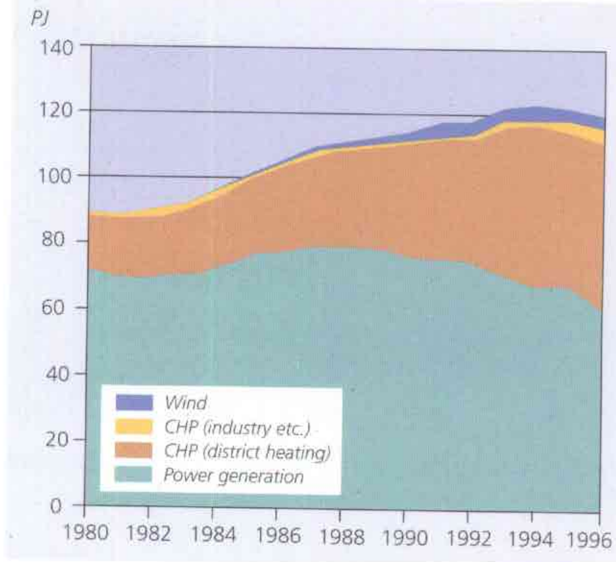


Figure 3.2.9 *Electricity production apportioned by source (Source: Energy Agency, 1996).*

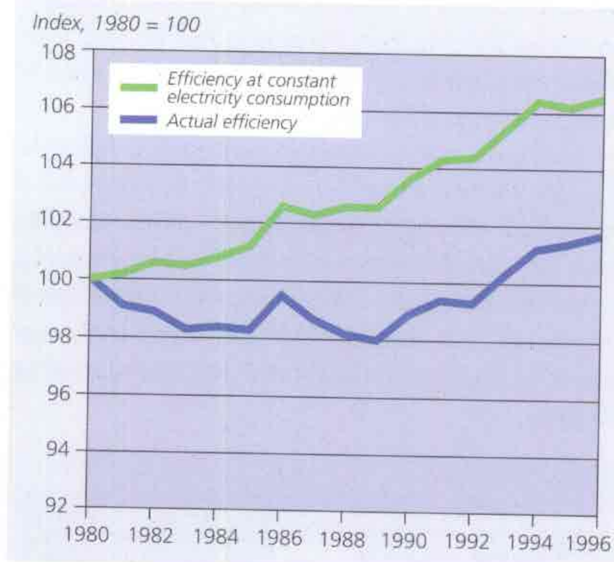


Figure 3.2.10 *Efficiency of the power supply system (Source: Energy Agency, 1997).*

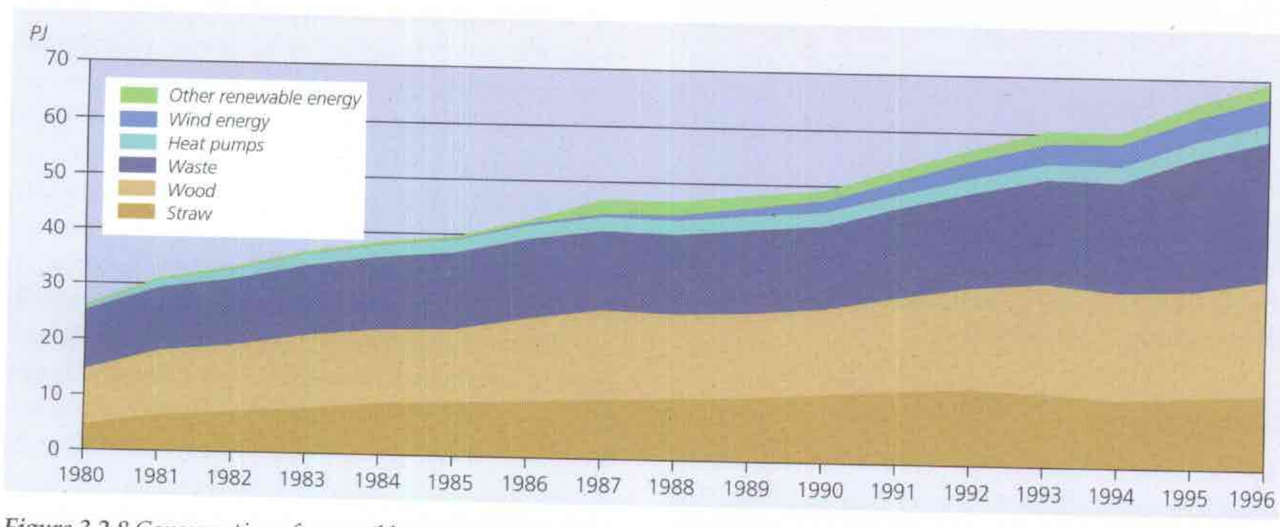


Figure 3.2.8 *Consumption of renewable energy (Source: Energy Agency, 1997).*
Note: Other renewable energy encompasses solar heating, hydroelectric power, geothermal energy, biogas, and fish oil.

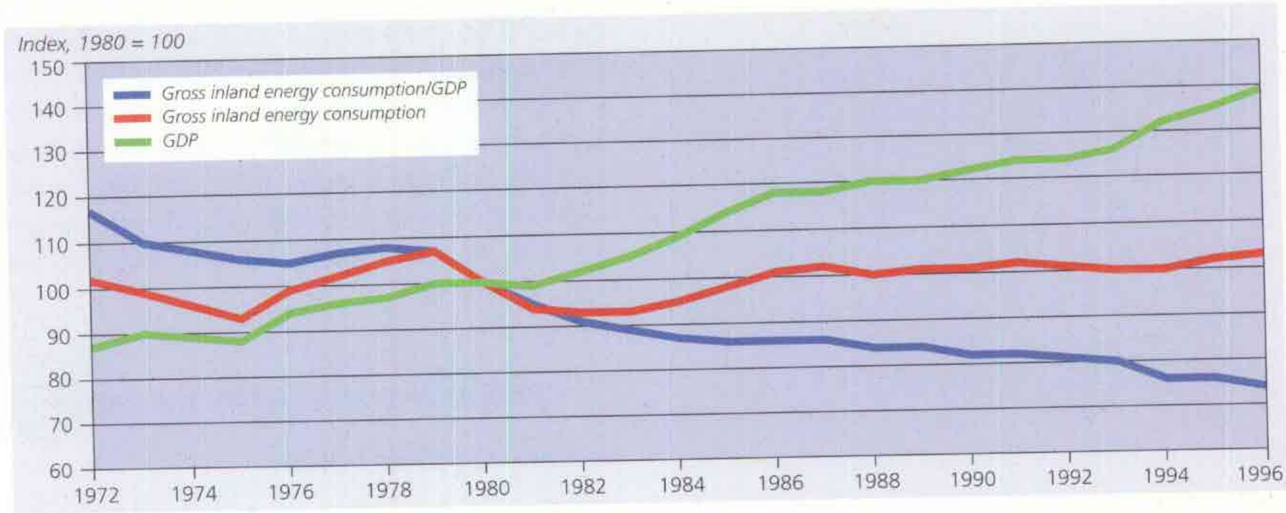


Figure 3.2.11 *Energy intensity (Source: Energy Agency, 1997).*

The tendency towards a fall in efficiency up to the end of the 1980s reflects the fact that routine effectivization of the electricity supply systems was unable to keep pace with the marked increase in electricity consumption during that period because the marginal efficiency of the power supply system is lower than the average efficiency. Routine effectivization of the systems is illustrated in *Figure 3.2.10* by calculating at constant electricity consumption. The effectivization that took place during the first part of the 1990s was due to implementation of the CHP programme.

Development in the efficiency of the overall energy system can be illustrated by examining the relationship between energy consumption and economic activity (GDP), i.e. the energy intensity. From *Figure 3.2.11* it can be seen that the overall energy efficiency of the country has increased over the last 20 years as the energy intensity has fallen.

3.2.3 Environmental impact of the use of energy

The most important environmental problem related to the use of energy is air pollution associated with the combustion of fuels. During combustion, the majority of the carbon and sulphur in fuels is converted to carbon dioxide (CO_2) and sulphur dioxide (SO_2), respectively. In addition, nitrogen oxides (NO_x) are formed from atmospheric and fuel nitrogen to an extent determined by the combustion technique employed.

Development in CO_2 emissions is closely correlated to the development in energy consumption and fuel use. As technologies for the abatement of flue gas CO_2 are not presently available, the CO_2 content will therefore be emitted directly to the atmosphere.

The amount of CO_2 emitted is markedly dependent on the type of fuel used, however. Thus natural gas results in 40% less CO_2 emission per unit energy than coal. The biomass-based fuels are considered to be CO_2 neutral in that the amount of CO_2 released during combustion corresponds to the amount taken up during growth of the plants.

From *Figure 3.2.12* it can be seen that CO_2 emissions fell markedly at the beginning of the 1980s. This is largely due to the effects of the second oil crisis at the end of the 1970s and beginning of the 1980s.

Prior to this fall there had been a marked increase that was primarily attributable to the power stations shifting from oil to coal. The increase in the mid 1980s was primarily due to the economic upturn after the crisis years at the beginning of the 1980s. Since the end of the 1980s, CO_2 emissions have been falling steadily as a result of the conversion to CHP, increasing use of natural gas as a fuel and the introduction of renewable energy sources.

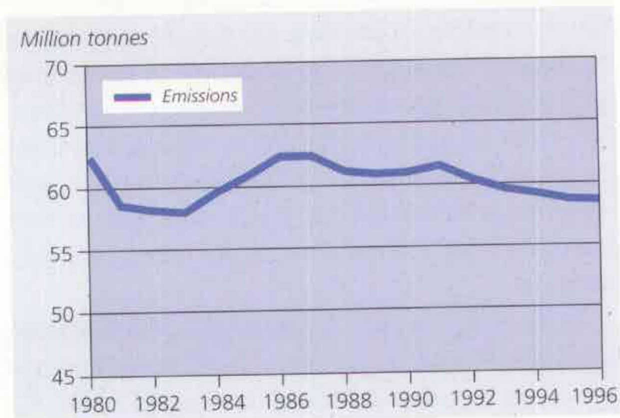


Figure 3.2.12 *Development in CO_2 emissions (corrected for climate and net import of electricity) (Source: Energy Agency, 1997).*

Development in SO_2 and NO_x emissions from Danish energy consumption is shown in *Figure 3.2.13*.

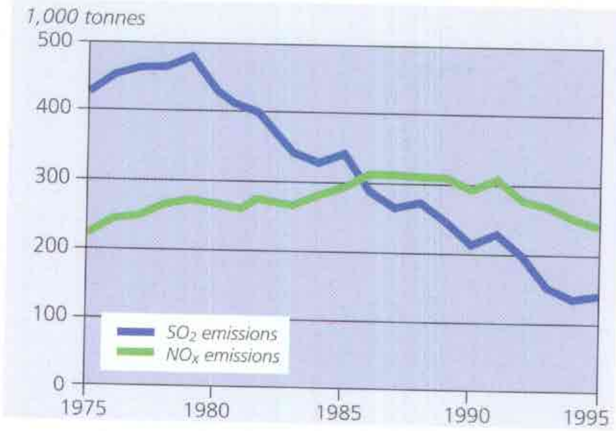


Figure 3.2.13 *Development in SO_2 and NO_x emissions (corrected for net import of electricity) (Source: National Environmental Research Institute and Risø National Labotatory, data from the CORIN-AIR database).*

SO_2 emissions are being reduced continually through reduction in the sulphur content of fuels, sulphur abatement of flue gasses from power stations and through removal of sulphur during the combustion process. NO_x emissions can be reduced through regulation of the combustion process and by subsequent flue gas abatement. Since the beginning of the 1980s, NO_x emissions have remained virtually constant as the abatement activities at the power stations have been largely balanced by the increase in NO_x emissions from traffic. The figure does not include emissions from international traffic related to Denmark (see *Section 3.3* on transport).

Apart from emissions to the air, the use of energy has numerous other impacts on the environment. Combustion of fuels at power stations, CHP stations and waste incineration plants thus generates slag and fly ash which have to be disposed of by landfilling or recycling. In addition, the use of energy leaves its mark on nature and the landscape in the form of oil and gas fields, technical infrastructure facilities, sites for wind turbines and land for biofuel crops, etc. Finally, there are negative environmental effects associated with fuel transport, waste water production and discharges of environmentally hazardous substances.

Even though by far the majority of environmental problems relate to the use of fossil fuels, there are also a number of notable environmental problems associated with renewable energy plants, depending on the type in question. Thus in addition to their negative impacts on the landscape, wind turbines can cause noise problems.

With respect to biomass, it is questioned whether the cultivational value of the soil deteriorates when the straw is removed from the fields for use as biofuel instead of being ploughed down due to the resultant reduction in the carbon content of the soil, cf. *Section 2.3.3*. In the case of purpose-grown biofuels (energy crops), the environmental impact of the use of pesticides and fertilizers have also to be taken into consideration. The various environmental pressures associated with the use of energy are summarized in *Box 3.2.1*.

3.2.4 Objectives and policy measures

Environmental objectives

Emission of the greenhouse gas CO_2 is the environmental problem that holds the most prominent place in Danish energy policy. The energy action plan from April 1996 - "Energy 21" - thus aims to fulfil the national objective of reducing annual CO_2 emissions by 20% in 2005 relative to 1988. This concomitantly supports fulfilment of Denmark's international obligations to stabilize CO_2 emissions by the year 2000 relative to the level in 1990.

In addition, the energy action plan strongly supports compliance with the international SO_2 and NO_x protocols of which Denmark is a signatory. According to these protocols, Denmark has to have reduced annual SO_2 emissions by 80% in 2000 relative to 1980 (the Oslo Protocol) and have reduced annual NO_x emissions by 30% in 1998 relative to 1986 (the Sophia Declaration).

The national CO_2 objective stems right back from the 1990 "Energy 2000 - Action Plan for a Sustainable Development" and the Government's "Transport Action Plan for Environment and Development". Energy 21 can thus be seen as part of the ongoing follow-up on the original action plans.

Up to the UN Climate Conference in Kyoto, Japan in December 1997, the EU countries proposed a combined reduction in CO_2, methane and nitrous oxide emissions by the industrialized countries of 15% relative to 1990. In addition, agreement had been reached on the internal allocation of the first 10% of this reduction.

This allocation between the EU Member States permitted some countries to increase their emissions during the period, while others had to reduce their emissions. For example, Germany and Denmark had to reduce emissions by 25% relative to 1990. This internal allocation is expected to be adjusted at the forthcoming EU council meetings in view of the fact that the final Kyoto agreement only commits the EU as a whole to reduce emission by 8%, cf. *Section 2.1*.

Acquisition of energy resources:

Fossil fuels:

- Impact on the landscape
- Impact on the fauna
- Release of dust, emissions and particulates during mining and transport
- Discharge of waste water
- Pollution of terrestrial and aquatic environments as a result of fuel spills
- Leaching of heavy metals etc. when storing fuels and waste products

Biomass:

- Impact on the landscape
- Impact on the fauna
- Leaching of nutrients
- Emission of CO_2, SO_2, NO_x, particulates, ash, heavy metals etc. during production and transport

Energy production and supply:

Wind turbines:

- Impact on the landscape
- Noise

Combustion of biomass (including waste):

- Emission of SO_2, NO_x, particulates, ash, slag, heavy metals, dioxins
- Impact on the landscape
- Noise
- Leaching of heavy metals etc. when storing waste products
- Discharge of waste water
- Discharge of cooling water

Solar energy:

- Release of antifreeze from solar panels
- Release of antifreeze/coolant from heat pumps

Fossil fuels:

- Upon storage (coal): Emission of dust, particulates
- Upon combustion: Emission of CO_2, SO_2, NO_x, particulates, ash, slag, heavy metals
- Impact on the landscape
- Noise
- Leaching of heavy metals etc. when storing waste products
- Discharge of waste water
- Discharge of cooling water

Energy consumption:

- Production of energy-consuming equipment and appliances
- Disposal of energy-consuming equipment and appliances

Box 3.2.1 *Environmental pressures associated with the energy sector.*

Energy 21

Energy 21 takes as its starting point the situation in 1994 and is based on economic forecasts involving greater economic growth than the earlier action plans. The plan describes two developmental scenarios for the Danish energy sector, a baseline scenario and a plan scenario. The former describes the expected development if no further energy policy measures are implemented after 1995. This scenario also assumes that the efficiency of electric appliances, processes etc. improves in line with "natural" technological development and in step with their replacement as they become worn out. On the supply side, it is correspondingly assumed that worn-out central power and CHP stations will be replaced with the newest and most effective coal-fired plants. With respect to energy policy measures, the baseline scenario encompasses the measures that have been implemented, among other things as part of the follow-up on Energy 2000 (and the Transport Action Plan). These include:

Levies: With implementation of the so-called "CO_2 legislative package" in 1993, a levy was imposed on fuels depending on the level of CO_2 emission resulting from their combustion. In the case of households, the levy is DKK 100 per tonne CO_2. Firms received a 50% refund of the levy while particularly energy-demanding industries were refunded more than 50%. However, in the subsequent 1995 "Green levies legislative package", companies' possibilities for obtaining the refund were curtailed concomitantly with improvement of the possibility for them to obtain subsidies for energy-saving measures.

Legislation on energy savings: Building regulations were tightened in 1995 for new buildings corresponding to a 20-25% reduction in heating requirements in relation to earlier. In addition, new legislation imposed efficiency requirements on electric appliances and equipment (1994).

Effectivization of the supply side: The follow-up on the so-called 20 March Agreement (from 1990) which among other things concerned expansion of decentral CHP, enhanced connection to collective supply systems and the use of natural gas at central power stations.

Renewable energy: Implementation of the 1993 biomass agreement (revised in 1997) on enhanced use of biomass for energy purposes, particularly in the CHP sector, and enhanced use of renewable energy in general in accordance with the Government's 1995 report "Renewable Energy - New Initiatives". As a result of these initiatives, renewable energy will account for a good 10% of gross inland energy consumption in 2005 as compared with 8% at present.

Integrated resource planning: Possibilities for implementing cost-effective energy savings are to be incorporated into supply capacity planning.

Given these preconditions and assumptions, the baseline scenario only yields a 12% reduction in CO_2 emissions by 2005, i.e. considerably below the target. In contrast to the baseline scenario, the Energy 21 plan scenario includes a number of further initiatives whereby it is expected that the CO_2 reduction target for 2005 can be fulfilled. The plan scenario up to the year 2030 illustrates that it will be possible to reduce CO_2 emissions to 50% of the level in 1988 (*Figure 3.2.14*), which is the long-term perspective in Energy 21 as well as Denmark's proposal in the international climate negotiations. The Energy 21 plan scenario only encompasses energy policy measures directed at the attainment of the target for 2005, however.

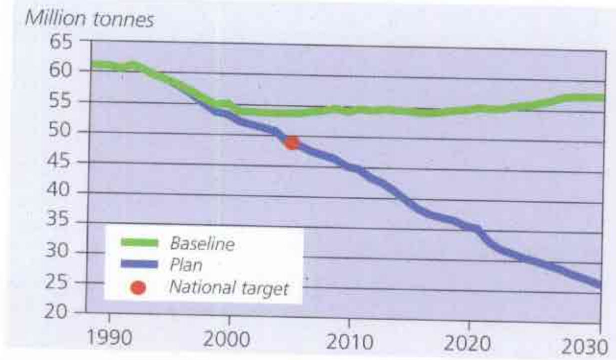


Figure 3.2.14 *CO_2 emissions according to the Energy 21 baseline and plan scenarios (Source: Ministry of Environment and Energy, 1996 and Energy Agency, 1997).*

These initiatives fall into three main groups:

- initiatives directed towards the attainment of further energy savings corresponding to just under a third of the remaining CO_2 reduction,
- initiatives directed towards the supply side of the same magnitude, and
- initiatives in the transport area (see *Section 3.3*).

The initiatives relating to *savings* centre around:

- The introduction of an electricity savings scheme for financing economically sound electricity savings measures in the household and public sectors.
- Laws concerning the promotion of energy and water savings in buildings in the public sector, in the service sector and in the household sector, which involves energy certification of buildings.
- A drive concerning product-oriented savings. This drive involves a package of initiatives concerning information, energy certification of products, organization of demand for energy-effective appliances (so-called buyer policies), voluntary agreements with producers of energy appliances, etc.

On the *supply side* the initiatives will comprise further expansion of renewable energy, primarily through support for research and for construction and demonstration projects, further effectivization of electricity and heat production, and a more rapid phase-out of coal to the benefit of natural gas and biomass.

In addition, reform work was started on *reforming* the regulatory framework for the power and heat sector, among other things with a view to ensuring continued consideration for the environment despite the general internationalization and demonopolization of the energy market, not least the forthcoming implementation of the EU Directive on the internal market for electricity.

The expected consequences of these further initiatives for future development in fuel consumption and final energy consumption are illustrated in *Figures 3.2.15* and *3.2.16*.

Figure 3.2.15 thus shows the development in fuel consumption for electricity and district heating according to the Energy 21 plan scenario. As is apparent from the figure, renewable energy will account for 20% of this fuel consumption by 2005 while the percentage accounted for by coal will have fallen markedly in relation to the current level.

Development in the total final energy consumption by the production, service and household sectors according to the Energy 21 plan scenario is shown in *Figure 2.3.16* compared with the actual development over the last few years. It can be seen that energy consumption is expected to increase slightly according to the Energy 21 plan scenario. In addition, the plan entails a shift in level in that the expected energy consumption in 1996 is considerably less than the actual energy consumption in 1996.

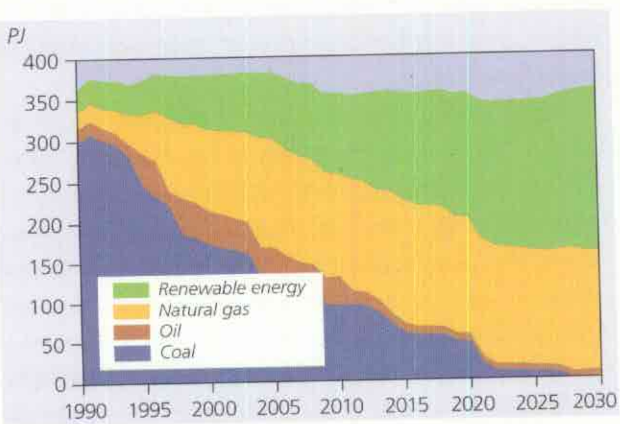


Figure 3.2.15 *Fuel consumption for electricity generation and district heating under the Energy 21 plan scenario (Source: Ministry of Environment and Energy, 1996 and Energy Agency, 1997).*

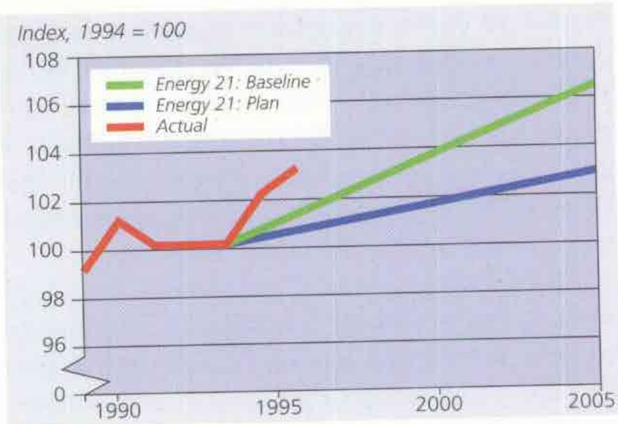


Figure 3.2.16 *Final energy consumption in the production, service and household sectors (Source: Ministry of Environment and Energy, 1996 and Energy Agency, 1997).*

Target achievement

The environmental strategy hitherto followed in the energy area has meant that from the environmental point of view, it has been possible to hold the recent tendency towards increasing final energy consumption in check through effectivization on the supply side in the form of enhanced connection to the collective heat supply system, enhanced co-production of electricity and heat, as well as conversion to natural gas. As a result of these measures, gross inland energy consumption has remained relatively constant and CO_2 emissions have not run out of control. *Figure 3.2.17* illustrates this by showing that the average CO_2 content of the fuel mix used has been decreasing steadily since the mid 1980s. The modest but increasing use of renewable energy has naturally also contributed to keeping CO_2 emissions down, but the significance of this must be considered minor in relation to that of the use of natural gas, for example.

CO_2 emissions in 1996 correspond to 96% of 1990 emissions, and much thus indicates that it will be

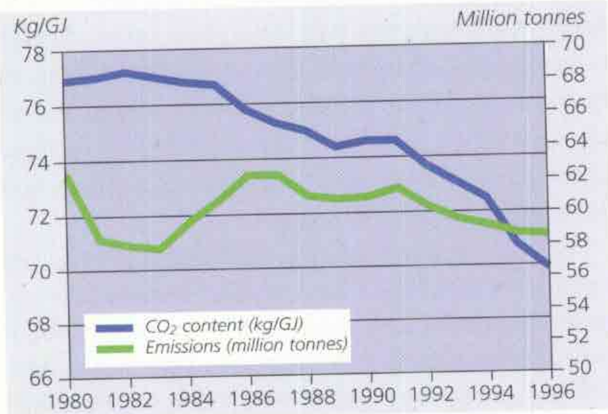


Figure 3.2.17 *CO_2 emissions in Denmark together with the average CO_2 content of fuels (Source: Energy Agency, 1997). Note: The curve for CO_2 content does not encompass transport.*

possible for Denmark to fulfil its international obligations to stabilize emissions in the year 2000 at the 1990 level. In contrast, it will probably be more difficult to live up to Denmark's national objective of a 20% reduction in emissions in 2005 relative to 1988. Thus in 1996, CO_2 emissions had only fallen by just over 4% relative to 1988.

With increasing demand from society for energy services, such a strategy naturally comes under increasing pressure since the effectivization potential on the supply side declines with time and since the possibilities for enhanced consumption of natural gas are limited in the more long term. Energy 21 therefore also prepares the ground for a strengthened effort for further use of renewable energy in the energy supply, while at the same time strengthening effectivization efforts and the conversion to natural gas. In parallel with this, the action plan also contains initiatives for savings and effectivization in the end uses.

This overall strategy must generally be considered robust. However, on both the supply side and the consumption side there are a number of conditions that will determine the success of the strategy. On the supply side, the success will thus largely depend on the extent to which natural gas is used in a way that does not block the enhanced use of renewable energy. Similarly, it is also imperative that the reform work mentioned above succeeds in creating frameworks for the power and heat sector able to ensure that a very free and internationalized energy market does not hinder either enhanced introduction of renewable energy in the tempo stipulated or the maintenance of the efficiency gains associated with the high level of CHP production that characterizes the Danish energy system.

As regards development in the use of renewable energy, it should be noted that expansion of wind energy as per 1997 is ahead of that stipulated in Energy 21. In particular, it seems that the expansion of offshore wind turbines will take place more rapidly than expected. On the other hand, implementation of the biomass agreement is some way behind schedule, although it is expected that the July 1997 revision of the biomass agreement will ease the introduction of biomass in the CHP sector.

On the consumption side the most important initiatives focus on levies and product-oriented efforts. At the present time, nothing certain can be said about the effect on energy consumption of the "CO_2 legislative package" and its follow-up in the "Green levies legislative package". The effect of the levies is to be assessed in 1998, but the first very preliminary estimates of the energy and CO_2 savings obtained in

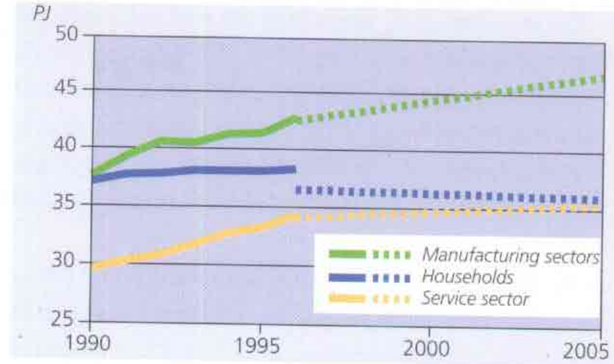


Figure 3.2.18 *Expected electricity consumption by sector according to the Energy 21 baseline scenario (Source: Ministry of Environment and Energy, 1996 and Energy Agency, 1997). (Note: The Data for 1996 are based partly on preliminary estimates. The solid lines represent actual consumption, while the broken lines represent expected consumption according to the Energy 21 baseline scenario).*

practice in the production sectors indicate that the expected reduction in CO_2 per DKK subsidy is on average slightly greater that originally expected. However, it has not been possible to spend as great a sum on subsidies as predicted when the CO_2 legislative package was adopted, and the expected effect of the levy package can therefore be delayed.

From the more general point of view, the actual increase in final energy consumption seen in recent years appears to have been greater than expected in the baseline scenario (*Figure 3.2.16*). This is most clearly seen in the case of electricity consumption, as shown in *Figure 3.2.18*. For all sectors, electricity consumption has thus increased more strongly than expected. This is particularly clear in the household sector, where electricity consumption was expected to fall. The further increase in electricity consumption in the service sector has been roughly neutralized by a fall in the other components of the final energy consumption in this sector, however. These observations seem to indicate that the levy package has not yet had as great an effect as expected from the Energy 21 baseline scenario.

This developmental tendency enhances expectations to the further measures in the Energy 21 plan scenario (see above), which entail an even more restrained development in final energy consumption. These measures largely focus on a product-oriented effort, assessment of the effects of which is new ground. Taking into consideration the overall development, it thus seems that the future environmental challenges for energy policy will largely lie on the energy consumption side. As regards assessment of target achievement for energy consumption in the transport sector, see *Section 3.3*.

3.3 Transport

3.3.1 Introduction

Danish society is characterized by high mobility with respect to people, goods and information. This physically manifests itself in the form of comprehensive and increasingly rapid transport systems that connect localities and regions in all directions, as well as in the form of increasing traffic connecting the many separate functions and activities of everyday life. At the same time, international trade is growing, the consumption of goods and services is becoming internationalized, and people are heading for still more distant destinations and adventures abroad. Transport and mobility have become key factors as regards development in production, consumption, lifestyle and culture.

This mobility also has a major impact on nature, the environment and man, see *Box 3.3.1*. The transport systems and the traffic they carry are primarily concentrated in urban areas which are concomitantly very vulnerable as people and their activities are also primarily concentrated here. This results in a number of specific problems including air pollution, noise, accidents and conflicts over the use of urban areas. These problems are examined in *Section 2.2* on the urban environment. Furthermore, the construction and maintenance of infrastructure in the countryside affect the landscape and ecological conditions for the local fauna, as well as people's aesthetic experience of their surroundings.

In recent years, there has been growing awareness of a number of more general consequences of the increasing traffic. These consequences mainly relate to the consumption of fossil fuels, which contributes to emissions of the greenhouse gas CO_2, to the consumption of nonrenewable oil resources, and to transboundary air pollution, especially by nitrogen compounds, sulphur dioxide and hydrocarbons. In urban areas, transport causes specific problems in the form of noise, emissions of harmful substances such as particulates and polycyclic aromatic hydrocarbons, and spillage of oil and oil residues to the soil and the aquatic environment. Motorized traffic thus contributes to environmental problems at all levels, e.g. climatic effects, acidification, eutrophication, damage to the flora and fauna, and effects on biodiversity. In addition, it influences the state of health in urban areas.

Traffic itself contributes directly to these problems. At the same time, continuous development of

Pressures	Examples of environmental indicators	Impact areas/compartments
Emissions to air	CO_2 NO_x, HC, SO_2 CO, Particulates, Benzene, etc.	Climate Ecosystems Health, Buildings
Noise	dB(A), Noise-plagued houses Noise-plagued landscapes	Health Aesthetics
Accidents	Fatalities, Injuries	Health Safety
Fuel consumption	Tonnes oil, gas, etc.	Resources
Materials consumption	Tonnes minerals, etc.	Resources
Waste	Tonnes waste Toxic substances	Groundwater, Health Aesthetics
Oil and chemical spills	Oil spills Waste chemicals Additives (e.g. MTBE)	Aquatic environment, Groundwater Soil, Health
Landscape impact	Infrastructure Disturbances	Local biotopes Biodiversity Aesthetics, Landscape
Urban environment	Vehicles Traffic Infrastructure	Quality of life Aesthetics Land use

Box 3.3.1 *Environmental impacts of transport systems.*

the transport systems makes it easier to increase the consumption of natural resources in general. Among other things, this takes place through the increased speed at which goods circulate, and the continuous spread of activities in society and globally that this development facilitates. Traffic's current trends and driving forces thus pose a major challenge with respect to sustainable development.

The direct environmental impact of traffic is immediately attributable to two general factors:

- The development in traffic expressed in kilometres
- The environmental impact per kilometre travelled

This chapter first examines the development in traffic and the underlying causes, thereafter the general environmental consequences, and finally, the objectives and policy measures for reducing the environmental impact of transport.

3.3.2 Development in traffic and transport

The immediate source of the environmental impact is the traffic itself, i.e. the distances travelled with the various modes of transport. The nature of the environmental impact depends on the type of traffic, i.e. private cars, lorries, trains, aircraft, ships, bicycles or walking.

Road traffic is primarily measured in kilometres travelled. In general, the road traffic has been increasing after a minor decline in the early 1980s, see *Figure 3.3.1*. Motorized road traffic has increased by almost 60% since 1980. This trend has not changed in recent years.

Traffic primarily derives from other needs and does not have a purpose in itself. Traffic increases because other activities create a demand for transport

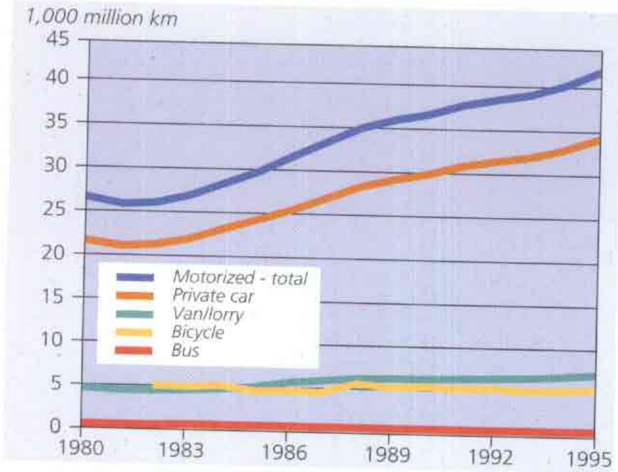


Figure 3.3.1 *Development in road traffic over the period 1980-95 (Source: Road Directorate, 1996).*

services and thus the use of transport systems. At the same time, the availability and quality of transport services influence the demand. The forces driving these trends differ between passenger and freight transport

Development in passenger transport

Passenger transport is undertaken by private car, bus, train, aircraft, ferry, bicycle or on foot. Passenger transport can be expressed in terms of the number of journeys made or as the total transport, i.e. the number of person-km travelled. The number of journeys expresses people's need to travel in connection with various tasks, whereas transport expressed as passenger-km also reflects how far it is necessary to travel.

The private car dominates in both contexts. Around 62% of journeys of more than 300 metres are made by car, either as the driver or as a passenger. Pedestrian and bicycle traffic account for 26% of the journeys. Public transport accounts for a little more than 10%. As the motorized modes of transport are primarily used in connection with longer journeys, they are even more dominant as regards transport, accounting for 94%. Of this, the private car accounts for 74% and public transport for approx. 20%. Many short journeys are also made by car, however, approx. 35% of car journeys being under 5 km.

As regards development in passenger transport, the number of journeys per person has not increased during the past 15 years. Thus it has apparently not been necessary to undertake more daily journeys. On the other hand, transport has been increasing, i.e. the distances have become longer. On average, Danish adults now travel approx. 35 km a day.

All in all, around 78,000 million person-km are now travelled per year in Denmark (excluding walking), see *Figure 3.3.2*. By far the greatest growth has been in car transport, which has increased by 61% since 1980. Bus and aircraft transport have also been increasing.

When calculating car transport, a constant occupancy of 1.8 persons per car is assumed. However, surveys show that in practice, occupancy has been declining to around 1.6. This means that traffic has actually grown more than transport. Consequently, the increase in passenger traffic by car is due to longer journeys and a slightly lower occupancy per car.

The total development in passenger traffic is the outcome of many factors. It is a balance between economic, technological, geographical and social factors,

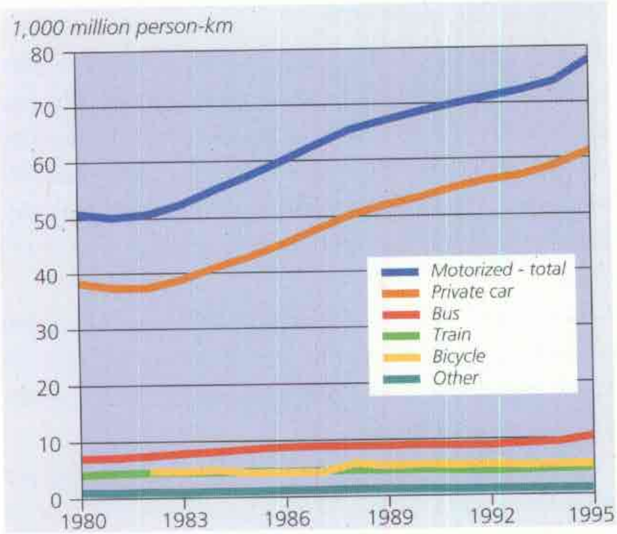


Figure 3.3.2 Development in passenger transport over the period 1980-95 (Source: Road Directorate).

each of which affect the individual's travel decisions. It is further influenced by the policy pursued, which affects transport demand and the availability of transport facilities.

Economic factors

The main economic factors behind the development in traffic are income and transport prices, although factors such as distribution of work and employment are also of importance. It is a well-known fact that increasing income generally increases transport demand, especially by car. This can be seen both over time, in the relationship between income groups in society, and in the relation between countries with different levels of income. The development in income affects the demand for transport in several ways, e.g. through increased car ownership. Danish studies show that the size of the car fleet increases in step with income. A high household income is often related to specialized jobs, which may imply a long journey between home and work. An increase in income also offers better possibilities for the purchase of time-saving and comfortable means of transport such as the car. A car makes it possible to save time and makes a long trip less inconvenient, but it also makes it easier to choose distant destinations. A high income may thus support a transport-demanding choice of housing and consumption.

Development in the private car fleet and car sales is shown in *Figure 3.3.3*. The car fleet has grown by approx. 20% over the period 1980-96, although the trend hides considerable variation in the car sales and car disposal. Car sales increased to a high level during the period 1984-86, which triggered general growth in the car fleet. After a period with lower sales, a heavy increase was seen again during the period 1993-94, when sales increased by 70%. At the same time, approx. 140,000 vehicles were removed from the car fleet in 1994, in about 65,000 cases most likely as a result of the scrap premium paid at that time. As a consequence, the size of the car fleet did not increase. In 1995, in contrast, when car sales were still considerable but few cars were scrapped, the car fleet increased by approx. 65,000 vehicles, which is the biggest increase in the car fleet since 1971. Growth in the car fleet continued in 1996 and thereafter.

All in all, development in the cost of domestic transport has followed the general development in prices since 1980. However, the price of cars and especially that of petrol has fallen below the general

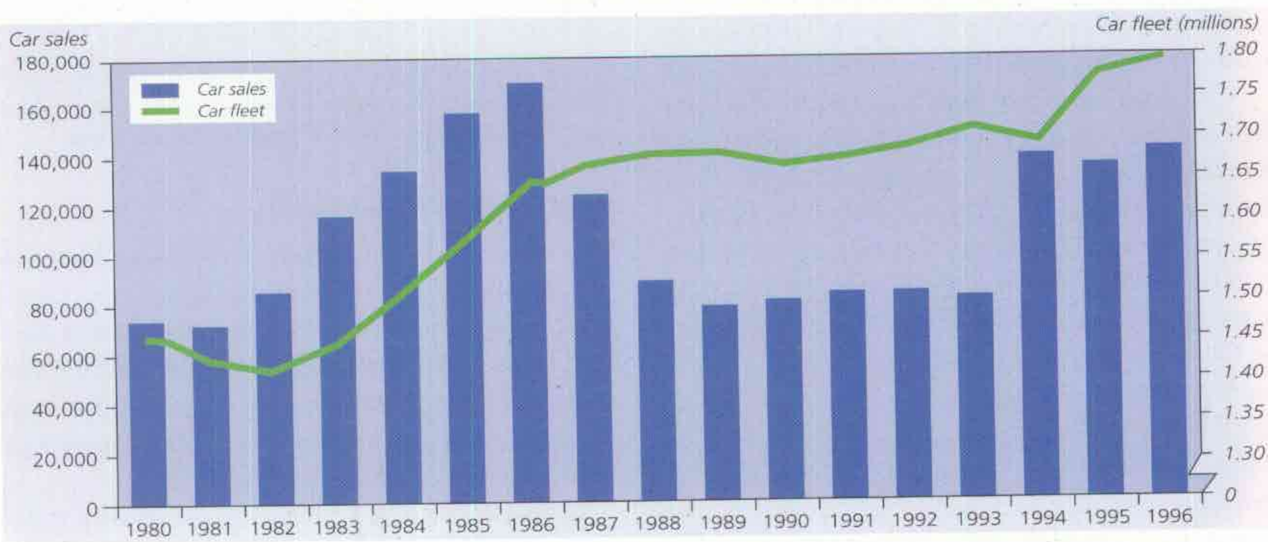


Figure 3.3.3 Development in the Danish private car fleet and car sales over the period 1980-96 (including delivery vans under 2 tonnes) (Source: Road Directorate, 1996, Statistics Denmark, 1996a and 1997).

price whereas the price of public transport and of vehicle repair and maintenance has exceeded the general price increase. Relatively speaking, it has thus become less expensive to travel by car. From 1994 to 1995, the price of petrol increased more than the consumer price index for the first time in 15 years. The relative fall in the price of petrol over the period 1980-95 is nevertheless still approx. 32%. Statistical analyses of the development during the past 15-20 years indicate that traffic increases by an average of 4% every time the price of petrol falls by 10%.

Technological factors

Transport technology consists of vehicles, infrastructure, fuels and information, all coupled together in large systems. The improvement of transport systems may lead to shorter travel time, increased range, better comfort, enhanced safety and less environmental impact per transport unit. However, the expansion of the systems may also impose limitations on non-motorized traffic in the form of barriers or detours. Moreover, servicing of certain areas may be limited. Technological development consequently affects both the volume of traffic and its distribution among the individual modes of transport.

The length of the Danish network of main roads remained largely unchanged (4,500 km) up to 1996, while major qualitative changes have been made. For instance, the Danish motorway system was extended from approx. 270 km to 790 km over the period 1972-1996, i.e. that it was almost tripled in 25 years, and further extension is planned.

The national railway system has been reduced considerably since the 1930s, while the capacity of a few sections has been increased. Major investments are currently being made in new and faster railway stock.

Construction of the fixed links across the Great Belt and the Øresund entails major changes for both road and railway traffic. For example, the journey time for passengers travelling by train between Copenhagen and Aarhus has been shortened by more than one hour. Ideas have been put forward regarding high-speed trains and considerable future expansion of the railway system which may further shorten journey time between selected travel hubs. Copenhagen Airport is also undergoing expansion at present, and a number of ferry services are introducing considerably faster ferries. These trends can be expected to result in increasing traffic. In general, the greater use of information technology is expected to enhance the capacity and hence also the volume of traffic.

Geographical factors

The location of everyday functions relative to one another is naturally a decisive determinant of transport needs. People inhabiting the countryside and small towns have to travel further to work, services and social contacts, and consequently travel considerably more than people inhabiting cities, see *Figure 3.3.4*.

The density and availability of different functions within a specific area are thus important determinants of how far one needs to travel in order to complete one's daily tasks.

The individual's choice of housing, workplace and destination within the current structure is also of great importance with respect to transport demand, however. It is largely access to fast transport facilities that determines how bound one is by the geographical structure.

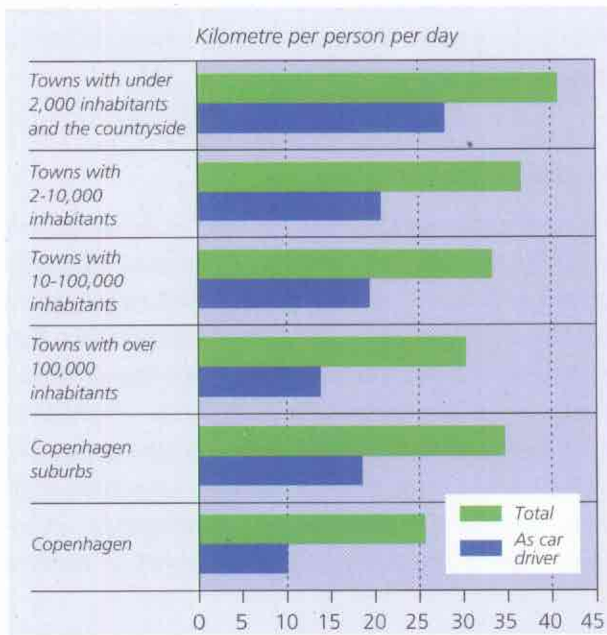


Figure 3.3.4 *Transport per person per day for various types of towns and areas. Figures are shown for transport as car driver and for total transport (Source: Road Directorate, 1996).*

Social and cultural factors

The volume of transport and its distribution according to mode of transport chiefly depend on day-to-day activities such as commuting, leisure and various errands (shopping, etc.). Leisure journeys account for approx. 39%, making them the main type of journey in terms of person-km. Then comes commuting, which accounts for approx. 35%.

The daily activity pattern also depends on social and cultural factors such as age, education, sex and family constellation. For instance, elderly people over 65 travel considerably less than younger people, while single persons travel less than couples with children, and women travel much less than men.

People often choose their mode of transport on the basis of how the various tasks can best be combined. *Figure 3.3.5* shows daily transport by the Danes apportioned by the various modes of transport for each type of journey. The car dominates in journeys combining errands and leisure journeys (88%), but accounts for as little as 70% in the case of commuting. On the other hand, the frequency of drive-alone car journeys is low in the case of leisure journeys, where several family members often drive together, and highest in the case of work-related journeys. Public transport is primarily used for commuting, where it accounts for 20%. Walking and bicycling are also primarily used for commuting, as well as for running errands. The choice of mode of transport is far from solely based on a rational decision on how to get from one destination to another in the most practical and economical way.

Thus for many people, the car means much more than just a means of transport. The car has become a deeply rooted part of modern society, and motoring as a social phenomenon both meets and creates a large number of needs. The car can both generate a sense of identity and status and contribute to meeting needs in other areas. *Figure 3.3.6* shows the many social and cultural functions of the car. These factors are important to take into account in strategies aimed at reducing the volume of transport and its environmental impact

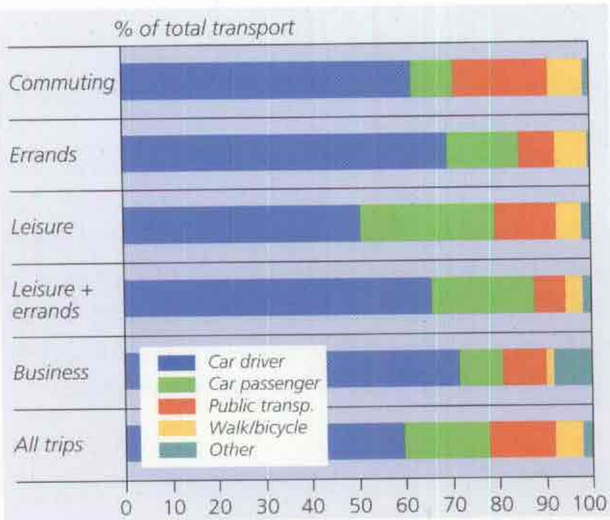


Figure 3.3.5 *Daily transport apportioned by main modes of transport for each journey purpose (Source: National Environmental Research Institute based on Statistics Denmark's data on transport habits for the period 1993-96).*

Future development

Figure 3.3.7 shows a model forecast of the development in passenger transport assuming status quo in other respects (i.e. without the effects of possible measures to reduce the growth in traffic) up to the year 2020 apportioned by the individual modes of transport. As is apparent, the future is expected to bring continuous heavy growth in passenger transport. The projection shown corresponds to the baseline scenario in Energy 21, the Ministry of Environment and Energy's action plan on energy (see *Section 3.2*).

When assessing future development, it is difficult to predict the interaction between the various factors affecting the volume of transport. In the above mentioned forecast, it is the level of income that prima-

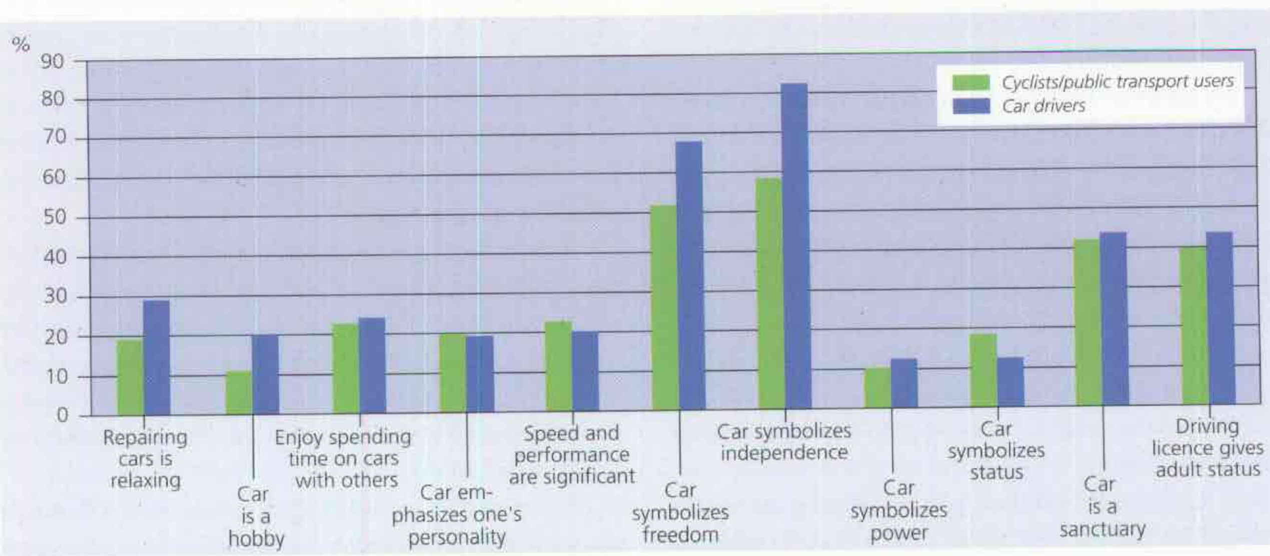


Figure 3.3.6 *The car's social and cultural functions. The bars indicate the percentage share of persons among motorists and cyclists/public transport users who agree that cars have the above mentioned social and cultural functions (Source: Jensen, 1997).*

rily determines development in the volume of traffic, i.e. transport is primarily considered a consumer product. Car traffic is thus forecast on the basis of a prognosis for economic growth, with the historical development being used to calculate how this growth will affect the size of the car fleet and the volume of traffic.

The forecast assumes that the car fleet is likely to reach saturation at approx. 550 cars per 1,000 inhabitants in the year 2030. At that time, almost every household will own a car, including 90% of single persons aged 18 to 60 without children. Many families will have more than one car. This level is very close to the current level in the USA, while the corresponding figure for Denmark in 1994 was about 320 cars per 1,000 inhabitants. Based on these assumptions, private car transport is expected to increase about 50% between 1994 and 2020.

The forecast of domestic aircraft traffic is based on the same economic prognosis; the growth in aircraft traffic is expected to be greater than that of cars, though, since aircraft traffic is more income-sensitive.

With regard to rail traffic, the Danish State Railways has prepared a specific prognosis according to which railway traffic is expected to grow by approx. 16% up to the year 2005 as a result of investments in infrastructure, rail stock, fixed links, etc. Thereafter, development will stagnate. Bus traffic is not expected to increase at all. Ferry traffic is simply expected to follow the development in car traffic. Finally, bicycle traffic has been forecast by keeping its share of the total passenger transport constant until the year 2005, whereafter bicycle traffic is assumed to remain stable. With all means of passenger transport, occupancy is assumed to remain constant, it being unknown to what extent occupancy will be affected by the economic conditions.

As shown in *Figure 3.3.7*, aircraft and ferry traffic will decrease markedly after the opening of the Great Belt Fixed Link. Aircraft traffic in Denmark is expected to fall by 32% and ferry transport by 60%. Both types of traffic are expected to increase again due to the economic growth, however. By 2010, aircraft traffic is expected to have reached the same level as prior to the opening of the Great Belt Fixed Link.

Future development in passenger transport is thus extremely dependent on economic growth development, expansion of the transport systems, occupancy, etc. The above mentioned forecast implies an annual growth in the car fleet of 165,000 vehicles, which is somewhat higher than hitherto. The question of a possible saturation point for the car fleet is much dis-

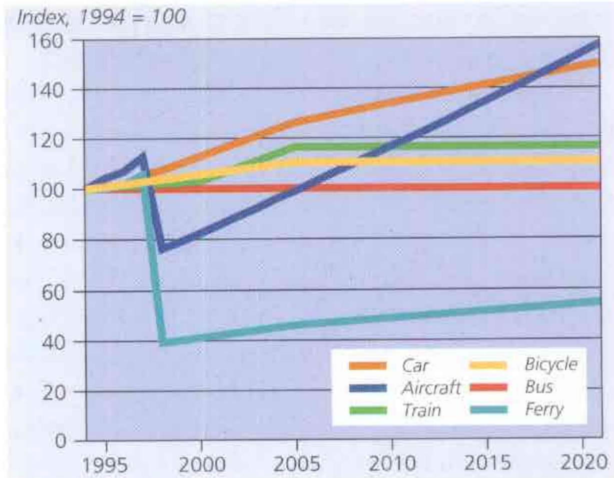


***Figure 3.3.7** Passenger transport forecasts (indexed to passenger-km for each mode) for the main modes of transport for the period 1994-2020 (Source: Ministry of Transport, 1996 (background material)).*

cussed. In many American cities, there is more than one car per adult.

Changes in settlement and family patterns, harmonization of vehicle taxation in Europe and other factors may also affect future development. Congestion and lack of possibilities for expansion may curb the volume of traffic. However, if it is mainly leisure and errand traffic that increases, it will probably be possible to meet much of the growth pressure.

Development in freight transport

Freight transport can be described in different ways. For each mode of transport one can calculate freight lifted, the number of journeys made or the traffic in kilometres. From this it is possible to calculate the freight transport expressed as freight moved (tonnes-km). *Figure 3.3.8* shows the development in freight transport over the period 1980-94 expressed as freight moved (tonnes-km) apportioned by mode of transport. In 1994, the total national freight transport amounted to approx. 14,000 million tonnes-km, excluding transit traffic.

Lorry haulage accounts for the major part of freight traffic, freight lifted and freight moved. As shown in *Figure 3.3.8*, it is mainly road haulage by large articulated lorries that has increased since 1980, presently accounting for approx. 55% of the total national freight transport. The share of freight carried by road is almost 80%. National freight transport by rail has been declining, although this has been countered by increasing (domestic) rail transport in connection with exports, etc. National freight transport by ship has varied between 1,700 and 2,500 million tonnes-

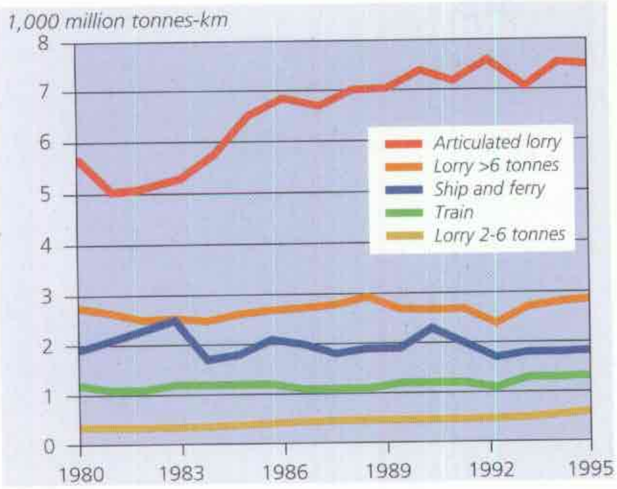


Figure 3.3.8 Development in national freight transport in Denmark over the period 1980-95 apportioned by mode of transport, including import- and export-related transport within Denmark (Source: Road Directorate).

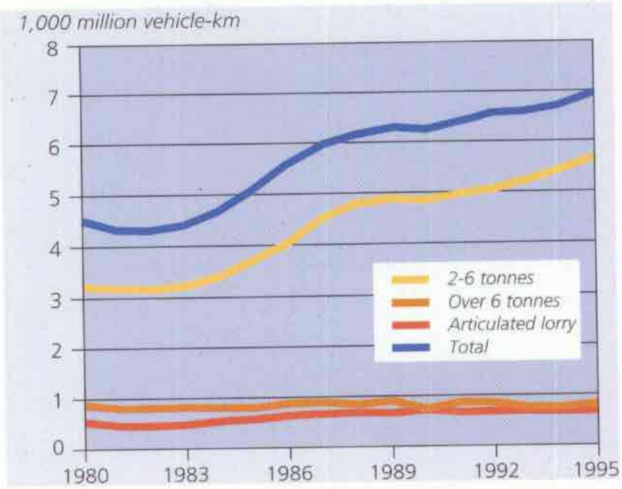


Figure 3.3.9 Development in van and lorry transport over the period 1980-95 (Source: Road Directorate).

km, partly due to conversion to pipeline transport. These trends correspond to those in the rest of Europe, where the share of freight carried by lorry is generally slightly lower than in Denmark, however.

The increase in road haulage by articulated lorry reflects various conflicting trends. The total amount of freight lifted increased until 1988, after which it declined due to the economic recession, which particularly affected the transport of building materials, etc.

The total amount of freight lifted has thus fallen by approx. 10% during the period 1984-94. In addition, there has been a drop in the number of lorries and trips by lorry. On the other hand, the size of the lorries has increased and the individual trips by lorry have become considerably longer. Thus the average trip by lorry has increased from 36 km to 67 km over the period 1984-95. One reason may be centralization of production and distribution. A declining amount of freight is thus being moved further in fewer but larger lorries. The number of trips by empty lorries has decreased, but because the lorries now used are larger, average capacity utilization has nevertheless decreased.

As shown in *Figure 3.3.9*, the conversion from medium-sized lorries to articulated lorries is reflected in the development in traffic. Total traffic by lorries over 6 tonnes has not increased. This is due to the fact that some of the above mentioned trends counteract each other: Fewer trips by lorry, declining amounts of freight and fewer empty trips pull in one direction, while the increase in trip length pulls in the opposite direction. The most obvious aspect of freight transport is the marked increase in traffic by small vans and lorries from 2-6 tonnes. These account for approx. 80% of the freight traffic, but only for approx. 5% of the freight moved (tonnes-km). Knowledge of the background for the development in freight traffic by delivery vans and lorries under 6 tonnes is limited, but it can be assumed that the vehicle taxation structure has encouraged the purchase of delivery vans weighing 2-6 tonnes.

Future development

The basis for forecasting the development is no more reliable in the case of freight transport than for passenger transport. Among other things the difficulties are due to the fact that development varies considerably for the various types of goods and products, and that the product value per unit weight changes over time. In a forecast prepared by the Ministry of Transport (see *Figure 3.3.10*), the total amount of freight moved is derived from a prognosis of economic growth in the manufacturing industry plus imports. It is expected that the correlation between economic growth and freight transport will gradually be moderated in future, since the value of the goods per unit weight will increase. On balance, a 50% growth in freight transport is predicted over the period 1994-2020.

The overall forecast has thereafter been apportioned by the individual modes of transport on the basis of the Ministry of Transport's more detailed assumptions and estimates. Firstly, it is expected that the opening of the Great Belt Fixed Link will reduce the share of national freight transport by rail, ferry and ship to the advantage of transport by lorry, see *Figure 3.3.10*. Secondly, freight transport by rail and ship is thereafter expected to remain at roughly the same level such that also future growth in freight

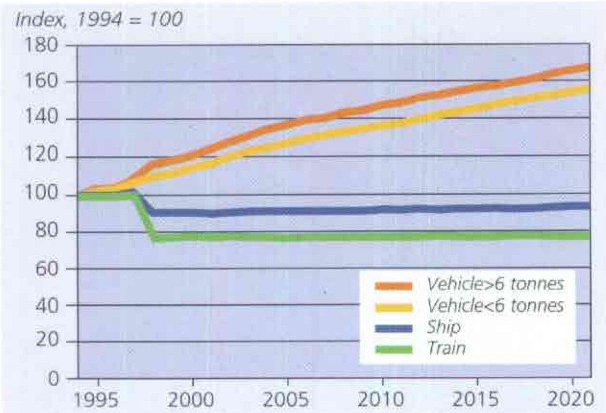


Figure 3.3.10 *Freight transport forecasts for the period 1994-2020 (Source: Ministry of Transport, 1996 (background material)).*

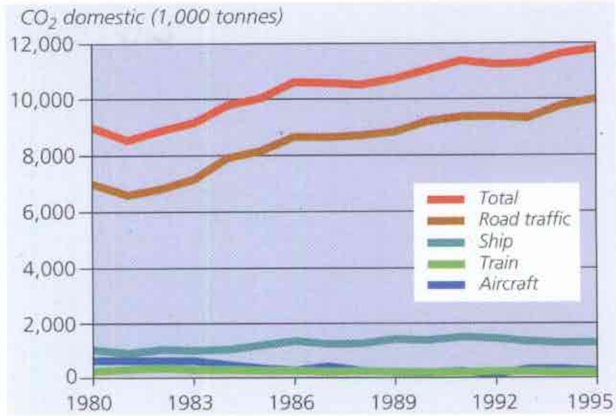


Figure 3.3.11 *CO_2 emissions from domestic transport over the period 1980-95 apportioned by mode of transport (Source: National Environmental Research Institute and Risø National Laboratory, data from the CORINAIR database).*

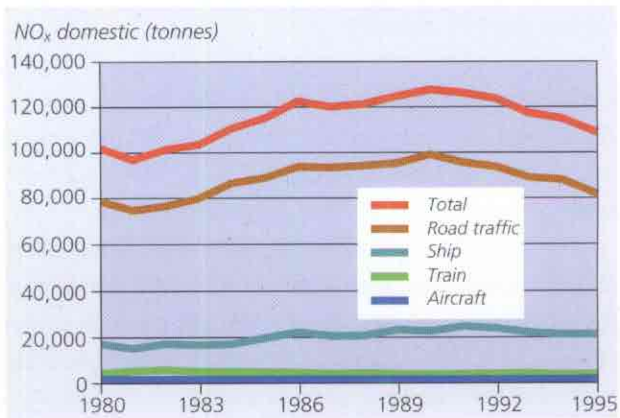


Figure 3.3.12 *NO_x emissions from domestic transport over the period 1980-95 apportioned by mode of transport (Source: National Environmental Research Institute and Risø National Laboratory, data from the CORINAIR database).*

moved will be accounted for by lorries and vans. As regards lorries, it is expected that the payload will continue to increase such that freight traffic by lorry will not increase as much as the freight moved.

3.3.3 Environmental impact of traffic

As mentioned in the introduction, traffic affects the environment in many different ways. This section deals exclusively with traffic's contribution to energy consumption and associated emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), hydrocarbons (VOC/HC), carbon monoxide (CO) and particulates, examining both the absolute emissions from each mode of transport and the share of total emissions. Noise and other types of nuisances in the urban environment are dealt with in *Section 2.2.* Accidents and ensuing injury and loss of lives have also to be taken into account when dealing with overall environmental impact of traffic.

Energy consumption and emissions

National traffic accounts for approx. 25% of the total final energy consumption. CO_2 emissions relatively closely follow energy consumption and therefore develop almost proportionally to the development in traffic, even though the development in the energy efficiency of the vehicle fleet must be taken into consideration. Development in the other types of emissions more depends on which technologies and fuels are employed. *Figure 3.3.11* illustrates the development in CO_2 emissions over the period 1980-95, while *Figure 3.3.12* shows the corresponding development in NO_x emissions. CO_2 emissions from the transport sector have increased by approx. 30% during the period. The predominant part of the growth is due to road transport, which presently accounts for approx. 85% of the sector's CO_2 emissions compared to just under 80% in 1980. CO_2 emissions have increased less than road traffic, which has increased by 60% during the same period, as mentioned in *Section 3.3.2.*

This is largely due to the fact that on average, new cars and other means of transport have become more energy-efficient since 1980. This trend has diminished over time, however, see *Figure 3.3.13*. The Figure shows a calculation of the average energy efficiency of new cars weighted according to actual car sales in Denmark. It seems that the consumers' choice of car counteracts the improvements in energy efficiency resulting from technological development. The same trend is seen in other countries such as Sweden, Norway, Germany, Great Britain, France, the USA and Japan, where the energy efficiency has stabilized after an increase in the early 1980s. Also, more energy-demanding types of ferry are being introduced with a view to reducing journey times.

Figure 3.3.13 Calculated energy consumption of new cars entering the Danish car fleet. Weighted average of the cars actually sold in Denmark during the year in question (Source: Konsumentverket and National Environmental Research Institute based on Statistics Denmark's vehicle database).

With regard to NO_x, HC and CO, however, emissions from new cars have decreased considerably in recent years. This has resulted in a fall in total emissions that is largely attributable to the introduction of the emission standards in 1990 necessitating the installation of catalytic converters on new private cars.

As an example, NO_x emissions from road traffic have decreased by approx. 18% over the period 1990-95. This development will continue in step with renewal of the car fleet and the introduction of further restrictions, see *Section 3.3.4*.

Environmental impact of international traffic

For various reasons, international traffic and its environmental impact are not fully included in the national surveys and forecasts. The "international" transport can generally be divided into three categories.

Firstly, Danish imports, exports and foreign tourism entail some transport within Denmark. This is largely included in the above national calculations but not in the forecasts. The environmental impact of this transport can be expected to increase in step with the growing international trade.

Secondly, there is some international transit transport via Denmark by road, rail or ship. This affects the environment in Denmark but for methodological reasons is not directly included in the calculations and forecasts shown. Transit transport is calculated separately for freight hauled by rail, however, and this has increased steadily and is now greater than total domestic freight haulage by rail. Transit freight haulage by lorry is not calculated, but preliminary estimates indicate that it only accounts for a minor share of the total traffic.

Thirdly, Danish imports and exports increase the amount of freight traffic in other countries as well as in international waters and airspace. This "real" international traffic is considerably greater than the above mentioned types, but does not directly affect the environment in Denmark. The contribution is not included in either the calculation or the forecasts presented above.

Figures 3.3.14 and *3.3.15* show the CO_2 and NO_x emissions from "real" international aircraft and ship traffic. It is apparent that nearly all of the marked increase is accounted for by international bunker ship traffic (i.e. ships that refuel in Denmark in connection with foreign travel) while emissions from international aircraft traffic have only increased slightly. Part of these increases could however be due to international shifts in the sale of fuels, rather than to actual increases in travel of this magnitude.

CO_2 emissions from the two categories of international traffic together account for 50% of emissions from the entire Danish transport sector. NO_x emissions from the international ship traffic alone are almost of the same magnitude as emissions from the domestic transport sector, namely approx. 125,000 tonnes per year.

"Real" international road and rail traffic is also considerable. Thus 58% of the total freight transport by Danish lorries takes place abroad. The amount of freight moved by lorry in international traffic has increased by 60% over the period 1984-93. Energy consumption and emissions have not been calculated as these should be fully or partly included in the national calculations of the countries in question. The environmental impacts of NO_x emissions from air-

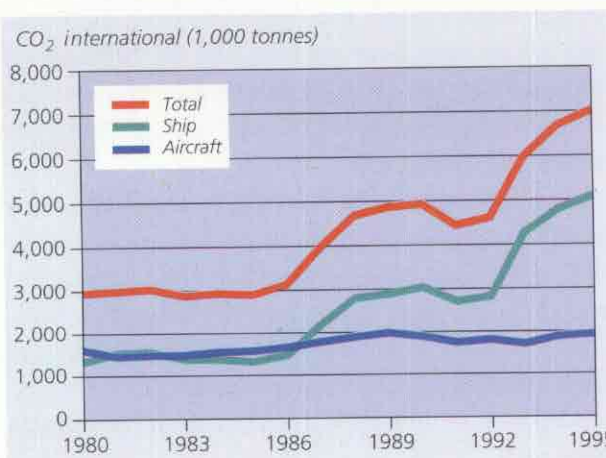


Figure 3.3.14 CO_2 emissions from international aircraft and ship traffic (Source: National Environmental Research Institute and Risø National Laboratory, data from the CORINAIR database). Note: Emissions from fuels sold in Denmark for international aircraft and ship transport).

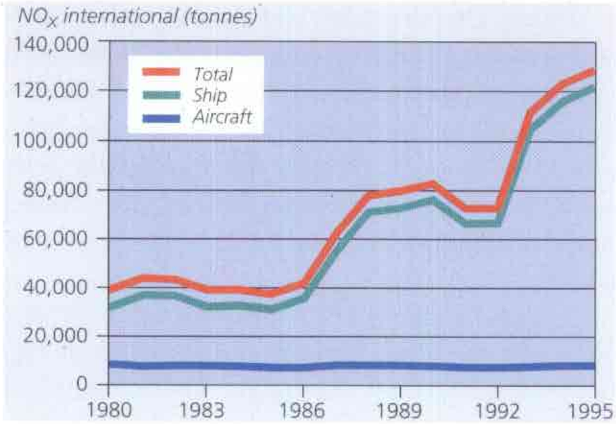


Figure 3.3.15 *NO_x emissions from international aircraft and ship traffic (Source: National Environmental Research Institute and Risø National Laboratory, data from the CORINAIR database). Note: In the case of international ship traffic, the data represent emissions from fuel sold in Denmark for that purpose. In the case of aircraft traffic, all aircraft movements taking place at a height of over 1,000 metres are considered to be international.*

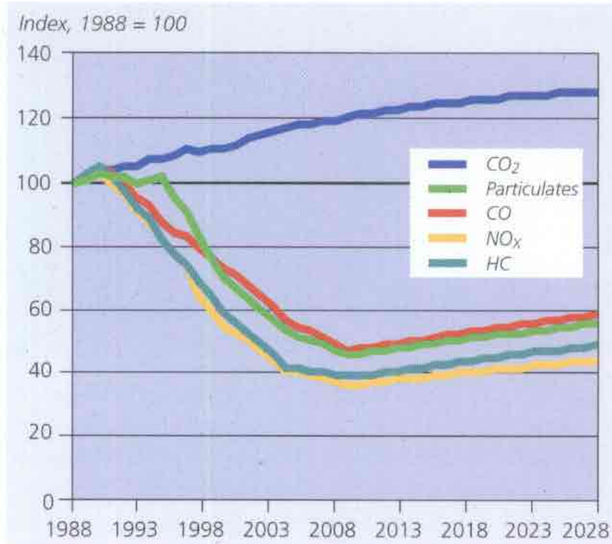


Figure 3.3.16 *Forecasts of transport sector CO_2, NO_x, CO, HC(VOC) and particulate emissions over the period 1988-2030 (Source: Ministry of Transport, 1996 (background material))*

craft, ships and terrestrial traffic are not directly comparable. For instance, it is thought that aircraft emissions in the tropopause and stratosphere may have climatic effects that do not occur when emitted at lower altitudes. Moreover, deposition of emissions on the open sea does not have the same environmental impact as deposition on coastal waters, on land or on urban areas. Growing international traffic is nevertheless likely to have considerable environmental effects which are not covered by regulations.

Future development in emissions

Future development in emissions is determined by future development in traffic (see *Section 3.3.2*) and the transport technology employed. Forecasts of the energy consumption and emissions from the transport sector have been prepared by the Ministry of Transport on the basis of the traffic forecasts described above (*Figures 3.3.7* and *3.3.10*). These are shown in *Figure 3.3.16*.

As shown in *Figure 3.3.13*, development in the energy efficiency of private cars has stagnated in recent years. This development has not been considered in the forecast, however. With respect to emissions per km of the other substances, it has been assumed that the effect of hitherto adopted regulations will take effect in step with renewal of the vehicle fleet.

As is apparent from *Figure 3.3.16*, emissions of NO_x, HC, CO and particulates are expected to decrease by 50-60% up to the year 2010, whereafter they will increase again. The decrease is mainly due to the effect of hitherto adopted requirements aimed at limiting emissions from road traffic. The above mentioned requirements do not include the planned tightening of the EU regulations in 2000 and again in 2005.

In contrast, CO_2 emissions are expected to increase by approx. 16% over the period 1988-2005 and by approx. 25% up to the year 2030. This is the effect of the growing traffic, which will only partly be countered by the expected improvement in the energy efficiency.

The forecasts are based on a number of assumptions, however. As regards energy consumption and CO_2, the forecasts assume a substantial improvement in energy efficiency as part of the general technological development in this field. For instance, it is assumed that the energy efficiency of the private car and lorry fleet will increase by 7% over the period 1995-2005 and by a further 15% over the period 2005-30. As regards delivery vans and lorries, the forecast deviates from the historical development, in which the energy coefficient in the transport sector (energy consumption per DKK) has in fact been increasing.

3.3.4 Objectives and policy measures

In Denmark as well as in other countries, overall action plans have been prepared laying down general national strategies and objectives for regulating the environmental problems caused by the transport sector. These action plans have to some extent been implemented through legislation, planning and levy policies. The policies correspond to developments in the international arena, in particular within the EU. The national action plans have also been followed up by local traffic and environmental action plans for larger urban municipalities. In these plans, specific targets and measures are stipulated for the individual urban areas. Furthermore, specific environmental action plans have been prepared for subsectors such as the Danish State Railways and the Road Directorate.

The overall environmental objectives for the transport sector in Denmark are stipulated in the Government's 1990 Transport Action Plan as followed up in "Transport 2005". The latter contains an overall traffic plan specifying concrete targets for emissions of CO_2, NO_X, HC and particulates, as well as for noise from domestic transport. Moreover, the targets are included in the Government's 1995 Nature and Environment Policy Paper. With respect to CO_2 emissions, the targets are also included in Energy 21. These targets must be met by various years during the period 2000-30.

In *Figure 3.3.17*, some of the emission targets are compared with the Ministry of Transport's forecast (see *Section 3.3.3*). Apart from the targets shown, emissions of particulates have to be reduced 50% by the year 2010, and NO_X and HC emissions must be further reduced up to the year 2030. The number of noise-plagued houses has also to be reduced. Thus by 2010, no more than 50,000 houses will be allowed to be exposed to more than 65 dB, roughly corresponding to a 65-70% reduction target.

As is apparent from *Figure 3.3.17*, it should be possible to meet the target of reducing NO_X and HC emissions to 60% of the 1988 level by the year 2000 given the forecast development in traffic and the emission requirements already adopted. However, these expectations should be compared to the reductions in emissions from traffic actually obtained since 1988, which were just under 11% by 1995 for NO_X and only 22% for HC emissions.

Even more stringent requirements are planned for a number of means of transport. As regards road transport in particular, the EU Member States have decided to markedly tighten vehicle emission standards for NO_X, HC, CO and particulates in 2000 and again in 2005. In 1997, the Member States adopted a concrete proposal submitted for consideration by the European Parliament. These factors have not been taken into account in *Figures 3.3.16* and *3.3.17*. This means that NO_X emissions in particular will decrease further than indicated in *Figure 3.3.17*. Moreover, it should also be noted that the air quality standards applying within the EU today are under revision, and are expected to be tightened considerably. An assessment will therefore be needed of the extent to which the existing emission reduction targets are sufficient to meet the tightened air quality standards.

With respect to the reduction target for CO_2 emissions, in contrast, the trend is the opposite. In the forecast, emissions are expected to increase to 16% above the 1988 level by 2005, whereas the target is to stabilize emissions at the 1988 level and thereafter reduce emissions. In addition, the actual development over the period 1988-96 shows that CO_2 emissions have already increased by roughly 16% during the period. At the EU level, the Commission expects that total CO_2 emissions from the transport sector will increase by 20% up to the year 2000 and by 36% up to the year 2010 relative to the 1990 level.

In 1996, the Government presented an overall action plan for reducing CO_2 emissions from the transport sector. This estimates that it is possible to reach the target of stabilizing CO_2 emissions at the 1988

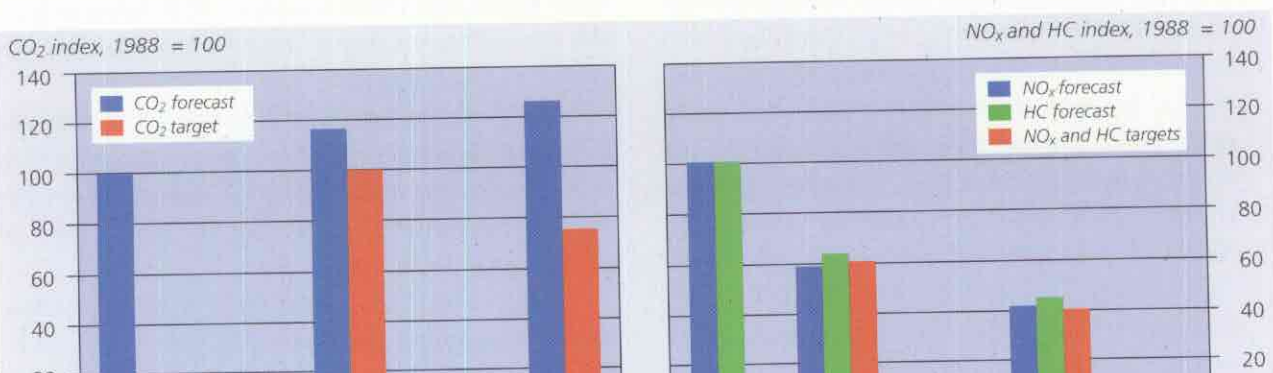


Figure 3.3.17 *Expected development in CO_2, NO_x and HC emissions from transport (assuming no new measures) shown in relation to the adopted emission targets (Source: Ministry of Transport, 1996 (background material)).*

level by the year 2005 if the price of petrol increases at roughly the same rate as the energy efficiency of new private cars. This of course necessitates that the energy efficiency of new cars actually increases. As is apparent from *Section 3.3.3* on the impact of traffic, the recent trend does not suggest that this will occur. According to the Government's action plan for reducing CO_2 emissions from the transport sector, the fuel levy increases already adopted are also inadequate to ensure that the target is met.

The concrete initiatives outlined in the action plan include:

1. An agreement with the automobile industry to increase car energy efficiency. In 1996, the EU Commission submitted a proposal for negotiations with the automobile industry within the EU aimed at reducing energy consumption by new cars. However, the latest reports from the Commission indicate that the negotiations are proceeding very slowly. Similar initiatives in the USA have previously proved quite successful, but these are based on statutory requirements rather than voluntary agreement.
2. Consumer information about the energy efficiency of cars. As the EU adopted regulations on the measurement of energy consumption in new cars that entered into force in 1997, it is now possible to provide more reliable consumer information. The Government has taken the initiative to prepare some consumer information material. Requirements on actual eco-labelling of cars would require amending EU regulations, however.
3. Differentiation of levies such that consumers are encouraged to purchase more energy-efficient cars. In May 1997, the Danish Parliament restructured the Danish vehicle taxation system with this aim. The former weight-based annual tax was replaced by one based on energy consumption in the case of new cars. At the same time both annual taxes and purchase taxes were linked to the price index. It is not intended to change the net revenue, and the effect on CO_2 emissions is expected to be modest (<1% reduction of total CO_2 emissions from the car fleet) since the vehicle annual taxes were already relatively closely linked to energy consumption. The symbolic value may well be of significance, however.
4. Traffic planning, public transport, etc. A number of investments have been initiated aimed at expansion of public transport, e.g. in the Greater Copenhagen area. This will help to maintain the proportion of total passenger transport accounted for by public transport, but it is not expected to result in any considerable reductions in the volume of car traffic or total emissions from traffic. In addition, the Government supports a number of local initiatives aimed at promoting environmental and road safety and improving environmental and energy-related aspects of bus operation, etc. These initiatives may be of great local significance, but they will have only limited effect on total CO_2 emissions from the transport sector.

A number of other planned initiatives will help limit the environmental impact of the transport sector. In the spring of 1997, Parliament decided to lower the prices of public transport by approx. 10% with effect from the autumn of 1997 and make it easier to use the same ticket on both busses and trains. Furthermore, Parliament decided to introduce a passenger levy on all domestic flights and to restructure vehicle taxes on delivery vans. To what extent these measures will contribute to attainment of the environmental targets remains to be seen.

Given the development in CO_2 emissions so far, it is doubtful whether the measures hitherto adopted in Denmark and the EU will ensure stabilization of CO_2 emissions from the transport sector and realization of subsequent reduction targets.

This is partly due to the fact that environmental policy in the transport sector has so far primarily focused on technical measures to reduce emissions rather than on regulation of traffic behaviour. As such, it has not been possible to adequately cope with the growth in traffic.

As regards international traffic, the trend is also moving in the wrong direction. Denmark's contribution to CO_2 and other emissions from international traffic has increased markedly in recent years, and there are no signs that measures will be taken to limit the environmental impact of the international transport in the near future.

As regards the noise target, a number of noise attenuation measures have been implemented which will considerably reduce the noise nuisance along the main railways and roads. For further information on urban traffic noise, see *Section 2.2.6*.

In contrast to CO_2, it seems that it will be possible to meet the emission reduction targets for NO_x, HC and particulates through the hitherto adopted or planned measures. As already mentioned, however, it may prove necessary to re-evaluate the emission targets on the basis of the planned tightening of air quality targets.

3.4 Agriculture, forestry and fishery

3.4.1 Introduction

The primary sectors of the economy - agriculture, forestry and fishery - play a central role for the development of nature and the environment in the Danish countryside and Danish marine waters. Agriculture exploits approx. 61% of the Danish land mass and forestry approx. 12%. The Danish landscape thus reflects this intensive interaction between man and the environment. Similarly, intensive fishery in the coastal and open marine waters exerts considerable pressure on the marine ecosystems. Production in the primary sectors, of which agriculture is economically dominant, has been slowly increasing during the 1980s and 1990s, although their share of the overall economy is decreasing, see *Figure 3.4.1*. Their commercial significance is still great, however, since they have historically been the nucleus of Danish commercial development and continue to form the basis for considerable production in the subsequent links of the chain of production. The primary sectors therefore continue to be the subject of considerable political attention. Since 1972 and the accession to the EC, later the EU, development in the primary sectors has largely been determined by developments on the European front and by EU policy in the area.

This section examines the development in agriculture, forestry and fishery and the associated pressures on the environment and nature over the last 15-20 years.

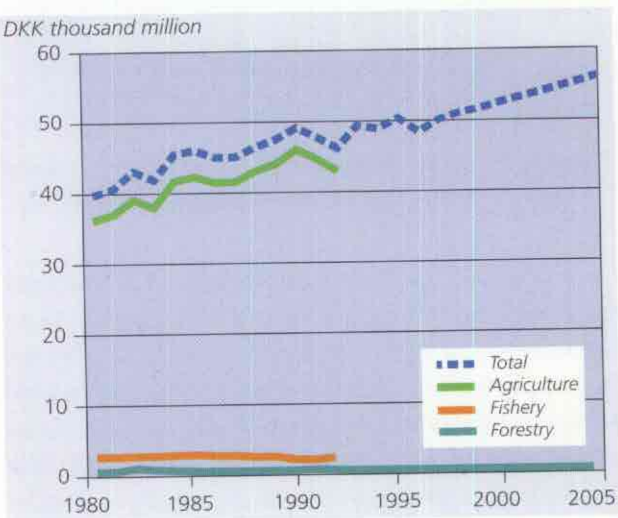


***Figure 3.4.1** Development in the production value of the primary sectors in constant (1980) prices (Source: 1980-95: Actual figures from the National Accounts, Statistics Denmark; 1995-2005: Forecast from the 1996 Medium Term Economic Survey, Ministry of Finance, 1996).*

3.4.2 Agriculture

Economic development in the agricultural sector

The importance of agriculture to the national economy has decreased steadily over the period examined here, namely 1980-95. Whereas agriculture accounted for 4.4% of the gross domestic product at factor cost in 1980, the figure had fallen to 3.5% in 1995. Agriculture continues to make a major contribution to foreign exchange earnings, however, even though the share has decreased. Agriculture-related exports thus accounted for 29% of total exports of goods in 1980 and 18% in 1995. These figures include the value added from industrial processing of agricultural products.

Development in the agricultural sector in the 1980s and beginning of the 1990s has been characterized by a greater increase in labour and production costs than in the price of agricultural products, see *Figure 3.4.2*. This is particularly true for labour costs.

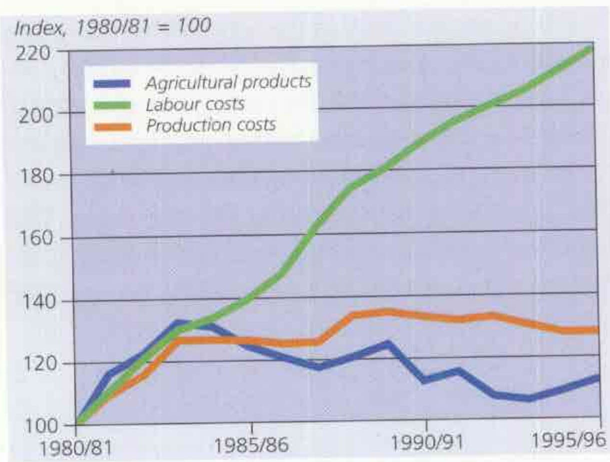


***Figure 3.4.2** Development in the agricultural prices, labour costs and production costs (Source: Hansen, 1995; National Environmental Research Institute, internal calculations). Note: Includes compensation for price drops awarded under the EU agricultural policy reform.*

As a result of the unequal development in prices, the ratio between the price of agricultural products and the input factors - the so-called terms of trade - has fallen by a total of 28% over the period 1980/81 to 1992/93 for the agricultural sector as a whole. The reduction in terms of trade has enhanced the incentive for agriculture to increase both production and productivity as compensation for the falling unit earnings.

Agricultural production as a whole has thus increased by about 30% over the period 1980/81 to 1995/96 or by just under 2% per year, see *Figure 3.4.3*.

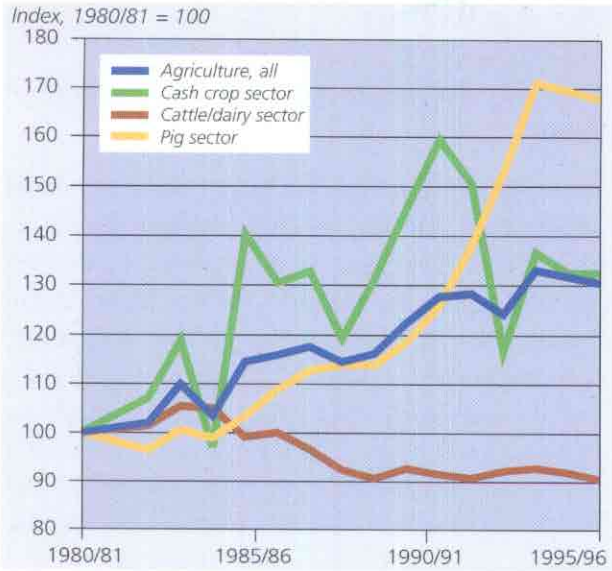


Figure 3.4.3 Indexed development in quantitative agricultural production distributed by sector (Source: Hansen, 1995; National Environmental Research Institute, internal calculations). Note: Coarse fodder production is included in the cattle/dairy sector and excluded in the cash crop sector.

The factor productivity in the agricultural sector has grown by a total of 39% in real terms or approx. 3% per year, see *Figure 3.4.4*. The increase in agricultural production encompasses a fall in production in the cattle/dairy sector (including coarse fodder) and a 50% increase in production in the pig sector. The trend in the cash crop sector (excl. coarse fodder), although varying markedly depending on weather conditions, is also towards increasing production.

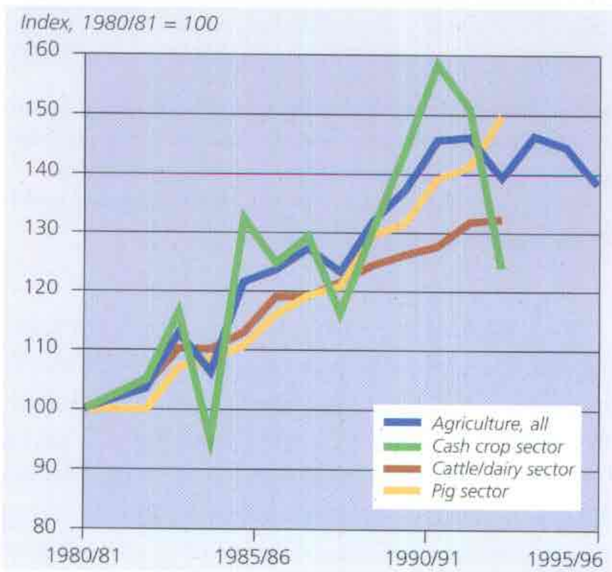


Figure 3.4.4 Development in factor productivity in agricultural sectors in constant prices (Source: Hansen, 1995; National Environmental Research Institute, internal calculations). Note: Coarse fodder production is included in the cattle/dairy sector and excluded in the cash crop sector.

The falling factor cost per unit produced is attributable to the implementation of more productive technologies in agriculture, especially labour-saving technologies. Labour productivity has thus almost doubled over the period 1980/81 to 1992/93. Part of the productivity increase is attributable to economy of scale due to the increasing size of the farms (*Figure 3.4.5*) and the increased concentration of livestock on the individual farms. In the case of the cash crop sector, greater field size has provided labour savings per hectare since the agricultural machines can be used in a more economically rational manner. Moreover, this incentive has increased in step with the introduction of more versatile agricultural machinery. In addition, utilization of the machine fleet has increased as a result of greater farm size, and machine costs per hectare have therefore decreased. As a result of the above mentioned economy of scale, average farm size has increased from 26 ha in 1980 to 40 ha in 1995, an increase of just under 1 ha per year.

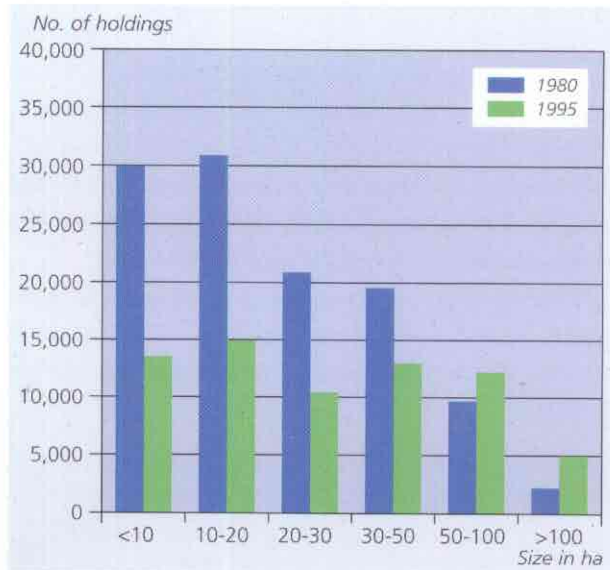


Figure 3.4.5 Farms distributed by size of holding (Source: Statistics Denmark, Agricultural statistics, various years).

The economy of scale in the form of labour savings and optimal use of facilities have also led to an increase in the size of livestock herds. The average size of pig herds has thus increased from 147 in 1980 to 518 in 1995, while the average size of cattle herds has increased from 48 in 1980 to 69 in 1995. The larger size of the farms with respect to area and number of livestock has increased capital requirements per holding. This has resulted in increasing specialization (*Figure 3.4.6*). The share of farms with neither cattle nor pigs has thus increased from just over 20% in 1980 to just under 40% in 1995. Correspondingly,

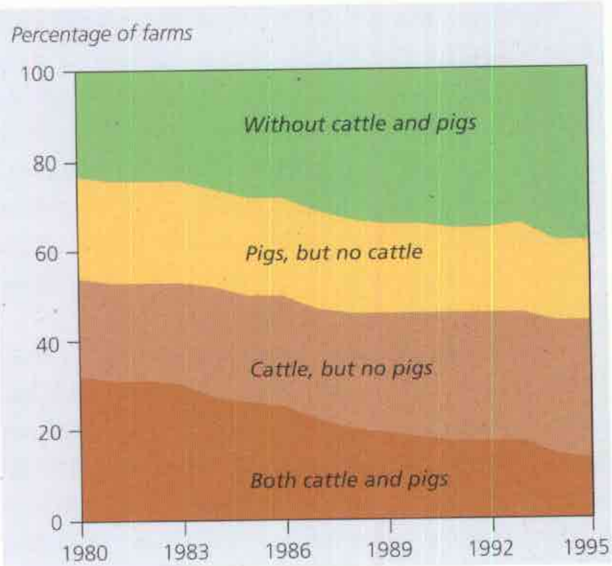


Figure 3.4.6 *The relative specialization of agriculture (Source: Statistics Denmark, Agricultural Statistics, various years). Note: The 1980 and 1981 figures are partially estimated.*

the share of farms with both cattle and pigs has fallen markedly from just over 30% in 1980 to just over 10% in 1995.

The productivity of pig farms has increased markedly. Production of slaughter pigs has increased from 15 million in 1980 to just over 20 million in 1995, i.e. an increase of approx. 33%. In terms of weight, however, production has increased by approx. 60% during the same period (*Figure 3.4.3*), while the total pig herd has only increased by 10%.

As a result of the EU milk quota scheme, total milk production has fallen from 5,117 million kg in 1980 to 4,676 million kg in 1995. During the same period, the average milk yield per dairy cow has increased by just under 40%. This has led to a marked reduction in the number of dairy cattle. The total cattle herd, which is dominated by diary cattle, has thus fallen by approx. 30% between 1980 and 1995 measured in livestock units.

Decreasing production in the cattle/dairy sector has also left its mark on crop distribution, see *Figure 3.4.7*. Because of the close correlation between production in the cattle/dairy sector and coarse fodder acreage, the share of agricultural land with grass has fallen from approx. 21% in 1980 to approx. 16% in 1995. The area with fodder beet has also fallen.

The share of agricultural land with cereals fell from approx. 63% in 1980 to approx. 53% in 1995. However, this encompasses both a 360% increase in winter cereals from 242,000 ha to 881,000 ha and a marked fall in spring cereals to 1/3 of that in 1980. In contrast, the area of rape has increased, although in

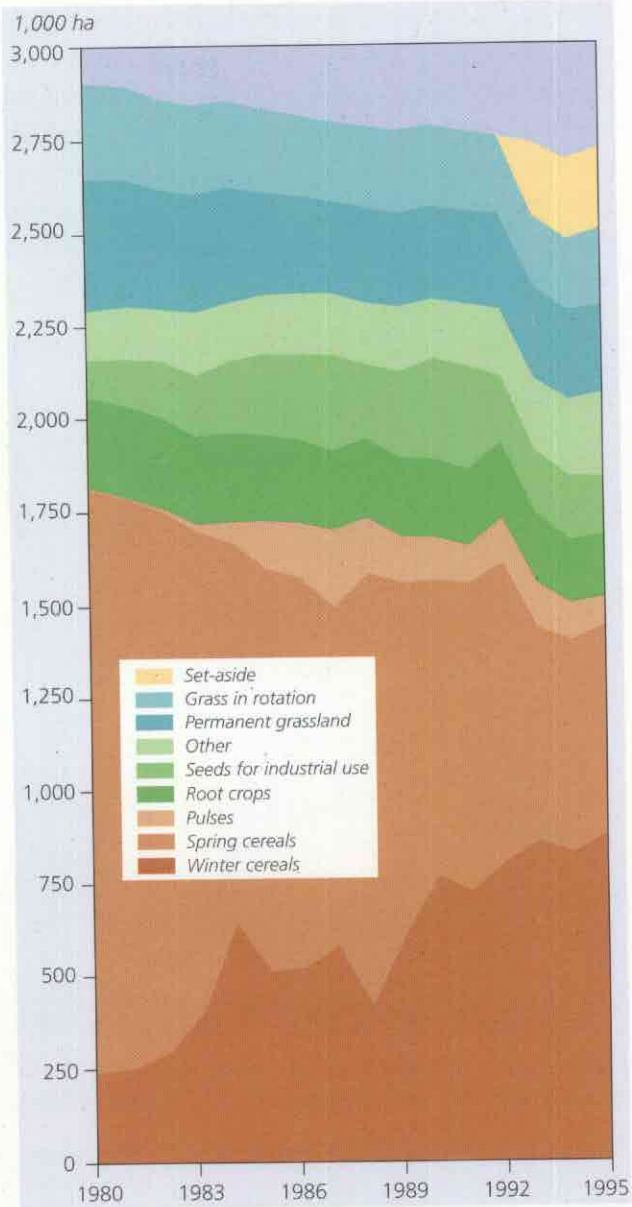


Figure 3.4.7 *Land use in agriculture (Source: Statistics Denmark, Agricultural Statistics, various years).*

this case too, the spring crop has largely been replaced by winter rape. In recent years, part of the rape has been cultivated as a non-food crop which, in accordance with the EU agricultural reform, may be grown on set-aside land. In 1995, the EU agricultural reform resulted in just over 9% of the agricultural area being set aside. Of this, 1% was accounted for by non-food rape, 1% by grass in rotation and 7% by permanent grassland.

The increasing specialization has also led to a regionalization of production which primarily reflects the economically/technologically most expedient production on the various soil types. For example, grass is the economically most expedient form of production on the sandy soils while cash crops are the most expedient on the clayey soils. As a consequence, cattle density is higher on the sandy soils in western Denmark, see *Figure 3.4.8*. On the other hand, cash crops, as represented here by winter cereals, are concentrated on the clayey soils of eastern Jutland and the island part of Denmark, see *Figure 3.4.9*. Pig production, which is characteristically independent of the type of land and crop, tends to be more dispersed, although with a heavy concentration in western Denmark.

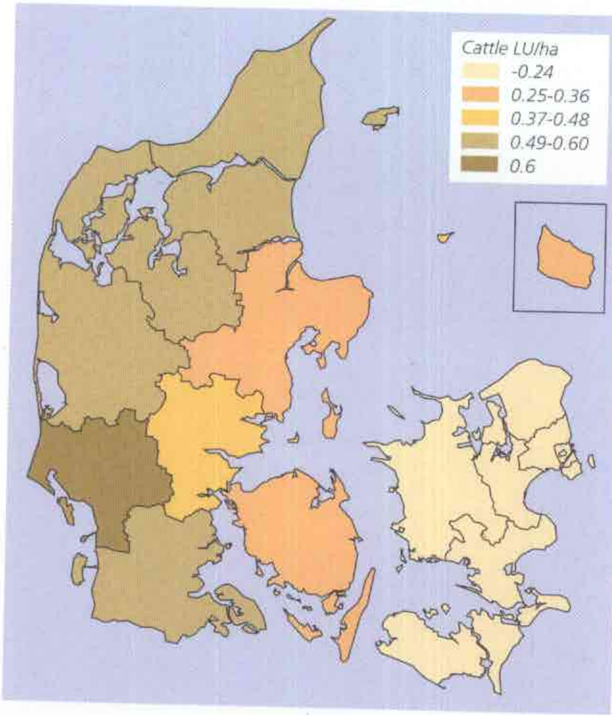


Figure 3.4.8 *Cattle density in livestock units (LU) per ha agricultural area in 1995 (Source: Statistics Denmark, 1996a).*

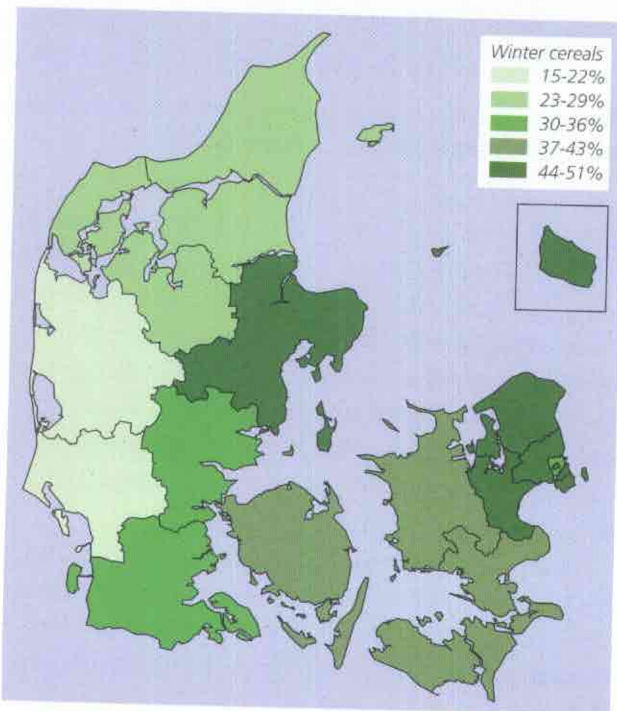


Figure 3.4.9 *Area of winter cereals expressed as a percentage of agricultural area in 1995 (Source: Statistics Denmark, 1996a).*

The increasing specialization and regionalization of agricultural production has a number of geographical effects. In certain areas of the country, there are farms which produce more livestock manure than can lawfully be applied to the farm's land according to livestock density limits. This is particularly the case with pig holdings, almost half of which produced more livestock manure in 1995 than could be disposed of on their own land.

Conversely, there are crop farms without livestock herds where no livestock manure is ever applied to the land. This might have a significant impact on soil quality in the long run because the carbon content of the soil will decrease, cf. *Section 2.3.3* on the terrestrial environment. Finally, the concentration of cattle farms in the western part of the country entails a loss of extensively managed grazing areas in the eastern part of the country.

Livestock density problems, especially in the pig sector, will worsen in the future, partly because of the expected increase in production and partly because of more stringent livestock density limits pursuant to the EU Nitrates Directive. A consequence might be that the pig farms purchase land from other agricultural sectors, thereby reducing agricultural diversity.

Organic farming

The number of organic farms has increased during the period examined. One of the characteristics of these farms is that pesticides and commercial fertilizers are not used. Despite the increase, the number of organic farms is still negligible. In 1996, there were thus only 1,166 organic farms corresponding to 1.8% of all farms.

The average organic farm has roughly the same amount of land as the conventional farms. Land use on the converted land differs markedly from that on the rest of the agricultural land, however (*Figure 3.4.10*), this being attributable to the fact that the organic farms are mainly cattle farms. The most obvious difference is the relatively small area with cereals and the large area with grass and green fodder.

The large area with grass and green fodder correlates with the large cattle herd, 84% of the livestock expressed in livestock units being accounted for by cattle herds, see *Figure 3.4.11*. Compared with conventional farms, the number of pigs is negligible.

In addition, there is a larger share of poultry in the form of laying hens. Taken together, 83% of the organic farms have livestock herds as compared with only 70% of all farms.

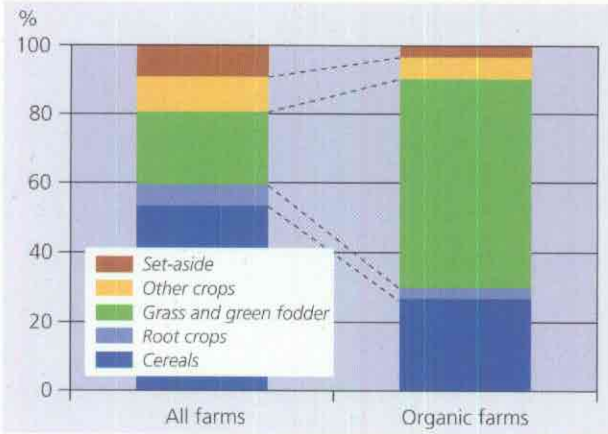


Figure 3.4.10 Land use on all farms and organic farms (Source: Statistics Denmark, 1996a). Note: Land use in the case of organic farms exclusively encompasses areas actually converted to organic farming.

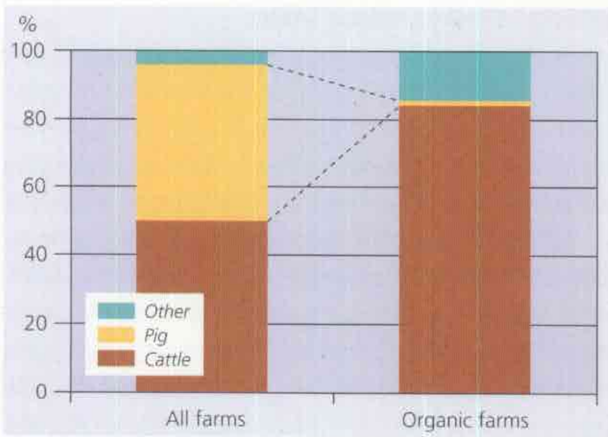


Figure 3.4.11 Livestock distribution by type of farm (Source: Plant Directorate, 1995). Note: Livestock distribution in the case of organic farms exclusively encompasses herds actually converted to organic farming.

Environmental pressures from agriculture

The effects of agriculture on nature and the environment are attributable both to cultivation of the soil *per se* and to the use of various auxiliary substances in production. From the environmental point of view, the focus is mainly on the use of the nutrients nitrogen and phosphorus, the use of pesticides and the emission of greenhouse gasses. The interventions of a more physical nature such as drainage, watercourse channelization, extension of field size, elimination of hedges and boundaries, etc. are also of great significance for the quality of nature and the environment. In addition, the geographic specialization of agriculture has local effects and generally reduces the diversity of the modern landscape.

Development in agricultural use of fertilizers

Nitrogen

Despite the fact that the agricultural area is falling slightly, the agricultural sector has managed to increase crop production by just over 2% per year, see *Figure 3.4.3*. This is despite the fact that nitrogen consumption in the form of commercial fertilizer per hectare (excl. set-aside land) was stagnant at the beginning of the period and decreased at the end of the period, see *Figure 3.4.12*. As the ratio between the price of agricultural products and nitrogen fertilizer has been decreasing for most of the period, the economically optimal fertilization level per crop has been displaced to a lower level. This is particularly

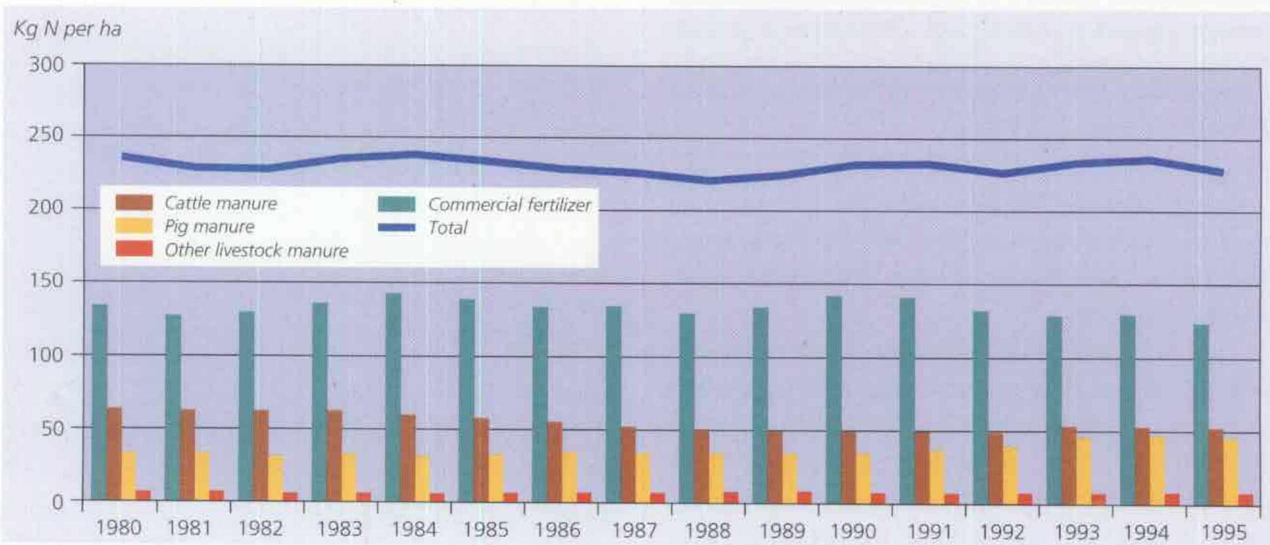


Figure 3.4.12 Nitrogen input per ha apportioned as commercial fertilizer and livestock manure ex store (Source: National Environmental Research Institute, internal calculations).
Note: The agricultural area excludes land set aside as grassland.

the case during the last few years, during which the EU agricultural reform has reduced the guaranteed price for cereals, etc.

For the agricultural sector as a whole, the amount of nitrogen in livestock manure fell during the first part of the period as a result of falling production in the cattle sector. In the 1990s, the amount of nitrogen in livestock manure increased as a result of increasing production in the pig sector. On the whole, the total amount of nitrogen applied per hectare has remained roughly constant during the period.

That the agricultural sector has nevertheless been able to increase crop production during the period is among other things due to better utilization of the nitrogen content of livestock manure. The utilization efficiency of nitrogen in livestock manure has thus increased by 20-25 percentage points between 1985 and 1995, see *Figure 3.4.13.*

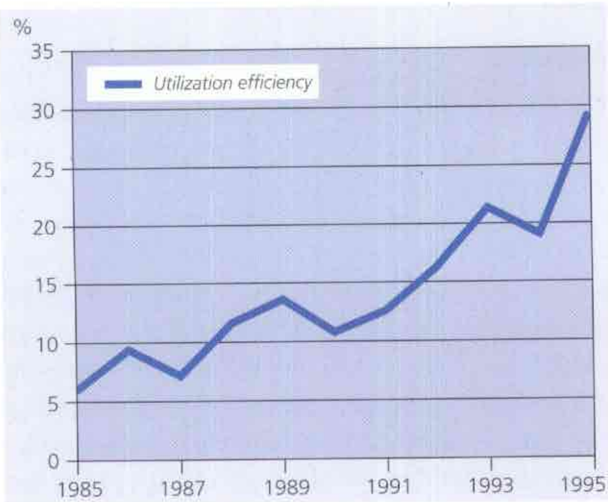


Figure 3.4.13 *Utilization efficiency for the nitrogen content of livestock manure (Source: National Environmental Research Institute, internal calculations). Note: The utilization efficiency of N in livestock manure is calculated as N fertilization norm less commercial fertilizer N applied divided by the total N content of the livestock manure applied.*

The estimated utilization efficiency is dependent on the estimation method used, and the level should therefore be viewed with caution. The trend is indisputable, however.

The improved utilization of livestock manure is primarily attributable to compliance with regulations on storage capacity, which has meant that a greater share of the livestock manure can be applied in the spring, when plant growth takes place. Storage capacity is thus sufficient to store 96% of all the livestock manure (expressed in livestock units) for 6 months and 72% for nine months, see *Figure 3.4.14.* In addition, developments in application technology

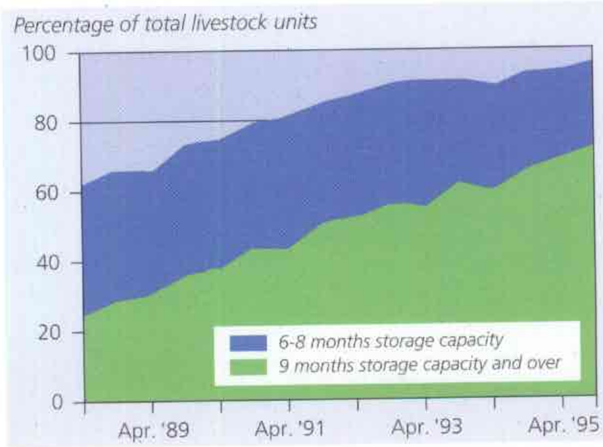


Figure 3.4.14 *Total livestock apportioned by manure storage capacity (Source: The Danish Farmers Union, various years).*

have made it possible to apply liquid manure to growing crops with the aid of trailing hoses, thereby minimizing ammonia volatilization.

Part of the increase in utilization efficiency is also due to the fact that a greater share of the livestock manure derives from pigs. This has a better 1st-year effect than cattle manure in that a higher percentage of the nitrogen in pig manure is in the form of ammonia.

Nitrogen loss from agricultural sources can be estimated from so-called field balances, where the difference between nitrogen input and removal is determined. Nitrogen balances are subject to a considerable degree of uncertainty, however. Nevertheless, the field balance shown in *Figure 3.4.15* clearly shows that the difference between nitrogen input and removal is narrowing.

The National Environmental Research Institute has calculated that leaching per hectare is lowest on crop farms, intermediate on cattle farms and highest

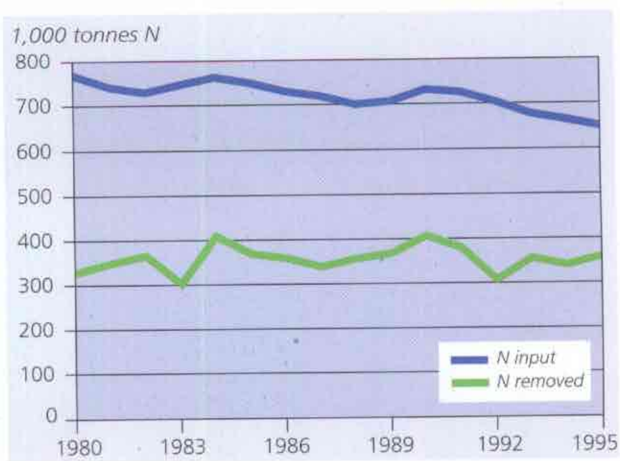


Figure 3.4.15 *Field balance for nitrogen input and removal (Source: Grant et al., 1996).Note: Nitrogen input is calculated as commercial fertilizer consumption + nitrogen fixation + deposition + excreted livestock manure - ammonia volatilization from livestock housing and manure stores.*

on pig farms. The difference in leaching mainly reflects the use of commercial fertilizer contra livestock manure since leaching has been shown to be greatest with livestock manure. Studies have also shown that considerable overfertilization takes place in areas where livestock manure is used. Moreover, the overfertilization increases with increasing livestock density.

In addition to nitrogen loss from fields, considerable loss takes place through ammonia volatilization from livestock housing and stores. *Figure 3.4.16*, which also includes ammonia volatilization associated with manure application, indicates that nitrogen loss by ammonia volatilization has decreased over the last 15 years although there has been an increase over the last 5 years due to increasing production in the pig sector.

In the latest report on the results of the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment (Grant et al., 1997), it was concluded that nitrogen leaching from agricultural land has been reduced since adoption of the Action Plan in 1987. Based on data from the fields in the agricultural catchment monitoring programme it has been calculated that leaching has decreased by approx. 17% between 1989/90 and 1995/96. However, it is concomitantly emphasized that no clear conclusion can be drawn from the measurements of watercourse nitrogen concentration during the period 1989-95 because climatic variations overshadow the changes caused by modified agricultural practice. Thus even when correcting for climatic variation, no clear reduction in watercourse nitrogen concentration can be detected during the period from the adoption of the Action Plan on the Aquatic Environment up to 1995. The delay between implementation of measures to reduce nitrogen loss until the effects can be measured in the aquatic environment can be considerable for certain types of soil due to the often long transport times for nitrogen underway from the root zone to watercourses and lakes. However, the results from 1996 indicate a reduction of 5-10% in the nitrogen concentration of watercourses draining clayey catchments over the last 4 years. In any event, the reduction that has taken place is far from the 50% reduction target stipulated in the Action Plan on the Aquatic Environment.

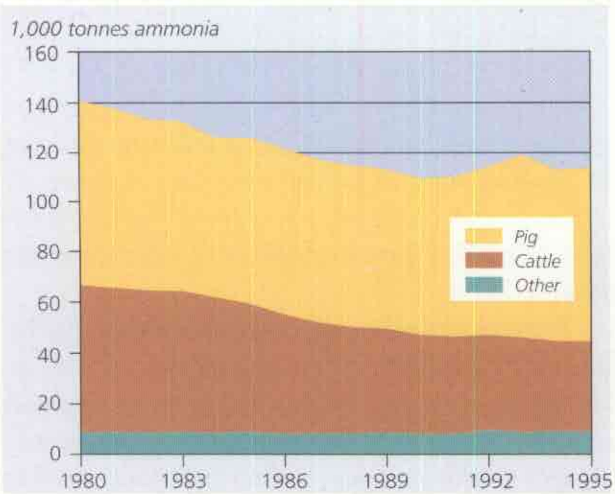


***Figure 3.4.16** Ammonia emissions from agriculture (Source: National Environmental Research Institute and Risø National Laboratory, data from CORINAIR database).*

Phosphorus

Consumption of phosphorus fertilizers has also fallen over the period, see *Figure 3.4.17*. The reduction is primarily attributable to a fall in the consumption of commercial phosphorus fertilizers, a fall that has sped up in the 1990s. The amount of phosphorus from livestock manure has been increasing, especially after

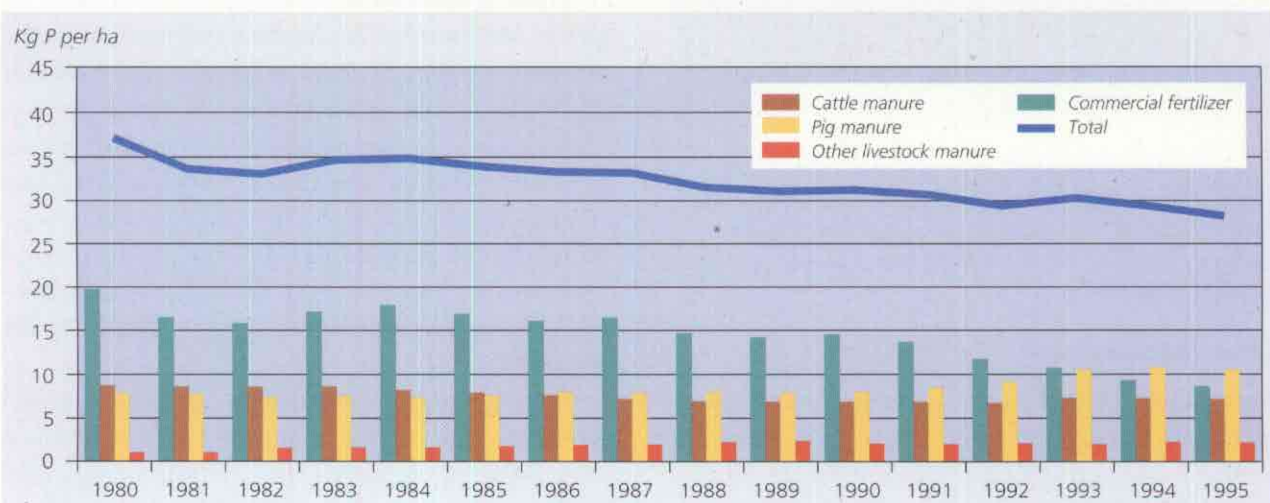


***Figure 3.4.17** Phosphorus input per ha apportioned as commercial fertilizer and livestock manure ex store (Source: National Environmental Research Institute, internal calculations). Note: The agricultural area excludes land set aside as grassland.*

1990, due to the increasing amount of pig manure being produced.

The field balance for phosphorus also shows narrowing of the difference between phosphorus input and removal, see *Figure 3.4.18*. Total inputs fell by approx. 37 million kg phosphorus between 1980 and 1995, corresponding to approx. 35%. The amount of phosphorus removed in the harvest fluctuated between 40 and 60 million tonnes phosphorus depending on crop mix and growth conditions. The poor harvest years in 1987 and 1992 are thus prominent. The narrowing of the ratio between phosphorus input and removal is of immediate benefit to the aquatic environment, but does not hinder continued leaching. Phosphorus normally binds to the soil, especially to clay particles. However, many years of overfertilization with phosphorus on some livestock farms has used up the soil's phosphorus-binding capacity. Phosphorus will thus be able to leach out of these soils, and continued over-fertilization with phosphorus will increase the risk of leaching. As phosphorus loading of our lakes is predominantly attributable to this diffuse source, cf. *Section 2.4.4* on the environmental state of lakes, the problem is attracting increasing attention.

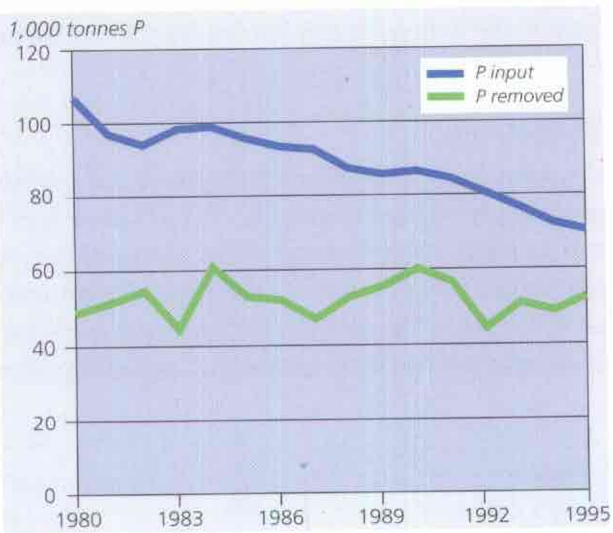


Figure 3.4.18 *Field balance for phosphorus input and removal (Source: Grant et al., 1996). Note: Phosphorus input is calculated as commercial fertilizer consumption + excreted livestock manure + bedding material. Phosphorus removal is calculated excluding vegetables.*

Greenhouse gasses

Agricultural production also contributes to emissions of greenhouse gasses in the form of carbon dioxide, methane and nitrous oxide, with methane and nitrous oxide accounting for the main share when expressed in terms of CO_2 equivalents, see *Figure 3.4.19*. Average greenhouse gas emissions during the period

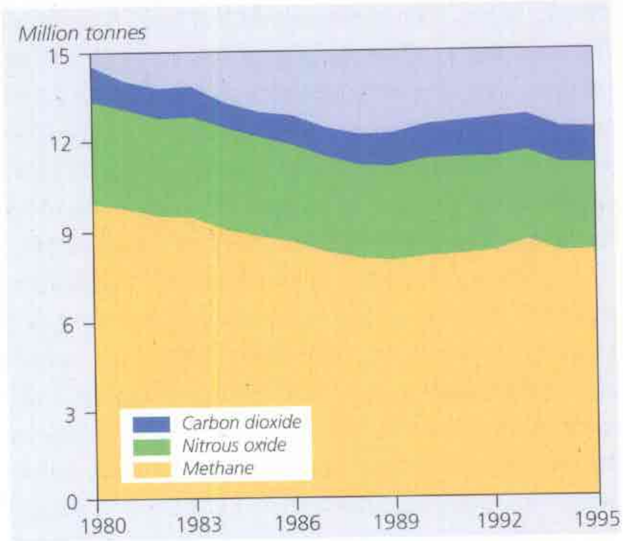


Figure 3.4.19 *Agricultural emissions of greenhouse gasses expressed in CO_2 equivalents (Source: Fenger et al., 1990; National Environmental Research Institute, internal calculations). Note: Calculated with Global Warming Potential (GWP) weighted for 100-year time horizon. CO_2 emissions are estimated at 1.2 million tonnes in the years 1993-95.*

totalled 12.9 million tonnes CO_2 equivalents per year. In comparison, total Danish emissions of carbon dioxide, methane and nitrous oxide are estimated to have been 71.6 million tonnes CO_2 equivalents in 1995.

The emitted carbon dioxide in the above calculations derives solely from the agricultural sector's consumption of energy. If one also includes the CO_2 emitted during manufacture of the auxiliary substances (primarily commercial fertilizers) used in agricultural production, the figure would be more than twice as great, with the production of commercial fertilizer accounting for the main part.

The methane emissions derive partly from the digestive processes in the livestock and partly from the decomposition of livestock manure under anaerobic conditions (e.g. in slurry tanks). The size of the livestock herd is the dominant factor of importance for methane emissions, and the fall in the total number of cattle during the first half of the period was accompanied by a corresponding fall in methane emissions. In the 1990s, emissions of methane are increasing again as a result of increasing production in the pig sector.

The nitrous oxide emissions result from microbial degradation of organic matter in the soil, which is stimulated by the application of both commercial fertilizer and livestock manure. The trend in emissions thus follows the slowly decreasing consumption of commercial and animal fertilizers.

Development in pesticide use

The use of pesticides to combat weeds, fungi and pests has become widespread in modern crop farming. Development in the use of pesticides expressed in terms of the amount of active substance and the application frequency is examined in *Section 2.5* on environmentally hazardous substances.

From there it is apparent that the use of pesticides has been reduced markedly over the last 10 years expressed in terms of the amount of active substance. If one examines the application frequency, however, which is an expression of the efficacy of the pesticides, there is no evidence of any clear decline and the figures are far from the targets stipulated in the Action Plan on Pesticides.

One of the reasons for this is the increasing replacement of spring cereals by winter cereals, which among other things are sprayed more intensively to prevent the formation of lodged grain and the overwintering of plant diseases. In 1994, winter cereals were thus sprayed 2.85 times and spring cereals 1.72 times.

Another reason might lie with the choice of plant variety, where crop yield is weighed against the plants' resistance to fungal diseases and lodged grain. Crop yield seems to have been the dominant selection criterion in recent years since sufficient amounts of strongly stemmed varieties of winter wheat and winter barley have been marketed to markedly reduce the use of growth regulators.

The reduction in pesticide consumption expressed in terms of the amount of active substance must be considered positive. However, because of the continued high application frequency, the pressure on the flora and fauna has not been reduced.

Development in nature content and landscape quality

As agricultural production commandeers just under 2/3 of the Danish land mass, it has a decisive influence on nature and landscape quality in the countryside.

Studies in the 1980s have shown that the nature content of arable land has become increasingly uniform and that there has been a general marked decline in the number of small biotopes in the countryside during the present century.

However, newer studies show that the number of biotopes such as coverts and small plantations has increased slightly in the last few years, especially in the western regions of the country. The amount of existing and newly planted hedgerow has also increased in the western part of the country over the period 1986-91, where hedges were replaced by multirowed hedgerows of broadleaved trees. During that period, 800 km of new hedgerow was planted annually. In the eastern part of the country, in contrast, the amount of hedgerow has declined, among other reasons due to field mergers and because the hedgerows are of less agricultural significance as there is less need for shelter.

The trend in field size is of significance for the amount of field boundaries and hence of significance for the wild flora and dispersal corridors for the wild animals. The extent of boundaries in the landscape is affected by the fact that the trend is towards larger farms with a greater area, among other means through the merger of farm properties and through renting land from other farmers. Over the period 1980-95, there was a marked reduction in the number of small farms (0-10 ha), see *Figure 3.4.5*. As hedgerows between farms are more stable than hedgerows between fields on the same farm, this development indicates a reduction in the number of these biotopes, cf. *Section 2.3.2*.

The extent and quality of the permanent grasslands is also of significance for nature quality in the countryside. The total area of permanent grassland has decreased from 252,000 ha in 1980 to 207,000 ha in 1995. If set-aside land with permanent grass is included, the total area of grassland actually increased to 398,000 ha in 1995.

The quality of nature on set-aside land and permanent grasslands differs markedly in character, among other things because conditions for the perennial herbs that characterize permanent grass on meadows and dry grasslands with a relatively long history of cultivation differ from conditions on set-aside fields. In addition to cultivational history, the differences are also attributable to the fact that set-aside land must not be grazed, the grass having instead to be cut. In addition, the significance of set-aside land for the nature quality in the countryside is declining since the set-aside scheme is being phased out.

As a supplement to land use, population development in the wild species found on or associated with arable land can be used as indicators of the trend in the quality of nature in the countryside. This development has been described in detail in *Section 2.3.2*, the general picture being one of deteriorating species diversity in the countryside as a result of fragmentation of the landscape and consequent isolation and segregation of biotopes.

Future perspectives for agriculture and the environment

Based on the hitherto structural development in agriculture, the Danish Farmers Union has prepared a scenario for the development of Danish agriculture up to the year 2005.

This scenario is considered to be an appropriate foundation for estimating the environmental effects that we can expect in the future.

Agricultural development up to the year 2005

The development observed from the 1970s until today as described above is expected to continue unless agricultural or environmental policy initiates regulatory measures that change this development.

The number of farm holdings is expected to decrease markedly from 76,000 in 1990 to 48,000 in 2005, whereby the average farm size will increase from 36 ha in 1990 to 53 ha in 2005. The reduction in the number of farms is expected to take place among the small farms through farm mergers, but also through the conversion of farmland to urban or other uses. Thus the total agricultural area can be expected to decrease by 200,000 ha from 1990 to 2005.

Future land use is expected to stabilize around the current distribution between spring and winter cereals. The area of coarse fodder is expected to fall as a result of the continued decline in the number of cattle farms. A marked increase in production can be expected in the pig sector. This will take place through a continued increase in productivity in that the number of slaughter pigs produced per sow is expected to increase from 17 in 1990 to approx. 22 in 2005. In all, annual production is expected to increase from approx. 16 million slaughter pigs in 1990 to 22 million in 2005. The size of the herds is also expected to increase markedly.

In contrast, the total number of cattle is expected to decrease up to the year 2005. The number of dairy cattle, which has already decreased markedly, is expected to decrease further from approx. 750,000 head in 1990 to just under 600,000 head in 2005. The size of the herds, i.e. the number of diary cows per farm, is expected to increase from an average of 34 in 1990 to 81 in 2005.

The hitherto structural development with respect to regional distribution of the total cattle herd is expected to continue unless it is regulated. The share of the total cattle herd accounted for by the western counties (Ribe, Ringkjøbing and Sønderjylland) will thus continue to increase.

Estimated environmental effects up to the year 2005

The reduction in the total agricultural area and the increasing total size of the pig and cattle herds will increase the amount of livestock manure produced per hectare because herd size will increase more than the increase in farm size. As a result, growing regional problems may arise as to compliance with current livestock density limits and the EU Nitrates Directive, cf. *Box 3.4.1* as this is already a problem in regions with high livestock density.

In order to comply with these requirements limiting how much livestock manure may be applied per hectare farmland in the regions with high livestock density, it will be necessary to transport excess livestock manure outside the regions. This is expensive because of the high transport costs. The current Agricultural Holdings Act limits the possibilities to redistribute livestock manure between farms and therefore also limits redistribution between regions. An alternative to redistribution is to improve utilization of the nutrient content of livestock feed, thereby reducing the nutrient content of the manure to the necessary extent.

Based on the forecast development in agriculture, it has been calculated that the difference between nitrogen input and removal per hectare cultivated land (i.e. the nitrogen surplus) will increase from a national average of 116 kg N per ha to 119 kg N per ha between 1995 and 2005. There is thus a risk that the positive trend so far with narrowing of the nitrogen surplus could turn in a negative direction. The calculations cover over major regional differences, however.

The reduction in the area of coarse fodder crops to the benefit of cereals and rape could entail increased consumption of pesticides. In addition, the reduction in the number of farms within each of the production sectors could lead to an increasingly uniform landscape as field size can be expected to increase with this trend.

Objectives and policy measures

A number of initiatives have been initiated in the agricultural area, including action plans and legislation that aim to reduce the negative impacts of agricultural production on the aquatic and terrestrial environments.

In recent years, measures have also been implemented that aim to regulate agricultural land use so as to promote consideration for landscape and nature quality. A number of these initiatives derive from national initiatives, e.g. the Action Plan on the Aquatic Environment, the Action Plan on Pesticides and the Action Plan for Sustainable Agriculture, while others comprise follow-up on EU Directives and accompanying measures associated with the 1992 EU agricultural reform.

Nutrients

Since 1986, a number of measures have been implemented to reduce nitrogen loss from agricultural sources. These efforts are primarily directed against livestock manure application practices and utilization of the manure nitrogen content, as indicated in *Box 3.4.1*.

Action plan/ initiative	Objectives, targets and description
NPo Action Plan (1986)	**Objective:** The NPo Action Plan aimed to reduce pollution with nutrients and organic matter. **Regulatory instruments:** Prohibitions/injunctions, consultancy, enhanced research efforts (NPo Research Programme). **Measures:** Minimum of 6 months storage capacity for livestock manure, ban on manure application from harvest to 15 October/1 November, ban on manure application on frozen soil, obligatory incorporation of manure within 24 hrs, livestock density limits (2 LU per ha), and subsidies in connection with improvement of storage capacity.
Action Plan on the Aquatic Environment (1987)	**Objective:** The Action Plan on the Aquatic Environment aims to reduce nitrogen losses from agricultural sources from 260,000 tonnes N/yr to 133,000 tonnes N/yr and phosphorus losses by 4,000 tonnes before 1993. **Regulatory instruments:** Prohibitions/injunctions, consultancy, monitoring of the state of the environment and agricultural practice (Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment). **Measures:** Storage capacity requirements (9 months, dispensation down to 6 months), obligatory crop rotation and fertilization plans, 65% green cover, obligatory incorporation of manure within 12 hours, livestock density limits (1.7 LU per ha for pig farms, 2.3 LU per ha for cattle farms and 2.0 LU per ha for other farms), obligatory manure redistribution agreements when manure production exceeds livestock density limits.
Action Plan for Sustainable Agriculture (1991)	**Objective:** The Action Plan for Sustainable Agriculture reiterates the objectives of the Action Plan on the Aquatic Environment but extends the deadline to the year 2000. **Regulatory instruments:** Prohibitions/injunctions and consultancy. **Measures:** Obligatory crop rotation and fertilization plans, obligatory fertilization budgets, minimum requirements on exploitation of N content of livestock manure (pig slurry: 45% by 1993, 50% by 1997; cattle slurry: 40% by 1993, 45% by 1997; solid cattle manure: 15% by 1995; other manure: 30% in 1993, 35% in 1994, 40% in 1997). Storage capacity: Sufficient to ensure compliance with manure N content utilization requirements, minimum 9 months, before the end of 1994. Ban on application of livestock manure in the autumn for crops other than winter rape and overwintering grass. Livestock manure to be applied to growing crops or incorporated immediately. Fertilization budget requirements: Tightened in 1996 such that expected yield and manure N content have to be calculated on the basis of norms.
Nitrates Directive (1991)	From 1999: Max. 170 kg N per ha in the form of livestock manure. Livestock density limits for cattle farms to be tightened in order to comply with the Directive. Implemented through revision of the Danish Statutory Order on Livestock Farms, Livestock Manure, Silage, etc.
Agricultural Holdings Act (1994)	Stipulates rules for maximum livestock herd size on each individual farm property as well as requirements as to how much land livestock farms have to own depending on the size of the herd.

Box 3.4.1 *Initiatives directed at nutrient loss from agricultural sources (Source: Hasler, 1997).*

The reduction in the total agricultural nitrogen surplus seen over the period 1990-95 (see *Figure 3.4.15*) must be considered a positive development.

However, based on the results of the Nationwide Monitoring Programme, the National Environmental Research Institute (NERI) concludes that the nitrogen concentrations in the open marine waters have not changed during the period since the adoption of the Action Plan and associated regulations. In contrast, a decrease has been detected in the phosphorus concentration in many marine waters.

NERI and the Danish Institute of Agricultural and Fisheries Economics (DIAFE) have used NERI's nitrogen-phosphorus model and DIAFE's sector model to calculate the effects of implementing the requirements stipulated in the current environmental action plans and the EU agricultural reform.

The effects have been calculated with respect to both nitrogen leaching from the root zone and nitrogen loading of the inner Danish marine waters (defined as input to the coastal waters). The latter is calculated to have been reduced by 14% relative to 1989. This is accounted for roughly equally by reduced use of commercial fertilizer, increased utilization of the nitrogen content of livestock manure, set-aside and the reduction in the total amount of agricultural land.

Moreover, using leaching functions and data from the agricultural catchment monitoring programme, NERI has calculated that leaching from the root zone has been reduced by 17% as a result of the measures implemented. Assuming fulfilment of all current requirements it has been calculated that it will be possible to reduce nitrogen leaching by approx. 32%.

As the overall goal of the Action Plan on the Aquatic Environment with respect to nitrogen is to reduce leaching from the root zone by half to 130,000 tonnes N per year, the calculations indicate that the objective cannot be attained with the measures required under the current action plans and the agricultural policy conditions in the 1992 EU agricultural reform. This conclusion is reinforced by the fact that the calculations underestimate leaching as compared with measured values.

One of the reasons why the target has not been met is that the requirements on utilization of the nitrogen content of livestock manure have not been fulfilled. Previous calculations by the Plant Directorate showed that the utilization percentage reported by farmers in their fertilization accounts was too high, and the regulations were therefore tightened in 1996. The above mentioned calculations do not encompass the latest revisions of the regulation.

That there is still a relatively long way to go before the target is reached is therefore partly attributable to lack of compliance with the existing requirements, and partly to the fact that these are insufficient to ensure attainment of the reduction target. The situation is made worse by the rapid development in pig production.

In connection with negotiations on the 1998 Government Budget, a framework agreement was entered into aimed at ensuring fulfilment of the 50% reduction in nitrogen loss from agricultural sources stipulated in the Action Plan on the Aquatic Environment.

The agreement, known as the Action Plan on the Aquatic Environment II, includes such measures as more stringent requirements on utilization of the nitrogen content of livestock manure, tightened nitrogen fertilization norms and tightened livestock density limits, as well as afforestation and wetland reestablishment programmes. In addition, a fertilization quota exceedence levy has been imposed.

Pesticides

As with nitrogen, objectives and action plans have also been drawn up on the pesticide front. These are summarized in *Box 3.4.2*. As is apparent from *Section 2.5.4*, the majority of these measures have been implemented. The use of a large number of pesticides has been prohibited and the amount of active substance used by the agricultural sector has fallen markedly. Expressed in terms of treatment frequency, however, there has not been any marked decrease in pesticide pressure on the environment. The 1998 Government Budget includes a number of measures to strengthen efforts on the pesticide front, see *Box 3.4.2*.

Agri-environmental measures

In addition to the objectives and requirements stipulated in the Action Plans on Pesticides and the Aquatic Environment, a number of measures with environmental objectives have been introduced in connection with the EU common agricultural policy which can help reduce the environmental impact of agriculture. These so-called agri-environmental measures and the current extent to which they have been implemented are summarized in *Table 3.4.1*.

The county authorities are responsible for designating the Environmentally Sensitive Areas (ESAs)

Action plan/ initiative	Objectives, targets, deadlines and description
Pesticide Action Plan (1986)	**Objective:** The Pesticide Action Plan aims to halve consumption of pesticides before the end of 1996 relative to average consumption in 1981-85. This applies to both treatment frequency and the amount of active substance sold. **Regulatory instruments:** Voluntary reductions in accordance with the objective, consultancy. In addition to the recommendations in the Action Plan, a number of initiatives were introduced in the 1990s to support fulfilment of the Plan's objectives: • Subsidies for pesticide-free border zones in Environmentally Sensitive Areas (ESAs). • The Chemical Substances and Products Act (amendment of 1993) prohibits selected pesticides considered particularly harmful to health and the environment (cf. the 10-point Programme). The amendment is motivated partly by the detection of pesticides in groundwater etc., and partly by the EU Directive on Plant Protection Products. • Pesticide levy introduced as per 1 January 1996.
Action Plan for Sustainable Agriculture (1991)	**Objective:** The Action Plan reiterates the objectives of the Action Plan on Pesticides. **Regulatory instruments:** Voluntary participation and spot checks. **Measures:** Education and spraying plans.
Government's 10-point Programme for protection of the groundwater and drinking water *(Groundwater Strategy, 1994).*	The 10-point Programme (points of significance for pesticide use): • Particularly environmentally harmful pesticides to be banned. • Organic farming to be promoted. • Particularly vulnerable groundwater abstraction areas to be protected. • Improved monitoring of groundwater and drinking water.
Government Budget (1998)	• Doubling of the pesticide levy. • Strengthening of the approval scheme. • Phase-out of the use of pesticides on public land and private gardens. • Possibilities for introducing cultivation restrictions in Environmentally Sensitive Areas.

Box 3.4.2 *Action Plan on Pesticides - objectives and regulatory instruments (Source: Ministry of Environment, 1986; Ministry of Agriculture, 1991; Ministry of Environment and Energy, 1994).*

Agri-environmental measure	Area
Reduction of nitrogen fertilization levels to 60% of norm	5,000 ha
Upkeep of grasslands	Approx. 40,000 ha
Undersowing of cereals with rye-grass	1,600 ha
20-year set-aside of land. Limited to Viborg, Aarhus and Nordjylland counties.	Negligible
Conversion to organic farming (not just in ESAs)	31,750 ha

Table 3.4.1 *Overview of agri-environmental measures (Source: Danish Directorate for Development, 1996).*

where funds can be provided to support conversion to environmentally sound agricultural practices. The ESAs so far designated total approx. 350,000 ha.

As shown in *Table 3.4.1*, however, agreements on conversion to environmentally sound agricultural practices have only been made for 13% of this area, the majority of which involves the grassland upkeep schemes.

3.4.3 Forestry

Development in forestry

Forestry differs markedly from the other forms of rural production because of its long crop rotation times, which can range from approx. 8 years for Christmas tree production to approx. 60 years for conifer production to around 150 years for oak production.

From *Figure 3.4.20* it can be seen that the increase in forest area over the last 100 years is attributable to an increase in the area of conifer forest. As a consequence, approximately 2/3 of the total forest area is conifer forest while only approx. 1/3 is broadleaved forest. The area planted with Christmas trees and ornamental greenery has increased from a negligible share in 1976 to approx. 4% in 1990.

Expressed in terms of growing stock, the conifer forests account for approx. 31 million m^3 (57%) and the broadleaved forests for approx. 24 million m^3 (43%) out of a total of 55 million m^3.

By far the majority of the conifer forest is located in Jutland (81%), while the majority of the broadleaved forest is located on the island part of Denmark (57%).

There can be considerable variation from one county to another, however, see *Figure 3.4.21*. The percentage of forest in the individual counties also varies, ranging from just under 7% in Sønderjylland county to just under 17% in Bornholm county. As is apparent from *Figure 3.4.22*, a very large part of forestry income derives from ornamental greenery and secondary production (hunting rights, etc.).

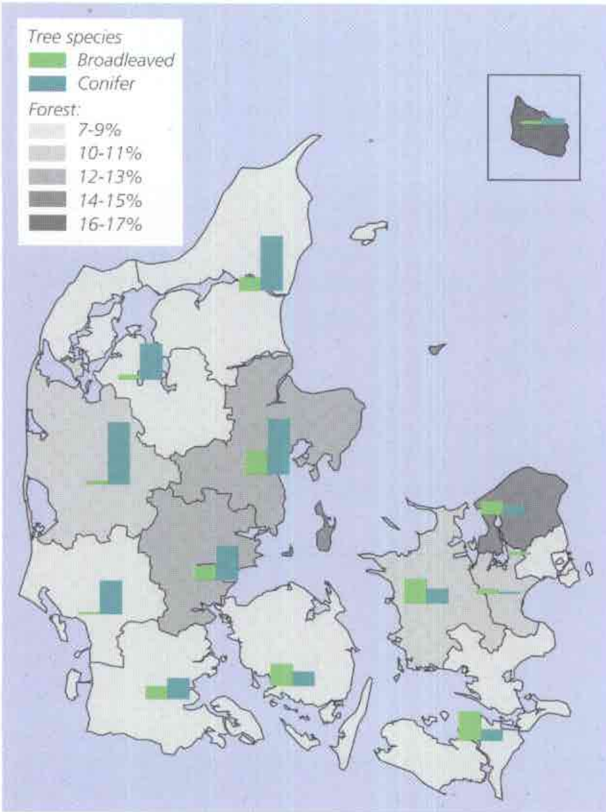


Figure 3.4.21 *Forest area apportioned by county and forest type (Source: Statistics Denmark, National Forest and Nature Agency and Ministry of Environment and Energy, 1994).*

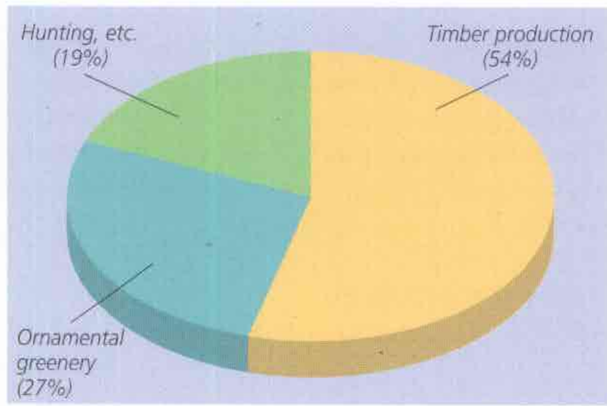


Figure 3.4.22 *Forestry gross margin apportioned as timber production, ornamental greenery and hunting, etc. (Source: Danish Forest Association, 1994). Note: Hunting, etc. encompasses all forms of by-production.*

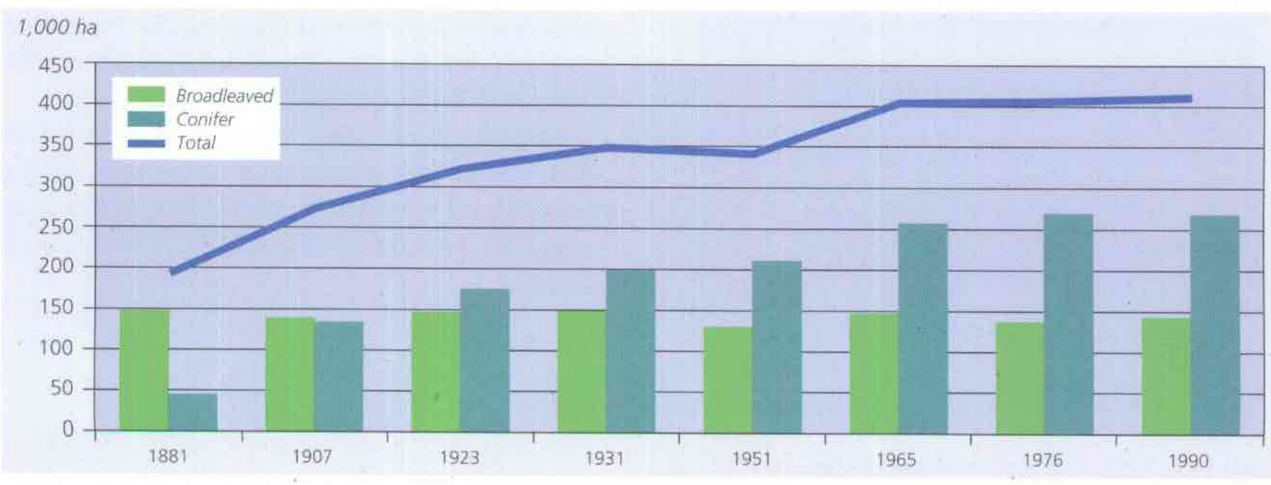


Figure 3.4.20 *Development in total, broadleaved and conifer forest area (Source: Statistics Denmark, 1996b).*

Fellings and net annual increment

Felling volume over the last 15 years is shown in *Figure 3.4.23* and can be seen to average around 2 million m^3 per year except in the first few years following major storm damage at the beginning of the 1980s, when felling volume was considerably higher.

Approximately 1/3 of the fellings is hardwood from broadleaved forests while 2/3 is softwood from conifer forests. Danish production of wood accounts for just under 30% of consumption, with the rest being imported. The majority of the imported wood comes from the other Nordic countries.

The share of timber in the fellings has been falling while the share of wood for fuel has increased correspondingly. This is due to increased felling of broadleaved trees for firewood that was initiated in the 1970s as a result of increasing oil prices, as well as to the production of fuel wood chips from conifers. As part of the 1993 Biomass Agreement and 1997 amendment, the power stations have to increase their use of fuel wood chips from forestry to approx. 200,000 tonnes per year.

In connection with the 1990 forest survey, the net annual increment was calculated to be 3.2 million m^3 total mass, of which 1.0 m^3 (30%) was hardwood and 2.2 million m^3 was softwood.

Even though the figures for net annual increment and felling are not immediately comparable because part of the increment must be deducted as unused wood that is left on the forest floor, *Figure 3.4.24* clearly shows that the growing stock is increasing. The increase is estimated to be of the order of 0.5-0.75 million m^3 per year. The majority of the increase is in the form of conifer and is due to the steady increase in forest area.

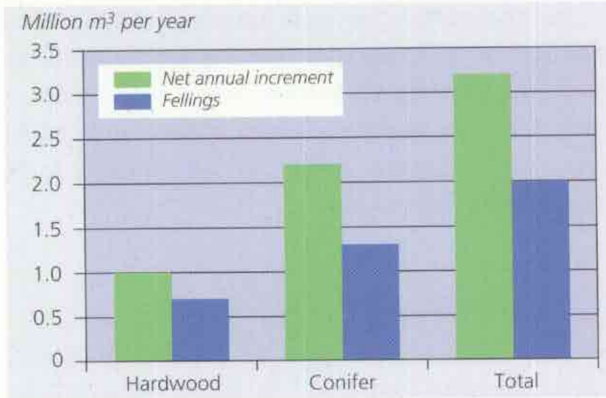


Figure 3.4.24 *Net annual increment and fellings in 1990 (Source: Statistics Denmark, National Forest and Nature Agency and Ministry of Environment and Energy, 1994).*

Silviculture systems

In Denmark, timber forest is the most common form of forestry. Timber forest entails that the forest is renewed by seeds or seedlings and is cultivated over a long time horizon in order to obtain closed stands of tall stemmed trees. Renewal of such stands can take place through clear-cutting and subsequent planting or through self-renewal. With clear-cutting, all the trees are felled at one time. With the other forms of forest management, however, felling is undertaken gradually over a number of years, which is considered to be a more gentle form of renewal.

Natural forests are of special interest with respect to preserving the biodiversity of Danish forests and preserving the gene pool. In Denmark, we operate with three categories of natural forest: Forest outside forestry (virgin forest), forest subject to special forestry practices, and original forest in forestal operation. The area of natural forest is estimated to be approx. 35,000 ha or 8% of the total forest area. Just under 80% of the area is privately owned.

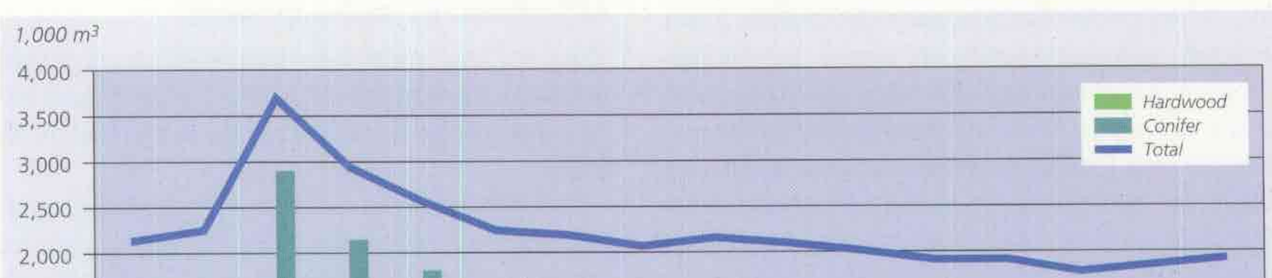


Figure 3.4.23 *Timber harvest over the period 1980-95 (Source: Statistics Denmark, Agricultural statistics, various years). Note: Wood chips included from 1984 onwards.*

The characteristic of virgin forest is that it is left free of all forestry practices from some point it its development. The area of private virgin forest in Denmark is estimated to be approx. 1,000 ha at present. In addition, a further approx. 3,500 ha in state forest is to be converted to virgin status.

Environmental aspects of forestry

For natural reasons, i.e. the long crop rotation times, forests are cultivated relatively extensively and the environmental impact of forestry is therefore minor. For example, the amount of pesticide used in forestry is limited and fertilization is only undertaken sporadically.

Consumption of pesticides in forestry is estimated to amount to 0.07 kg active substance per ha, as compared with 1.7 kg active substance per ha on arable land under crop rotation. Compared with other forms of land use, forestry therefore appears as an environmentally sound management form, and an increase in the forest area therefore makes a positive contribution to reducing the pressure on nature and the environment.

Landscape, flora and fauna

Forests generally have considerable landscape value. They enrich our experience of the landscape, endow it with variation, frame the open spaces in the landscape and provide it with perspective. On the other hand, though, forests can also block views and hide important features in the landscape. From the landscape point of view, broadleaved forests are often preferred.

The environmental state and biodiversity of forests are affected by forestry (e.g. choice of tree species, felling, drainage, fertilization, use of pesticides, forest structure, and the continuity of forestry). Key biological elements of natural forest ecosystems (e.g. wetlands, old/dying trees and dead wood) are important biotopes for a large number of forest organisms. These can be favoured by using forestry practices that ensure a closed forest climate over a very long time horizon (e.g. selective felling and self-renewal) and which create variation (e.g wetlands and clearings).

Groundwater

The groundwater under our forests is normally considered to be well protected. Groundwater formation is slightly less (approx. 5%) under forest than in the open countryside because the large leaf surface area of the tree crowns enables considerable evaporation to take place. Groundwater formation under conifer forest is less than under broadleaved forest due to the greater surface area of the leaves and because the needles are not shed in winter. Only small amounts of nitrogen usually leach from forests (0-5 kg per ha per year) compared with agricultural soils.

Studies indicate that the nitrogen content is significantly lower in groundwater under forests than under agricultural soils. Soil acidification processes in forests often render the water acidic depending on the natural buffering capacity of the soil. Acidification is greatest under conifers due to greater deposition of air-borne particles in conifers, more rapid growth and poorer metabolism with subsequent formation of organic acids.

CO_2 cycle

Considerable amounts of carbon are stored in trees. The forests are therefore a part of the global carbon balance as decomposition of trees releases CO_2. CO_2 can be stored by increasing the forest area. In forests, an average of 600 to 900 tonnes CO_2 per ha is stored during a tree generation. In addition to the trees, CO_2 is also stored in the organic matter in the forest floor and in the finished wood products. Moreover, when used as an energy source, wood can replace fossil fuels and hence limit the amount of CO_2 in circulation. In the long run, an equilibrium will be reached where the amount of CO_2 stored corresponds to the amount released.

Objectives and policy measures

There is a long tradition for sustainable management in Danish forestry as the Forestry Act has helped ensure that fellings do not exceed the net annual increment.

With the growing awareness of nature and environmental interests in the 1980s and 1990s, however, further focus has been placed on the ecological significance of forests. Increasing attention is also being given to the significance of forests with respect to recreation and outdoor life as forests attract a considerable part of the population to these activities, cf. *Section 3.8*.

Forest policy is thus characterized by three key objectives:

Strategy/ action plan/ law	Objectives and description
Goal of doubling the forest area, *(Forestry Act, Ministry of Environment, 1989 and Ministry of Environment and Energy, 1996)*	The objective is to double the forest area within one tree generation (80-100 years) from 12% to 25% of the Danish land mass. During the 1990s, the State has acquired approx. 750 ha annually for afforestation. Private afforestation amounted to approx. 1,200 ha annually, of which approx. 1,000 ha were not subsidized under the Forestry Act. Total afforestation thus amounted to approx. 2,500 ha annually.
Strategy for Danish natural forests and other forest types worth preserving, *(Natural Forest Strategy, National Forest and Nature Agency, 1992a)*	**The Natural Forest Strategy** is to be implemented over 50 years in three phases: 1. To safeguard original forest, oak coppices, grazing forest, coppice forest and primeval forest-like forests in the state forests. 2. By the year 2000: To ensure the existence of at least 5,000 ha of virgin forest, 4,000 ha of forest under traditional forestry practices, and the identification of special areas where forest biodiversity is to be preserved. 3. By the year 2040: To ensure the existence of at least 40,000 ha of original forest, virgin forest and forest managed by traditional forestry practices. A large part of the area will continue to be managed as ordinary diversified timber forest. Up to the end of 1996, almost 10,000 ha had been designated in state forests, of which 4,000 ha are to be allowed to revert to virgin forest and 5,500 ha are to be managed by selective felling or as grazing forest and coppice forest. Up to the end of 1996, management agreements had been entered into with private forest owners encompassing approx. 800 ha of virgin forest and approx. 950 ha managed by traditional forestry practices.
Strategy for the preservation of the tree and shrub biodiversity and gene pools, *(National Forest and Nature Agency, 1992b)*	**The Biodiversity and Gene Pool Strategy** concerns the tree and shrub species used as cultivated plants in Danish forests and landscapes. The objective is to preserve genetic variation. 1,800 ha have to be designated before the year 2004 and so far, areas have been designated in state forests. All state forests have been systematically examined, and potential populations for preserving the gene pool have been identified for 16 of the 39 shrub species encompassed by the strategy programme and the 18 species of broadleaved trees. As a combination between plant breeding and preservation, 29 *ex situ* populations of 18 species have either been established or propagated. The work is coordinated with other European countries in the EUFORGEN cooperation.
Strategy for Sustainable Forestry *(National Forest and Nature Agency, 1994)*	**The Strategy for Sustainable Forestry** is a step in the Danish follow-up on the 1992 Rio Conference. The strategy focuses on initiatives aimed at sustainable development of forests at both the national and international levels and on ensuring that economic and ecological sustainability go hand in hand. As a follow-up to the Strategy, the Government presented a position paper on an overall Danish forestry policy to Parliament in 1994. This encompassed the following central points: 1. The amount of forest is to be increased through state and private afforestation. 2. The possibilities for enhancing the contribution made by afforestation to the overall CO_2 budget are to be investigated. 3. The sale of forest products is to be promoted through subsidies for product development and increased use of wood chips as biofuel. 4. The quality of forests is to be enhanced through increased subsidies for broadleaved forest, nature management and traditional forestry practices and measures to improve forests. 5. Strengthening of research, dissemination of information and in-service training concerning sustainable forestry.
Forestry Act of 1989 with amendments of 1996 *(Ministry of Environment, 1989, and Ministry of Environment and Energy, 1996)*	**The Forestry Act** of 1989 aims to protect the Danish forests and increase the forest area. The Act stipulates that forestry has to be sound and diverse and that forestry's stability, productivity and property structure has to be improved. This objective is to be achieved through information and subsidies. Under the Forest Reserve Order of 1805 and the Forestry Act, approx. 90% of Danish forest is permanently protected as forest and its sustainable exploitation ensured. In **the 1996 amendment** of the Forestry Act, emphasis was placed on the intangible and ecological values of forests as a consequence of national and international strategies. This objective is to be achieved through a number of new subsidy schemes aimed at: 1. Improving the stability of forests. 2. Improving the long-term productivity and health of forests. 3. Supporting the biological diversity of forests and contributing to the establishment of new forests.

Box 3.4.3 *Forestry strategies, action plans, laws and objectives.*

- To enhance and improve wood production.
- To enhance the ecological values and biodiversity associated with forests through operational strategies that pay due consideration to these objectives. These include the Natural Forest Strategy and the Biodiversity and Gene Pool Strategy.
- To reduce the general pressure of society on nature and the environment through the plan to double the forest area within a tree generation.

While the latter objective in particular might seem ambitious, the forest area has in fact increased at the same relative rate over the last two centuries, having doubled twice from approx. 3% at the time the Forest Reserve Order was passed in 1805 to approx. 12% today.

Whether or not the forest area doubles again depends on developments within both forestal and agricultural production. The afforestation hitherto undertaken has mainly been on heath and other agriculturally unproductive areas. In contrast, the afforestation now being undertaken is on arable land taken out of agricultural production, and will therefore depend on the relationship between economic conditions in forestry and in agriculture. Particularly high priority is being accorded to afforestation in the vicinity of urban areas.

A doubling of the forest area within the course of a tree generation will necessitate average afforestation of approx. 5,000 ha per year. In comparison, average afforestation in the first part of the 1990s amounted to approx. 2,500 ha per year. Afforestation is expected to increase in the coming years, however, as a result of improved possibilities for support.

The environmental consequences of increasing the forest area by approx. 5,000 ha per year can be roughly estimated as follows: If felling volume is assumed to increase by 1% per year, the growing stock will increase, but the rate of increase will decline in step with the increase in felling. In the first decade, the surplus growing stock will be 9.7 million m^3, increasing to 12.9 million m^3 over the period 2010-2020. In the period 2030-2040, however, the surplus will fall to 9.5 million m^3. The environmental effects of this course of events should be seen in relation to the fact that it is agricultural land that is being converted to forest.

If leaching of nitrogen and phosphorus from forests is assumed to be 2 kg N per ha and 0.05 kg P per ha, respectively, and corresponding leaching from agricultural soils is taken to be 80 kg N per ha and 0.3 kg P per ha, respectively, doubling the forest area will reduce total annual nutrient leaching by 32,500 tonnes nitrogen and 104 tonnes phosphorus. In relation to the Action Plan on the Aquatic Environment this corresponds to 26% of the reduction target for nitrogen losses from agricultural sources and just under 3% of that for phosphorus.

Based on pesticide use by agriculture in 1994, consumption of active substances amounts to 1.72 kg per ha. Assuming that pesticide consumption in forestry amounts to 0.07 kg active substance per ha, doubling the forest area will reduce total pesticide consumption by 688 tonnes active substance. This reduction corresponds to 18% of agricultural consumption of pesticide active substance in crop production.

Danish calculations show that if the forest area is doubled evenly over the course of a tree generation, 305 million tonnes CO_2 will be stored in the wood within 150 years corresponding to permanent annual storage of 2 million tonnes CO_2. In comparison, total Danish emissions of CO_2 in 1995 amounted to just under 60 million tonnes.

3.4.4 Fishery

Development in fishery

Around 1.5-2 million tonnes of fish and shellfish are caught annually in Danish marine waters - the North Sea, the Skagerrak, the Kattegat, the Belt Seas and the Baltic Sea. The fishery sector employs approx. 20,000 persons with catching, farming, processing and selling fish. In many parts of the country, fishery is of great economic significance.

Fishery has a considerable impact on the marine ecosystem, especially on the commercial fish species. At the same time, the overall environmental quality of our fish waters is of considerable importance for fishery.

The term "sustainable" exploitation of resources is perhaps more easily understandable with respect to fishery than anywhere else. Moreover, as the fish resources are fundamentally transboundary in nature, their management is increasingly an international matter, one that in Denmark's case is largely handled by the EU.

While landings of both fish for human consumption and fish for processing to fish meal and oil have remained relatively constant over the last 10 years, the monetary value of the fish has fallen during the 1990s, especially in the case of human consumption species (*Table 3.4.2*). Among other reasons, this is due to increased competition from other fishing nations. The declining earnings combined with increased efficiency of the fishing fleet have led to a marked fall in both the total tonnage of the fishing fleet and the total number of crew members.

At the end of 1996, the Danish fishing fleet consisted of approx. 3,000 vessels, including vessels of under 5 GRT/GT. The smaller vessels of under 21 metres in length accounted for over 90% of the fleet and 80% of employment on board the vessels. The majority of the vessels fish with gillnets or trawls. There are more than 1,300 gillnet fishing vessels, virtually all of which are small. In addition, over 500 small vessels are used in connection with pound net fishery. The fleet includes approx. 1,000 trawlers, which are generally larger vessels of over 15 GRT. In addition, there are around 10 seine vessels which conduct specialized fishery for herring and mackerel. The seine vessels are all large, averaging over 600 GRT.

Only a few of the largest trawlers fish in distant waters, while the majority mainly fish in the Danish marine waters.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Ship data										
No. of crew members	8,197	7,589	7,270	6,945	6,682	7,277	6,530	6,392	6,215	5,886
Total tonnage GT/GRT	136,399	126,442	122,460	118,720	114,307	110,258	96,358	98,051	96,107	94,804
Production: Landings by Danish fishermen:										
Consumption landings										
• Weight in 1,000 tonnes	491	488	464	442	469	486	472	486	465	413
• Value in DKK million	3,023	2,629	2,709	2,935	3,040	2,617	2,045	2,160	2,190	2,244
Industrial landings										
• Weight in 1,000 tonnes	1,165	1,434	1,412	1,017	1,267	1,454	1,130	1,376	1,521	1,253
• Value in DKK million	528	881	948	550	722	868	607	744	829	771
Foreign trade										
Exports										
• Weight in 1,000 tonnes	748	797	765	734	881	917	946	975	7,265	1,086
• Value in DKK million	12,037	12,496	12,808	13,435	14,769	13,969	14,523	13,889	13,787	13,982
Imports										
• Weight in 1,000 tonnes	506	557	616	611	632	783	774	803	810	826
• Value in DKK million	5,823	5,840	6,429	6,953	7,484	7,216	6,699	7,265	7,305	7,854

Table 3.4.2 *Key figures for development of the fishery sector over the period 1987-96. (Source: Directorate of Fisheries, 1997). Note: GT = Gross Tonnage, indicating the ship's full volume. GRT = Gross Registered Tonnage, an old measure that gives the ship's full volume minus certain of the rooms on the ship.*

Development in the fish stock

The size of the fish stock depends on a complicated interplay between the pressure from fishery, hydrographic and climatic changes, and the general environmental quality of the fish waters.

Even though the fish stocks have always fluctuated for natural reasons, it is clear that human activity currently exerts a decisive influence, and that some of the commercial fish species are overfished.

The state of the commercial fish species in the Danish marine waters is assessed annually through a research and advisory cooperation with the International Council for the Exploration of the Sea (ICES). In order to evaluate the state of the fish stocks and the pressure from fishery the scientists have identified a number of biological reference points. Examples of a biological reference point are a specific fish mortality rate (i.e. the percentage of the fish stock that is caught) or a specific level for stock size. An important biological reference point used in evaluation of the state of the fish stocks is the Minimum Biologically Acceptable Level (MBAL). If the spawning stock declines below the MBAL, the stock will be in danger of collapsing and the pressure of fishery should immediately be reduced. A short description of the development and state of the four commercially most important North Sea fish species is given below.

Herring

Herring are present in all Danish marine waters. The stock structure is very complicated with a mixture of spring spawners and autumn spawners. Many of the herring we see in our estuarine fjords belong to small local stocks. The most important stocks from the point of view of fishery are the autumn spawning stock in the North Sea and the spring-spawning stocks in the Skagerrak, Kattegat and the western Baltic Sea. The annual herring catch in the North Sea peaked in 1965 at 1.2 million tonnes when purse seine nets were introduced, cf. *Figure 3.4.25*. After 1965, the catch fell rapidly and in 1977, a total ban was imposed on herring fishery in the North Sea. Fishery was reopened in 1981, and the herring catch increased in the years thereafter, peaking in 1988 at 875,000 tonnes. The catch has since fallen again, however. The MBAL for herring in the North Sea is considered to lie at a spawning stock of 800,000 tonnes. The spawning stock was estimated to be approx. 500,000 tonnes in 1995/96, which is considerably under the MBAL. In order to rebuild the stock, a number of restrictions were imposed on herring fishery in 1996.

Mackerel

The annual mackerel catch in the North Sea peaked in 1967 at 930,000 tonnes, cf. *Figure 3.4.26*. The mackerel stock in the North Sea has since collapsed and is therefore estimated to be in need of the highest degree of protection. The mackerel stock currently found in the North Sea does not belong to the North Sea stock, but to a stock which spawns west and south of the British Isles. This stock migrates into the North Sea in the summer and remains there until the middle of winter.

Cod

Cod fishery is undertaken in all Danish marine waters with several different stocks being fished. The cod stock in the Skagerrak is closely connected with the North Sea stock while the cod stock in the Kattegat and Belt Seas is closely connected with the cod stock in the western Baltic Sea. The interactions between the stocks in the form of migration and transport of eggs and larvae with the sea currents are not fully understood. Assessment of the state of the stocks and the biological advisory work is undertaken jointly for the stocks in each of the following areas: the North Sea-Skagerrak, the Kattegat-Belt Seas-western Baltic Sea, and the eastern Baltic Sea.

The annual cod catch in the North Sea peaked at just under 350,000 tonnes in 1972, cf. *Figure 3.4.27*. After a further peak of 300,000 tonnes in 1981, the catch has fallen steadily to a level of around 100,000 tonnes in the 1990s. Since the mid 1960s, the spawning stock has been declining to the present level of around 75,000 tonnes, which is well below the estimated MBAL of 150,000 tonnes.

Recruitment to the cod stock in the North Sea has remained at a relatively low level throughout the late 1980s and early 1990s, and the spawning stock has therefore remained relatively small during this period. As fish mortality is very high for the Baltic Sea cod stock, the ICES recommended a reduction in fishery in 1996 so as to enable the spawning stock to increase.

Plaice

Most of the plaice caught in Danish waters are from the North Sea plaice stock. The annual plaice catch from the North Sea increased from 75,000 tonnes to 170,000 tonnes over the period 1957-89, but has since fallen to under 100,000 tonnes in 1995, cf. *Figure 3.4.28*. The spawning stock was estimated at 212,000 tonnes at the beginning of 1995, which is well below

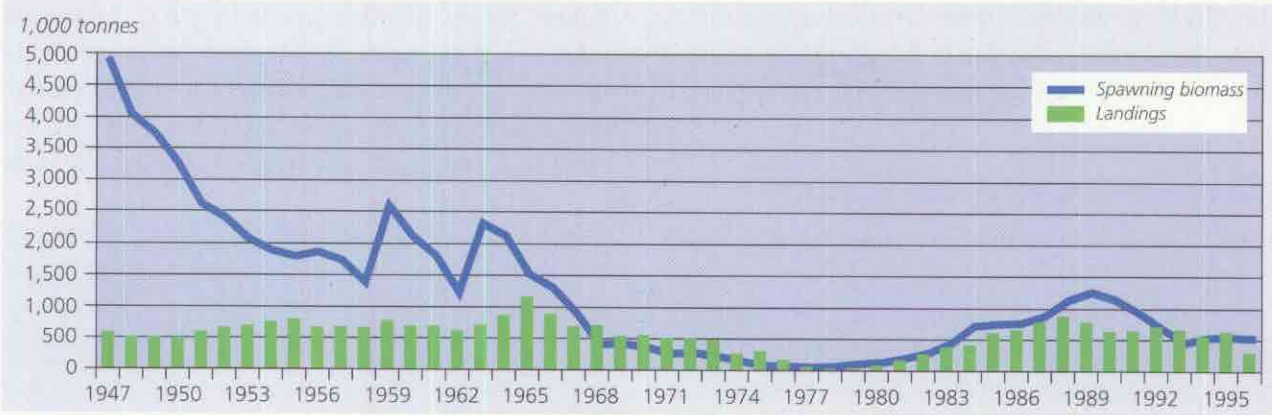


Figure 3.4.25 Herring landings and spawning biomass in the North Sea (Source: ICES, 1997).

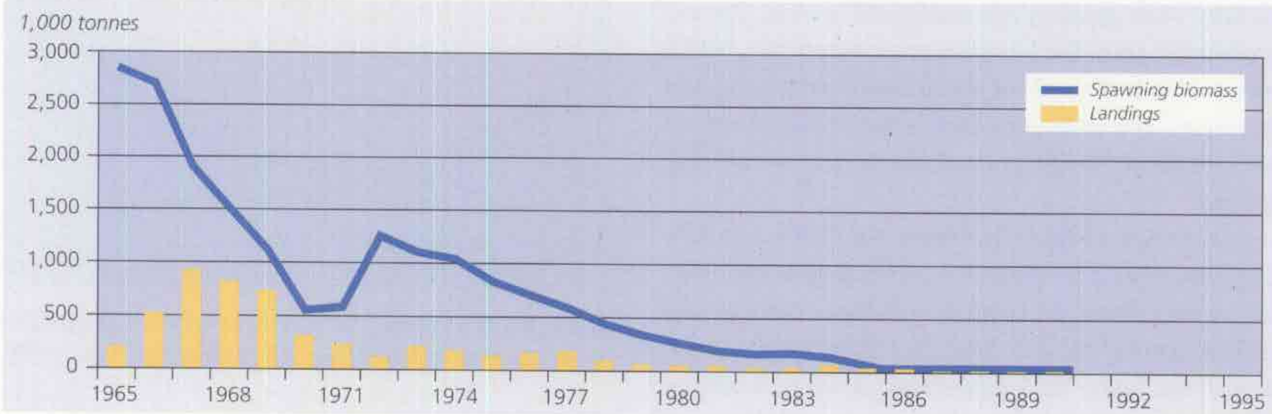


Figure 3.4.26 Mackerel landings and spawning biomass in the North Sea (Source: ICES, 1997).

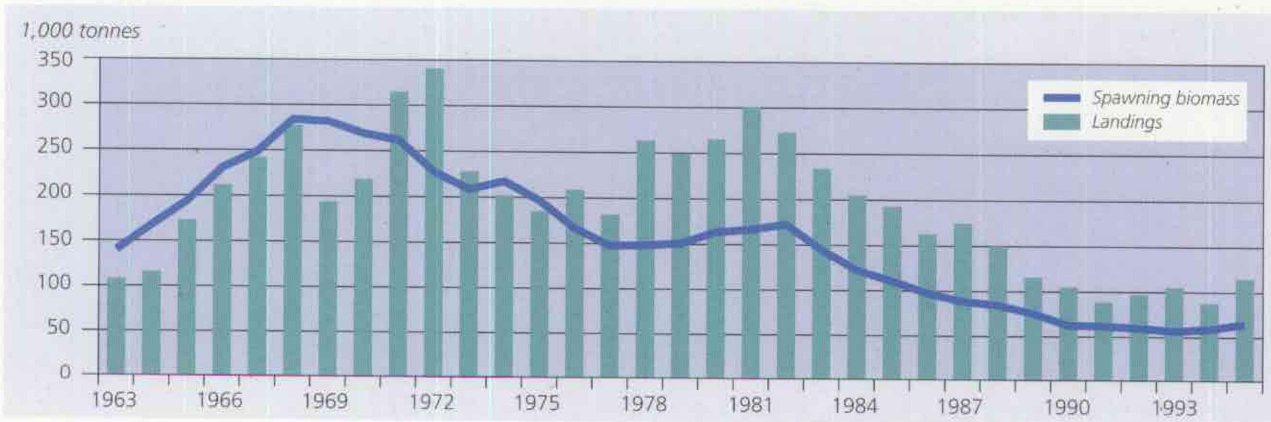


Figure 3.4.27 Cod landings and spawning biomass in the North Sea (Source: ICES, 1997).

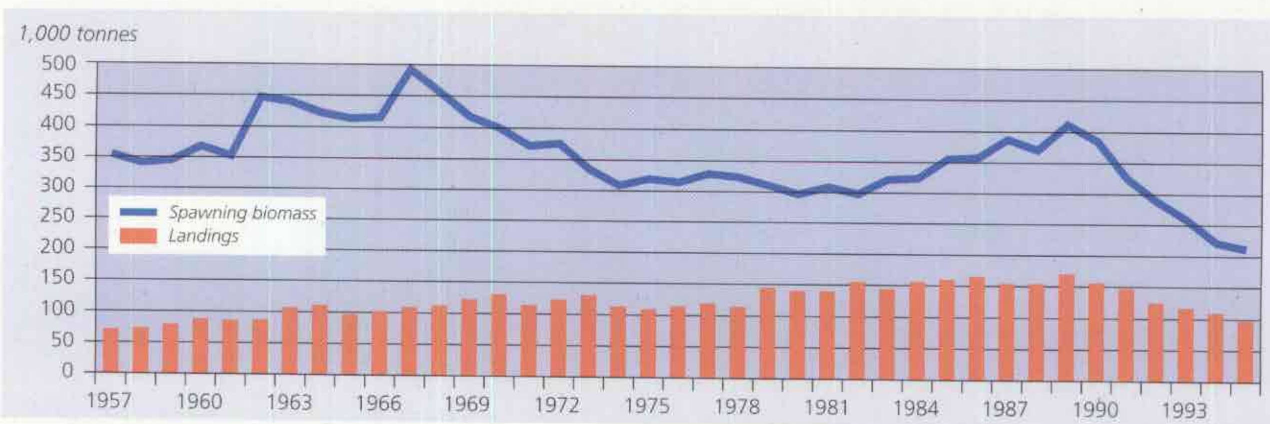


Figure 3.4.28 Plaice landings and spawning biomass in the North Sea (Source: ICES, 1997).

the MBAL of 300,000 tonnes. It is estimated that a major, prolonged reduction in fish mortality is necessary to restore the spawning stock to the MBAL level.

Development in North Sea fishery

In order to be able to understand the impact of fishery on the marine environment it is important to bear in mind that fishery has a long history and that modern fishery makes use of a large number of different types of fishing gear. *Figure 3.4.29* shows the percentage of total North Sea fish landings taken by various gears in 1989. Over half of the landings derive from fishery with small-mesh industrial trawls. The remainder mainly derives from purse seine nets, which are used to catch pelagic species such as herring and mackerel, and from otter trawls, beam trawls, seines and ringnets, which are used to catch roundfish and flatfish.

As a result of development in the North Sea fishery, total annual landings have increased from 1 million tonnes fish at the beginning of the century to 1.75 million tonnes around 1960, cf. *Figure 3.4.30*. At the end of the 1960s, the catches had grown to 4 million tonnes, whereafter they gradually fell to 2.5 million tonnes in recent years. Development in the catches of the most important categories of fish (roundfish, flatfish, pelagic fish, and industrial species) have been less consistent. As a result of a number of unusually large

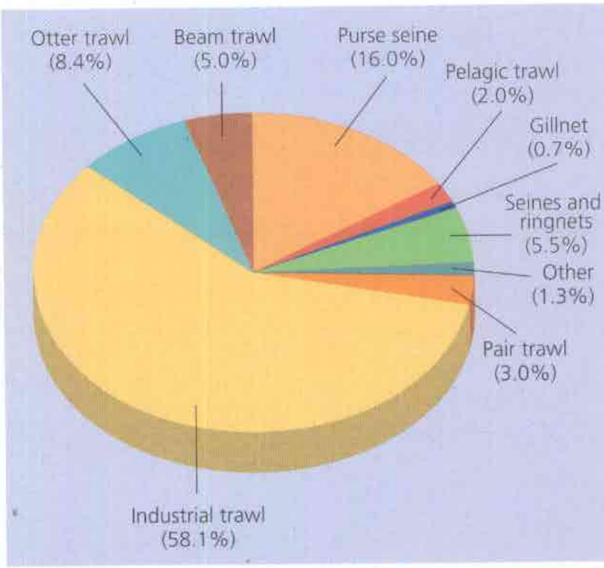


Figure 3.4.29 *Percentage of total North Sea fish landings taken by various gears in 1989 (Source: North Sea Task Force, 1993).*

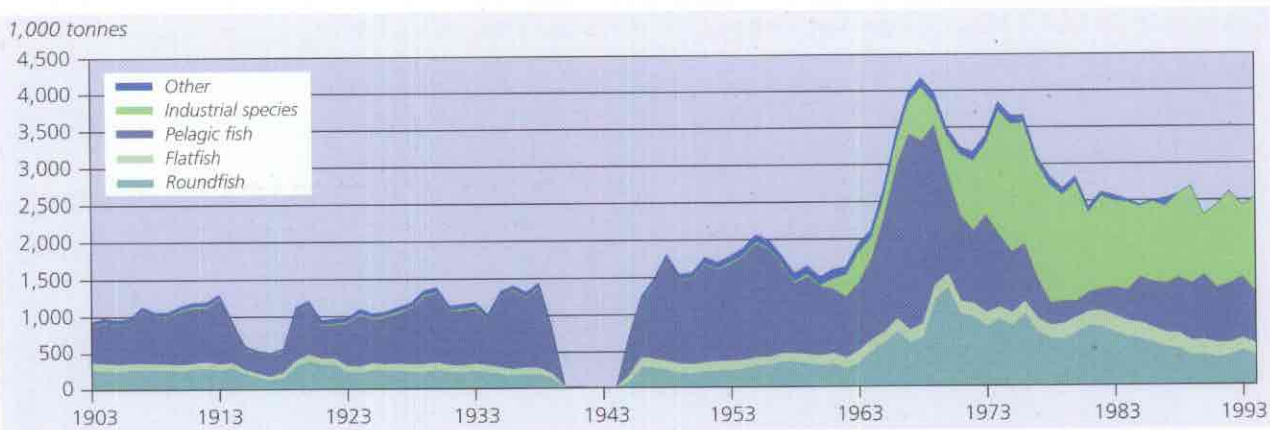


Figure 3.4.30 *Development in total North Sea fish landings (Source: Gislason, 1995; ICES, 1997).*

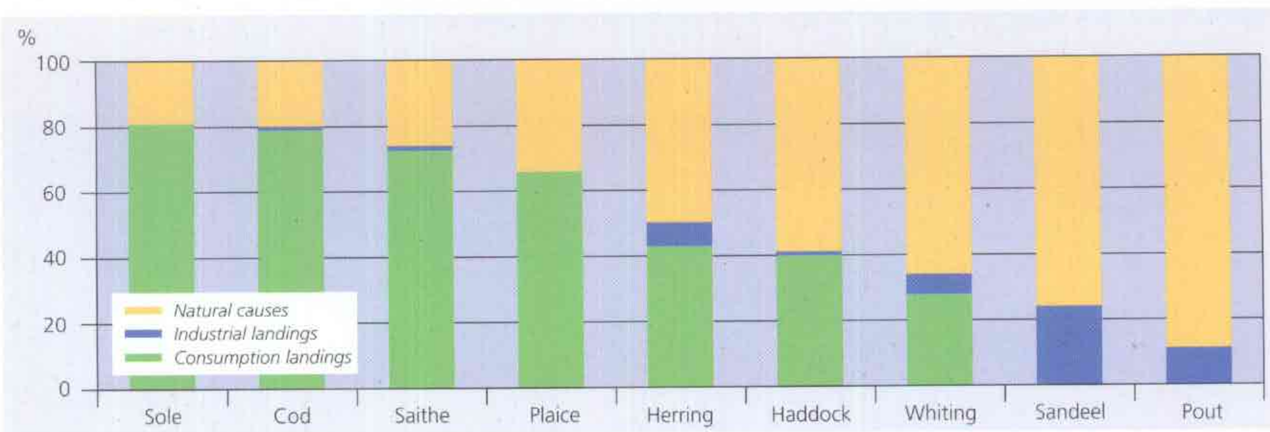


Figure 3.4.31 *Percentage of the total production of a number of the North Sea fish stocks caught for human consumption or industrial use, or removed by natural causes (Source: Gislason, 1995).*

year groups, catches of the most important roundfish (cod, haddock, whiting and saithe) increased in the 1960s. From a peak in 1970, catches of roundfish have since fallen gradually. The catches of pelagic fish, mainly herring and mackerel, declined sharply around 1970, while the catches of industrial species (pout, sprat and sandeel) increased during the same period, cf. *Figure 3.4.30*.

The herring catch has increased in recent years, while the catches of cod and haddock have fallen to the lowest level in the last 30 years. In the case of flatfish, landings of sole have remained at a constant level since the 1950s except for an increase in the last couple of years. Landings of plaice have increased gradually up to 1989, whereafter they have fallen markedly up to 1995, cf. *Figure 3.4.28*.

Total industrial landings have remained at a largely unchanged level since the 1970s, even though there have been major changes in the species composition of the catch.

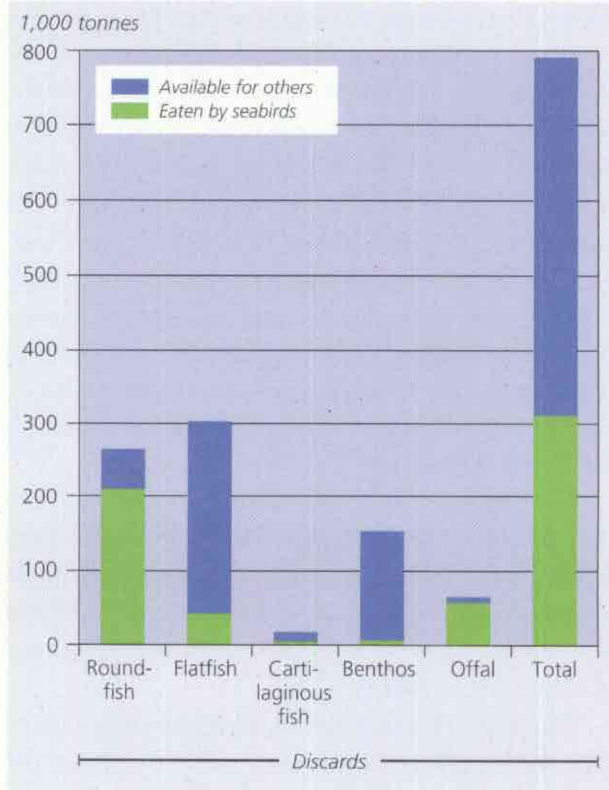


Figure 3.4.32 *Fish and offal discarded from fishery in the North Sea (Source: Garthe et al., 1996).*

Environmental impact of fishery

Fishery affects the marine ecosystem both directly and indirectly. The direct effects of fishery are primarily that fish, especially large individuals, are removed from the ecosystem.

Depending on how selective the fishing gear is, fishery for commercial species results in a varying degree of by-catch of undersized fish and non-target species. When catching fish for human consumption, by-catches of fish and shellfish are usually discarded overboard.

Discards vary from fishery to fishery, but are estimated to average around 25% of the total catches of fish for human consumption. Discards of by-catches and offal are an important food source for a number of animals, e.g. seagulls and other seabirds, whose stocks are thereby maintained at artificially high levels., cf. *Figure 3.4.32*. The general increase that has been observed in a number of seabird stocks can to some extent be linked to discards and hence to easier access to food.

The benthos and fish that are damaged or killed during fishery but not retained in the gear will also be eaten, but in this case mainly by animals that seek their food on the bottom.

Gear that is drawn along the bottom disturbs the seabed and can damage or kill benthic invertebrates and hinder the growth of eel grass. The bottom material is resuspended, and rocks and boulders are displaced. Depending on the nature of the seabed, some fishing gear such as beam trawls and parts of gear such as otter boards completely disturb the upper centimetres or more of the seabed. Studies of the resultant mortality among a limited number of benthic invertebrates show that between 15 and 55% of the animals left in the wake of a beam trawl are dead or dying.

Birds and marine mammals such as seals and porpoises can become entangled in fishing gear and drown. Considerable local by-catch of seabirds can also occur, especially in gillnets. The species caught are primarily those which dive after food. In the case of the porpoise, studies indicate that by-catches in gillnet fishery can be considerable, but that insufficient information is available to be able to determine how great a part of the stock is killed in this way.

In the long run, fishery has indirect effects on both fish stocks and the ecosystem. Fishery involves selective fishing for specific species and sizes of fish. This changes not only the size composition of the individual fish stocks, but also the balance between large and small fish in the ecosystem. Changes take place in the balance between predators and prey and in the ratio between competing species, changes that in the longer run will change the structure of the food chains. In addition, high pressure of fishery can affect the genetic composition of the fish stocks. All in all, fishery thus changes the conditions for life in the sea.

When investigating the impact of fishery on say the North Sea, it is important to remember that the ecosystem is subject to considerable natural fluctuations due to variation in the physical environment, sea currents and water temperature. The North Sea ecosystem is thus in constant change. Moreover, fishery is only one of many anthropogenic pressures and it is therefore difficult to isolate the effect of fishery. In addition, fishery has a long history, and many of the changes that fishery might have caused probably took place long before biologists began to collect information seriously.

The majority of our knowledge on the North Sea thus derives from a period when the level of fishery did not differ markedly from the present level. All in all, therefore, it is not surprising that only a few of the changes hitherto observed can be unambiguously attributed to fishery.

The limited knowledge on the relationships in the ecosystem makes it largely impossible to forecast the long-term effects of fishery on the individual species in the ecosystem. An important exception to this rule is the effects of prolonged overfishing of a single species. Slowly growing species with low fecundity are particularly at risk of local extinction.

The farming of fish in marine and terrestrial saltwater fish farms results in the loss of nutrients and organic matter to the aquatic environment. In areas with poor water exchange, this can result in a highly eutrophic benthic community. Immediately below the fish cages, the sea floor can become completely devoid of all higher forms of life. In addition, a number of substances used as antibiotics are discharged into the water.

The release of fish and fish fry can lead to undesirable changes in the species composition of the waters in question, and problems can arise with genetic uniformity of the fish stocks.

Objectives and policy measures

Danish fishery is under the administrative jurisdiction of the EU. Thus the national efforts primarily consist of administering the EU quotas and other joint preservation measures and regulating local fish stocks such as mussels and fishery close to the coasts.

The objective of EU fishery policy is to ensure preservation and rational exploitation of the fish stocks. The policy primarily encompasses stipulation of quantitative limits on the exploitation of the fish stocks. Each year, limits are stipulated for the maximum amounts that may be caught within the Community and for the distribution of the maximum catches between the individual Member States through the allotment of quotas. Quota allotment is undertaken on the basis of a fixed allotment scheme adopted in 1983. The stipulated catches and quotas are based on scientific advice on the development of the individual stocks.

In addition, a number of technical preservation measures are also stipulated. The most important are: 1) stipulation of the minimum mesh size and minimum sizes of fish to protect young fish, 2) identification of closed areas with a high concentration of young fish where fishery is prohibited and 3) stipulation of maximum by-catch percentages.

Finally, the EU stipulates rules for the size of the fishing fleet because continued development of fisheries technology generates overcapacity in the fleet's catch potential relative to the available fish resources. In order to ensure balance between fleet capacity and resources, multi-year targets have thus been stipulated for the size of the individual Member States' fleets, and a scheme for scrapping fishing vessels has been established to promote a reduction in capacity.

3.5 Industry

3.5.1 Introduction

In the period immediately after the first Environmental Protection Act entered into force in 1974 the environmental debate and environmental administration largely focused on direct industrial emissions and discharges of pollutants to air, water and soil. These problems have now been reduced as a result of better process control, the establishment of treatment and abatement measures and the introduction of cleaner production methods. The focus has therefore switched to the indirect environmental impact of industry.

The indirect environmental problems relate to industry's consumption of resources and energy, as well as to the problems associated with the onward circulation of industrial products through society, eventually to end up in society's waste streams.

Whereas the control instruments for reducing direct industrial emissions and discharges were mainly based on injunctions, approvals and supervision, the measures aimed at dealing with indirect environmental problems have focused on financial incentives in the form of levies and subsidies, as well as education and voluntary agreements.

The development of Danish industry and the associated environmental problems are examined below.

3.5.2 Structural development of industry

The total value of industrial production in real terms is used as an indicator of the total turnover of resources. Over the period 1985-95, the value of industrial production in real terms (1980 prices) increased by approx. 20% from well over DKK 230,000 million to just under DKK 280,000 million, see *Figure 3.5.1*. This is primarily due to an increase in the value of production within the chemicals industry and the iron and metals industry. In contrast, production in branches such as textiles and clothing, and stone, clay and glass has declined. The value of industrial production comprises approx. 30% of total national production.

In 1995, employment in industry was at the same level as that of the early 1980s, see *Figure 3.5.2*. In the intervening years, though, employment in industry has reached as high as 560,000 employees. In 1995, the industrial labour force comprised approx. 18% of the total employed population in Denmark. The significance of industrial production is thus much greater than the significance of industrial employment.

Figure 3.5.1 *Development in the value of industrial production in 1980 prices. The figures for 1980-95 are from the National Accounts (Source: Statistics Denmark). The forecasts for 1995-2005 are from the 1996 Medium Term Economic Survey (Ministry of Finance, 1996).*

Figure 3.5.2 *Development in employment in the industrial sector over the period 1980-2005. The figures for 1980-95 are from the National Accounts (Source: Statistics Denmark). The forecasts for 1995-2005 are from the 1996 Medium Term Economic Survey (Ministry of Finance, 1996).*

According to the Ministry of Finance's Medium Term Economic Survey for the period up to the year 2005, a continuous increase is expected in the value of industrial production as well as in industrial employment. The value of production is thus forecast to reach just under DKK 320,000 million in 1980 prices by the year 2005, corresponding to an increase of approx. 15% over the period 1995-2005. Employment in the industry is expected to reach well over 530,000 by the year 2005.

Since the early 1970s, the share of total employment and total value added accounted for by industry has been slowly decreasing. In absolute figures, however, industrial employment has remained roughly constant, and the value of production has increased considerably in real terms. Thus when there is talk of a transition away from an industrial society towards a service society, this only applies in a relative but not absolute sense. Moreover, there is nothing to indicate that this transition will in itself result in a less resource-demanding society. This problem is examined in more detail in the section on the service sector. Danish industry is characterized by its many small enterprises. Approx. 3/4 of all Danish industrial enterprises have less than 50 employees. On the other hand, the large enterprises account for a relatively larger share of the jobs since only approx. 35% of the jobs are found in enterprises with less than 50 employees.

Localization of industry

The relocation of industrial jobs from the Greater Copenhagen area - particularly to Jutland - has continued in the 1990s. Thus in 1995, as many as 58% of the jobs in industry were located in the part of Denmark west of the Great Belt, see *Figure 3.5.3*. In the area east of the Great Belt, the majority of the industrial jobs congregate in the Greater Copenhagen area and surrounding counties. In contrast, those west of the Great Belt are more widespread, being distributed throughout all the counties of Jutland.

The trend in the industry is drawing in the direction of international markets. Among other things, this means a greater degree of specialization and increasing use of subcontractors to produce components (outsourcing).

The localization of industry outside the traditional centres, increased use of sub-contractors and rationalization principles inspired by Japanese production systems involving minimization of stocks, etc. impose extreme demands on the transport of raw materials and semi-manufactured products. This probably contributes to the current trend in domestic road haulage, where the average transport distance in km is increasing more than the amount of freight transported. Thus each tonne of freight transported by lorry was hauled an average of 42 km in 1985 but 53 km in 1995, see *Figure 3.5.4*.

The increase in transport distance is attributable to declining capacity utilization and increasing distances between consignors and consignees. Average capacity utilization in domestic road haulage was approx. 45% in 1985, but had fallen to around 40% in 1995. The increase in traffic over the period was almost exclusively due to an increase in the number of km covered on trips over 99 km, while the share accounted for by short trips has decreased correspondingly.

The spread of industry to peripheral counties, specialization and the increased turnover of resources in the individual enterprises naturally impose great demands on the environmental authorities. Efforts therefore need to be made to ensure that the authorities in the small municipalities have the necessary expertise to undertake environmental supervision, also when it

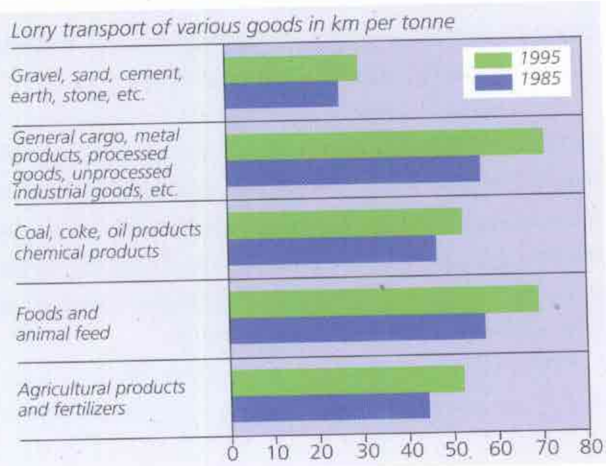


Figure 3.5.4 *Average transport distance in km per tonne for various groups of goods transported by lorry (>6 tonnes total weight) in 1985 and 1995 (Source: Statistics Denmark, 1986 and 1996a).*

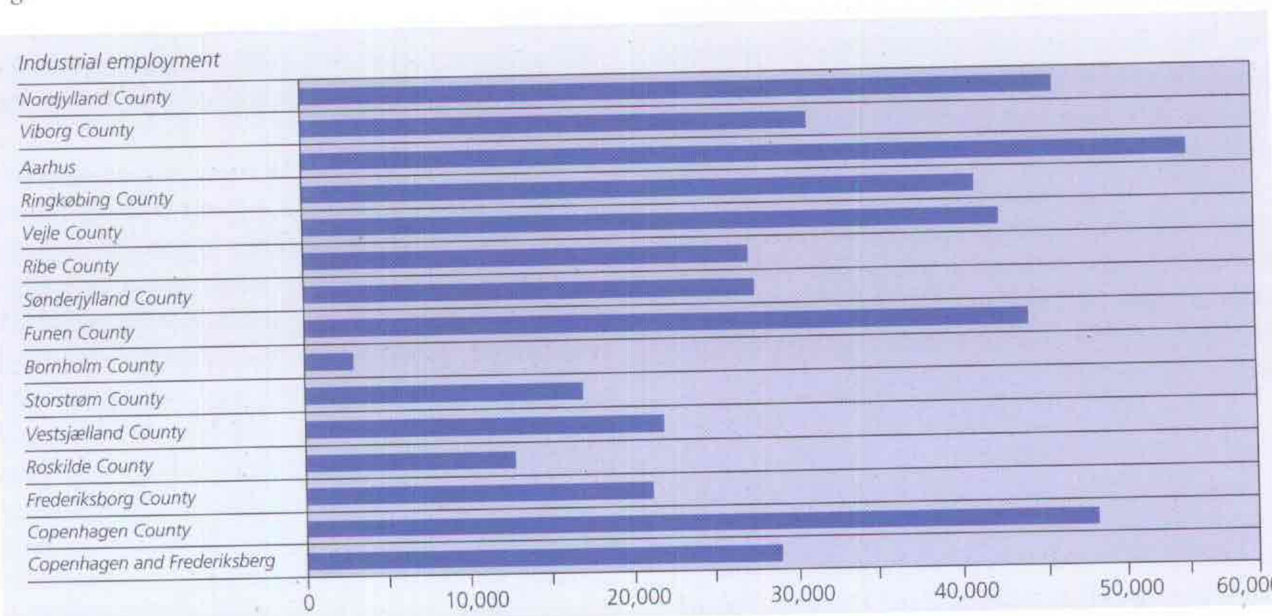


Figure 3.5.3 *Number of employees in the industrial sector in the individual counties in 1995 (Source: Statistics Denmark, Municipal Statistics Database).*

comes to the more specialized productions. Since a major part of Danish industry is comprised of small enterprises, it is also important that special efforts are made in counties and municipalities to work with these enterprises on their (often specific) premises.

3.5.3 Environmental impact of industry

Systematic, continuous monitoring of industry's resource consumption and environmental impact is not undertaken. The data vary considerably depending on the resources and discharges in question. The present section is therefore based on the available data with the reservation that the data and statistics are of a very variable quality and that the category "industry" is not fully consistent.

Energy consumption by industry

In 1995, the final energy consumption by the production sectors amounted to 166 PJ, corresponding to 26% of total final energy consumption in Denmark. Of this, industry accounted for 117 PJ, corresponding to 19% of total final energy consumption. These figures do not include energy consumption for the transport of freight and persons to and from industrial enterprises, or energy consumption for the production of district heating.

Energy consumption by industry has varied considerably over the past 20 years, see *Figure 3.5.5*. The general tendency has been a decrease in consumption up to 1983 and an increase thereafter. If one examines energy consumption relative to the gross domestic product at factor cost, energy intensity decreased considerably up to 1983. Thereafter it remained constant, although with a tendency towards an increase in recent years. There is no simple explanation for the development in industrial energy consumption. It is affected by the size of the industrial production, energy prices, structural changes and changes in the relative size of the branches, as well as by the introduction of new production processes, materials and techniques. Finally, energy control and cost-saving measures also affect energy consumption.

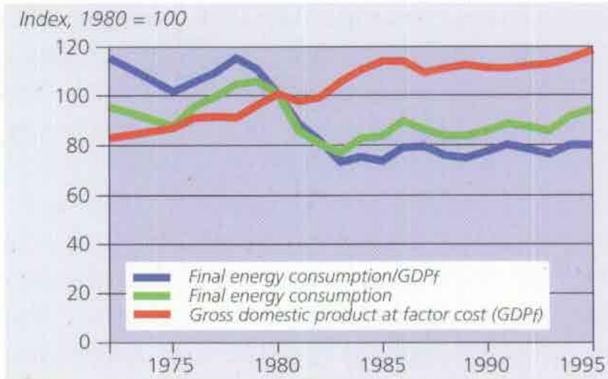


***Figure 3.5.5** Energy consumption in the industrial sector over the period 1975-95 together with gross domestic product at factor cost (GDP_f) and energy intensity (Source: Danish Energy Agency, 1995).*

In absolute figures, energy consumption is highest in the food, drink and tobacco industry, the chemicals industry, the iron and metals industry, and the stone, clay and glass industry. Some of the industries are quite large, however, while others are very energy-intensive, see *Figure 3.5.6*.

The major part of industrial energy consumption is accounted for by a relatively small number of enterprises. Thus 150 very heavy industrial enterprises account for 75% of industry's energy consumption.

Industry's share of CO_2 emissions depends on the CO_2 intensity of the energy consumption, industry's energy intensity and the size of production. According to the 1996 Medium Term Economic Survey, industrial production is expected to increase by 15% in

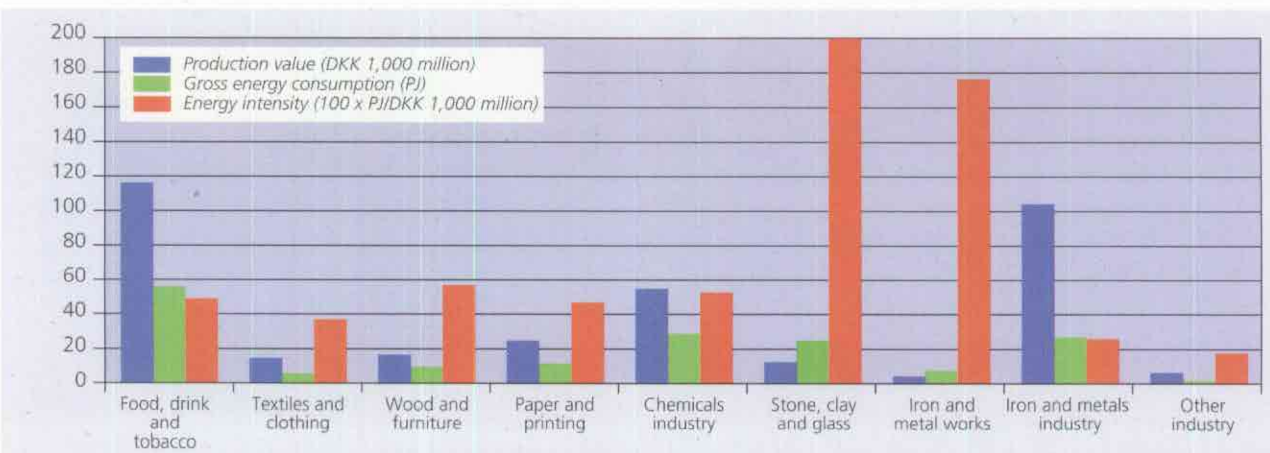


***Figure 3.5.6** Production value, energy consumption and energy intensity for the various branches in 1992 (Source: Statistics Denmark, 1996b).*

real terms over the period 1995-2005, see *Figure 3.5.1*. The total increase in industrial production over the period 1988-2005 will thus amount to approx. 30%. The Government aims to reduce total CO_2 emissions by 20% over the period 1988-2005. If CO_2 emissions from industry increase in step with production, it will be extremely difficult to meet the CO_2 reduction target. It is therefore necessary to considerably reduce both energy intensity and CO_2 intensity in industry. This poses a major challenge, however, since energy intensity in this sector has been largely constant since the mid 1980s and has even increased at the end of the period. In 1995, a number of green levies were imposed on industry to reduce energy consumption and emissions of CO_2 and SO_2. The result of these initiatives will be assessed in 1998.

Water consumption by industry

Water consumption by industry amounts to approx. 166 million m^3 per year, of which 87 million m^3 per year is pure groundwater. Consumption is highest in the food, drink and tobacco industry and the chemicals industry (*Figures 3.5.7* and *3.5.8*). The high water consumption in the chemicals industry is primarily accounted for by sea water for cooling purposes, and hence is of little consequence to the groundwater resource. Time series are only available for the total commercial consumption of water from the public supply, and not for industry alone. This has decreased by approx. 20% during the past 10 years. As already mentioned, a very large part of industry's water consumption, especially for cooling purposes, is in the form of sea water. In addition, a very large part of the water consumed by industry originates from industry's own abstraction wells.

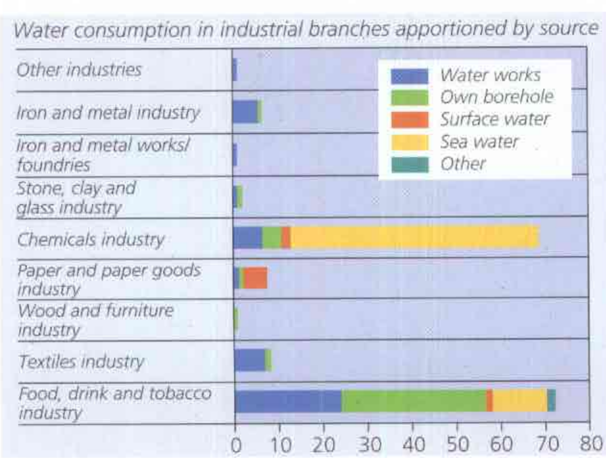


Figure 3.5.7 *Water consumption in branches of industry in million m^3 apportioned by branch and source (Source: Danish Environmental Protection Agency, 1994a).*

In order to limit water consumption by households, water levies have been introduced. Industry is not subject to these levies, however, and hence does not have the same incentive to reduce water consumption. It is believed that there are considerable possibilities to reduce water consumption within all branches, especially in enterprises which have considerable water consumption for processes. Cleaner technology projects with the primary aim of reducing water consumption have proven effective. Thus projects within the abattoir branch have reduced water consumption by an average of 25%.

There are good possibilities for using secondary water in industry, e.g. water from remedial abstraction, water from permanent groundwater lowering, groundwater which does not meet quality requirements for drinking water, rainwater, sewage, etc.

Raw materials consumption by industry

Raw materials consumption by industry expressed in tonnes is shown in *Table 3.5.1*, which includes all types of products, raw materials and semi-manufactured products. The table has been produced using the input-output tables from Statistics Denmark, which are based on the product statistics and the foreign trade statistics. Only the flows of traded goods are included in the accounts. This can be of quantitative significance for certain enterprises, for example those that use gravel, sand and clay from their own depositories.

The food, drink and tobacco industry is the branch with the greatest input of resources. This is because it processes large quantities of raw materials from agriculture and market gardening. Then follows the chemicals industry and the stone, clay and glass in-

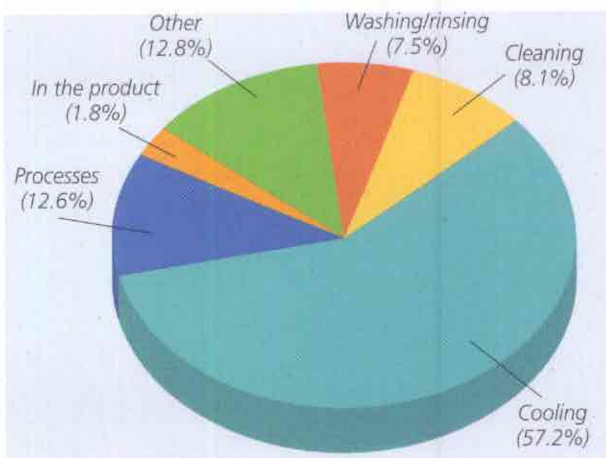


Figure 3.5.8 *Water consumption in the industrial sector apportioned by use (Source: Danish Environmental Protection Agency, 1994a).*

Branch	Input in 1,000 tonnes	Output in 1,000 tonnes	Waste in % of input
Food, drink and tobacco	21,013	11,606	45
Textiles and clothing	392	174	56
Wood and furniture	2,644	2,387	18
Paper and printing	1,614	2,089	+29
Chemicals industry	14,219	14,529	+2
Stone, clay and glass products	13,831	13,910	+3
Iron and metal works	591	1,278	+116
Iron and metals industry	3,508	2,306	34
Other industry	114	101	11

Table 3.5.1 *Input and output of goods from industry in 1990 expressed in tonnes (Source: Ole Gravgård, Statistics Denmark, provisional figures).*

dustry. The large share of resource inputs accounted for by the chemicals industry is primarily attributable to the oil refineries and the asphalt industry.

If the consumption of raw materials (i.e. input) is compared to the output from various branches, the difference is to some degree an expression of the amount of waste generated. The figures must be treated with reservation, though, since only traded goods are registered. Water is not included in the raw materials consumption, but processes whereby water is supplied to or removed from the products can affect the balance.

That the raw materials balance is positive for the paper and printing industry and for iron and metal works is due to the fact that not all the recycled paper and scrap metal are registered. Finally, staggering of stocks of both raw materials and finished goods may play a role.

At the present time, figures for raw materials consumption by the various branches of industry are only available for 1990, and hence it is not possible to assess the trend. The Danish Environmental Protection Agency has carried out a number of materials flow analyses, in particular for heavy metals, but also for aluminium, steel, nickel and PVC.

These analyses show that the use of aluminium is increasing markedly. In 1994, aluminium consumption for the production of finished goods in Denmark amounted to 120,000 tonnes. The consumption of steel is stagnant. PVC consumption is constant and amounted to approx. 90,000 tonnes in 1988, as well as in 1994-95. The share of hard PVC has increased, whereas that of soft PVC has decreased. The consumption of mercury has declined considerably. The consumption of lead has been reduced by approx. 20%.

In addition, industry also uses a large number of chemical substances and products that may have a profound environmental impact, even in small quantities. The iron and metals industry uses the greatest number of different chemical products, followed by the chemicals industry.

Emissions and discharges from industry

Emissions and discharges from industry include gaseous emissions, discharges with waste water, and solid waste. To this must be added the environmental impact arising during the life cycle of the products. Environmental problems associated with industrial plants (e.g. in connection with accidents or scrapping) and noise will not be examined here.

Emissions to the atmosphere

Industrial emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) are closely related to industrial energy consumption, depending on the magnitude of this consumption as well as the fuels used and the degree of flue gas abatement. In addition, a number of volatile organic compounds (VOCs) are emitted in connection with the use of energy. Industrial emissions of these substances are shown in *Figure 3.5.9*. The figures shown do not include emissions from power stations resulting from production of the electricity etc. purchased by industry.

Since 1983, CO_2 emissions from industry have been relatively constant, cf. the section above on energy consumption by industry. Emissions of SO_2 have decreased markedly since 1978 and are currently less than 1/4 of the 1978 level. This is due to flue gas abatement measures and the introduction of low-sulphur fuels. Over the period 1993-95, SO_2 emissions from industry have increased by 5%. Industrial emissions of NO_x have been at the same level

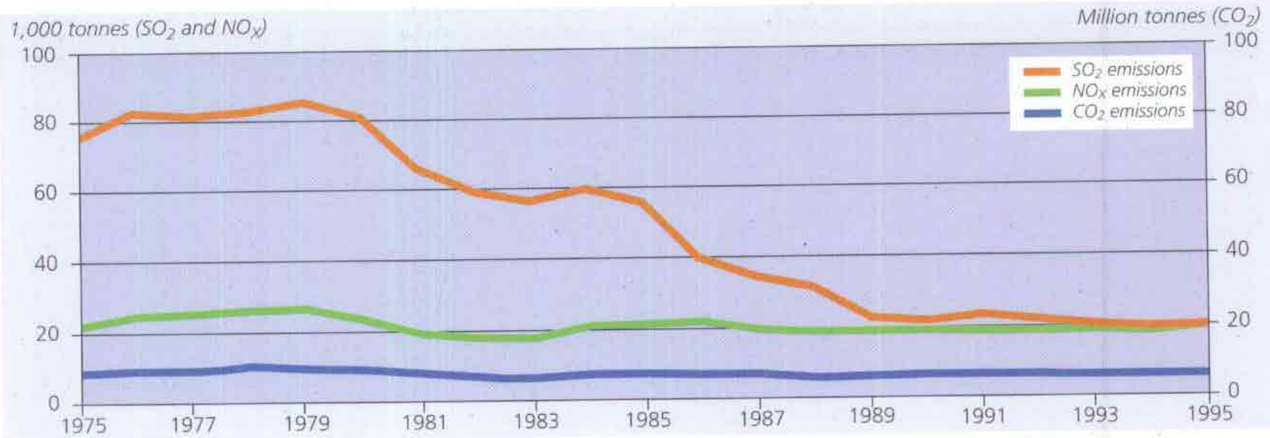


***Figure 3.5.9** Energy-related CO_2, NO_x and SO_2 emissions from in house energy production within the industrial sector over the period 1975-95 (Source: National Environmental Research Institute and Risø National Laboratory, data from the CORINAIR database).*

for the past 25 years, i.e. around 20,000 tonnes. From 1993 to 1995, however, emissions increased by 9%.

In addition to the energy-related emissions, industry also emits process-related substances and particles to the atmosphere. The available knowledge is relatively limited, though. In 1990, industry emitted 19,200 tonnes of volatile organic compounds (VOCs), see *Table 3.5.2*. The branches mainly responsible for these emissions are the vehicle repair industry, the iron and metals industry, the wood and furniture industry and the food, drink and tobacco industry. An agreement has been entered into with the Confederation of Danish Industries on a 40% reduction of VOC emissions before the year 2000 relative to 1988.

The use of ozone layer depleting substances in industrial processes and products has practically come to an end, see *Section 2.1.2*, and Denmark is in compliance with the requirements of the Montreal Protocol on the phase-out of CFCs before the end of 1995. Part of this consumption has been substituted by HCFCs, which also deplete the ozone layer although to a lesser extent than CFCs. HCFCs must be phased out before the year 2002.

Discharges to streams, lakes and the sea

Waste water from industry is discharged either via municipal waste water treatment plants or direct industrial outfalls. It is estimated that approx. 50% of the input to waste water treatment plants originates from industry such that 50% of total organic matter loading of recipient waters and 40% of nitrogen and phosphorus loading derive from industry, see *Table 3.5.3*.

Discharges of nitrogen and phosphorus from industry have been decreasing markedly since the Action Plan on the Aquatic Environment entered into force, see *Figure 3.5.10*.

The present sources are primarily untreated sewage from the fishing industry in northern Jutland.

Discharges of organic matter measured as biological oxygen demand (BOD_5) have also been reduced considerably. Here too the main sources are the fishing industry, as well as the paper and cellulose industry and the sugar industry, located in Nordjylland county, Roskilde county and Storstrøm county, respectively. The introduction of biological waste water treatment plants has reduced the discharges considerably in 1995, and industry has generally met its part of the reduction targets for nitro-

VOC emissions from industry in tonnes/yr	1988	1990	Target year 2000
Food industry	3,100	2,550	
Wood and furniture industry	3,800	3,100	
Iron and metals industry	4,600	4,300	
Vehicle repair industry	7,575	5,150	
Plastics industry	1,525	1,300	
Printing industry	1,500	1,550	
Chemicals industry	1,900	1,250	
Total	*24,000*	*19,200*	*14,400*

***Table 3.5.2** Emissions of VOCs in connection with industrial processes in 1988 and 1990 together with the agreed target for the year 2000 (Source: Danish Environmental Protection Agency, 1995).*

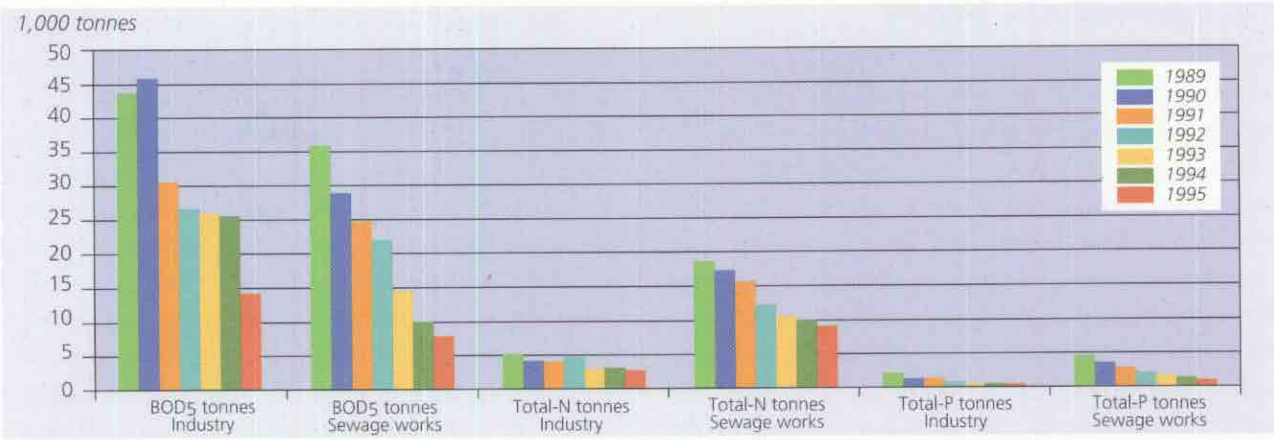


***Figure 3.5.10** Discharges of nitrogen, phosphorus and organic matter (BOD_5) from public sewage works and direct industrial sources for selected years (Source: Danish Environmental Protection Agency, 1996a).*

gen, phosphorus and organic matter loading of the aquatic environment stipulated in the Action Plan on the Aquatic Environment.

Industrial waste water discharges include a number of substances that are harmful to the environment and health, of which only few are registered. Industrial discharges of heavy metals and environmentally hazardous substances are estimated to have been reduced considerably over the past 10 years as a result of cleaner technologies and the establishment of treatment plants. Discharges of selected substances from waste water treatment plants and industrial point sources are shown in *Table 3.5.3*. Industry's share includes all the discharges from waste water treatment plants which do not originate from households and hence encompasses not only discharges from industry, but also discharges from the whole of the commercial and public sectors. Direct industrial discharges of environmentally hazardous substances (List I and List II substances) are small compared to discharges from the numerous waste water treatment plants, the only notable exceptions being chromium and copper.

	Waste water treatment plants					Direct industrial discharges
	Input		Discharges		Industry's share	
	Total	Industry	Total	Industry		
Nitrogen, phosphorus, organic matter	*tonnes/yr*	*tonnes/yr*	*tonnes/yr*	*tonnes/yr*	*%*	*tonnes/yr*
BOD_5	178,500	89,250	7,782	3,891	50	13,768
Total-N	36,500	14,600	8,939	3,576	40	2,472
Total-P	8,300	3,320	1,236	495	40	206
List I substances	*kg/yr*	*kg/yr*	*kg/yr*	*kg/yr*	*%*	*kg/yr*
Mercury	2,000	1,875	800	750	94	20
Cadmium	1,400	1,263	1,000	900	90	11
List II substances	*kg/yr*	*kg/yr*	*kg/yr*	*kg/yr*	*%*	*kg/yr*
Chromium	19,300	18,875	2,900	2,800	98	553
Copper	76,000	51,211	3,800	2,500	67	1,935
Nickel	23,200	20,603	18,000	16,000	89	472
Silver	8,000	7,766	200	200	97	0.5
Zinc	163,600	112,370	45,000	31,000	69	326
Arsenic	18,800	18,713	16,000	16,000	100	51
Lead	-	-	-	-	-	225
Nonylphenol	7,000	4,686	350	235	67	-
Di(2-ethylhexyl)phthalate	120,000	112,681	12,000	11,000	94	

***Table 3.5.3** Total and industrial inputs to and discharges from public waste water treatment plants of nitrogen, phosphorus, organic matter and selected environmentally hazardous substances, together with percentage of each discharge accounted for by industry. Direct industrial discharges are also shown (Source: Danish Environmental Protection Agency, 1996a).*

Waste generation by industry

In 1995, industry generated 2,563,000 tonnes of waste. From 1994 to 1995, the amount of industrial waste increased by 254,000 tonnes. However, the majority of this increase (219,000 tonnes) is attributable to enterprises which started reporting in 1995, but which should also have reported in 1994. Recycling of industrial waste in 1995 lay at a level within the target for the year 2000. In contrast, landfill accounted for 30% of all industrial waste in 1995, which is considerably higher than the target for the year 2000. The reduction in the share of industrial waste disposed of by landfill from 1994 to 1995 is primarily due to the introduction of cleaner technologies in the sugar industry, which has reduced the amount of sugar beet soil from 260,000 tonnes in 1994 to 215,000 tonnes in 1995, see *Figure 3.5.11.*

The amount of building and construction waste in 1995 totalled 2,559,000 tonnes, thus exceeding the amount expected in the year 2000, see *Figure 3.5.12.* The building and construction sector is highly cyclical and the large amount of waste in 1995 is therefore not surprising. The waste management targets for the year 2000 have been more than met, however, since 85% was recycled and only 13% landfilled. The 1995 figures confirm this development, which was already apparent in 1993 and 1994. Following a decline in the beginning of the 1990s, the amount of waste oil and chemicals sent to the national waste processing firm Kommunekemi A/S by approx. 7,000 customers has been increasing slightly since 1993, see *Section 3.9.* The increase seen in recent years primarily stems from large-scale remediation of contaminated sites.

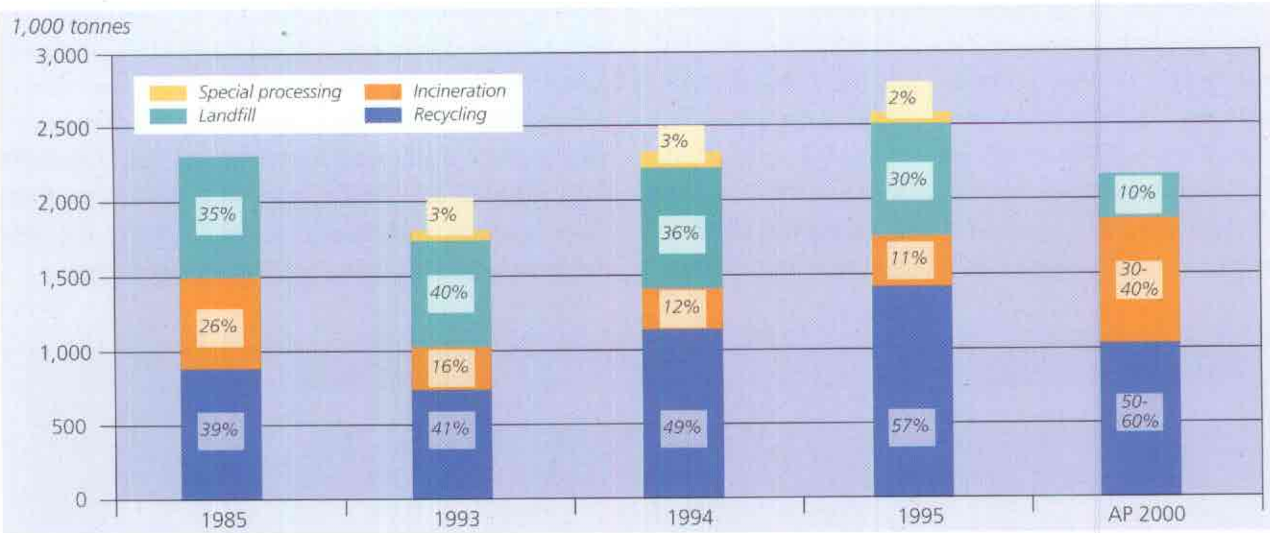


Figure 3.5.11 *Industrial waste apportioned by form of management over the period 1985-95 together with the Action Plan target for the year 2000 (AP-2000) (Source: Danish Environmental Protection Agency, 1994b and 1996b).*

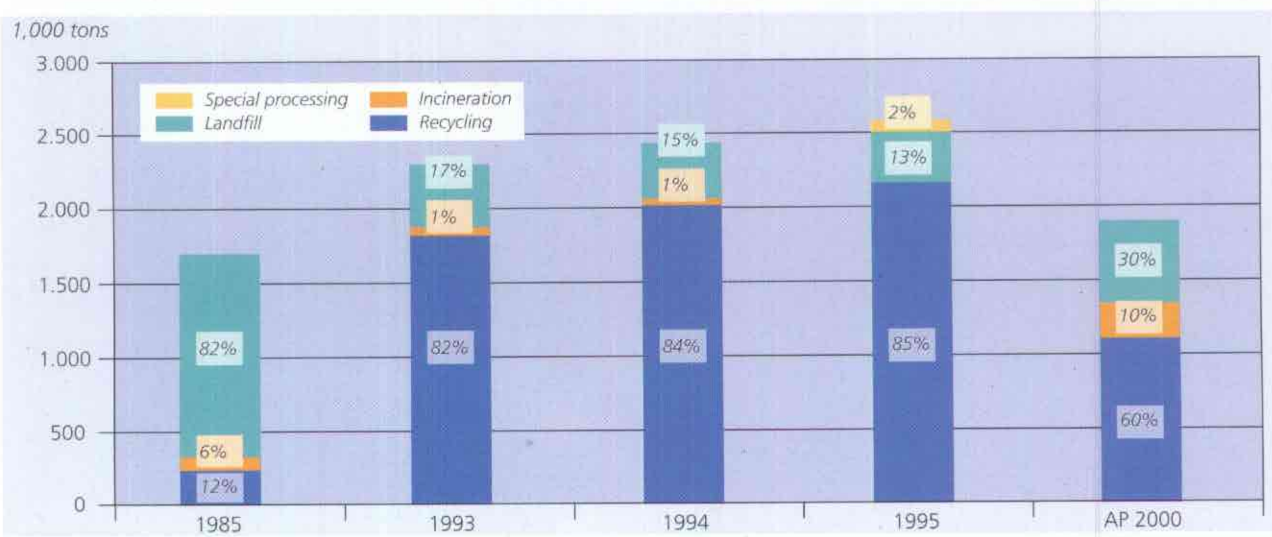


Figure 3.5.12 *Building and construction waste apportioned by form of management over the period 1985-95 together with the Action Plan target for the year 2000 (AP-2000) (Source: Danish Environmental Protection Agency, 1994b and 1996b).).*

Environmental impact of products

As mentioned earlier, the first period of environmental policy and administration from the early 1970s onwards focused on direct sources, i.e. on pollution from the individual enterprises. However, it subsequently became apparent that these sources are only part of the overall life cycle from extraction of the raw materials to disposal of the discarded products, and that it might therefore be more expedient to optimize this overall cycle instead of focusing on individual phases separately, see *Box 3.5.1*.

Industrial enterprises thus make a number of decisions that have environmental consequences beyond their own enterprise: Selection and dimensioning of materials thus affect the environment and resources in the phases preceding industrial production, just as product design has environmental consequences in the subsequent phases - i.e. consumption and waste disposal. Thus in addition to the conventional source-oriented strategy, environmental initiatives directed at industry since the early 1990s now also take a more holistic approach.

3.5.4 Objectives and policy measures

Industry's environmental problems are regulated through a number of different Acts and Statutory Orders. Of these, the Environmental Protection Act and related Statutory Orders are the most important. The Environmental Protection Act was passed in 1973 and has regularly been amended on a minor basis. In 1992, the Act was revised completely with the emphasis thereafter being placed on prevention and the use of cleaner technology.

At the same time, a number of new control measures were introduced: Environmental agreements, environmental auditing, eco-label schemes, consultancy schemes and powers to use financial control instruments. The Act and the Statutory Orders are amended regularly, among other things to meet a number of international obligations, primarily in relation to the EU, but also in relation to other agreements. In this context, future amendments must be anticipated in connection with implementation of the EU Directive on integrated pollution prevention and control (the IPPC Directive, Council Directive 96/61/EEC).

In addition, there are a number of international agreements which are not included in the Act or accompanying Statutory Orders, but which are implemented administratively by the environmental authorities.

Established enterprises

One of the central regulatory measures in the Environmental Protection Act is the requirement for environmental approval in connection with establishment or expansion of a number of specific types of enterprise (the so-called listed enterprises). In connection with the 1992 revision of the Act it was decided that enterprises established before the Environmental Protection Act entered into force in 1974, and which had hitherto been exempt from environmental approval requirements, had to undergo environmental approval within a 10-year period up to the year 2004. It was estimated that a further 3,000 enterprises would then be encompassed by the environmental approval system. By far the majority of those so far encompassed have submitted applications, of which some are still being processed by the authorities.

Action Plan on the Aquatic Environment

The 1987 Action Plan on the Aquatic Environment stipulates that annual nitrogen and phosphorus discharges from industry are to be reduced by 3,000 tonnes and 2,800 tonnes, respectively. This is to be achieved by applying best available techniques to reduce all discharges exceeding 66 tonnes nitrogen per year or 7.5 tonnes phosphorus per year. The results of the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment show that by 1996, annual nitrogen discharges from industry had been reduced by 3,460 tonnes relative to 1984, and annual phosphorus discharges by 3,240 tonnes. The requirement to reduce discharges through the application of best available techniques has now been met by all the enterprises subject to approval requirements except the fishing industry and the sugar industry, where such techniques are expected to be implemented in the coming years.

International marine agreements

Through international agreements such as the North Sea Declaration (PARCOM) and the Baltic Convention (HELCOM), Denmark is committed to reduce discharges of a number of environmentally hazardous substances to the marine environment by 50% in 1995 relative to 1985.

It is difficult to assess the extent to which this target has been met since there are a large number of diffuse sources of unknown size. For the majority of substances, however, industrial discharges via waste water are estimated to have been reduced by at least 50%.

		Unit	Material manufacture	Production	Consumption	Disposal	Transport	Total
Resource consumption		***Unit***						
Crude oil		g	17,000	5,500	13,300	-900	1,600	36,500
Natural gas		g	14,000	900	8,700	-80	90	23,610
Coal		g	36,000	11,000	265,000	-90	10	311,920
Lignite		g	6,400	-	-	-50	-	6,350
Uranium ore		g	0.45	-	-	-0.01	-	0.44
Dammed water for hydroelec.		l	12,000	550	12,000	-40	-	24,510
Aluminium	Al	g	1,900	-	-	-1,430	-	470
Iron	Fe	g	38,500	-500	-	-28,500	-	9,500
Copper	Cu	g	1,040	-	-	-940	-	100
Manganese	Mn	g	230	-2	-	-170	-	58
Nickel	Ni	g	14	-3	-		-	11
Zinc	Zn	g	17	-	-	-	-	17
Calcium carbonate	$CaCO_3$	g	6,600	-	-	-	-	6,600
Quartz	SiO_2	g	150	-	-			150
Sodium chloride	NaCl	g	970	20	-			990
Wood (soft)		g	9,880	40	940	-2,500	-	8,360
Ground water		l	2.1	51	-	-	-	53
Unspec. water		l	265	1.2	2	-0.5	0.3	268
Unspec. fuel	(oil equivalents)	g	900					900
Unspec. resources		g	210					210
Materials and auxiliares for which resource consumption is not calculated								
Epoxy powder		g	810					810
Isocyanate		g	3,650					3,650
Trichlorofluoromethane	CFC11	g	555					555
Dichlorofluoromethane	CFC12	g	100					100
Polyol		g	2,500					2,500
Scalant		g	220					220
Emissions to air								
Carbon dioxide	CO_2	g	168,000	50,300	779,000	-3,400	4,100	998,000
Carbon monoxide	CO	g	840	10	130	-20	60	1,020
Nitrogen oxides	NO_x	g	510	200	2,900	-40	60	3,630
Sulphur dioxide	SO_2	g	780	440	4,140	-10	10	5,360
Nitrous oxide	N_2O	g	6	2	50	0	0	58
Unspec. particulates	(dust)	g	120	20	380	-70	5	455
Trichlorofluoromethane	CFC11	g		30	180	320		530
Dichlorofluoromethane	CFC12	g		0	20	60		80
Hydrocarbons	HC	g	550	260	5,990	0		6,800
Volatile organic compounds (VOC)		g	20	5	15	0	15	55
Unspec. aldehydes		g	0.2	0.1	2.7	0		3
Dioxin		mg	0.0007	0				0.0007
Epichlorohydrin		mg	5					5
Arsenic	As	mg	4	0	7	0		11
Lead	Pb	mg	8	6	30	0		44
Cadmium	Cd	mg	0.6	0.2	0.7	0		1.5
Copper	Cu	mg	6	4	60	0		70
Mercury	Hg	mg	1	0	10	0		11
Manganese	Mn	mg	5,000					5,000
Vanadium	V	mg	230	280	550	0		1,060
Discharges to water								
Chemical oxygen demand	COD	g	40	1	0	0	0	41
Total nitrogen	Total-N	g	0.03	0.007				0.037
Totalt phosphorus	Total-P	g	1	1				2
Hydrocarbons		g	3	0	0	0	0	3
Unspec. oils		g	1.4	0.5	0.3	0	0	2.2
Unspec. anionic detergents		g		0.5				0.5
Unspec. nonionic detergents		g		1.1				1.1
Lead	Pb	mg	20	0				20
Cadmium	Cd	mg	10	0				10
Chromium	Cr	mg	650					650
Copper	Cu	mg	100	10				110
Nickel	Ni	mg	690	2				692
Zinc	Zn	mg	180					180

			Material manufacture	Production	Consumption	Disposal	Transport	Total
Waste								
Unspec. hazardous waste		g	125	3				128
Unspec. dust and heavy metals		g	5					5
Unspec. industrial waste		g	180					180
Unspec. radioactive waste		g	0.05	0	0	0	0	0.05
Unspec. slag and ash		g	2,200	890	21,000	-20	0	24,070
Chromium-containing slag		g	50					50
Polyvinyl chloride	PVC	g		20		540		560
Epoxy powder		g		20				20
Unspec. plastic		g				9,280		9,280
Polyurethane foam	PUR	g				6,200		6,200
Steel		g				8,500		8,500
Aluminium		g				440		440
Copper		g				100		100
Unspec. bulky waste		g	20,700	6,400	154,000	-50	0	181,050
Working environment								
Repetitive work		hr	0.001	0.080	0.003		0.006	0.091
Noise sufficient to damage hearing		hr	0.050	0.790	0.427		0.009	1.276
Neurotoxins		hr	0.004	0.051	0.014			0.069
Allergenic substances		hr	0.008	0.413	0.071		0.007	0.499
Substances interfering with reproduction		hr	0.002	0.050				0.052
Carcinogenic substances		hr	0.005	0.052	0.051			0.108
Accidents		No.	5.6×10^{-6}	113×10^{-6}	17.2×10^{-6}		0.25×10^{-6}	136.05×10^{-6}

Box 3.5.1 The box on this and the adjacent page shows the results of a life cycle analysis of a refrigerator. It can be seen that in the case of many of the environmental parameters, the environmental impact of actual production is small in relation to the impact of the preceeding and subsequent stages in the life cycle (Source: Wenzel et al., 1996). Note: Negative values under the heading "disposal" indicate recycling.

Cleaner technology

In order to promote the introduction of cleaner technology in industry, a support scheme has been established under the Council for Recycling and Cleaner Technology.

Analytical review, demonstration and development projects relating to cleaner technology can be wholly or partly financed by the support scheme. Subsidies granted during the period 1990-96 amounted to DKK 50-90 million annually and resulted in approx. 70 completed projects annually.

The VOC agreement

In 1995, the Minister for Environment and Energy entered into an agreement with industry to reduce industrial emissions of organic solvents (the VOC agreement). The target is to reduce VOC emissions by 40% before the year 2000 relative to the 1988 level. The agreement is based on 12 subplans prepared by individual branches and individual enterprises. Responsibility for the implementation and reporting of the agreement lies with industry, which is to review implementation of the agreement in 1998. The reductions are to be met through the introduction of cleaner technology within the branches/enterprises where the greatest effect can be obtained.

Green accounts

In 1995, Parliament passed legislation on the preparation of green accounts. The purpose of green accounts is to ensure that the general public has easy access to information on the environmental impact of heavy industrial enterprises.

The Act requires a selection of the enterprises subject to the environmental approval scheme to publish information on their consumption of energy, water and raw materials. In addition, they are required to provide information about the pollutants that are used in production and which are discharged to the environment or sent out from the enterprises in the products or waste. The Act only requires the publication of factual information, and does not require the enterprises to undertake actual environmental improvements or otherwise enhance their environmental efforts. The first green accounts were to be submitted to the Danish Commerce and Companies Agency on 1 July 1997 at the latest. In early November 1997, approx. 1,200 accounts had been received. Efforts have been made to help those of the enterprises encompassed by the requirement to publish green accounts who want to introduce environmental management. Thus up to 1 June 1996, such enterprises were able to apply to postpone submission of their first green accounts for a maximum of three years provided they implement an environmental management system. The Danish Environmental Protection Agency has granted such postponements to 160 enterprises.

Environmental management

Environmental management entails systematic work with environmental conditions in an enterprise, and encompasses analysis of the environmental conditions and identification of the most important environmental pressures, preparing an environmental policy, setting targets and preparing action plans on the environmental front. At the same time, an environmental management system must be established which assigns responsibility and competence and ensures control and audit. Some enterprises design their own environmental management system, while others base their system on the existing environmental management standards BS 7750 (on the way out) or ISO 14001 (from 1996).

The EU Eco-Management and Audit Scheme (EMAS) is more comprehensive than the standards. In order to be registered under the EMAS scheme, enterprises have to implement an environmental management system and prepare an environmental statement. The latter has to be made available to the general public. Both the system and the statement have to be approved by an accredited auditor, thereby enhancing the scheme's credibility. In late January 1998, 43 Danish enterprises were registered under the EMAS scheme.

By implementing environmental management in accordance with EMAS, ISO 14001 or other schemes, the enterprise commits itself to comply with statutory requirements and to regularly improve its environmental efforts. In order to promote work with environmental management and auditing among small and medium-sized enterprises, a support scheme has been established by the Danish Environmental Protection Agency and the Danish Agency for Trade and Industry.

Over the period 1995-99, a total of DKK 120 million have been allocated for this purpose. Subsidies can be granted for development and testing of tools and methods, development and testing of educational activities and for information activities. In early July 1997, a total of approx. 50 projects had been initiated under the support scheme.

Product-oriented environmental initiatives

As already mentioned, the source- and enterprise-oriented strategy to cope with industry's environmental problems has now been supplemented with product- and life cycle-oriented initiatives. Among other things, these encompass the development of methods and tools to enable enterprises to analyse the environmental consequences from a life cycle perspective and thereby optimize the design of their products. Such tools are being developed in various connections, for example in the so-called EDIP project (Environmental Development of Industrial Products), which has been undertaken as a collaboration between the Technical University of Denmark and a number of Danish agencies, organizations and enterprises.

It is also important to develop incentives for enterprises to implement such optimization in practice, however. In a market economy, the various actors are naturally only responsible for their own enterprises, and not for society as a whole. It is therefore necessary to incorporate incentives into the market to promote a broader sense of responsibility.

In relation to resource consumption by industry, such market incentives typically consist of levies on the resources. Formerly, they were mainly imposed on the consumption link. However, in its latest package of energy legislation, the Government has started a new development whereby industry is also subjected to this form of market management. With respect to the environmental consequences in the consumption and waste disposal link, one of the methods slowly being introduced is return schemes for discarded goods. Such schemes give industry joint responsibility for ensuring responsible waste disposal and minimizing waste generation. Such joint responsibility can be incorporated in product design in that emphasis can be placed on ensuring that the product can easily be separated and recycled and that its life cycle is as long as possible.

The Danish Environmental Protection Agency has paved the way for enhanced efforts on this front through the publication in November 1996 of a discussion paper entitled "Intensified Product-oriented Environmental Action". This sets the stage for a wide range of initiatives directed at selected parts of industry.

3.6 Service

3.6.1 Introduction

Environmental policy and administration have hitherto mainly focused on the heavy industrial sectors - agriculture, industry, energy and transport - whereas the service industries have been regarded as fundamentally immaterial and hence without any great impact on nature and the environment. However, the service sector encompasses approx. 2/3 of the total labour force and accounts for approx. 2/3 of the gross domestic product at factor cost (GDP_f). Provision of services by the sector thus entails considerable movement of the people who provide and purchase these services and of the physical products on which these services are based. The resultant environmental impact is far from insignificant, and hence merits examination. The structure of the service sector and its environmental impact are examined below.

The increasing provision and use of services also cause changes in the whole manner in which society works. The transition from industrial society to service society changes the interaction between society and the external environment. There is some uncertainty among social scientists as to the magnitude of the changes that more service, easier communication and more flexibility actually entail for the way society works, and hence uncertainty as to the environmental consequences of this development. This aspect is examined later in the present section.

3.6.2 Structure and development of the service sector

The term service industries is a generic term for a number of industries that are most easily defined by way of negation: Service industries are industries which neither manufacture nor process physical objects - as distinct from agriculture, fishery, industry, and construction. Repair and maintenance firms are often included under the service industries, however. In *Figure 3.6.1*, which is based on National Accounts data, the service sector is divided into the following branches:

- Trade (wholesale and retail)
- Finance (banking, insurance, etc.)
- Transport (railways, buses, taxis, haulage contractors, shipping, aircraft transport, post and telecommunications)
- Other services (hotel and restaurant, consultancy, private health, household service)
- Public service

The service sector has increased its production by just under 40% between 1980 and the present day, see *Figure 3.6.1*. The figure shows the actual development up to 1995, while the curves from 1995 onwards are Ministry of Finance forecasts. The sector accounts for approx. 2/3 of the total GDP_f and employment in Denmark - a figure which has been increasing since the late 1960s.

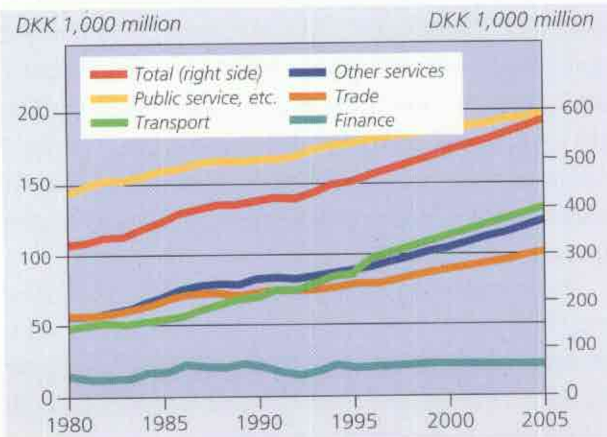


Figure 3.6.1 *Production in the service sector in 1980 prices. The figures for 1980-95 are from the National Accounts (Source: Statistics Denmark). The forecasts for 1995-2005 are from the 1996 Medium Term Economic Survey (Ministry of Finance, 1996).*

The service sector experienced heavy growth in the early 1980s, followed by stagnation in the late 1980s and renewed growth since around 1993.

All in all, the heaviest growth was seen in the transport sector (which includes telecommunications) and other services (tourism and consultancy). The growth in trade and public service is more moderate, whereas financial growth is stagnant.

Employment in the service sector is also expected to increase in the years ahead. According to the forecast in the Ministry of Finance's 1996 Medium Term Economic Survey, employment within the service sector as a whole is expected to increase by 232,000 or 13% over the period 1995-2005; within the other sectors, employment is expected to increase by 41,000 over the same period, corresponding to 5% growth. The service sector's share of total employment is thus expected to increase to approx. 70% by the year 2005.

Certain selected branches of the service sector are examined in more detail below: Retail trade, tourism and communications. Retail trade was selected because it is presently undergoing extensive restructuring, which is of considerable importance for the future pattern of urban development. Tourism and communications were selected because these areas are currently experiencing rapid growth.

Retail trade

Shop floor space has grown considerably in recent years. Thus over the period 1987-94, 1,260,000 m^2 of new shop floor space was built. If operated as well-managed shops, this could serve 1.2 million people. Additional development projects have subsequently been planned that could serve a further 400,000 people. It might thus be fair to say that there is considerable excess capacity in available retail floor space in Denmark. This considerable investment in shop floor space has been accompanied by increasing concentration of the groceries trade in large stores. Thus in 1993, just under 1,600 department stores, discount markets, discount shops and supermarkets accounted for as much as 60% of grocery sales, up from 51% just 5 years earlier.

Over the period 1987-94, more than 50% of all new shop floor space was established outside town centres, typically on the outskirts of towns where access by car is easier. This resulted in sharpened competition with the retailers in present town centres.

Over the period 1987-94, more than 50% of all new shop floor space was built in towns with over 20,000 inhabitants (outside the Greater Copenhagen area), see *Figure 3.6.2.* Only 1/4 of the total population live in these towns. In contrast, there has been a substantial "underestablishment" of new shop floor space in small towns.

As a consequence of this development, the retail trade is ailing in a growing number of towns. Unless the present trend alters, the availability and variety of shopping goods will even become threatened in relatively large towns such as Hobro, Skanderborg and Frederiksværk with 8,000-16,000 inhabitants. Towns of 4,000-8,000 inhabitants such as Sorø, Hadsten and Ringe will probably only be able to sustain a shop network offering standard goods. In smaller towns such as Ølgod, Dronninglund and Fakse with 2,500-4,000 inhabitants, it will probably only be possible to sustain a few shops offering shopping goods. These towns will therefore loose their character of a place of work and residence, and consumers without a car will have limited possibilities to shop. The outlook for the development in villages is even more drastic. Concentration of the retail trade has reduced the number of villages having at least 1 grocery store from 1,390 in 1988 to 930 in 1994.

The continued trend towards concentration of the retail trade thus seems to change conditions in the surrounding catchment with resultant general weakening of the shop network in surrounding towns. Investors prioritize car-oriented shop and shopping centre locations, thereby enhancing customer dependence on cars.

Tourism

Tourism in Denmark increased markedly in the 1980s and the early 1990s, but has since stagnated. Among other things, the growth was due to increased marketing of Denmark as a vacation spot, both at home and abroad. Over the period 1960-80, the number of holiday cottages increased significantly, while the increase in Danish tourism in recent years has mainly been facilitated through increased letting of existing accommodations, especially holiday cottages. About 15% of the coastal zone is presently occupied by or designated for holiday cottages and holiday/recreational facilities (see *Section 3.8* on outdoor recreation and tourism). Including unregistered overnight stays by tourists in their own holiday cottages, tourist bed-nights totalled approx. 100 million

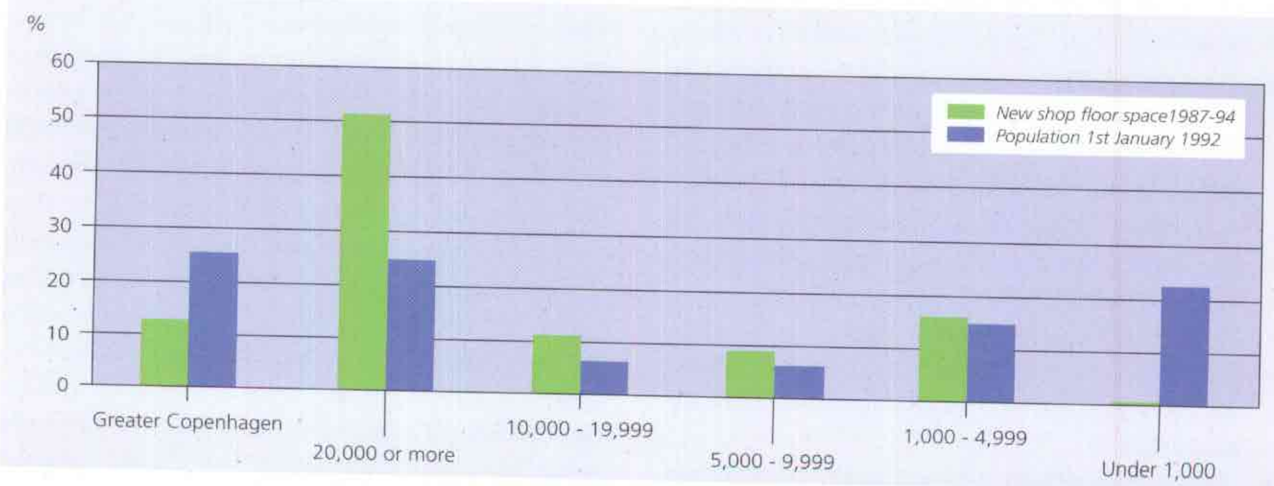


Figure 3.6.2 *New shop floor space in the period 1987-94 and population in 1992 apportioned by town size (Source: Spatial Planning Department, Ministry of Environment and Energy, 1995a).*

Figure 3.6.3 Development in registered tourist bed-nights in Denmark over the period 1989-95 (Source: Danish Tourist Board, 1996).

in 1991. Of this, approx. 50% was accounted for by Danes and the remaining 50% by foreign tourists. In contrast to registered tourist stays (*Figure 3.6.3*) in hotels, holiday centres, camping grounds, youth hostels, etc., which are reported to Statistics Denmark, these figures are not calculated regularly, however.

As is apparent from *Figure 3.6.3*, the total number of registered tourist bed-nights increased by just under 50% from 1989 to 1995. Of the just over 44 million bed-nights in 1995, coastal tourism accounted for approx. 30 million, corresponding to approx. 70%. The growth has primarily taken place on the holiday cottage front rather than other forms of overnight stays. Half of all registered foreign tourist bed-nights in Denmark are made by Germans in rented holiday cottages.

Tourism has grown to become Denmark's fourth largest industry with roughly 100,000 jobs and a turnover of approx. DKK 40,000 million. The majority of overnight stays by foreign tourists are made along the southern part of the west coast of Jutland, north of the Wadden Sea, see *Figure 3.6.4*.

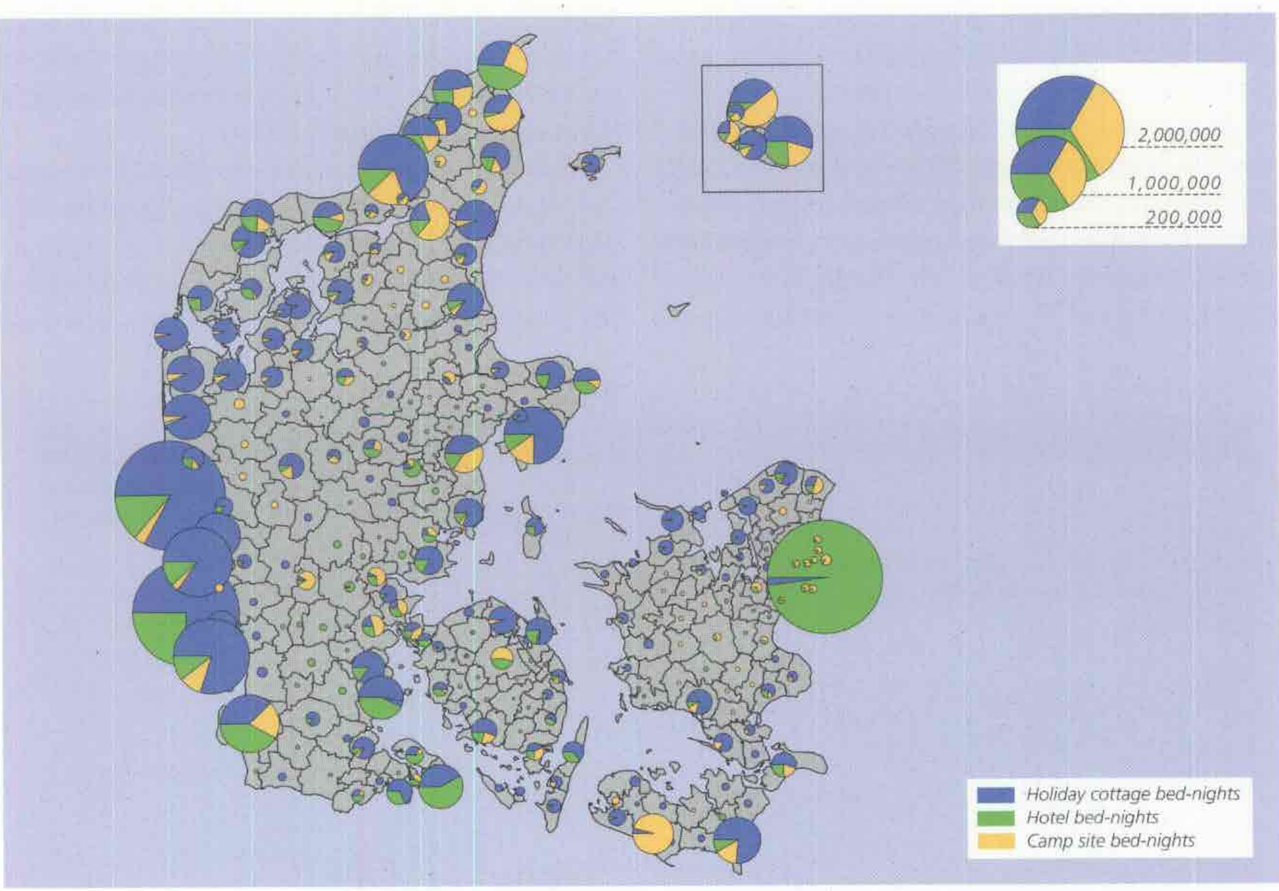


Figure 3.6.4 *Foreign tourist bed-nights shown for each municipality (Source: Spatial Planning Department, calculated on the basis of Statistics Denmark, 1994a) Note: The map shows bed-nights made by foreign tourists in holiday cottages, hotels/holiday centres and camp sites. Bed-nights in harbours and youth hostels are not included.*

Hotel bed-nights are the dominant form of overnight stay in Copenhagen, which alone accounts for 1/3 of all hotel bed-nights made by foreign tourists in Denmark. North Jutland also has a large number of hotel guests, especially from Sweden and Norway.

Communications

Communications, media and advertising play an increasingly important role in everyday life. A considerable part of leisure time is spent on television and video. Consumption is affected by advertising in the form of both unsolicited printed matter and spots produced for and shown in the electronic media. Other means of communication such as daily newspapers, local weeklies and radio are still widespread, even though they are not as expansive as the pictorial media. Media and advertising considerably influence the image of the surrounding world that each individual forms, and hence are important for the future development of society.

Statistics Denmark compiles data on turnover and employment within the so-called resource area communications, which encompasses private businesses supplying communication services. These include service branches such as media, telecommunications and computer software, as well as the production of printed matter and communications equipment, including computers. The resource area thus consists of branches with different positions along the chain of production, e.g. manufacturing industries such as the paper and printing industries and service industries such as advertising and media, trade in radio and TV sets, as well as various support industries such as manufacturers of photographic equipment and distribution of daily newspapers.

The central parts of the resource area, i.e. advertising and media (primarily TV, radio, video and daily newspapers), create demand and production in the other parts of the resource area. The resource area occupies a work force of approx. 150,000, of which media and advertising account for approx. 50%, see *Table 3.6.1*. The companies within the resource area account for approx. 8% of total exports of goods and services. The media and advertising world consists of a large number of small, diverse firms with many part-time employees. In addition, there are a few large workplaces, especially TV stations. The remaining part of the resource area includes a number of large and well-established firms, primarily within telecommunications, daily newspapers and the paper industry.

The information sector as a whole is considerably broader than the resource area communications. In the first place, some communication tasks are performed within the public sector. This applies to some mail and telecommunication services. Secondly, the educational sector and part of the public administration sector can also be grouped under the information sector. This broad perception of the concept of information was used by Sundbo and others (1983) to quantify and characterize the information sector in Denmark over the period 1950-80.

Table 3.6.2 shows employment within the information sector, understood as those industries whose final objective is the provision of information. As is apparent from the table, the sector has grown heavily since 1950, but now seems to be approaching a saturation

Communications				
	Number of firms	Turnover DKK 1,000 million	Total employees (thousands)	Full time employees (thousands)
Paper/printing industry	2,922	15.3	23	17
Media equipment manufacturers	459	8.9	11	5
Support services, production	239	4.1	4	4
Media	5,655	21.2	41	22
Post and telecommunications	63	19.9	15	15
Advertising, information technology, etc.	11,201	29.3	31	23
Media equipment, wholesale trade	3,891	44.0	25	20
Media equipment, retail trade	1,728	3.5	5	3
Total	*26,158*	*146.3*	*156*	*111*

Table 3.6.1 *Overview of the branches that comprise the resource area communications, November 1994 (Source: Statistics Denmark, 1996).*

Employment 1950-94		
Year	Employment (thousands)	Percentage of total employment
1950	194	10.8
1960	244	12.4
1970	352	16.1
1978	537	21.2
1987	645	24.1
1994	668	25.6

Table 3.6.2 *Employment in the information sector over the period 1950-94 (Source: 1950-78: Sundbo et al., 1983; 1987-94: Business Statistics Database, Statistics Denmark).*
Note: The figures for 1987 and 1994 follow the definition in Sundbo et al., 1983, and are therefore comparable with the figures in Sundbo et al., 1983.

point with somewhat over 25% of the workforce. This is probably attributable to the fact that information processing and the provision of information play an increasing role in a large number of other industries whose final objective is the provision of other services and physical products.

The service society

As mentioned above, the service sector has increased its relative share of total employment and production over the last 20-30 years, mainly at the expense of agriculture and industry. This development is also expected to continue in the years ahead, and there has consequently been some talk of a transition from an industrial society to a service society. Some social scientists have forecast this development and proposed a future scenario that they refer to as a "dream society" or a "cultural society", where production of stories and tales rather than material goods will constitute the driving force of the economy.

It is widely held that this development implies increasing dematerialization of the economy and hence a society characterized by lower consumption and less impact on the environment.

Advertising agencies, TV companies and banks are at first sight much cleaner firms than steel mills, cement works and pig abattoirs, etc. In reality, however, the notion that the service society is a generally less material or resource-consuming form of society is incorrect.

While it is true that the service sector represents an increasing share of value added, it is also apparent from the preceding sections on industry and agriculture that this is not accompanied by reduced agricultural or industrial production - to the contrary.

Moreover, the picture which forms of decreasing industrial production and increasing service sector production is often distorted as production within these sectors is usually compared in current prices. This overlooks the fact that the productivity increase in industry is considerably greater than that in the service sector. Thus within the OECD countries, the average annual increase in productivity over the period 1960-94 was 3.6% in industry but only 1.6% in the service sector. Expressed in real terms, thereby taking into account the different growth in productivity, industrial output is considerably greater than that of the service sector.

Industry's share of GDP over the period 1960-94 is illustrated in real terms for the OECD countries in *Figure 3.6.5.*

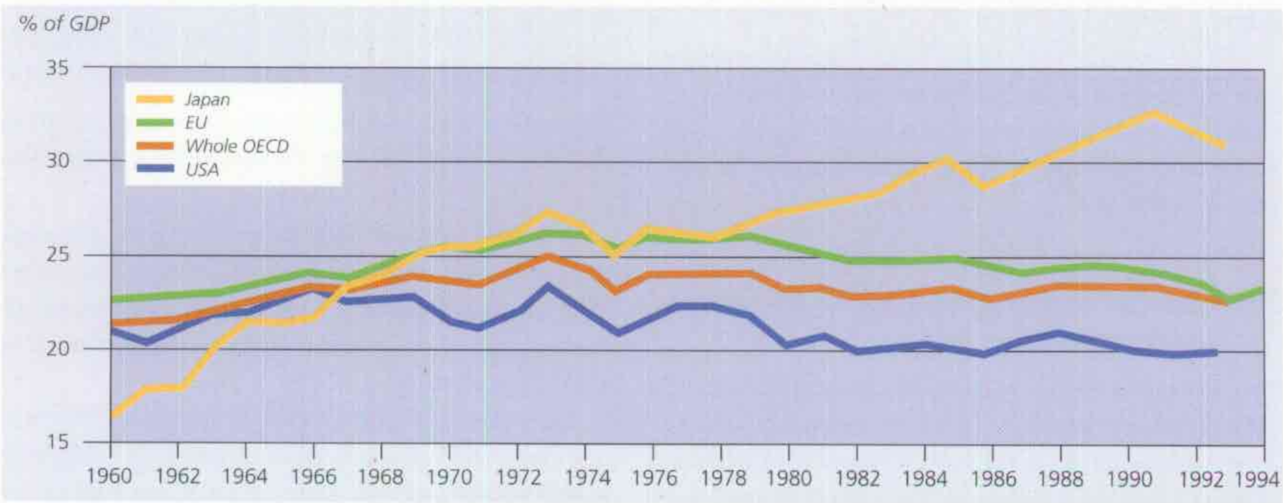


Figure 3.6.5 *Industry's share of gross domestic product (GDP) illustrated in real terms for the OECD countries over the period 1960-94 (Source: Rowthorn and Ramaswamy, 1997).*

It can be seen that for the OECD as a whole, industry has maintained the same relative share of the economic output since 1970, the share having decreased slightly in the case of the USA and the EU, but increased considerably in the case of Japan.

The picture which thus emerges is of a society in which increased productivity and production within the primary sectors and industry free resources for the development of a service sector. The service sector's more immaterial services do not replace material production, but instead supplement it and generate increased demand, especially for new and sophisticated industrial products. The entire information and media area is a good example of this, and the relationship between the service sector's immaterial services and material production is clearly shown in the indirect energy consumption generated by the sector elsewhere in the economic cycle, as mentioned below.

The overall conclusion is thus that a growing service sector does not *per se* foster a less resource-demanding society with less impact on the environment. Some of the services provided by the sector consist of developing cleaner technologies and production methods, developing a more environmentally friendly infrastructure, and repairing and maintaining the material goods produced and consumed by society.

These service activities have a positive environmental impact. However, the low increase in productivity in the service sector as compared to industry constitutes a barrier to the development of these activities. Services have consequently become relatively much more expensive than industrial products, a situation further aggravated by the Danish tax system since the tax burden is primarily directed at labour.

Those parts of the service sector whose services can be substituted by industrial products thus have difficulty in competing and as a result, the use-and-throw-away mentality is in effect encouraged by economic incentives.

3.6.3 Environmental impact of the service sector

As discussed above, the transition from an industrial society to a service society does not necessarily reflect a dematerialization of the economy and the development of less resource-demanding and more environmentally friendly production. The service sector must be seen in relation to the economy as a whole as the sector largely demands supplies from the primary and more resource-demanding industries. Moreover, the service sector itself imposes a number of pressures on the environment, both direct and indirect. These are described below. The picture given here is of necessity fragmentary; in contrast to the agricultural and transport sectors, systematic environmental statistics are not available for the service sector.

Consumption of energy and resources

The service sector's share of total industrial energy consumption is approx. 34%, corresponding to approx. 13% of total national energy consumption. Since 1980, total final energy consumption by the service sector has been relatively constant at roughly 80 PJ, though with a tendency towards a slight increase in the 1990s, (see *Figure 3.6.6*). The development in the total energy consumption reflects declining consumption by the public service sector and increasing consumption by the private service sector.

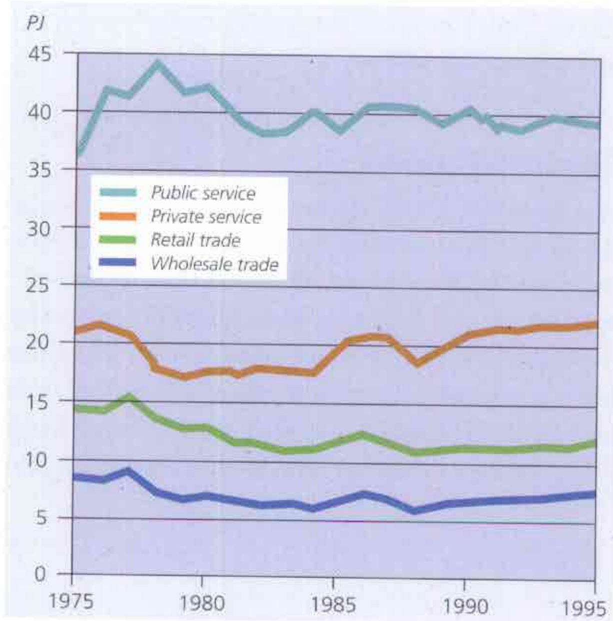


Figure 3.6.6 *Net energy consumption in the service sector in PJ (Source: Energy Statistics, Danish Energy Agency, 1996).*

It is often believed that the service sector is far less energy-intensive than the manufacturing industries. This assumption is valid provided that only the direct energy consumption from the sector itself is taken into account.

However, a slightly different picture emerges if one also takes into account the fact that the economy is interconnected and that increased activity in for instance the service sector necessitates enhanced input of supplies from other branches at home and abroad. According to the 1990 Input-Output Tables from Statistics Denmark (1994b), the total direct and indirect energy consumption associated with DKK 1 million of output is:

- Industry 1.12 TJ
- Private service sector 0.92 TJ
- Public service sector 0.41 TJ

Total energy consumption per unit output in the private service sector is thus comparable to that in industry, while that in the public service sector is considerably lower.

In addition to energy, the service sector also demands a number of other material resources. As already mentioned, the sector employs 2/3 of the workforce, and consequently requires considerable floor space. Over the period 1986-96, floor space occupied by the service sector increased by approx. 20%, whereas the total floor space only increased by approx. 11%, see *Table 3.6.3*. Floor space occupied by the service sector thus increased by 17.2 million m², corresponding to just under 50% of the total growth in industrial floor space. In 1996, total floor space occupied by the service sector amounted to approx. 104 million m², corresponding to approx. 1/3 of total industrial floor space. Hence floor space per employee is low in the service sector as compared to other sectors.

There are no systematic calculations of the consumption of other resources by the service sector. As an information-heavy sector, it uses a considerable amount of information technology which in the form of discarded computers, printers, etc., increasingly ends up as waste and causes problems due to its high content of environmentally hazardous substances, especially heavy metals. In general, waste generation by the service sector is increasing markedly, as discussed below.

Waste

Development in the amount of waste from the institutional, trade and office sectors is shown in *Figure 3.6.7* apportioned by form of treatment. Marked growth is seen over the period 1985-95. The total

Danish building stock

Floor space (1,000 m²)	Building stock 1996	Growth 1986-96	Growth in %	Share of total stock	Share of total growth
Service sector	104,521	17,211	19.7	16.6	27.5
Agriculture	130,859	9,116	7.5	20.8	14.6
Industry, etc.	56,727	9,980	21.3	9.0	15,.9
Housing, etc.	336,936	26,294	8.5	53.6	42.0
Total	*629,042*	*62,601*	*11.1*	*100.0*	*100.0*

***Table 3.6.3** Danish building stock apportioned by sector in 1986 and 1996 (Source: Municipal Statistics Database, Statistics Denmark).*

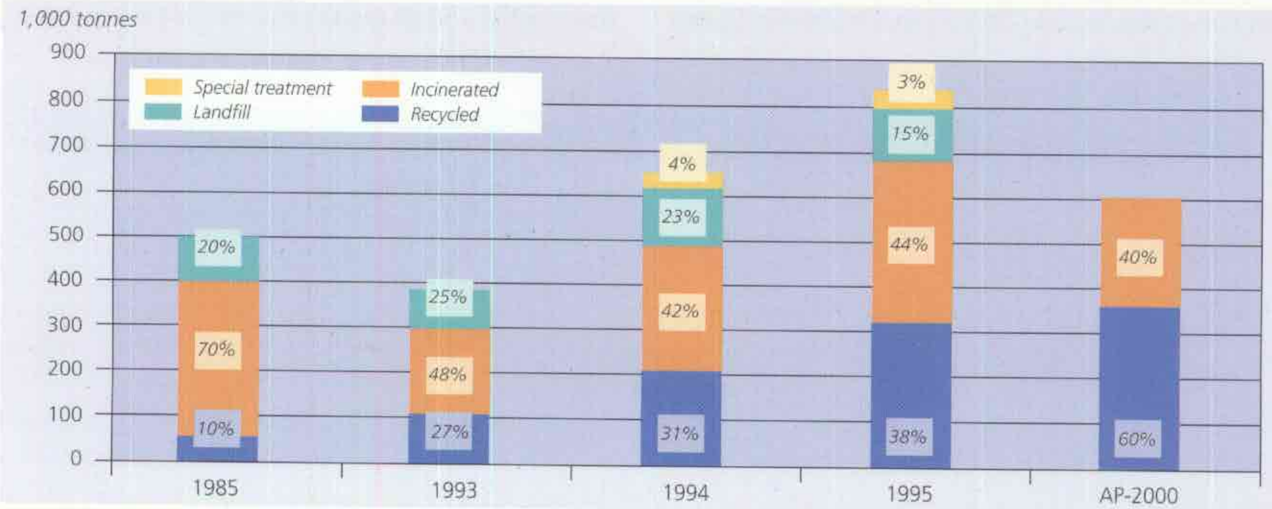


***Figure 3.6.7** Waste generation by the institutional, trade and office sectors apportioned by form of treatment (Source: Danish Environmental Protection Agency, 1992, 1994 and 1996).*

amount of waste in 1995 was 834,000 tonnes, which is over 200,000 tonnes more than expected in the year 2000 according to the Action Plan on Waste and Recycling (AP-2000 in *Figure 3.6.7*).

A calculation based on the general forecast for economic development (see *Section 3.1*) and assuming proportionality between sector activity and waste generation shows that the amount of waste generated by the service sector will increase by an average of approx. 2% a year over the period 1995-2000. Thus the total amount of waste generated by the service sector in the year 2000 will be about 925,000 tonnes, i.e. over 50% more than expected.

Total recycling of waste from the institutional, trade and office sectors has increased to 317,000 tonnes or 38% of the total amount of waste. Landfill has declined to 128,000 tonnes, corresponding to 15%. Thus both the landfill and recycling targets for the year 2000 are far from being met.

Transport and service

The service sector generates traffic in the form of commuting by employees and transport by customers, patients and others to and from the services provided. In addition there is a certain amount of freight transport, mainly generated by the retail trade.

Development in service-related transport can be assessed on the basis of the transport habits surveys in 1975 and 1994-96. These surveys throw light on the daily transport for different purposes in the 16-74 age group living in Denmark. Tourist trips are not included.

On weekdays, service-related transport accounts for at least 50% of the total passenger transport. Service-related transport has increased by 54% between 1975 and 1994/96 (see *Table 3.6.4*). On the whole, this increase corresponds to the general increase in total passenger transport.

While total commuting has increased by 27%, service-related commuting has increased by 41%. Education-related trips remain the same, whereas transport to amusements, sports, outdoor recreation, etc. has increased by 129%. The growth in professional transport is even greater, although the figure is subject to great uncertainty. Shopping traffic has increased by 28%, but this is probably an underestimate because errand traffic at weekends is not included in the calculations. Other studies indicate that this type of transport has increased considerably more.

The growth in service-related transport is partly attributable to the general growth in the service sector as well as to the increasing spatial segregation of services. A decentralized retail trade structure with maintenance of local business communities in a number of towns should be able to curb this growth.

Land use by the service sector with emphasis on tourism

The tourist industry occupies land, and in certain areas places pressure on nature. On the other hand, the life blood of the tourist industry is high environmental and landscape quality. Thus in the long run, overexploitation of nature by tourism will undermine the tourist industry. The tourists mainly focus on the coastal zone, and it is particularly in this zone that tourist activities dominate with respect to building and construction.

A 1990 survey thus showed that 1,007 tourist facilities were located within the coastal zone, i.e. within about 3 km of the coast. These included hotels, camp sites, marinas, golf courses, water amusement parks, course centres and other holiday and re-

Transport			
	km/person/day		
	1975	1994/96	Growth (%)
Commuting to service sector jobs	4.5	6.4	41%
Education	1.6	1.6	0%
Shopping	2.4	3.0	28%
Other leisure and service trips	1.9	4.3	129%
Professional	0.6	1.5	150%
Total service-related transport	*11.0*	*16.9*	*54%*

Table 3.6.4 *Weekday transport for service-related purposes in 1975 and 1994/96 (Source: Calculations made by the National Environmental Research Institute based on Statistics Denmark's 1975 and 1992-97 Transport Habits Surveys).*

creation facilities. A total of 386 were located in the open countryside, including 95 of the 177 camp sites with over 200 units. The remaining tourist facilities were located in connection with towns or holiday cottage districts (see also *Section 3.8.4*).

In addition, a considerable amount of land in coastal areas has been reserved for holiday and recreation developments, some of which were designated as long ago as the 1970s but have not yet been developed. The county Regional Plans currently in force contain approx. 70 as yet undeveloped sites designated for major tourist accommodation facilities. Attempts are being made to reduce the number, however. The regional, municipal and local plans also provide for considerable new development or expansion of holiday hotels in connection with towns and holiday facilities near the coast. The present revision of the Regional Plans will include a review of designated development sites with a view to re-evaluating and deleting those that have long remained undeveloped. In certain areas, tourism and outdoor recreation in the wider sense place considerable pressure on nature. This aspect is examined in detail in *Section 3.8* on outdoor recreation and tourism.

3.6.4 **Objectives and policy measures**

Since the service sector is a highly varied sector with a number of different environmental problems, no overall efforts on the environmental front has been directed at this sector such as is the case with agriculture, the energy sector, etc. The problems relating to resource and energy consumption by the service sector are tackled within the framework of the general efforts in these areas. Measures such as green procurement policy, eco-labels and energy labelling of products, environmental management and green accounts are thus also directed at the service sector.

According to the Environmental Protection Act, public authorities have to comply with the provisions of the Act when establishing and running public enterprises and in connection with procurement and consumption of goods, services, etc. The Ministry of Environment and Energy has thus issued a circular requiring all government institutions to draw up, adopt and follow a green procurement policy.

Efforts to promote green procurement in the public sector also include preparation of a large number of purchasing guidelines directed at public procurement officers, as well as at purchasing departments in private business. Spatial planning problems in the service sector, which mainly relate to the tourist industry and the retail trade, are regulated under the Town and Country Planning Act.

The Act thus stipulates the principle of sharp demarcation of Denmark into urban zones, country zones and holiday cottage districts. Moreover, with a view to safeguarding environmental and landscape quality of the open Danish coasts, the Act now also stipulates principles for spatial planning within the coastal zone so as to keep it free of built-up sites that do not need to be near the coast.

In the coastal zone, justifiable building and construction projects have to be located inland of existing buildings so as to preserve the open coasts. New holiday and recreation facilities must be justified in the context of the County's overall tourism policy considerations, and have to be sited in connection with existing urban communities or existing large holiday and recreation facilities. Moreover, it is not permitted to designate new holiday cottage districts within the coastal zone, and existing holiday cottage districts must remain as recreational areas.

Provisions have also been inserted into the Nature Protection Act extending the sand dune and beach protection zone from 100 to 300 m such that new buildings and other facilities are no longer permitted within 300 m of the coastline. The exact trajectory of the extended 300 m zone is currently being determined by the Coastal Conservation Commission.

It is the responsibility of the county councils to ensure implementation of the provisions of the Town and Country Planning Act concerning the designation of urban developments, industrial districts and holiday/recreation facilities.

In order to facilitate regulation of development within the retail trade, the Act was amended in 1997. The purpose of the amended Town and Country Planning Act is to counteract concentration of the retail trade in the 20-30 largest towns. The Act aims to ensure maintenance of shop variety in smaller and medium-sized towns, as well as in individual quarters in large towns. The Act requires municipal councils to stipulate shopping zones in the Municipal Plans and fix limits for the maximum floor space of new shopping developments and the conversion of existing buildings to shopping facilities.

Furthermore, the plans also have to ensure that new shopping sites are zoned in places with good accessibility for all types of traffic, including pedestrians, cyclists and public transport. As something new, the Act also stipulates that new shopping areas have to be located in the central part of towns or urban districts.

3.7 Households

3.7.1 Introduction

The household sector comprises an important part of society and the economic cycle. Based on an economic description of society, households comprise the penultimate link in the overall life cycle of goods and products: from extraction of raw materials, processing and distribution to consumption and finally to waste disposal. Consumption is an active and controlling element in this chain of events since the magnitude and nature of consumption to some extent determines the preceding and following elements in the cycle.

The individual consumer's lifestyle determines the magnitude and composition of consumption, and hence of the resultant environmental impact. Consumer lifestyle is determined by a number of factors, e.g. economy, culture, social relations, habits, knowledge, etc. In addition, consumer behaviour is affected by a large number of economic and structural conditions which the individual consumer has only a marginal influence on: the supply of goods, location of workplaces and shops, organization of the infrastructure, etc.

The main features of Danish households and trends in the pattern of consumption are summarized below followed by an examination of the resultant environmental impact and finally, a description of environmental policy measures on the household front.

3.7.2 Danish households

Since 1955, the number of households in Denmark has increased from 1.4 to 2.3 million. The size of the average household has fallen from more than 3 persons in the 1950s to just over 2 persons in the 1990s, see *Table 3.7.1*. In the same period, the employment rate of women has increased considerably, see *Table 3.7.2*.

	1955	1970	1980	1990	1993
Number of households (x 1,000)	1,373	1,797	2,000	2,229	2,286
Average no. of residents per household	3.13	2.69	2.47	2.25	2.22
Number of residents			Percentage of households		
1 person	14.6	23.7	27.9	33.5	34.8
2 persons	27.6	29.5	31.6	33.0	33.0
3 persons	21.4	18.5	16.1	15.1	14.7
4 persons	18.7	16.7	16.5	13.4	12.7
5 persons or more	17.7	11.6	7.9	5.0	4.8
Type of house					
Single-family house	45.5	49.5	57.7	58.6	59.6
Multi-family house, apartments, etc.	54.5	50.5	42.3	41.4	40.4
Installations					
Central heating	34.3	84.0	91.3	94.9	95.9
Own bathroom	36.1	71.1	84.0	89.7	91.2

Table 3.7.1 *Development in the number of households over the period 1955-93 (Source: Statistics Denmark, 1995).*

	1950	1960	1970	1981	1995
Men	88	84	79	76	83
Women	28	23	42	64	76

Table 3.7.2 *Employment rate for men and women over the period 1950-95 (Source: Statistics Denmark, 1996).*
Note: The figures are not fully comparable as calculation of the employment rate has changed several times. From 1940 to 1970, it is the percentage of those actively engaged in employment. From 1976 to 1995, it is the percentage of the primary workforce that normally has paid work as its chief occupation.

Households have become smaller and, at the same time, more integrated in society's production and division of labour. Both of these trends combined with enhanced general prosperity have led to markedly increasing household consumption.

From the early 1970s to the mid 1990s, private consumption has increased by approx. 50% in real terms. The trend from 1980 onwards is shown in *Figure 3.7.1*.

According to the Ministry of Finance 1996 Medium Term Economic Survey, the trend seen up to 1995 is expected to continue with approx. 40% real growth in private consumption from 1995 to 2005. The overall effect of these trends has been a radical change in household lifestyle from being a relatively independent unit with considerable productive, social and cultural functions to one that is far more integrated in and dependent on a differentiated society and its services in the form of goods and services. Modern households are highly characterized by the notion that "outside" is the place where one produces and earns money, while "home" is the place where one consumes and uses money.

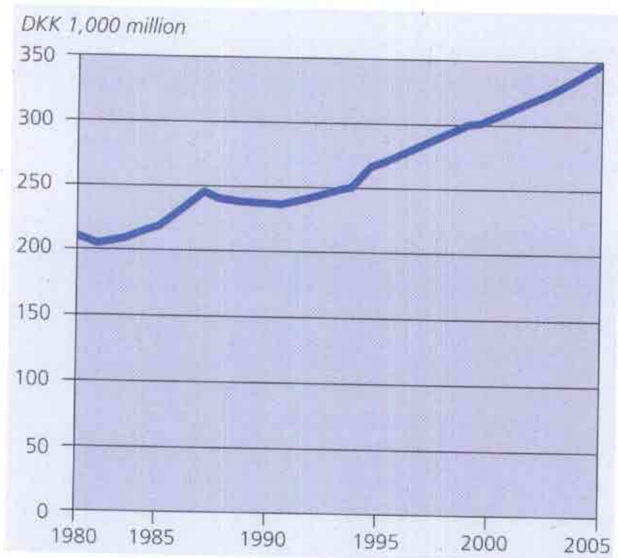


Figure 3.7.1 *Development in private consumption expressed in constant (1980) prices. The figures for 1980-95 are from the National Accounts (Source: Statistics Denmark). The forecasts for 1995-2005 are from the 1996 Medium Term Economic Survey (Ministry of Finance, 1996).*

This development is of relevance with regard to the environmental impact of households as increasing general prosperity and associated increasing consumption place increased pressure on the environment along the whole life cycle from production to final disposal as waste. In addition, the lifestyle changes accompanying the new family patterns enhance demand for resource- and energy-demanding household aids, as well as for transport.

3.7.3 Environmental impact of households

Households affect the environment both directly and indirectly. The direct impact is that related to the consumption of products. The indirect impact is that related to production or disposal of the products. This is illustrated in *Figure 3.7.2*.

The purchase of an ordinary cooker is an example of how the choice of cooker and the manner in which it is used determine the overall environmental impact from cradle to grave. The environmental impact of the different phases in the cooker's life cycle is summarized in *Table 3.7.3*.

The amount of material used to produce the cooker may vary considerably from 40 to 68 kg. Differences

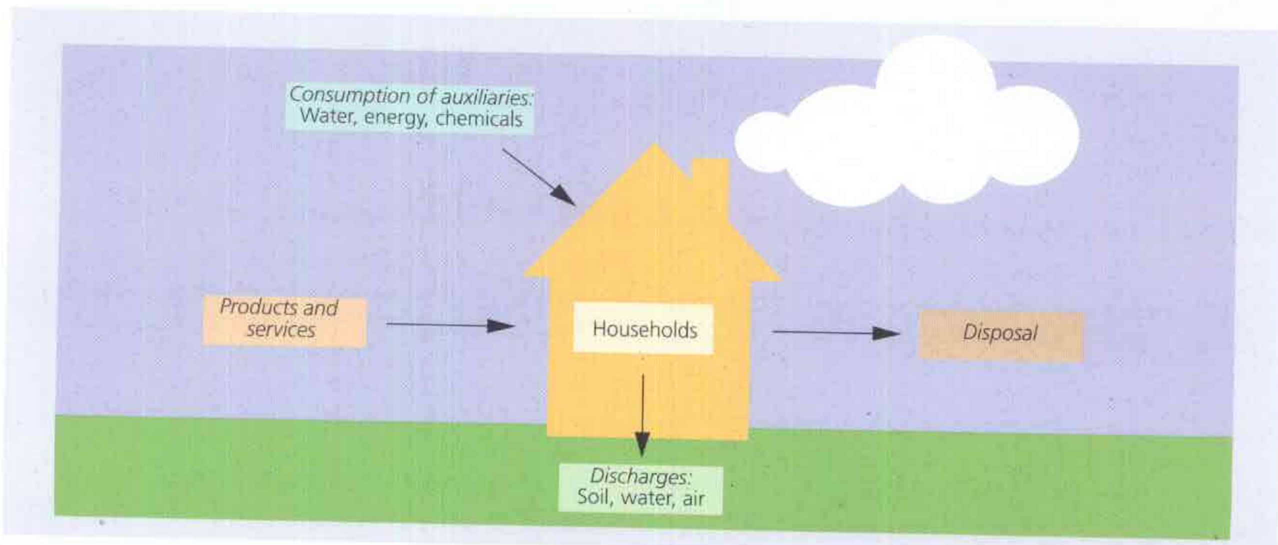


Figure 3.7.2 *Model of household resource consumption and environmental impact.*

	Production of raw materials	Manufacture of cooker	Use of cooker	Disposal of cooker
Raw materials consumption	+++	+	+	+++
Energy consumption	+	+	+++	0
Environmental impact				
•Global	+	0	+++	0
•Regional	+	0	+++	+
•Local	+++	+	+	+
Health impact				
•Working environment	+	+	0	0
•Consumers	+	0	+++	0
Risk of accidents	0	0	+	0

Table 3.7.3 Environmental impact and life cycle of an average kitchen cooker. +++ indicates a high environmental impact during the phase in question, + indicates a smaller environmental impact during the phase in question, and 0 indicates that the environmental impact during the phase in question is without practical significance or impossible to measure (Source: Danish Environmental Protection Agency, 1996a).

in the hotplate technology chosen e.g. gas, solid plates, induction, etc. also influence the cooker's energy consumption.

For example, the production of a gas cooker only requires 45% of the energy needed to produce a standard electric cooker. Once the cooker has been purchased, it is largely consumer behaviour which determines the cooker's environmental impact: Will the oven be filled up? Will the afterheat be used? Do the pots and pans have a flat bottom? Tests have shown that energy consumption for cooking can be more than halved by good cooking habits. When the cooker is eventually discarded, part of it is recycled and part is disposed of by landfilling. In the case of an average 58 kg cooker, 22 kg ends up on a landfill.

There is therefore considerable environmental potential in changed demand and consumer behaviour as regards reducing the environmental impact of all the phases of a product's life cycle.

Further examination of the environmental impact of households is subdivided into:

- Products and services
- Consumption of auxiliaries
- Discharges from households
- Solid waste

Products and services

Private consumption has not only increased. Its composition has also changed, as is apparent from the National Accounts, see *Table 3.7.4*.

More money is spent on housing. Among other things, this is due to growth in the housing stock. During the same period, the share of the household

Consumption in DKK 1,000 million (1980 prices)	1975 *194*	1980 *208*	1985 *230*	1995 *272*
Consumption in % of total				
Food and beverages	27	25	23	20
Fuels, electricity, gas, heat	6	12	6	5
Clothing and footwear	6	12	6	5
Transport and communications	15	3	17	18
Furniture and fittings, household services, etc.	9	8	7	6
Housing costs	17	19	19	21
Other	20	21	22	25

Table 3.7.4 Development in private consumption over the period 1975-95 in constant (1980) prices (Source: Statistics Denmark, 1996).

budget used for food, etc., has decreased correspondingly.

The Danish Environmental Protection Agency and the Consumer Agency of Denmark have examined which household activities are of greatest significance with respect to the environment and resources.

The study shows that eating accounts for more than a third of a family's total consumption of resources and discharges to the environment. The next third is accounted for by car transport and heating, while the final third is accounted for by clothes and laundry, personal hygiene and health, cleaning, and those leisure activities undertaken in the home.

The results are based on a model family's consumption determined from the Consumer Agency of Denmark's family budget. The model family consists of two adults and two children.

The calculation includes a life cycle assessment of the model family's consumption of a total of 812 products related to 22 household activities. By way of example, the environmental impact of the activity "toothbrushing" was determined by adding the environmental impact of the toothbrush, the toothpaste, the toothmug and the water used. Moreover, the environmental impact of each activity was subdivided into that attributable to resource use and that attributable to discharges, of which the former reflects the impact of resource input for household consumption, while the latter reflects household discharges.

Table 3.7.5 shows the overall environmental impact of the model family's household activities expressed in terms of both resource use and discharges.

Eating comprises the main item on the environmental impact budget. The reason is that it requires large amounts of energy and materials to produce, process, transport, cool and cook the foods, and to clean up afterwards. In the case of a hamburger, for example, over half of the environmental impact takes place before the hamburger even ends up in the shopping trolley. A further quarter of the environmental impact is associated with cooking the hamburger, while the remaining quarter is accounted for by storage, dishwashing, serving and shopping.

What we buy and how we consume depends on our lifestyle which is formed through the habits and routines of everyday life. Much depends on the manner in which our everyday life is organized, the location of our home, the way we live, etc.

Differences in lifestyle - how we choose housing, transport, food, etc. - can considerably affect the associated environmental impact. A study from Aalborg University illustrates just how great these differences can be, see *Table 3.7.6*.

	Resource use in percent of total	Discharges in percent of total
Eating	38%	36%
Clothes and laundry	7%	8%
Personal hygiene/health	10%	4%
Leisure (at home)	15%	12%
Cleaning	2%	1%
Heating	14%	12%
Transport (car)	14%	27%

Table 3.7.5 *Model family's relative resource consumption and environmental impact (Source: Consumer Agency of Denmark, 1996a).*

	Family A	Family B	Family C	Family D
Housing	6,876	6,876	7,984	16,137
Heating	87,665	82,375	75,567	23,232
Electricity	50,054	20,002	19,013	339
Transport	219,760	83,098	7,309	688
Food	8,330	7,014	5,439	3,913
Total	*372,685*	*199,365*	*115,312*	*44,309*

Table 3.7.6 *Environmental impact expressed as primary energy consumption in MJ per year for four types of family (Source: Christensen, 1997).*

The study was based on four different, fictitious families composed of two children and two adults modelled so as to reflect a number of ordinary habits and lifestyles. Family A represents the "American" lifestyle with two cars and a house with central heating. They also eat too much. Family D represents the other end of the spectrum - the "radical, green" lifestyle family that cycles, lives in a low-energy house and eats more organically produced foods and more vegetables than average.

As is apparent from the table, the difference can be significant. The family with the "American" lifestyle uses 5 times as much energy on transport alone as the "radical, green" family uses in total.

Consumption of auxiliaries

Household consumption of auxiliaries encompasses water, energy and a number of chemical substances ranging from nail polish to detergents to pesticides.

Water

Out of a total groundwater consumption of 493.2 million m^3 in 1994, households accounted for 300.7 million m^3. Household water consumption has declined by almost 20% during the last 10 years. Development in water consumption is illustrated in *Figure 3.7.3.*

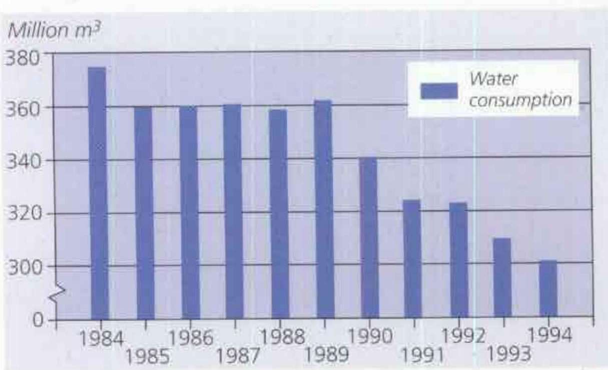


***Figure 3.7.3** Household water consumption over the period 1984-94 (Source: Statistics Denmark, 1996).*

On average, each Dane uses 170 litres of water per day, mainly for bathing, toilet flushing, washing and cleaning, see *Table 3.7.7.* There is still considerable potential for further water savings in respect of these uses, however.

	National average
Food	9
Bathing	39
Personal hygiene	20
Toilet flushing	34
Laundry	25
Dishwashing and cleaning	34
Miscellaneous	9
Total	*170*

***Table 3.7.7** Water consumption in litre per person per day apportioned by use (Source: Danish Environmental Protection Agency, 1996b).*

Energy

Households use energy for heating, electric appliances and transport. Transport is discussed separately in *Section 3.3* and will not be discussed here. Development in household energy consumption (excluding transport) is shown in *Table 3.7.8.*

Over the period 1972-90, household energy consumption has declined by almost 30%, but has subsequently increased again by approx. 10% up to 1995 (if climate corrections are taken into account, however, consumption has only increased by about 1%).

The decline in total consumption is due to savings for heating purposes. The reduction in energy consumption for heating is a result of efforts initiated following the energy crises in the late 1970s concerning insulation of houses, conversion to district heating, renewal of installations and improved energy control. Since 1974, the heating demand per m^2 has been halved and there is still a considerable potential for further reductions. Heat consumption has been in-

Energy consumption in TJ	1972	1980	1990	1995
Electricity	23,427	30,670	35,960	37,731
District heating	40,416	37,880	47,838	60,655
Other heating, etc.	173,372	136,522	85,287	89,251
Household consumption, total	*237,215*	*205,072*	*169,085*	*187,637*

***Table 3.7.8** Household energy consumption over the period 1972-95 excluding transport (Source: Energy Agency, 1996).*

creasing slightly again during the 1990s, among other things due to growth in the housing stock.

Despite increasing energy prices, there has been a considerable growth in the electricity consumption due to the increased use of electric appliances. Electricity consumption for appliances has doubled since the 1960s as a result of the introduction of washing machines, clothes driers, TVs, stereo sets, lamps, cookers, refrigerators, food processors, hand-held blenders, electric toothbrushes, computers, printers, potato peelers, and water beds. Electricity consumption currently accounts for almost 20% of household energy consumption.

Since the late 1980s, the growth rate of the household appliance pool has declined, see *Figure 3.7.4*, and new appliances have concomitantly become more energy-efficient, see *Figure 3.7.5*.

As a result, growth in household electricity consumption has been declining since the early 1990s.

Chemicals

Household consumption of chemical substances contributes to discharges of a number of environmentally harmful substances.

Retail sales of chemical substances were last determined in 1985 by the Danish Environmental Protection Agency, see *Table 3.7.9*. As is apparent, consumption of cleaning agents, textile treatment products, auto care products and surface protection products is considerable.

Since 1985, phosphate consumption in detergents has decreased by 30-50% and has been replaced by zeolites and other alkaline substances. This is largely attributable to the desire to reduce the discharge of phosphates to the aquatic environment.

Surface protection products, which mainly encompass paints, varnishes and wood preservation products, are other major sources of chemical discharges to the environment, although no independent estimate is available of total consumption in pri-

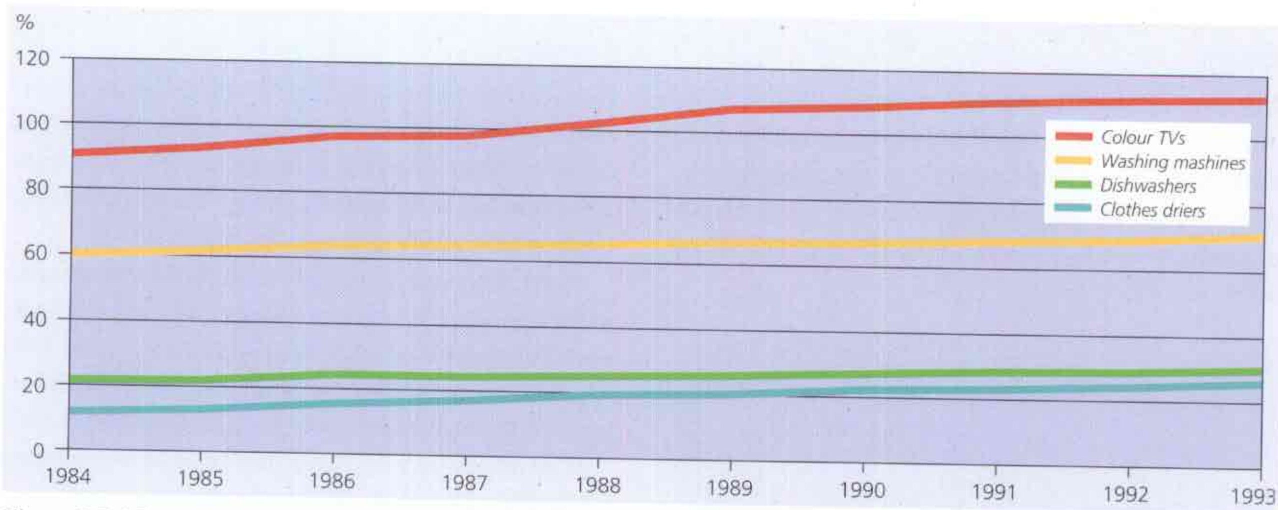


Figure 3.7.4 *Percentage ownership of household appliances (Source: Danish Association of Power Companies, 1994).*

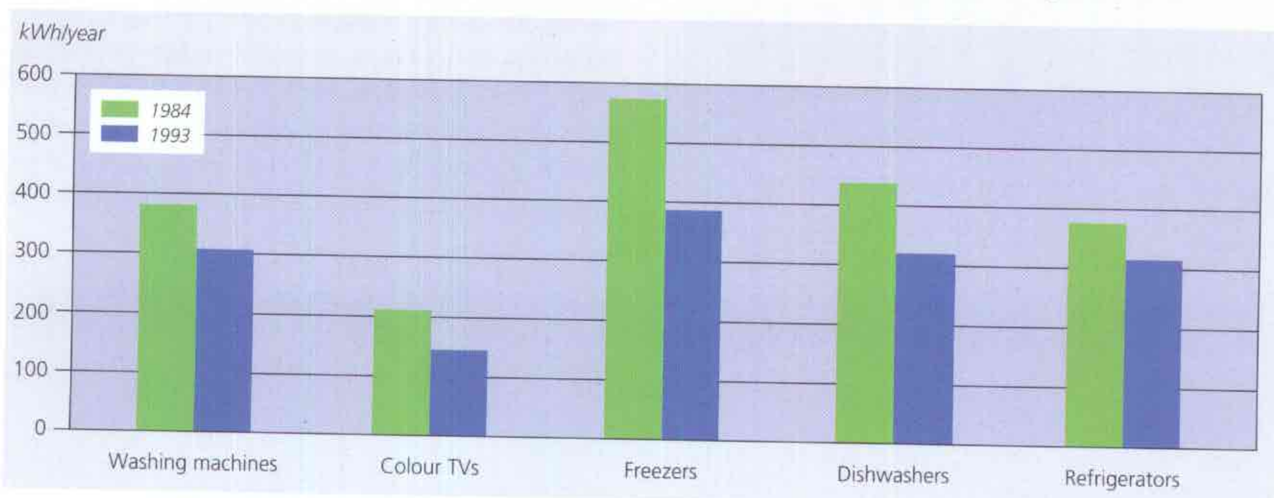


Figure 3.7.5 *Annual electricity consumption by new household appliances (Source: Danish Association of Power Companies, 1994).*

Product group	1,000 tonnes per year in 1985
Cleaning agents	70.0
Metal polish	< 0.1
Decalcifiers	2.0
Textile treatment products	50.0
Impregnation and leather treatment products	0.3
Surface protection products	22.0
Glue, sealants, etc.	4.4
Furniture and floor polish, etc.	0.2
Auto care products, incl. motor oil	100.0
Photographic chemicals	< 0.1
Swimming pool chemicals	0.3
Pesticides	< 0.1
Fertilizers	17.5
Artists paint	< 0.1

***Table 3.7.9** Retail sales of chemicals in 1985/86 (Source: Danish Environmental Protection Agency, 1990).*

vate households. However, there has been a major shift to more environmentally friendly water-based products in recent years.

In connection with the above mentioned analysis of the environmental impact of household activities, an environmental assessment was made of the chemical products used by the model family, see *Table 3.7.10*. This showed that the chemical products with the greatest environmental impact were those that the model family used in large quantities.

The textile detergents were considered to have the greatest environmental impact followed in descending order by hair care products and body shampoo, toilet cleaners and universal cleaners, all of which are used in quantities exceeding 3 kg per model family per year. Cosmetics (excluding shampoo, conditioner and soap), which are used in small quantities (0-150 g per year), were considered not to affect the external environment. Annual consumption of pharmaceuticals by the model family is low (4-5 products) and the basis for an environmental assessment is weak.

Discharges from households

Discharges to water

Sewage from Danish households contain 112,000 tonnes of organic matter (measured as biological oxygen demand), 23,000 tonnes of nitrogen and 5,000 tonnes of phosphorus. Of this, almost 100,000 tonnes of organic matter, almost 20,000 tonnes of nitrogen and just over 4,000 tonnes of phosphorus are discharged to sewage treatment plants, see *Section 3.5* on waste water discharges from industry. The remaining amounts are discharged partly from buildings located

Product name	Content and amount when assessed	Group	Consumption (kg/yr)	Score
Laundry detergents	10% AEO, 7.5% AS, 1% phosphonates	III	15.4	15
Hair care products and body shampoo	10% AES, 2.5% BET, 1.5% FAA	III	7.9	8
Toilet cleaner	2% KAT, 2% LAS	II	3.3	5
Universal cleaner	2% LAS, 3% anion tenside, 5% nonion tenside	III	5.0	5
Washing-up liquid	28% anion tenside, 8% nonion tenside, 1% amphoteric tenside	II	1.4	3
Hand soap	1% EDTA	III	3.4	2
Film and developing	2.5% EDTA	III	2.1	2
Scouring powders	5% AEO, 5% LAS	III	2.0	2
Naptha	100% alkanes/alkenes	I	0.25	1
Chlorine	5% Na hypochlorite	III	0.75	1
Surfactants	15% AEO	III	0.50	1

***Table 3.7.10** Household chemical products ranked according to the hazard they pose to the aquatic environment. The number in Roman numerals under the heading "Group" expresses the dangerousness of the constituent chemicals to the aquatic environment. The number under the heading "Score" expresses the dangerousness relative to the amount used by a standard family. A high score indicates a high impact on the aquatic environment. Chlorine thus has a low score because a standard family uses so little. Most of the chemical constituents listed represent various organic solvents and surfactants (Consumer Agency of Denmark, 1996a).*

outside the sewerage system, see *Section 3.9* on sewage and waste. Almost 90% of households are currently connected to the sewerage system and associated treatment plants.

The above mentioned figures of phosphorus discharges include phosphorus from approx. 40,000 tonnes of detergents and 25,000 tonnes of cleaning agents used by households each year. Detergents and cleaning agents previously comprised a major source of phosphorus discharges, but within the last 10 years the use of phosphate in detergents has been reduced by 30-50%, corresponding to 2,500 tonnes of phosphorus.

Detergents and cleaning agents also contaminate the aquatic environment with surfactants that are toxic to aquatic organisms. A wide range of other substances used in households in smaller quantities are also discharged via sewage.

Emissions to the air

Household energy consumption for heating, electricity and transport contributes to the energy-related emissions of CO_2, SO_2 and NO_X. These emissions are discussed further in *Section 3.2* on energy and *Section 3.3* on transport.

Direct household emissions of CO_2 and SO_2 from individual domestic heating have been decreasing markedly since the 1970s as a result of the transition to collective heat supply. Direct CO_2 emissions currently amount to approx. 5 million tonnes, corresponding to approx. 8% of total Danish CO_2 emissions and 1/3 of the level in the early 1970s. These direct emissions are expected to decrease further to 3.6 tonnes by the year 2005. Direct SO_2 emissions from households have also decreased to under 1/10 of the level of the early 1970s, and currently amount to approx. 7,000 tonnes, corresponding to approx. 3% of the total energy-related emissions.

Emissions from fireplaces and wood-burning stoves only account for a minor part of total CO_2 emissions, but may give rise to emissions of polycyclic aromatic hydrocarbons (PAH) and dioxin. PAH formation is greatest when combustion is poor, whereas dioxin formation mainly depends on the type of fuel used. It is thus estimated that households account for 75% of total PAH emissions. As regards dioxin, a recent survey has markedly lowered the supposed level of emissions from fireplaces and wood-burning stoves so that this is now considered to be marginal compared to emissions from waste incineration plants and the iron and metals industry.

Finally, households emit volatile organic compounds (VOC) contained in a number of household chemical products, especially paints and varnishes. In 1990, these emissions were estimated at approx. 7,000 tonnes, or approx. 1/3 of VOC emissions from industry, see *Section 3.5.3*.

Solid waste

Waste from households consists of household waste, bulky waste and garden waste. Household waste consists of organic waste, paper, bottles, glass and residual waste. *Figure 3.7.6* shows that the amount of household waste increased by more than 25% between 1985 and 1994, but fell slightly between 1994 and 1995. Recycling of household waste has more than doubled during the period, thus accounting for 14% in 1995. This is still far below the 40-50% recycling target for the year 2000 stipulated in the Government's Action Plan for Waste and Recycling (AP 2000 in *Figures 3.7.6 - 3.7.8*).

According to the target, landfilling of household waste is supposed to be reduced to 0% by the year 2000. In both absolute and relative terms, landfilling of household waste decreased between 1985 and 1995. The majority of household waste was still incinerated in 1995. The landfilling of combustible waste has been prohibited since 1 January 1997, and it is now only permitted to dispose of household waste by landfilling on isolated islands without direct land connection to an incineration plant. Landfilling as a means of waste disposal is thus expected to be negligible in 1997.

In 1995, the amount of bulky waste from households was 618,000 tonnes, see *Figure 3.7.7*. The amount of bulky waste increased considerably between 1985 and 1994, but only slightly between 1994 and 1995. The amount of bulky waste is considerably greater than expected in the year 2000.

Considerably more bulky waste was incinerated in 1995 than in 1985. While the amount of bulky waste disposed of by landfilling has increased in absolute terms, it has decreased markedly in relative terms as the total amount of bulky waste has increased by over 100%.

In 1995, the amount of garden waste was 326,000 tonnes (*Figure 3.7.8*) which is below the expected level for the year 2000. This may be due to increased home composting of garden waste. In 1994, recycling of garden waste was already above the target for the year 2000. Compared to 1985, the disposal of garden waste by landfilling has decreased markedly.

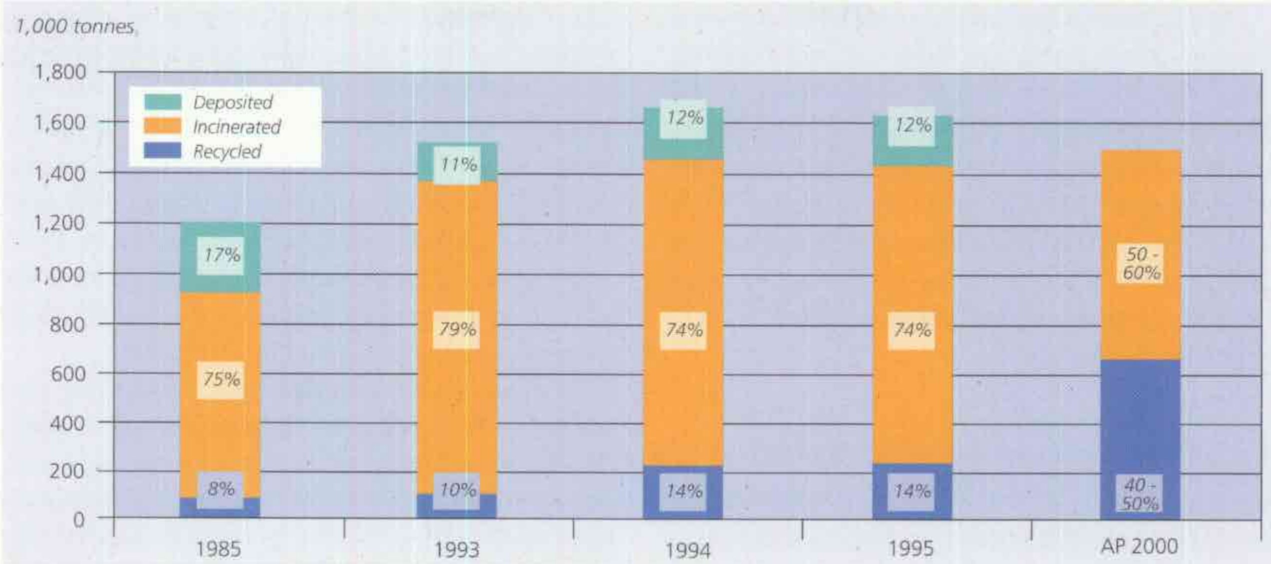


***Figure 3.7.6** Amount and fate of household waste (Source: Danish Environmental Protection Agency, 1992, 1994a and 1996c).*

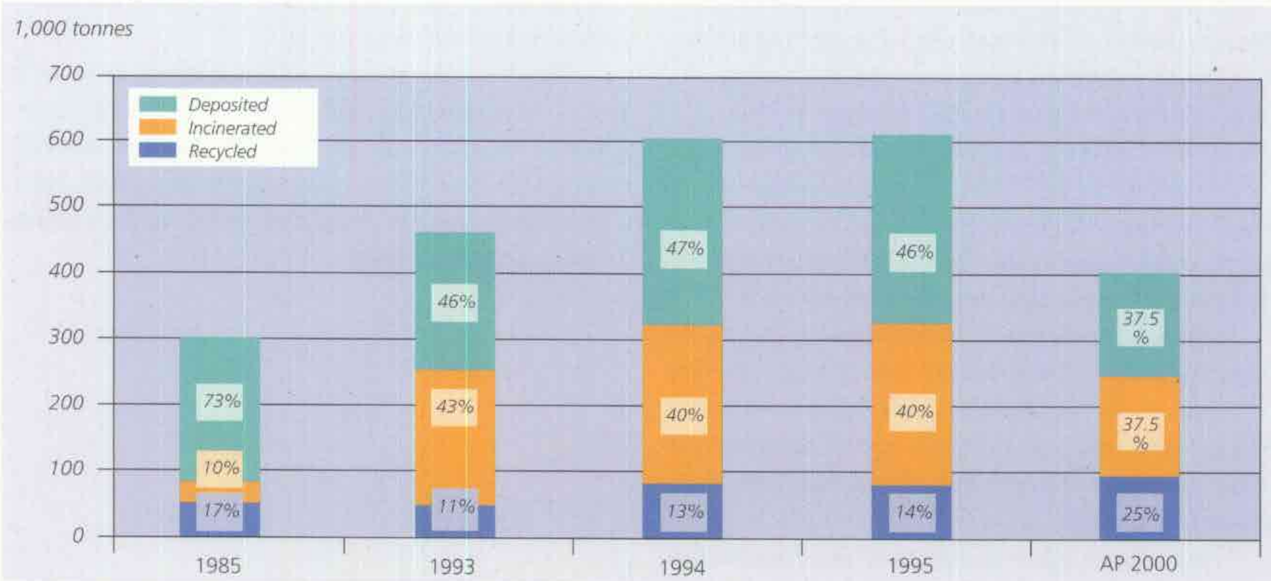


***Figure 3.7.7** Amount and fate of household bulky waste (Source: Danish Environmental Protection Agency, 1992, 1994a and 1996c).*

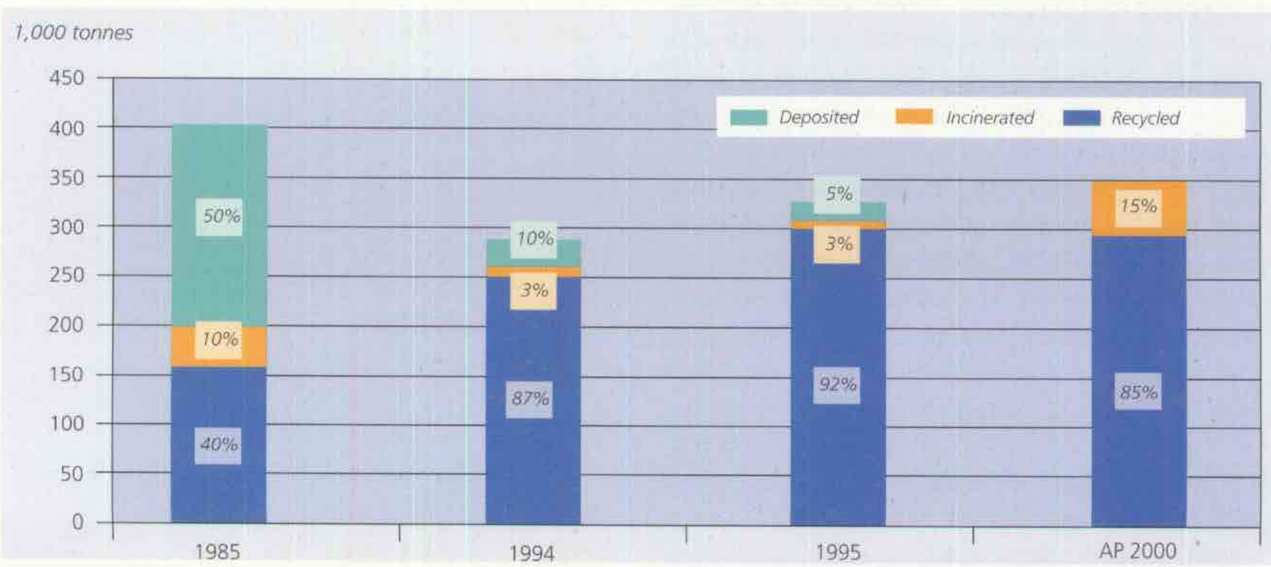


***Figure 3.7.8** Amount and fate of household garden waste (Source: Danish Environmental Protection Agency, 1992, 1994a and 1996c).*

A calculation based on the general forecast for economic development (see *Section 3.1*) and assuming proportionality between sector activity and waste generation shows that the amount of waste generated by the household sector will increase by an average of approx. 2.1% a year over the period 1995-2000. Thus the total amount of waste generated by the household sector in the year 2000 will be about 2.9 million tonnes, corresponding to just under 30% more than expected.

3.7.4 **Objectives and policy measures**

In the 1970s and 1980s, environmental policy measures on the household front typically consisted of developing the public infrastructure that manages supplies to and discharges and flows from households: Sewerage and connection to waste water treatment, modernization of the waste sector, including sorting household waste at source, conversion to more efficient and less environmentally harmful heating systems such as district heating, renewable energy, etc.

Since the late 1980s, these initiatives have been supplemented with measures directed towards changing the behaviour of households, both with respect to daily housekeeping and as consumers (see *Box 3.7.1*).

In relation to the daily housekeeping, efforts are being made to motivate households to more environmentally sound behaviour in the form of reduced energy consumption, reduced water consumption, reduced transport and reduced consumption of resources in general.

These efforts have consisted of information activities, tightening of building regulations, levies on energy and water, etc., and, in some cases, the use of subsidies (for insulation, solar heating systems, etc.). The efforts have been extremely successful with respect to household energy consumption for heating and with respect to water consumption. In relation to household electricity consumption, however, two opposing tendencies prevail: On the one hand, the increase in the number of electric household appliances continues. On the other hand, these household appliances are becoming more energy-efficient. These two tendencies largely counterbalance each other such that household electricity consumption is stagnant. As regards resource consumption in general and transport, it has not yet been possible to change the overall trend, and both areas still show significant growth.

With respect to households as consumers whose choice of product affects the impact on nature and the environment on the preceding and following stages in a product's life cycle, efforts currently focus on motivating consumers to purchase more environmentally sound products. These efforts primarily consist of promoting various forms of product standards and eco-labels, and running information campaigns in combination with various forms of encouragement to manufacturers to produce more environmentally friendly products - see *Section 3.5* on the product-oriented environmental policy.

In a number of individual areas, these efforts have paid off well. Thus the past 5 years have seen a breakthrough for a number of organically produced foods, organic solvent-based paints have largely disappeared from retail outlets, leaded petrol has almost been phased out, the phosphate content of detergents has been reduced considerably, and energy labelling of refrigerators and freezers has increased the sale of more energy-efficient models.

These positive results only encompass a few niche areas, however. A broader effect would necessitate a more systematic commitment to a product-oriented environmental policy where all the important actors and barriers are involved and where the levy instrument also plays a part.

Examples of environmental policy measures on the household front

Infrastructure
- Sewerage/connection to sewage works
- Waste management, including sorting
- Collective heat supply, including district heating from CHP plants and enhanced use of renewable energy

Information and knowledge
- EU Eco-label (the Flower)
- Nordic Eco-label (the Swan)
- Energy labelling of refrigerators, freezers, washing machines, dishwashers and clothes driers
- Danish red Ø eco-label on organic foods
- Forthcoming blue and green Ø eco-labels on fish and non-food products
- Product comparisons from the Consumer Agency of Denmark and the Consumer Council
- Fact sheets from the organization "Green Information"
- Danish indoor climate labelling
- Classification and labelling of chemical products and substances
- Miscellaneous campaigns with brochures and TV spots
- Individual water metering
- CE labelling of toys
- Experimentation with "Green municipalities", "Green Guides", "Green families", Agenda 21
- Energy labelling of houses and buildings

Standards
- Energy standard requirements for new buildings

Subsidies
- The Green Fund
- Action Plan for Cleaner Technology, 1993-97
- Action Plan for Waste and Recycling, 1993-97
- Urban ecology initiatives
- Miscellaneous subsidies for energy savings

Levies and charges
- Refuse collection charges
- Water levy
- Energy levy
- Waste levy
- Fuel levies
- Plastic carrier bag levies
- Green levies on cars
- Levies on packaging
- Parking fees

Voluntary agreements
- Agreement on PVC packaging between organizations representing the Danish plastics industry and the Minister for the Environment
- Agreement on reducing the VOC content of paints and varnishes between the organizations representing the Danish paint and varnish industry and the Danish EPA

Examples of laws and regulations that provide more detailed instructions
- Statutory Order on subterranean household oil storage tanks
- Prohibition of the installation of electric heating in new buildings
- Building regulations
- Municipal refuse regulations
- EU Cosmetics Directive
- Prohibition of the sale of products releasing nickel
- EU Packaging Directive
- Regulations on individual water meters in multistorey buildings

Box 3.7.1 *Examples of environmental policy measures on the household front (Source: Danish Environmental Protection Agency, 1997).*

3.8 Outdoor recreation and tourism

3.8.1 Introduction

The Danish landscape, with its diversity of sea, beaches, lakes, streams, countryside, meadows, heaths, forests and parks, provides the setting for a great number of outdoor recreational activities for the enjoyment of both the local population and tourists.

These outdoor activities occupy a special and increasing part of the population's leisure time, and are undertaken both as part of normal everyday life in the form of short-lasting activities near the home, as well as in the form of tourist activities during day trips or overnight stays away from the home environment.

Practically the entire population participates in outdoor recreational and/or tourist activities, many people using them to wind down, strengthen social ties and rebuild physical and mental resources to be able to cope with the pressure of normal everyday life. Good access to nature and high environmental quality are important preconditions for both outdoor recreation and tourism.

On the other hand, outdoor recreation and tourism also affect nature and the environment. In a number of countries, the pressure is tremendous, resulting for example in the wearing down of nature in the Alps and excessive property development and pollution along the Mediterranean coast.

While Denmark has avoided problems of this extent through careful planning and legislation, increasing outdoor recreation and tourism have placed increasing pressure on natural ecosystems, especially in the coastal areas.

The impact of outdoor recreation and tourism on nature, on the participants and the local population is difficult to measure. Moreover, it is very much a question of how great a change one is willing to tolerate relative to one's wishes and expectations. The type and extent of outdoor recreation and tourism considered acceptable thus vary from person to person and from area to area, involving a balance of interests between various land uses and between various types of activity and their magnitude.

In Denmark, an ordinary walk in the forest or in the countryside is accorded high priority, and other activities have to be fitted with this. In some areas, special zones are designated for activities considered difficult to accommodate among the more peaceful activities, e.g. shooting ranges, golf courses, motocross tracks, and to some extent also windsurfing. Other activities are regulated by limiting them to certain times of the year, e.g. hunting.

3.8.2 Extent and trends

Outdoor recreation

Danes devote considerable time to outdoor recreation, and the total membership of the 86 outdoor organizations grouped under the Outdoors Council is approx. 15 million. A large part of the population thus belongs to more than one outdoor organization.

Physical activities have increased during the last 20 years, the number of people participating in sport and exercise having increased from 15% of the adult population in 1964 to 47% in 1993 to a large extent due to increased participation by women. During the same period, the percentage of the adult population belonging to a sports club has increased from 12% in 1964 to 30% in 1993. Only a minor part of these sports and exercise activities can be counted as outdoor recreation, however.

As is apparent from *Figure 3.8.1*, a large part of the population regularly participates in a number of outdoor activities, especially cycling, hiking/rambling and jogging.

Apart from the organized activities, there are also many unorganized outdoor activities, e.g. walks and bicycle rides. According to a National Institute of

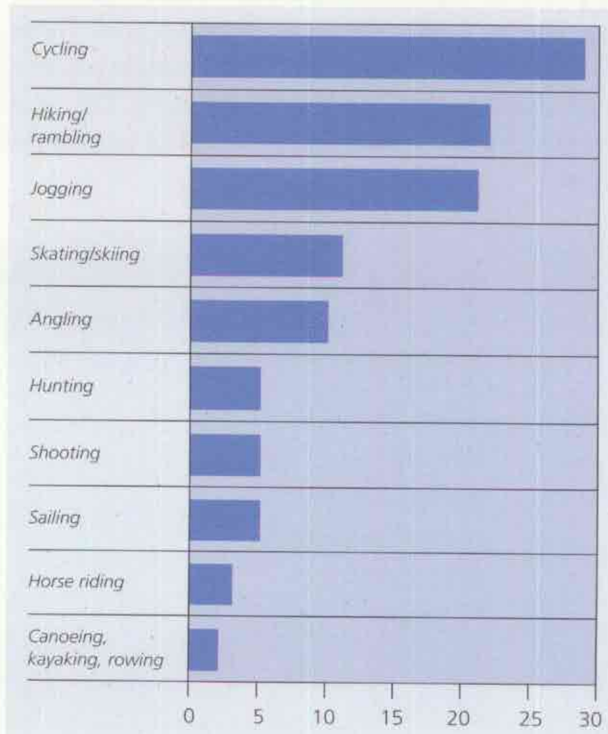


Figure 3.8.1 *Percentage of the adult population regularly participating in various leisure activities (Source: Fridberg, 1989).*

Social Research survey, 96% of the population frequently go for a walk. Thus of those surveyed, 45% had been out for a walk within the last week and 76% within the last month. Only 4% never go for a walk.

The most frequent activity was a walk in the forest. In addition, many went for a walk in the open countryside or along the beach, though less frequently. Parks and green areas were less visited since 31% never went for a walk in this type of area.

The most recent studies of outdoor recreation give an overview of the types of nature that the population visit most frequently on their trips to the countryside (*Figure 3.8.2*). Not surprisingly, forests (67%) and beaches (48%) are the most frequently visited areas. Next come farmland (34%) and lakes (22%). It is also common to visit several types of nature during the same visit.

Visits to the forest are among the most popular leisure activities. Around 91% of the adult population go for a walk in the forest at least once a year, and the "ordinary" Dane visits the forest approx. 10 times each year. This means that the Danish forests are visited approx. 50 million times a year. The figure has increased by approx. 25% between 1976-77 and 1993-94. This is partly due to population growth and partly to a true 15% increase in the number of visits. At the same time, visits have become shorter.

Visits to forests are now made closer to home than they were 20 years ago, and transport time is therefore less. The use of private cars in connection with forest visits has declined, with an increasing number of people instead running or cycling to the forest. The car is nevertheless still used in almost 50% of all visits to the forest.

Figure 3.8.3 *Activities undertaken by survey respondents during their most recent visit to a forest (expressed as percentage of all visitors) (Source: Jensen and Koch, 1997).*

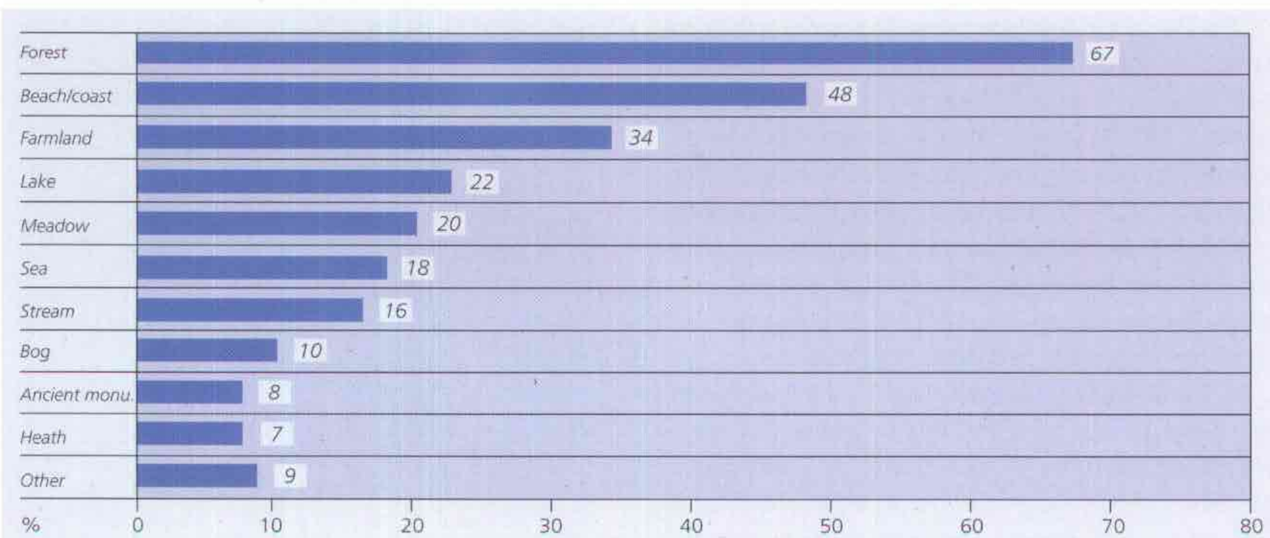


Figure 3.8.2 *Type of nature visited during most recent visit to the countryside/landscape (expressed as percentage of all visitors). Note: Survey respondents could cross off more than one type of nature (Source: Jensen, 1997a).*

On the whole, the activities of the forest visitors *(Figure 3.8.3)* have remained virtually unchanged during the last 20 years. By far the majority of visitors engage in activities which have little immediate impact on the forest as an ecosystem, e.g. "went for a walk" or "enjoyed nature".

Surveys of urban outdoor recreation show that institutions and associations are frequent users of urban parks and green areas. On average, child care centres, schools, sports clubs and outdoors associations make 100 park visits a year or about 2 a week. Park visits typically last 1-2 hours and the visit pattern varies with both the time of year and time of day.

On average, town dwellers visit parks and green areas just under 3 times a week *(Figure 3.8.4)*, the frequency ranging from 2.2 weekly visits in the winter to 3 weekly visits in the summer. The most frequent visitors are children aged 7-16 years, whereas the most seldom visitors are elderly people aged 71 years or more.

The use of parks and green areas depends on their accessibility and quality. However, the pressure on urban land resources makes it tempting to commandeer green areas for property development. Traffic infrastructure and noise are other threats to the green areas and their recreational value. The above mentioned surveys show that outdoor recreation among Danes is rather extensive. Moreover, both the forest surveys and the surveys of sports and exercise indicate an increasing trend in outdoor recreation.

Tourism

Tourism in Denmark grew markedly over the period 1988-92, but has since stagnated *(Figure 3.6.3* in *Section 3.6.2)*. The increase in the number of visitors is mainly attributable to existing holiday cottages being rented out. Of the registered visits, approx. half were made by Danes, and the remaining half were made by foreigners visiting Denmark.

Coastal tourism accounts for 69% or 30.5 million registered tourist overnight stays. Tourism has become Denmark's fourth largest industry with approx. 80,000 jobs and a total turnover of approx. DKK 43,000 million.

The holiday activities undertaken by Danes include a number of outdoor activities *(Figure 3.8.5)* such as long walks (78%), visits to natural attractions and sights (69%) and sunbathing (53%). Nature is thus an important component of the holiday activities preferred by Danes.

3.8.3 The importance of nature and the environment for outdoor recreation and tourism

Outdoor recreation depends entirely on the presence of natural countryside and landscapes to visit. Forest visitors particularly look for peace and calm, but also value lakes, streams and wildlife. Broadleaved forests are more appreciated than coniferous ones, old forest more than young forest, and open forest more than dense forest. Moreover, visitors particularly appreciate natural forest and forests managed in an environment-friendly manner.

Motorized traffic, large groups of visitors, mountain bikes and unnatural elements such as icecream stalls and playgrounds, waste, pesticides, etc. are unwanted in the forest. User conflicts may arise depending on what the individual user expects fom a visit in nature. These conflicts are due not only to more intensive land use, but also to the clash between different activities and expectations. Segregation of activities by means of local zoning can often solve the problems.

Surveys of the holiday motives of German tourists in Denmark emphasize the importance of nature

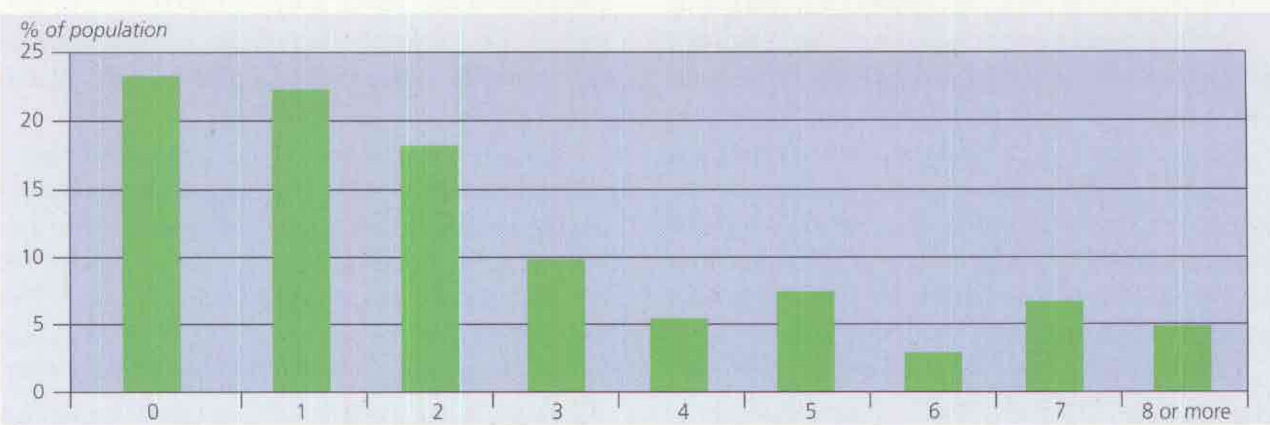


Figure 3.8.4 *Number of visits to parks and green areas during the preceding 7 days (expressed in percent of the population) (Source: S. Holm, unpublished observation).*

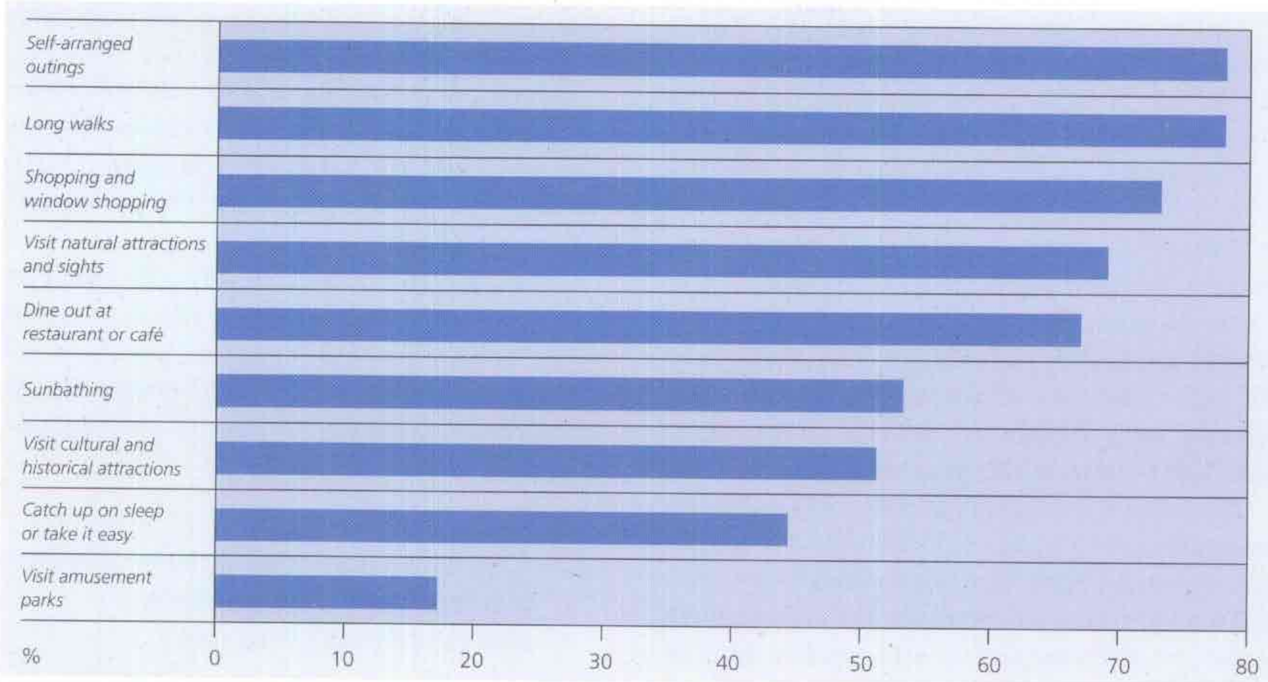


***Figure 3.8.5** Activities undertaken by Danes during holidays in Denmark (Source: Danish Tourist Board et al., 1993).*

and the environment for tourism. In a survey in which tourists were asked to evaluate 600 elements, 8 of the 10 accorded the highest priority concerned nature. The pleasant estuarine fjords, free access to nature and angling occupied the first three places. Balanced tourism on nature's premises and the comprehensive legislation on nature and environment also lay among the 10 most valued elements.

Seventy percent of foreign tourists mention Danish nature as the most important reason for choosing Denmark as their holiday destination. On the west coast of Jutland, for example, nature is the main tourist attraction.

Environmental awareness has generally increased in the population. This affects outdoor recreation and tourism since more and more people demand environmentally sound lodging facilities and behaviour.

Environmental awareness varies among the groups of tourists on the west coast. An indicator of this is the fact that more German than Danish tourists renting holiday cottages consider that the waste recycling system to be of considerable or some importance. German tourists consider it a "critical factor", whereas Danes consider it "possibly critical". Moreover, 20% of the German tourists are dissatisfied with the present systems, compared to only 9% of the Danish tourists.

Camping tourists are less environmentally aware than tourists renting summer cottages. But also in this case, German campers attach greater importance to the recycling systems than do the Danish tourists.

Geographical areas of special importance

Denmark is a relatively small and densely populated country highly affected by modern society. This makes it difficult to reserve areas exclusively for a single or a few activities. Instead the various activities have to be distributed both temporally and spatially. Outdoor possibilities vary on a national basis since public areas are unevenly distributed. Outdoor recreation is usually undertaken near the home in parks and green areas, as well as in nearby forests.

In contrast, tourism is concentrated in less built-up areas with special natural qualities such as water, forest, dunes, etc. From the geographical point of view, tourism is concentrated at the coasts (*Figure 3.8.6*), especially the west coast of Jutland, and to a lesser extent the east coast of Denmark. The coast of Lolland and the islands south of Funen are also well visited. On Zealand, the number of bed-nights is high along the coasts and in Copenhagen. Bornholm is also a major Danish tourist area.

Figure 3.8.6 is based on both registered bed-nights (hotels, etc.) and bed-nights by domestic tourists staying in their own holiday cottages, etc. Near big cities such as Copenhagen, i.e. in northern and western Zealand and around Aarhus, many bed-nights are accounted for by domestic tourists overnighting in their own holiday cottages. Along the west coast of Jutland, in northern Jutland, in Copenhagen and on Bornholm, in contrast, renting to foreign and domestic tourists dominates.

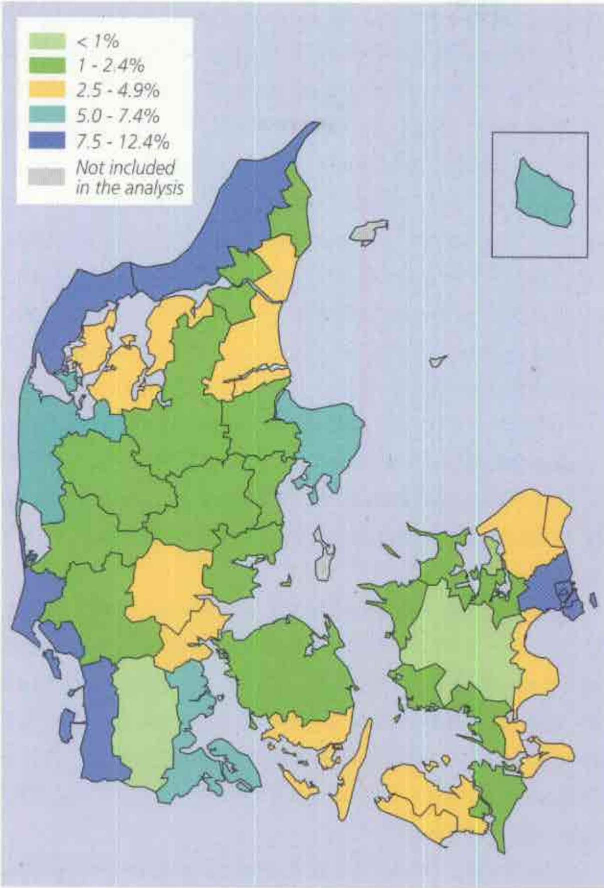


Figure 3.8.6 Distribution of tourists in Denmark (Source: Framke, 1996, based on data from Danish Tourist Board, 1992).

Bathing water quality

Bathing water quality is a very important factor in coastal tourism. In 1996, approx. 97% of the 1,310 beach monitoring stations met the bathing water quality requirements, which corresponds to the 1995 level.

In general, bathing water quality has improved since 1985 *(Figure 3.8.7)*. Measurements in 1996 resulted in bathing prohibitions at 17 beaches in 1997, compared to 19 in 1996. Pollution may result in unpleasant surface scum and obnoxious smells which interfere with outdoor recreation and tourism in the area.

3.8.4 Impact on the environment and local areas

Land use and pressure on the landscape

Approximately 15% of the coastal zone is presently built-up or reserved for holiday cottage districts or other holiday and leisure facilities. In 1996, there were 194,908 holiday cottages in Denmark, of which 189,426 were situated in the 180 coastal municipalities. In 1997, there were 195,712 holiday cottages in Denmark, of which approx. 97% were situated in the coastal municipalities. The number of holiday cot-

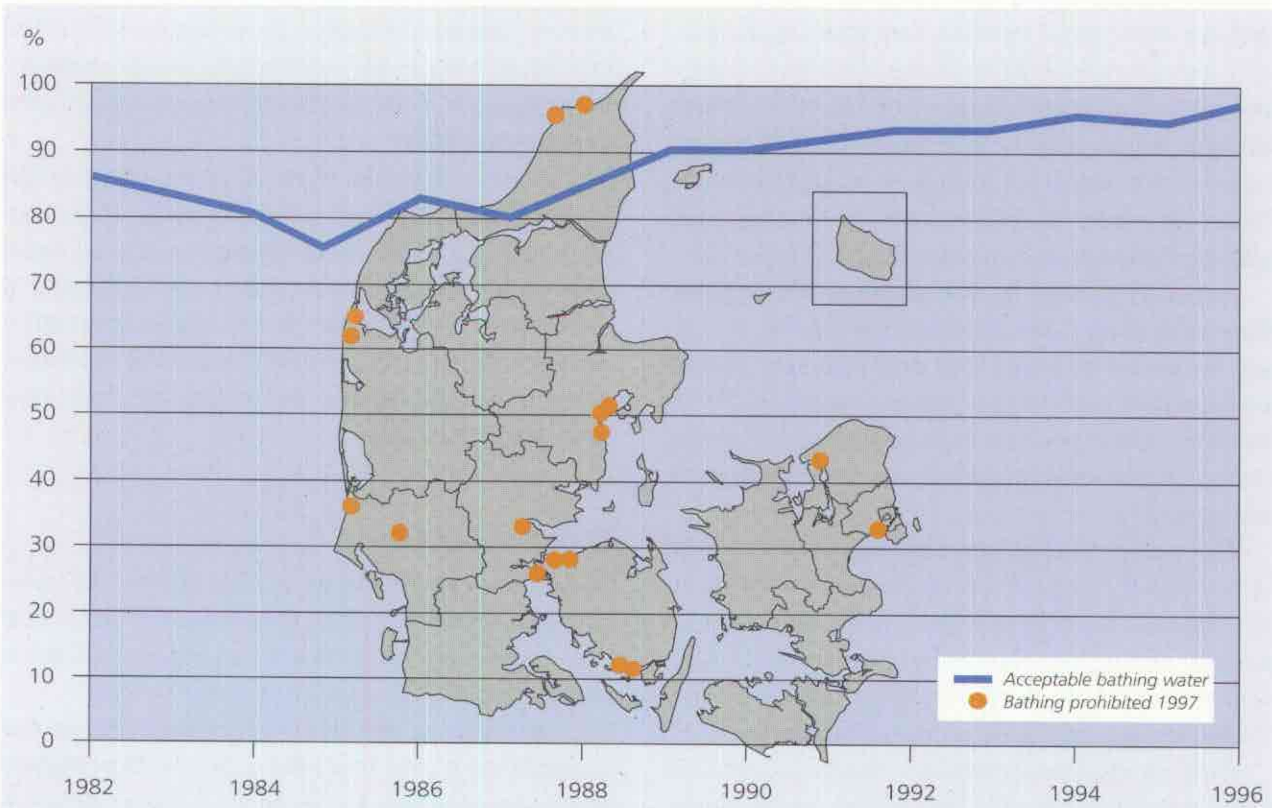


Figure 3.8.7 Bathing prohibitions in 1997 together with the percentage of beach monitoring stations with an acceptable bathing water quality over the period 1982-96 (Source: Ministry of Environment and Energy, 1997).

tages increased by 840 in the coastal municipalities in 1996 but decreased by 6 in the non-coastal municipalities.

In 1983, the total area of existing and planned holiday cottage districts in coastal areas, excluding the counties of Copenhagen, Frederiksborg and Roskilde, amounted to 42,438 ha. In addition, there are a large number of other lodging sites in the country, including approx. 970 inns and hotels, 540 camp sites and 100 youth hostels. In 1990, 414 of the camp sites were situated in coastal areas. There are also over 700 primitive camp sites in Denmark, as well as a large number of other lodging facilities such as bed & breakfasts, rooms to let, etc.

In 1990, 31% of the west coast of Jutland, 26% of the coasts near open marine waters and 31% of the glacial boundary coasts were designated for holiday and leisure facilities. The same year, approx. 12% of planned coastline usage was for holiday cottages, while 3% was for holiday and leisure facilities. In addition there were 248 marinas, of which approx. 150 were located in or near urban areas or holiday cottage districts. Other leisure facilities occupying land in Denmark in 1997 included 138 golf courses and at least 27 canoe hire centres.

Environmental impact

Outdoor and tourist facilities contribute to the society's general consumption of resources (e.g. energy and water) and general impact on the environment (sewage, waste, etc.). Around half of the holiday cottages are not connected to the sewerage system and hence contribute to diffuse nutrient loading from sparsely built-up areas, as described in *Section 2.4.*

A spot check from the Blåvandshuk Municipality shows that daily water consumption per holiday cottage is somewhat greater than in houses used all year round, where water consumption is approx. 155-180 litres per person per day. In the case of hotels, water consumption is estimated at approx. 400-500 litres per person per day.

The corresponding figure for camp sites is 60-80 litres while that for holiday chalets, etc. is 100-200 litres. Water consumption by tourists is seasonal, though, and is geographically concentrated in the coastal zone where the groundwater supply can be locally limited, especially on the small islands.

Waste production in holiday cottages is estimated to be approx. 30% of the amount of single-family houses since they are only used for part of the year.

Energy consumption for heating in connection with tourism is generally low, as it mainly takes place in the summer. However, holiday cottages are used more and more often out of season, thereby resulting in increased energy consumption. Over the period 1986-95, power consumption for holiday cottages has increased by 35% while total power consumption has only increased by approx. 18%. Almost all holiday cottages (92.5%) are heated by wood-burning stoves or electric radiators, while only a few percent have central heating. Holiday cottages are estimated to be less well insulated than houses used all year round and therefore relatively more energy-demanding. Furthermore, stoves and fireplaces cause a certain amount of air pollution. In 1994, power consumption by holiday cottages accounted for 1.9% of the total consumption.

Less people use the car when they visit the forest. In 1976-77, 55.5% went by car, while the number was down to 48.5% in 1993-94. Based on calculations of car use in connection with the approx. 50 million annual forest visits in Denmark it is estimated that a total of 615 million kilometres are driven for this purpose each year.

Compared to the total national traffic by private car in 1993 of 30,064 million kilometres, this corresponds to approx. 2%. Approximately 38% of the passenger transport in Denmark is for travel between home and leisure activities, of which part is related to tourism/outdoor recreation. In connection with travel to lodging facilities and especially to holiday cottages, the private car is the most dominant means of transport (approx. 80%).

On some stretches of road, particularly in the coastal zone with summer holiday traffic, daily traffic in July is approx. twice as great as annual mean daily traffic. Summer traffic is thus very significant in some areas, and periodically has a significant effect on the traffic pattern. However, this traffic is concentrated in the peak season and on holiday chalet take over/hand over days.

Pressure on nature

In general, Danish nature is little affected by most common types of outdoor recreation. However, outdoor recreation and tourism may cause local wear and tear on the flora and disturb the wildlife.

The sensitivity of different types of nature to recreational use varies. In coastal areas, the most vulnerable types of nature are marshland, beach meadow, grey dunes and sand heath. Pebble heath is the least vulnerable type of heath. Sloping commons are more vulnerable than flat commons. The most vulnerable types of marsh are bog marsh and water fen. Lobelia lakes and springs are particularly vulnerable. However, biological variation among the various natural ecosystems and the challenges posed by recreational activities are too different to allow an exact method capable of determining the sensitivity of natural ecosystems to recreational exploitation.

No systematic nationwide analyses of the impact of outdoor recreation and tourism on nature are available. The problems of wear are particularly visible locally in certain coastal areas comprised of vulnerable sand dunes etc., where visitor density is high, e.g. Skallingen and Rømø. Thus on Rømø, almost three quarters of the local population and almost half of the tourists consider the overburdened areas and wear on nature to be one of the three most crucial problems.

In urban forests, the pressure on nature has increased in line with the growth in cities and the population's desire for outdoor recreation. Outdoor recreation develops continually, and action sports are becoming more and more popular. The majority of these recreational activities do not have a very great impact on nature, however. A few activities such as horse and mountain bike riding are damaging, though, especially in the very popular forests.

In car parks and near cities, local wear can be seen in the form of trampled footpaths, etc. The vegetation is worn down and the soil is compacted, which increases the risk of erosion. The paths are repaired regularly, though, which compensates for the wear. The paths help channelize people past the vulnerable areas, and they are usually laid in such a way as to ensure that users nevertheless still enjoy the nature they traverse.

Disturbance of wildlife

Human traffic and outdoor activities such as hunting and sailing may disturb wildlife. The disturbances interrupt the animals' natural daily activities, cause stress and trigger flight behaviour, thereby increasing their energy consumption and hence their need for food.

Some of the tourist areas in this country are located near natural ecosystems of importance to wildlife. For instance, many areas of ornithological interest and bird migratory routes are located at the coasts. Wildlife is often vulnerable during the breeding season, but this usually lies in the spring, before the tourist season starts. Local conflicts between breeding birds and tourists can be alleviated by temporarily fencing off the breeding grounds on the beach, as with the endangered Kentish plover on Rømø. Seals prefer secluded areas away from human activity such as sandbanks, military areas, etc., as opposed to public beaches.

Surveys of human disturbance of roe deer show that the distance to the source of disturbance and the possibilities for cover are important determinants of the effects of the disturbances. When a disturbance causes a roe deer to flee, the type of disturbance (cycling, off-trail hiking, loose dogs, etc.) is largely unimportant. A single daily disturbance that makes a roe deer flee increases its daily energy consumption by 9-11%. Repeated disturbance such as orienteering races lasting over a period of 6 hours enhances daily energy consumption by 82%. This cannot be counterbalanced by increased food intake, and therefore diminishes the animal's energy reserves. In the case of a well-nourished roe deer, 10-11 days of continuous disturbance will completely drain the animal's energy reserves.

The impact of disturbance varies depending on the season. The animals feel more secure in the summer where it is easier to hide in the vegetation. To some extent, roe deer can become emotionally habituated to the disturbances, but their flight behaviour still results in the same loss of energy. Anthropogenic disturbances of motion and activity patterns have also been recorded for red deer and water birds.

Another problem is that many water birds have been wounded by lead shot. Thus with certain species, over a third of the older birds have lead shot in their bodies. In the case of pink-footed geese and eider ducks, more than one bird is wounded for every bird bagged.

Hunting has also resulted in the dispersal of lead shot in the environment. This problem is expected to diminish in the future, though, as a consequence of the ban on hunting with lead shot

3.8.5 Objectives and policy measures

The desire to facilitate and regulate outdoor recreation is a common feature of virtually all Danish land use legislation from the Ministry of Environment and Energy. The efforts made at the state, county, municipal, commercial and private levels to the environmental, natural and historical aspects of our society also improve the quantitative and qualitative possibilities for outdoor recreation, thereby creating better conditions for tourism.

With respect to tourism, it should be noted that the development of new summer cottage districts in coastal areas is prevented by the 1994 Coasts Act which stipulates an extended 3 km wide planning zone, a coastal zone and a 300 m wide beach preservation zone (currently being designated). The Act also severely curtails the possibilities to develop coastal land for other holiday/leisure purposes. The enjoyment value of coastal nature is thereby assured for the future.

The overall picture of tourism is that it cannot pay to increase bed-night capacity in the hotel and holiday centre industry, not even in the areas that are fully booked in the peak season.

Quantitative and qualitative development of tourism in Denmark thus necessitates both a longer season and greater dispersal.

In recent years, a number of eco-labelling schemes have appeared aimed at ensuring the standard of outdoor recreation and tourism. One of these is the Blue Flag pertaining to bathing water quality and a number of recreational beach facilities.

Another is the Green Key, a Danish eco-label for hotels and youth hostels. These have to undergo extensive environmental audit and fulfil a large number of criteria in order to be able to use the eco-label. Approximately 70 of Denmark's approx. 800 hotels have now been granted the Green Key eco-label. It is planned to extend the Green Key eco-label to other types of lodging facilities, and a pilot project on eco-labelling of holiday chalets has been undertaken on the island of Møn.

Work is also being undertaken on the systematic development of "Green Destinations", among others by the Tourism Development Centre. A project in the Haderslev-Vojens valley has analysed nature and tourism on the basis of criteria for sustainable tourism, and has defined suggestions for local indicators of tourism.

The public right to roam freely in the countryside along field tracks, etc. was strengthened by the 1992 Nature Protection Act. Moreover, one is now allowed to roam in uncultivated, unfenced areas. Structural development in agriculture results in closure of field tracks. At the same time, agricultural land (approx. 265,000 ha in 1996) has been set aside, of which some has recreational value. In addition, county and municipal authorities are expanding the footpath system in close cooperation with landowners so as to ensure free access to the agreed routes.

In autumn 1997, a new project called "Traces in the Landscape" was initiated whereby landowners voluntarily open for public access along simple "traces" in the landscape.

Recreational areas close to housing are particularly well used for outdoor activities - also by children, especially when they are in safe cycling distance. Thus when developing cities and traffic infrastructure, it is important not to create obstacles to outdoor recreation.

Access to rich and varied outdoor recreation is greatest on publicly owned land, of which the majority is administered by the Ministry of Environment and Energy through the National Forest and Nature Agency. The Ministry currently administers approx. 185,000 ha, corresponding to 4% of the Danish land mass. This includes approx. 105,000 ha forest, corresponding to approx. 30% of total Danish forest acreage. Since 1989, nature management funds have been used to acquire 12,542 ha of land, of which almost half is to be used for afforestation.

The majority of the land administered by the Ministry comprises key locations for outdoor recreation and tourism. This is both because the land often lies close to densely populated areas or major holiday areas. For historical reasons, large parts of the country are virtually devoid of public forest, however.

Efforts are being made to manage the land in such a manner as to facilitate outdoor recreation, especially unorganized outdoor recreational activities. Moreover, a special effort is being made to establish a large number of additional public facilities such as bonfire and barbecue sites, bird watching towers, adventure playgrounds, etc. in the various areas and to increase public awareness of the recreational value of these areas.

An understanding of nature is central to public support of nature protection. In this respect, the nature guide scheme is a powerful educational tool that aims to provide qualitative experiences and enhance understanding of natural, environmental and cultural relationships.

During the period 1992-95, the number of nature guides has increased from approx. 104 (corresponding to approx. 90 full-time positions) to 170 (corresponding to approx. 134 full-time positions). In the same period, the number of visitors using the guides has increased from approx. 440,000 to approx. 640,000.

A number of surveys show that the population's knowledge of current rules on access to the countryside are limited. Sign erection programmes are thus being undertaken in both state and private forests explaining public rights of access.

3.9 Waste water and waste

3.9.1 Introduction

Management of waste water and waste are not societal sectors in the usual sense, but are environmental sectors that receive and collect waste water and waste from the various sectors of the economy. The waste water sector thus processes the majority of the household sewage and waste water from the service and industrial sectors, as well as stormwater runoff from roads, paved areas and roofs. In addition to receiving waste from the various sectors of the economy, the waste sector also receives sludge from sewage treatment works and residual products from power stations, and is responsible for processing and disposal of the waste.

3.9.2 Waste water management

For health and hygiene reasons - and subsequently for environmental reasons - a comprehensive system has gradually been established for the disposal of waste water from houses and businesses. The waste water problems increased in parallel with the increasing amounts of waste water generated by industrialization, the increasing urban population and the construction of sewers. Initially, attempts were made to alleviate the hygiene and health problems and the immediate environmental effects by dilution, i.e. by ensuring effective mixing of the waste water by discharging it to less sensitive recipients.

Effective treatment of the waste water with a view to more general protection of the environment was not systematized until the 1970s and 1980s in connection with the regional recipient quality plans and the Action Plan on the Aquatic Environment (see *Section 2.4.6*).

This has resulted in a relatively centralized waste water treatment system. Among other things, the aim has been to treat the sewage close to a recipient able to tolerate discharge of the treated sewage effluent. In addition, larger sewage treatment works offer considerable savings in construction and running costs as compared with a larger number of small works.

Waste water production and treatment

In 1995, total waste water inputs to municipal sewage treatment works amounted to 802 million m^3 comprised of household sewage, industrial waste water, groundwater infiltrate and stormwater runoff. Construction and operation of the sewerage systems and treatment works are financed by connection fees and consumer charges per cubic metre waste water. As a consequence, households and commercial enterprises in particular have been interested in reducing the amount of waste water they discharge.

Total inputs of organic matter in the waste water from households and industry amount to approx. 8.3 million person equivalents (1 person equivalent (p.e.) corresponds to the amount of organic matter produced by one person).

Of this, approximately half derives from households and the other half from a broad spectrum of commercial enterprises. In addition, further organic matter is input to the treatment works with stormwater runoff. For some years now, total inputs of organic matter and nitrogen have remained largely unchanged. In contrast, total inputs of phosphorus have fallen by approx. 1/3 over the last 10 years as a result of a switch to the use of phosphate-free detergents.

The waste water and stormwater inputs also contain a variety of human pathogens, heavy metals and persistent organic pollutants. Studies indicate that inputs of heavy metals and persistent organic pollutants to the sewage treatment works from industry are falling. Some of the industrial enterprises discharge their waste water directly to recipients, cf. *Section 3.5* on industry.

Virtually 100% of the households and commercial enterprises in urban areas are connected to the municipal sewerage systems and treatment works. In rural areas, however, the waste water is generally discharged individually to septic tanks etc. or directly to surface waters.

Sewerage systems

The total area of Denmark serviced by sewerage systems is approx. 223,000 ha, corresponding to approx. 5% of the country. There are two different sewerage systems:

- Combined systems, where waste water and stormwater runoff are channelled to the sewage treatment works via a single conduit, and
- Separate systems, where waste water and stormwater runoff are channelled in separate conduits to the sewage treatment works and to the recipient, respectively.

Each system accounts for approx. 50% of the total area serviced by sewerage systems. The older urban areas are typically serviced by combined systems whereas the new urban areas are typically serviced by separate systems.

The combined sewerage systems become overloaded during severe storm events and therefore contain overflows from where the water is led directly to the recipient. Stormwater from the separate systems is either led directly to the recipient or via storage reservoirs.

The reservoirs even out runoff events and enable some treatment of the stormwater by sedimentation and retention of oil and suspended matter. Storage reservoirs have been established in approx. 1/3 of both the combined and separate systems.

Sewage treatment works

There are 1,675 municipal sewage treatment works in Denmark excluding the very small works with a capacity under 30 p.e. (corresponding to the sewage from approx. 10 households). In recent years, these have been upgraded and expanded, and more treatment steps have been added, especially in the case of the larger works. As a result, approx. 94% of the waste water is treated both mechanically and biologically. Moreover, 80% of the waste water undergoes phosphorus removal while 70% undergoes nitrogen removal, cf. *Table 3.9.1*.

The table also shows the average degree of treatment for the various types of sewage works. The degree of treatment is the percentual reduction obtained for the fraction in question. In 1993, the sewage treatment works removed 93% of the organic matter in the waste water, 64% of the nitrogen and 76% of the phosphorus. In 1995, the degree of treatment had improved even further.

The treatment works also reduce the waste water content of pathogens such as bacteria, viruses and protozoa. Finally, some of the environmentally hazardous substances are degraded during the treatment processes, while other substances end up in the sewage sludge or are discharged to the recipient in the treated sewage effluent. Heavy metals are also retained in the sewage sludge to some extent.

Scattered dwellings

There are a total of 352,000 dwellings not connected to sewers. Of these 236,000 are homes while 116,000 are holiday cottages and allotments. The main part of these buildings have local treatment by means of septic tanks, i.e. simple sedimentation and separation of floating matter.

Hereafter, the sewage effluent is led directly to watercourses or lakes, or to percolation systems. In certain areas with groundwater abstraction, all the sewage (or sometimes just that from the toilets) is drained into subterranean containment tanks for subsequent collection.

	Sewage treatment works		Discharges			Degree of treatment		
	1995		1993			1993		
Treatment level	Number	% of total sewage	Organic matter	Nitrogen	Phosphorus	Organic matter	Nitrogen	Phosphorus
			Tonnes/yr			%		
Untreated	5	-	1,765	307	71	-	-	-
Mechanical	627	1	3,943	3,943	190	53	21	31
Mechanical+biological	538	17	4,639	4,419	872	93	37	41
Mechanical+phosphorus removal	20	1	309	162	13	88	27	86
Mechanical+biological+ nitrogen removal	6	1	99	77	18	95	71	63
Mechanical+biological+ phosphorus removal	239	10	950	1,622	94	96	58	88
Mechanical+biological+nitrogen and phosphorus removal	240	69	2,423	3,295	501	98	83	91
Total discharge 1993			*14,128*	*10,787*	*1,763*	*93*	*64*	*76*

Table 3.9.1 *Distribution of sewage treatment works by treatment level in 1995 and amount of discharges and degree of treatment in 1993 (Source: Danish Environmental Protection Agency, 1994a and 1996a)*

Green sewage treatment

Green sewage treatment means a more environmentally friendly form of sewage treatment whereby efforts are made to reduce water consumption, reuse storm water and waste water (for example for toilet flushing) and increase the use of local percolation of storm water. The objective is to reduce the amount of sewage and stormwater led to the municipal sewage treatment works and to reduce periodic stormwater loading of watercourses, etc. At present, green sewage treatment only accounts for a minor part of the total waste water collection and treatment.

Environmental impact of waste water management and environmental initiatives

Sewer network

The sewer network is currently in a poor state of repair, which entails considerable environmental risks. Because of infiltration of groundwater, the sewage treatment works have to treat a large amount of water unnecessarily.

In areas where the sewers are located below the groundwater table, 50% infiltration is normal. Infiltration rates as high as several hundred percent are also seen, however. Infiltration of groundwater enhances energy consumption because of the larger amounts of water and results in poorer treatment at the treatment works. In areas with a low groundwater table and a permeable bedrock, the waste water might be able to leak out of the sewers and possibly pollute the groundwater.

The Municipalities have estimated that 20% of the sewers need to be renovated. It should be noted that the Municipalities are only aware of the state of approximately half of the sewers. From the mid 1980s until today, sewer renovation activity has increased markedly.

Sewage treatment works

Discharges of both nutrients and organic matter from municipal treatment works have decreased markedly in recent years and the Action Plan on the Aquatic Environment targets have almost been met (*Figure 3.9.1*).

Sewage treatment at the municipal treatment works generates a number of waste products in the form of oil, fat, sand, gravel, siftings and sludge. These waste products are discussed in *Section 3.9.3*. Although the upgraded waste water treatment works partly remove the heavy metals and persistent organic pollutants in the waste water, some are still discharged in the treated effluent. In addition, microorganisms and odours are released to the air from uncovered treatment facilities.

Discharges of organic matter and phosphorus via stormwater outfalls sometimes comprise a major part of discharges to watercourses and lakes, especially lakes in urban areas. Discharges from the com-

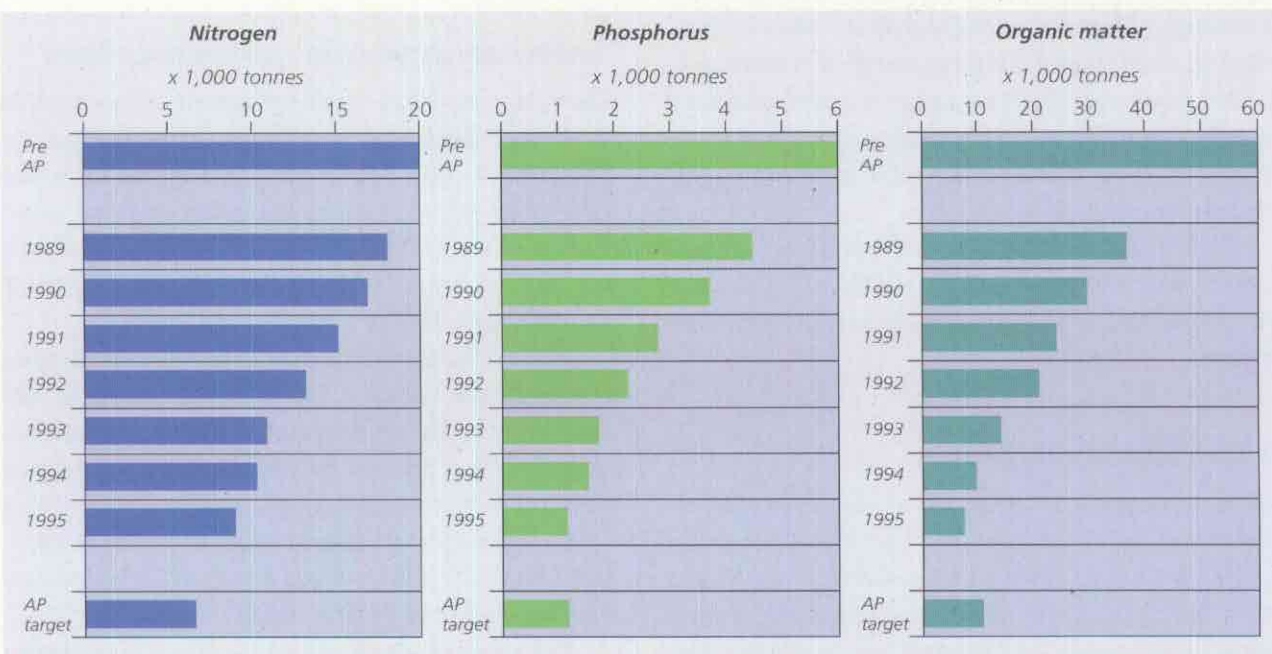


Figure 3.9.1 *Development in discharges from sewage treatment works. AP = Action Plan on the Aquatic Environment (Source: Danish Environmental Protection Agency, 1994a and 1996a).*

Type of dwelling	Discharges in tonnes per year		
	Organic matter	Nitrogen	Phosphorus
Holiday cottages and allotments	82	17	5
Scattered dwellings and small villages	4,286	1,123	256
Other	10	3	1
Total	**4,378**	**1,143**	**262**

Table 3.9.2 Annual discharges from scattered dwellings located outside the sewerage system in 1995 (Source: Danish Environmental Protection Agency, 1996a)

bined sewerage system overflows contain mixed sewage and stormwater and there is therefore the risk that pathogens etc. can be transferred to man. In certain municipalities, the presence of stormwater outfalls has necessitated the prohibition of bathing at otherwise good beaches. The separation of sewerage systems and the construction of storage reservoirs have therefore been accorded high priority for some years, which has helped reduce the number of bathing prohibitions. New calculations have shown that considerable discharge of certain heavy metals takes place via stormwater outfalls. For many substances, including zinc, copper and lead, these discharges are of the same magnitude as or larger than the total discharges from the sewage treatment works.

Scattered dwellings

In some years time, when the measures stipulated in the Action Plan on the Aquatic Environment have been fully implemented, discharges from scattered dwellings will account for a significant share of total loading of the aquatic environment. A reduction in loading from scattered dwellings is a precondition if quality objectives for watercourses and lakes are to be met at the local level. Calculated total annual discharges are given in *Table 3.9.2.*

In 1995, scattered dwellings accounted for approx. 16% of total nitrogen loading and 28% of total phosphorus loading of watercourses and lakes from point sources.

3.9.3 **Waste management**

Waste management consumes resources and affect the environment, not just in connection with actual waste processing, but also in connection with transport and in the form of loss of the resources contained in the discarded materials and products. From the environmental point of view the optimal solution is therefore to reduce the amount of waste generated. To the extent that waste generation cannot be avoided, recycling will usually be the most sound solution from the environmental and resource points of view. The next best solution is incineration coupled with utilization of the energy produced. Landfill is considered to be the most unsound solution with respect to the environment and resources.

Waste production in the various sectors of the economy has been examined individually in the respective sections of this report. The present section focuses on the primary development in the total amount of waste and its distribution between the various routes of disposal, although a separate account is included of waste from sewage treatment works (sludge) and power production (slag, fly ash, etc.). Thereafter follows an examination of the various routes of disposal focusing on their environmental impact. Finally, the section closes with an examination of current environmental strategies and objectives in relation to waste management.

Total waste generation - and management

The total amount of waste generated in Denmark in 1995 was approx. 11.5 million tonnes, having increased 25% since 1985. The latest figures for waste generation in 1996 confirm the previous years' trend towards increasing waste generation since the total has now increased to 12.9 million tonnes, i.e. a 12.6% increase since 1995.

Due to erroneous registration, though, the increase is actually just over 10%. This total increase hides considerable variation between the individual sources, however. Slag, fly ash, etc. from power production have thus increased by 37% from 1995 to 1996 as a result of considerable exports of electricity. In addition, there has been a 20% increase in garden refuse and building and construction waste.

In the case of household waste, waste from institutions, retail and offices and waste from manufacturing enterprises, there has been a moderate increase of 2-

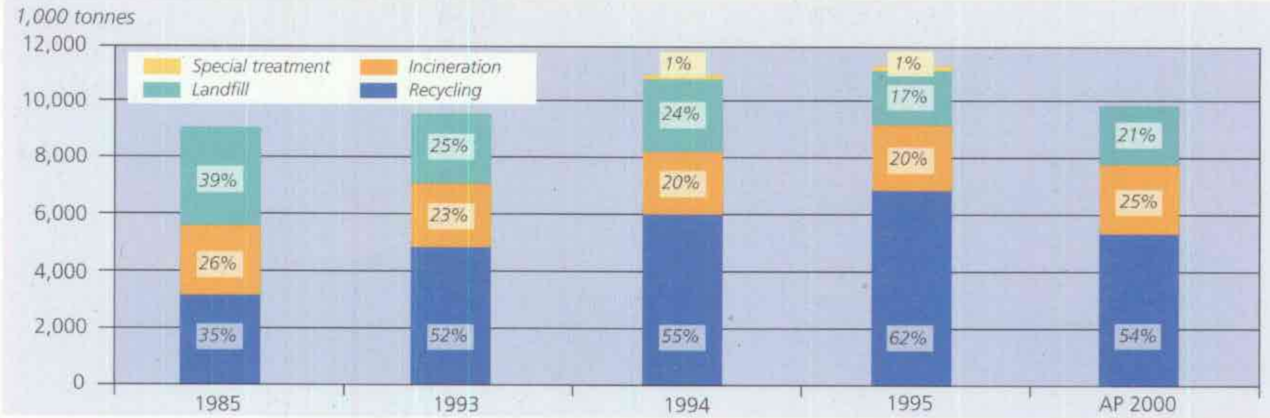


Figure 3.9.2 *Total solid waste in Denmark apportioned by route of disposal (Source: Danish Environmental Protection Agency, 1992a, 1994b, 1996b and 1997a).*

Waste production									
	Recycling		Incineration		Landfill		Special management		Total
Source	1,000 tonnes	%	1,000 tonnes	%	1,000 tonnes	%	1,000 tonnes	%	1,000 tonnes
Households	628	24	1,466	56	501	19	15	1	**2,610**
Institutions/retail and offices	317	38	365	44	128	15	24	3	**834**
Manufacturing, etc.	1,446	56	278	11	779	30	59	2	**2,563**
Building and construction	2,173	85	18	1	321	13	46	2	**2,559**
Sewage treatment works	918	77	175	15	101	8	1	0	**1,195**
Slag, fly ash, etc. (coal)	1,564	92	0	0	135	8	0	0	**1,699**
Other	0	3	4	60	2	37	0	0	**6**
Total	**7,046**	**62%**	**2,306**	**20%**	**1,969**	**17%**	**145**	**1%**	**11,466**

Table 3.9.3 *Waste production in Denmark in 1995 apportioned by source and route of disposal (Source: Danish Environmental Protection Agency, 1996b and 1997a). Note: Recycling of sewage sludge has been updated relative to the waste statistics, thereby affecting the total amount of waste.*

3%. The general picture, though, is that waste generation far exceeds the target of 9.8 million tonnes for the year 2000 stipulated in the Action Plan on Waste and Recycling.

In 1996, 60% of waste was recycled, 19% was incinerated, 20% was landfilled and 1% required special management. Despite the increasing amounts of waste, the Action Plan target that 54% of waste should be recycled, 25% incinerated and 21% landfilled by the year 2000 (AP 2000) has thus been met (*Figure 3.9.2*). There are considerable differences between the different forms of waste, however (*Table 3.9.3*). (The latest waste statistics for 1996 are published in Environmental Review No. 13, Danish Environmental Protection Agency, 1997).

Waste	Amount in tonnes dry matter
Siftings from mechanical grates	5-10,000
Sand and gravel from sand traps	50-100,000
Oil/fat from fat traps	Unknown

Table 3.9.4 *Waste from municipal sewage treatment works other than sludge in 1994 (Source: Danish Environmental Protection Agency, 1995).*

Waste from sewage treatment works

Waste from sewage treatment works consists of oil, fat, sand and gravel, which are normally deposited in controlled landfills, and siftings, which are either incinerated or landfilled (*Table 3.9.4*). The treatment works also generate sewage sludge. The amount of sewage sludge and routes of disposal are shown in *Figure 3.9.3* (expressed in wet weight). Upgrading and expansion of the sewage treatment works in accordance with the Action Plan on the Aquatic Environment can be expected to increase the amount of

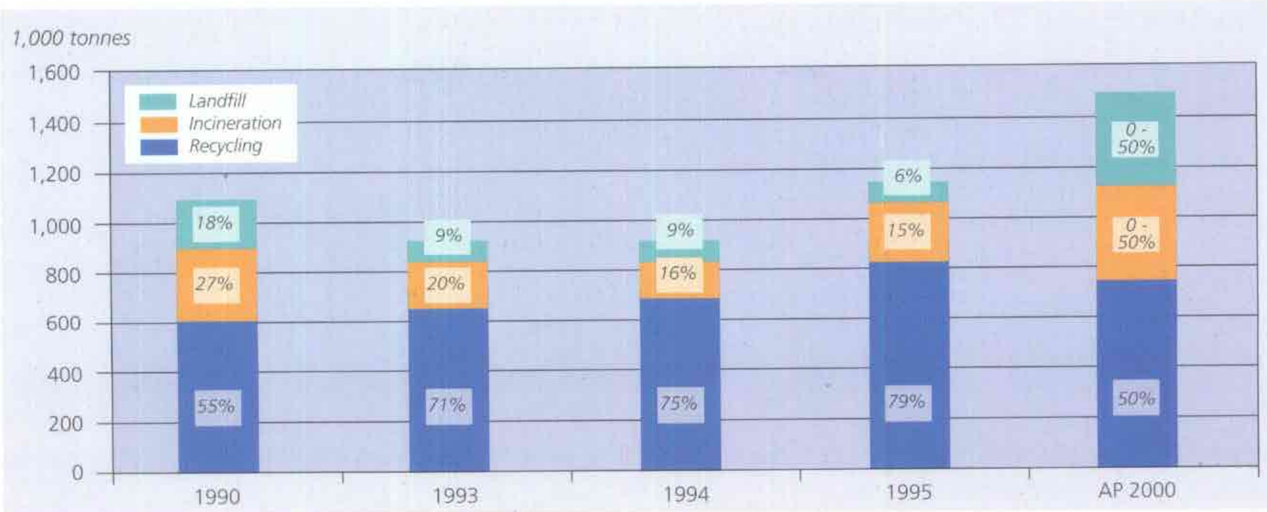


Figure 3.9.3 *Sewage sludge in Denmark apportioned by route of disposal (Source: Danish Environmental Protection Agency, 1992a, 1994b, 1996b and 1997a).*

sewage sludge generated in the coming years. By far the majority of the sludge is recycled and applied to agricultural soils. It should be noted that the recycling of sewage sludge expressed in dry weight did not increase between 1995 and 1996.

If the sewage sludge is to be used for agricultural purposes, it has to comply with limit values for cadmium, mercury, lead and nickel, as well as for chromium, zinc and copper. In addition, processing of the sludge and the application method have to meet certain hygiene standards. Attention is particularly focused on the heavy metals as these cannot be degraded in the treatment works, but accumulate in the sludge.

At some treatment works, the sludge concentrations of heavy metals exceed the limit values, thereby precluding application of the sludge on agricultural soils.

Waste from power production

The amount of residual products from coal-fired power stations, i.e. fly ash, gypsum, residual products from flue gas abatement, sulphuric acid and slag, varies somewhat from year to year. In 1994 and 1996, for example, the amount of residual products was particularly high because Denmark was a net exporter of electricity during these two years. As is apparent from *Figure 3.9.4*, the distribution between landfill and recycling also varies considerably. Thus in some years, material might be removed from landfills to be recycled as filling material in building and construction projects.

Environmental impact of waste

The environmental impact of waste largely depends on the route of disposal used. There are three main

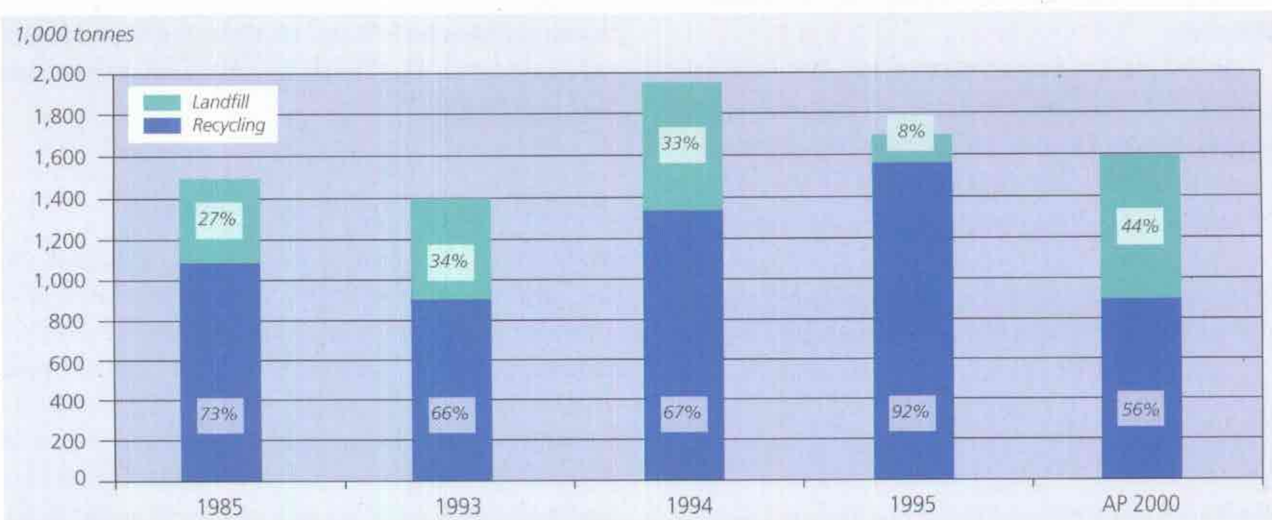


Figure 3.9.4 *Waste from Danish energy production apportioned by route of disposal (Source: Danish Environmental Protection Agency, 1992a, 1994b and 1996b).*

routes of disposal, namely landfill, recycling and incineration. In addition, a minor part of the waste contains hazardous substances and requires special management (waste oil and chemicals).

Landfill

Landfill is the route of disposal generally accorded lowest priority. Problems already arise when it comes to selecting landfill sites, among other reasons because they cannot be located in the open coastal stretches or areas of recreational, historical or landscape value. In addition, there are pollution problems in the form of leachate and the emission of greenhouse gasses. The latter is particularly a problem when organic matter is landfilled. A further problem is that it takes 100-200 years for landfills to fully stabilize, which limits the possibilities for future generations to use the sites and leaves them with the need to undertake monitoring and possibly also to undertake remedial measures.

Landfills were formerly located mainly in the countryside, for example in disused gravel pits, and groundwater protection measures were inadequate. Regulations governing the establishment of landfills have gradually been tightened, however, and landfills are now established as near to the coast as possible, but without coming into conflict with other land use interests

The environmental impact of landfill leachate can be reduced by organizing the landfills in a number of special depositories where the composition of the waste is known, and by ensuring that these only contain waste that can stabilize after a limited period of years. Treatment of leachate from the various types of waste can then be optimized and monitoring of certain landfill depositories can be terminated earlier. Leachate can affect recipients and pose a threat to the groundwater. No analysis is available of total leachate production in Danish landfills.

Total methane emissions from Danish landfills totalled 70,500 tonnes in 1990 increasing to 72,000 tonnes in 1995. These emissions are expected to be reduced in future as the landfilling of waste that can be incinerated has been prohibited since 1 January 1997.

Recycling

The aim of recycling is to establish a closed cycle for the materials in the waste. Recycling entails considerable savings on raw materials and energy and hence helps economize on resources. The consequent savings on raw materials result in corresponding savings in pollution from the production of raw materials. It is necessary to collect the recyclable fractions of the waste separately in order to ensure the quality and purity of the materials. While this entails extra transport, the energy consumption for transport has to be weighed against the transport needs if new raw materials are used instead, as well as the higher energy consumption associated with production based on new raw materials. Finally, cleaning and preparation of recycled materials cause pollution, and this too has to be evaluated in relation to alternative new production of the materials.

Organic matter can be recycled by processing it in composting plants or biogas plants to produce compost and biogas. Compost contains organic matter (including humus) and plant nutrients, and can therefore be used as a soil improver and fertilizer. Compost can thus substitute for commercial fertilizer, which is energy-intensive to produce and typically contains cadmium. Apart from degassed biomass, the processing of organic matter in a biogas plant also generates biogas. In contrast, processing of organic matter in a composting plant leads to the consumption of energy.

In 1995, just over 535,000 tonnes of organic waste were processed in composting and biogas plants, see *Figure 3.9.5*. Of this, the majority was garden and park refuse (434,000 tonnes or 81%), while just under 35,000 tonnes of organic household waste was processed by 12 composting plants and 2 biogas plants. Of the organic household waste, 15,000 tonnes were processed

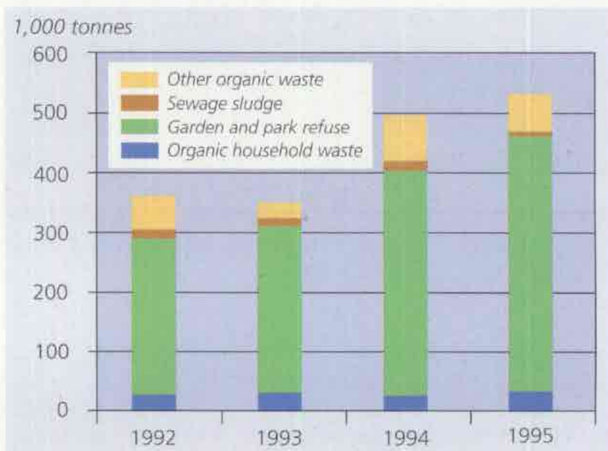


***Figure 3.9.5** Amount of organic waste input to biological treatment plants (composting and biogas plants) over the period 1992-95 (Source: Rendan A/S, 1997a). Note: Not all biogas plants that process waste are included in the above figures. According to the Danish Environmental Protection Agency (1996b), an additional 59,000 tonnes of sewage sludge and 120,000 tonnes of other organic waste, including industrial waste, were processed by biogas plants.*

in high-technology composting plants, 8,000 tonnes in low-technology composting plants and 12,000 tonnes in biogas plants.

There has been a marked increase in the amount of garden and park refuse sent for composting over the years 1990-1995, while there has been a more moderate increase in the amount of household waste sent for biological processing.

Recycling of paper and card reduces the need for incineration plants and hence is also a strategy for reducing CO_2 emissions. When returned paper is used as the basis for the production of recycled paper, energy consumption is only 1/2 to 1/3 of that required when paper is produced from wood. This energy saving is considerably greater than the energy that can be generated from incineration of the paper.

During the first half of the 1990s, total consumption of new paper amounted to approx. 1.2 million tonnes annually. In 1995, 537,000 tonnes of paper were collected for recycling. Of this 385,000 tonnes were used in Denmark to produce 330,000 tonnes of new paper. Consumption of returned paper exceeded production of new paper because impurities etc. are removed in the pulping process. The remainder of the paper collected for recycling was exported or stored, see *Figure 3.9.6*.

Paper consumption in 1995 amounted to 232 kg per inhabitant, and an average of 102 kg per inhabitant was returned for recycling. Percentual return was thus 44%, having increased from 31% in 1985.

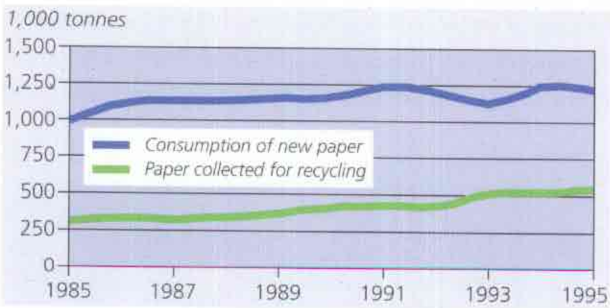


Figure 3.9.6 *Development in consumption of new paper and amount of paper collected for recycling over the period 1985-95 (Source: Rendan A/S, 1996a).*

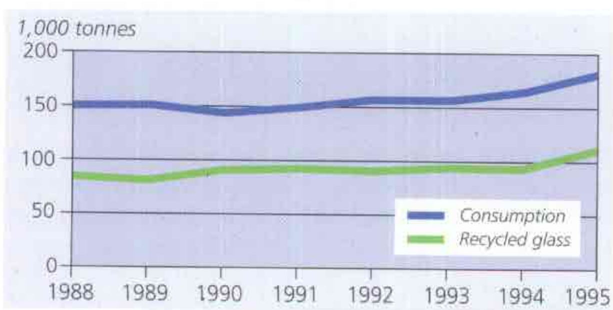


Figure 3.9.7 *Development in consumption and recycling of glass over the period 1988-95 (Source: Rendan A/S, 1996b).*

Recycling of glass reduces the amount of waste, especially that sent to landfill, and reduces energy and resource consumption. Relative to the production of new glass, the savings are greater with reuse (i.e. refilling) than with actual recycling (i.e. the use of glass fragments in production). Consumption of glass containers has been increasing and amounted to 181,265 tonnes in 1995. The majority of the increase is accounted for by jam jars, etc. The total amount of glass collected in 1995 was just over 122,656 tonnes, corresponding to 68% of the total consumption. Of this, 111,341 tonnes were recycled, corresponding to 61% of total consumption, see *Figure 3.9.7*. The refilling percentage for wine and alcohol bottles was approx. 30% in 1995.

Recycling of building and construction waste considerably reduces consumption of resources such as stone and gravel and reduces the need for new landfills. In the period 1993-95, there was an overall increase in the total amount of building and construction waste sent to recycling plants. This also applies to the individual fractions. The absolute increase has been greatest for concrete and asphalt (see *Figure 3.9.8*).

There has been a corresponding increase in output from the plants (crushed and uncrushed materials), with most of this being accounted for by crushed asphalt. Crushed brick/concrete and uncrushed concrete have also increased considerably, however. A certain amount of building and construction waste is also recycled without passing through the recycling plants.

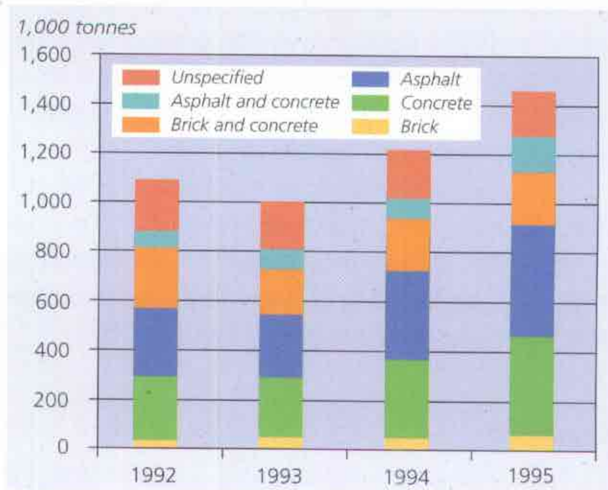


Figure 3.9.8 *Development in building and construction waste input to recycling plants over the period 1992-95 apportioned by type (Source: Rendan A/S, 1997b).*

Incineration

When waste is incinerated, the energy content is expended once and for all. With recycling, in contrast, the process can be repeated many times before the energy content of the waste is expended. Effective utilization of the energy content of nonrecyclable waste is preferable to energy production on the basis of fossil fuels.

Moreover, incineration reduces the volume of the waste to approx. 10% and the weight to approx 30%. Air pollution from waste incineration can be reduced considerably through improved incineration conditions and effective flue gas abatement. However, emissions of acidic flue gasses (e.g. hydrochloric acid), heavy metals, dioxins, etc. cannot be avoided completely.

Flue gas abatement at waste incineration plants results in residual products corresponding to approx 5% by weight of the waste incinerated. In addition, slag is produced corresponding to 20-25% by weight of the waste incinerated. At present, landfill is the only possible route of disposal for residual products from flue gas abatement, and the material is difficult to deposit due to its water solubility. Slag can be recycled provided it complies with limit values for certain heavy metals, but has otherwise to be sent to landfill.

Residual products from waste incineration are not included in the figures and tables shown earlier for amounts of waste and routes of disposal as this would entail the waste being counted twice. *Figure 3.9.9* shows the amount of residual products (slag, fly ash and residual products from flue gas abatement) and routes of disposal.

The figures for 1994 to 1995 are merely indicative of the amounts sent for disposal and must not be confused with the amounts generated. Thus the 120,000 tonnes increase from 1994 to 1995 does not represent a corresponding relative increase in the amount of waste incinerated. The increase primarily reflects the fact that the waste incineration plants often store the residual products, subsequently to dispose of them in large portions depending on market conditions.

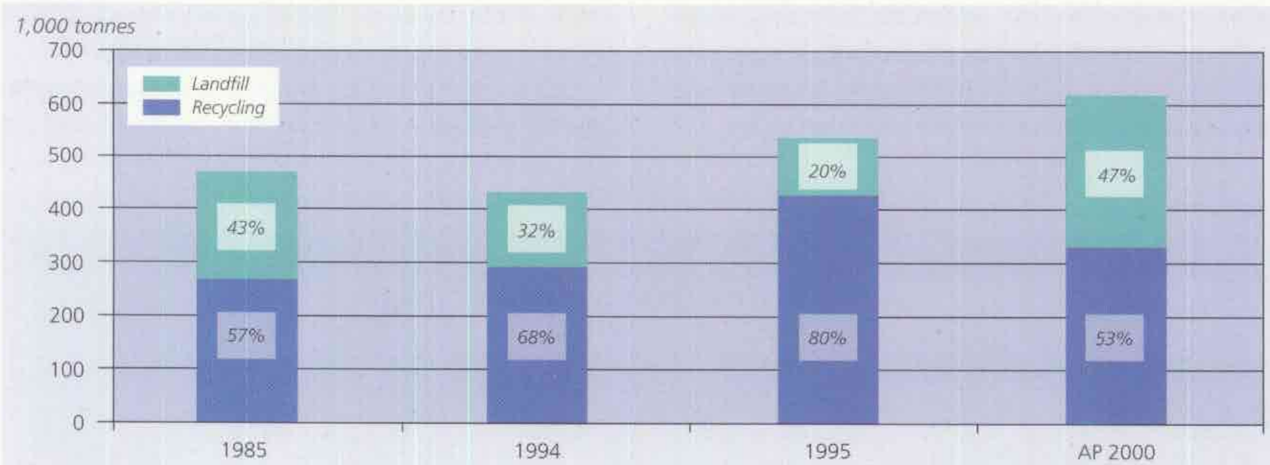


Figure 3.9.9 *Waste from incineration plants apportioned by route of disposal (Source: Danish Environmental Protection Agency, 1992a, 1994b and 1996b). Note: AP 2000 refers to the targets in the Government's Action Plan on Waste and Recycling 1993-97.*

Figure 3.9.10 *Development in amount of hazardous waste input to the waste processing firm Kommunekemi A/S over the period 1987-95 apportioned as waste chemicals and waste oil (Source: Kommunekemi A/S).*

Special waste management

Part of the waste generated is considered hazardous waste and the majority of this fraction undergoes special management, primarily at the national waste processing plant, Kommunekemi A/S.

Development in the amount of waste oil and chemicals sent for processing at Kommunekemi A/S over the years 1987-95 is shown in *Figure 3.9.10.* As is apparent, inputs have been falling slightly since 1991 although there was a 3% increase from 1994 to 1995. This increase is primarily attributable to large-scale remediation of contaminated sites.

The amount of waste oil sent to Kommunekemi A/S has also fallen steadily throughout the period shown apart from a slight increase from 1994 to 1995. The background for this fall is the increasing amount of waste oil that is sent to district heating plants.

The part of the hazardous waste that does not undergo special management is recycled, incinerated or landfilled under particularly safe conditions. *Table 3.9.5* shows the amount of hazardous waste in 1995 apportioned by source and route of disposal. Both primary and secondary sources are included, the latter being the waste incineration plants. Among the primary sources, industry dominates. A corresponding analysis is not available for previous years.

Objectives and policy measures

The Government's Action Plan on Waste and Recycling 1993-97 stipulates targets for the waste area for the year 2000. These targets are shown in *Table 3.9.6.* The overall objective on the waste front is to reduce the amount and environmental impact of all types of waste.

Given that society's activities unavoidably result in waste production, the objective is to exploit the resources in the waste as best possible - firstly the materials and thereafter the energy content. With respect to waste management and disposal, the objective is to reduce their environmental impact as best possible, including working environment problems.

To implement the environmental objectives, a number of measures have been initiated:

Cleaner technology in the waste area is a preventative strategy that can ensure reduced waste generation, among other things through better utilization of resources.

Recycling is generally the waste disposal route accorded highest priority as it ensures optimal utilization of the resources. The target is to recycle 54% of the total amount of waste by the year 2000.

Incineration of waste exploits its energy content, and air pollution can be reduced considerably by

Hazardous waste in 1995

	Recycling	Incineration	Special management	Landfill	Total
Primary sources					
Lead accumulators	12,282				**12,282**
Waste oil input to district heating plants		19,200			**19,200**
Waste oil and chemicals to Kommunekemi A/S*			89,900		**89,900**
Asbestos				7,300	**7,300**
Hospital waste		7,800	2,800		**10,600**
Sulphuric acid (coal-fired power stations)	22,000				**22,000**
Waste oil and chemicals from other primary sources	10,300	2,200	2,700		**15,200**
Total from primary sources	*44,582*	*29,200*	*95,400*	*7,300*	***176,482***
Secondary sources					
Filter dust from flue gas abatement	9,991				**9,991**
Fly ash and flue gas abatement products from waste incineration plants			18,900	44,400	**63,300**
Total from secondary sources	*9,991*		*18,900*	*44,400*	***73,291***
Total from primary and secondary sources	*54,573*	*29,200*	*114,300*	*51,700*	*249,773*

Table 3.9.5 *Total production of hazardous waste in 1995 (Source: Danish Environmental Protection Agency, 1996b). Note: In totalling primary and secondary waste, a small amount of waste is counted twice. * Kommunekemi A/S is the only authorized waste chemicals and oil processing firm.*

Targets for year 2000								
	Recycling		Incineration		Landfill		Special management	
	1995	AP-2000	1995	AP-2000	1995	AP-2000	1995	AP-2000
Source	%	%	%	%	%	%	%	%
Household waste	15	40-50	74	50-60	12	0	0	-
Bulky waste	14	25	40	38	46	38	0	-
Garden refuse	92	85	3	15	5	0	0	-
Institutions/retail and offices	38	60	44	40	15	0	3	-
Manufacturing, etc.	56	50-60	11	30-40	30	10	2	-
Building and construction	85	60	1	10	13	30	2	-
Sewage treatment works	77	50	15	25	8	25	0	-
Slag, fly ash, etc. (coal)	92	56	0	0	8	44	0	-
Other	3	0	60	0	37	0	0	-
Total	*62*	*54*	*20*	*25*	*17*	*21*	*1*	-

Table 3.9.6 *Year 2000 targets for routes of waste disposal for the different types of waste compared with the situation in 1995 (Source: Danish Environmental Protection Agency, 1992a, 1996b and 1997a).*

effective flue gas abatement. The target during the 1990s is therefore to redirect all combustible waste that is not intended for recycling and which does not cause special problems to plants combining waste incineration with utilization of the energy content. This corresponds to approx. 25% of all waste.

Landfill is the waste disposal route accorded lowest priority because the resources in the waste are not utilized and there is considerable risk of pollution from landfills. The objective for landfilling of the remaining waste is therefore to redirect waste from inland waste dumps and landfills to major landfills located as near to the coast as possible during the 1990s. As far as concerns the total amount of waste, the waste statistics show that waste generation amounted to approx. 11.5 million tonnes in 1995 and 12.9 million tonnes in 1996, which far exceeds the 9.8 million tonnes expected in the year 2000 (see *Figure 3.9.2* and *Table 3.9.3*).

This should be seen in the context that the total amount of waste in 1996 (12.9 million tonnes) already exceeds the amount forecast for the year 2000 as a result of exceptionally high growth between 1995 and 1996. Between 1994 and 1995, the amount of waste only increased approx. 0.6%.

It can thus be concluded that efforts made to date to reduce the amount of waste, especially those made within the cleaner technology area, have not been adequate.

The cleaner technology initiatives so far undertaken have not placed any great emphasis on waste minimization. In future, however, waste generation is to be taken into account on an equal footing with other emissions. In accordance with the product-oriented environmental policy, the use of environmental management and overall life cycle assessments is to be enhanced on the cleaner technology front. A further major problem is that current industrial products consist of complex materials and components that make recycling of the discarded products difficult. Technologies have therefore to be developed that can separate, sort and manage current products. Moreover, greater emphasis should be placed on recycling when designing new products.

The overall target for recycling for the year 2000 has been more than met since recycling had already reached 62% in 1995. The degree to which the target has been met varies markedly among the individual sources, however. Thus while the recycling target has been more than met for building and construction waste, waste from sewage treatment works and slag, fly ash, etc., recycling of waste from institutions, retail and offices and from households lags far behind.

With regard to household waste, the Action Plan states that the main contribution to an increase in recycling is to come in the form of recycling of the organic fraction. The number of composting and biogas plants that process household waste has only increased slightly, though. Biogas plants for the combined management of household waste and livestock manure seem to hold great promise as biogas production offers greater environmental advantages than composting (without energy utilization). However, the technique is not yet fully developed. During the follow-up programme in the biogas area, which is being undertaken as a joint programme between the Ministry of Foods, Agriculture and Fisheries and the Ministry of Environment and Energy, developmental work is being undertaken aimed specifically at solving the technical problems concerning the processing of organic household waste.

As regards incineration, total incineration capacity in 1993 was 2.3 million tonnes per year shared between 31 plants. At the beginning of the 1990s, there was widespread conversion of the waste incineration plants from heat production to combined power and heat production. In connection with this conversion, incineration capacity was adjusted to the amounts of waste expected to be sent for incineration in the future.

The prohibition on the landfilling of combustible waste that entered into force on 1 January 1997 must be expected to further strain the incineration capacity. The amount of combustible nonrecyclable waste will be monitored regularly in order to ensure that there is sufficient incineration capacity for the combustible waste produced while at the same time trying to promote recycling, cf. *Table 3.9.7*.

Total remaining waste dump capacity in 1994 was 24,7 million tonnes shared between 64 waste dumps. The remaining landfill capacity in 1994 was 6.7 million tonnes shared between 49 landfills. However, the amount of waste sent to landfill is expected to decline markedly as a consequence of the above mentioned prohibition on the landfilling of combustible waste combined with higher and more differentiated waste disposal levies. At the national level, additional landfill capacity is therefore unlikely to be needed in the future, see *Table 3.9.8*.

The overall objective for the waste area is to reduce the amount of waste with the focus being on hazardous substances in the waste. A number of these substances can be avoided by replacing them in products. There will be a long transitional period during which waste will arise that contains hazardous substances, however.

Many products have a long lifetime and products will continue to be sold in the future that are not produced on the basis of cleaner technology principles. The objective is to reduce the use of chemical substances and products that create waste problems and to enhance recycling of hazardous waste. Initiatives on the hazardous waste front are undertaken in close connection with general efforts in the chemicals area, see *Section 2.5*.

Number of incineration plants and incineration capacity

	1989	1993	1994/95	
No. of incineration plants	38	31		31
Theoretical capacity (1), in 1,000 tonnes	2,164	2,329	District heating (2) Combined heat and power	1,217 1,315
Nominal capacity (1), in tonnes/hour	313	335	District heating (2) Combined heat and power	174 188

Table 3.9.7 *Number of incineration plants and incineration capacity in 1989, 1993 and 1994/95 (Source: Rambøll and Hannemann, 1990; Danish Environmental Protection Agency and Danish Energy Agency, 1994; and information from the plants). Notes: (1) Calculated on the basis of the nominal capacity assuming 7,000 hours of operation per year. (2) District heating capacity can be restricted under the provisions of the Heat Supply Act.*

Waste disposal site capacity

	1992	1994	1992	1994
	Waste dumps		Landfills	
Number of sites	60	64	70	49
Remaining disposal capacity, in million tonnes	30.9	24.7	14.3	6.7
Annual filling rate, in million tonnes	2.1	1.7	0.9	0.12

Table 3.9.8 *Waste disposal site capacity in 1992 and 1994 (Source: Danish Environmental Protection Agency, 1992b and 1997b).*

4. Cross-cutting summary

4 Cross-cutting summary

4.1 Introduction

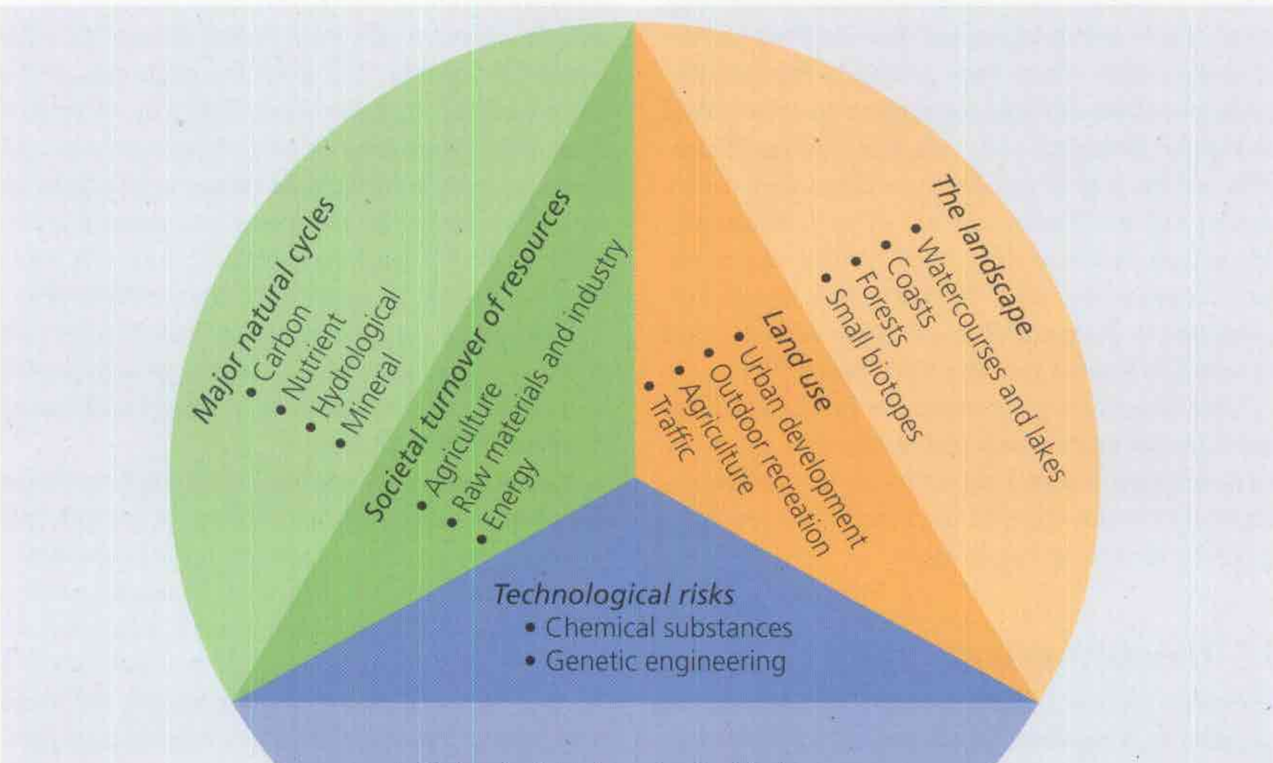
The two preceding chapters examine the state of the environment and the anthropogenic pressures from two perspectives: the environmental perspective and the societal perspective. In the examination from the environmental perspective, the environment was subdivided into a number of subsystems such as the atmosphere, landscape, soil, aquatic environment and urban environment to which were added a number of cross-cutting issues such as environmentally hazardous substances, genetic engineering and the cultural environment. In the examination from the societal perspective, society was subdivided into a number of sectors such as energy, transport, agriculture, industry, service, households, outdoor recreation and waste disposal. These subdivisions largely reflect the way in which the environmental and sector administrations have each organized themselves and hence are well-suited for disseminating the expertise that has accumulated in these administrations. However, there are a number of cross-cutting relationships in the state of the environment, in the environmental pressures and in the environmental policies that are blurred by such a highly subdivided examination of the issues. In the present chapter, the detailed examination made earlier will therefore be summarized in the form of some main features and tendencies.

4.2 Three types of environmental problems

If one examines the environmental processes described in the preceding sections, three general features emerge:

1) Pressures on major natural cycles

Firstly, our environment is regulated by a number of major natural cycles and balances. Examples are the hydrological cycle, the carbon cycle and associated climate balance, the nutrient cycle, the ozone balance, and the acid-base balance in a number of ecosystems. A number of the major cycles are regional or global in character and they are affected by virtue of the magnitude of societal turnover of resources and the associated emissions to the environment.



Figur 4.1 Three types of environmental pressure: Major natural cycles, land use and technological risks.

2) Land use

Apart from these natural cycles, nature and its various ecosystems are also characterized by a geography that anchors the cycles in a highly varied landscape structure, creates local variations in the cycles and forms the basis for a specialized and diverse nature. The physical and geographical structures and features in the landscape have formed over thousands of years during which the ecosystems and life forms have adapted themselves to the prevailing conditions. These structures in nature and the landscape are affected by the extent and character of society's use of the land. Examples are our extensive physical regulation of the hydrological cycle, our intensive exploitation of the soil for food production and the conversion and fragmentation of the landscape by urban development and transport infrastructure.

3) Technological risks

In addition to these major relationships in the environment, life is regulated by a multitude of complicated chemical, biological and ecological processes and balances which vary from organism to organism and from ecosystem to ecosystem. Man's development of new technologies and their implementation in society from where they spread to the environment affect these microprocesses and pose the risk of unwanted biological and ecological changes. Examples are the use of radioactive substances, widespread use of medicine, the use of environmentally hazardous chemical substances and the use of genetic engineering. Only the latter two aspects are examined in the present report. It has been decided to term this type of problem *technological risks*.

This three-faceted perspective on the environment and society is illustrated in *Figure 4.1*. An overall description of man's impact on the state of the environment is provided below based on these three types of environmental problem.

4.3 The major natural cycles

The major natural cycles are affected by virtue of the magnitude of resource turnover in society, which is dominated by the following three main production processes: 1) Turnover of resources in relation to the production of foods, 2) Turnover of resources in relation to energy production and 3) Turnover of resources in relation to manufacturing of materials.

The general growth in production and consumption has led to widespread growth in a number of society's central commodity streams, as described in the preceding sections.

In quantitative terms, output from the agricultural sector has thus increased by approx. 30% since 1980. During the same period, industrial output has increased approx. 40% in real terms, passenger transport has increased by approx. 60% and freight transport by approx. 40%. These increases in the commodity streams have exerted rising pressure on the associated flow and turnover of resources. Final energy consumption has thus increased by approx. 15% since the beginning of the 1980s. Within industry, households and the service sector, the amount of waste has increased by 25-50% over the period 1985-95.

These increases in some of society's central activities have not led to a corresponding increase in emissions to the environment, however. These have generally been reduced, and in many areas considerably so. Since the end of the 1980s, the agricultural sector has reduced its fertilizer consumption, improved the utilization efficiency of nitrogen in livestock manure and reduced leaching of nitrogen by 15-20%. During the same period, discharges of nitrogen, phosphorus and organic matter from industry and municipal sewage treatment works have been reduced by 60-80%. Emissions of SO_2 from power stations have decreased by approx. 70% since the beginning of the 1980s, and NO_x emissions have fallen by about 25% since 1990. Emissions of NO_x, hydrocarbons and particulates from traffic have begun to fall again after an increase in the 1980s and are expected to decrease by 50-60% up to the year 2010. Total CO_2 emissions have fallen by approx. 4% from 1988 to 1996.

In several areas, environmental pressure per unit production has fallen more than the growth in production. It has been possible to increase the efficiency of resource use in society.

The increase in the efficiency with which resources are used in society has been achieved through two types of measure: On one hand, through the establishment of treatment and abatement measures, and on the other hand, through the implementation of more environmentally effective production methods and changes in behaviour. Characteristically, the areas where the greatest reductions in environmental pressure have been achieved are the areas where it has been possible to apply treatment and abatement technologies. In the areas where treatment and abatement measures are not yet available and where efforts must therefore be solely directed at changing production methods and behaviour, there has been considerable problems with meeting the reduction targets.

ety's differentiated production processes and diverse commodity streams.

Approximately 20,000 chemical substances are currently marketed in Denmark in approx. 100,000 different products, and approx. 200 new chemical substances are placed on the market in the EU each year.

In the coming years, the number of genetically modified microorganisms and plants intended for placing on the market will probably increase markedly. While the technological risks were formerly restricted to a few relatively well-defined substances, organisms and effects for which a scientifically based risk assessment was reasonably manageable, the picture is now more complicated.

Examples of this include the discovery that a number of substances affect the hormonal systems of man and animals, and the increasing use of more and more refined genetically modified plants where a "package" of different types of trait is incorporated into the plants. In relation to the technological risks, science has in many areas reached the limit of where it can demonstrate clear cause and effect relationships. In the words of the German sociologist Ulrich Beck, we have developed a "risk society" where we are increasingly exposed to risks of human origin whose effects we cannot fully foresee. For this reason, the discussion of how to manage the risk society politically and institutionally gains in urgency. An element of this discussion is determination of the role to be played by science and the scientific institutions.

4.6 Scope of the environmental problems

The focus of the present report has been on the environmental problems facing Denmark and the current state of the Danish environment. This is naturally because the aim of this report is to evaluate Danish endeavours on the environmental front. However, the nature of the majority of the environmental problems is such that this perspective is often too narrow to permit full understanding of their extent and character.

Firstly, many of the processes in the environment are transboundary and some of them are even global. Secondly, growing internationalization of our economies and societies means that pressures on the environment are increasingly driven by transboundary economic and social processes. Thirdly, a number of the changes in environmental state are of such a character that it is only meaningful to view them over a long time horizon, just as efforts to deal with these problems of necessity have to be long-term.

The geographic and temporal scope of the environmental problems is referred to numerous places in the individual sections earlier in this report. In this concluding section, the threads will be gathered together.

Temporal dimension

The temporal dimension is central to all the three types of environmental problem described above. In relation to pressure on the major natural cycles and balances in nature, there is a reaction time of decades and in certain cases centuries between the point when the pressure starts to the time when an effect is detectable. Such temporal delays apply, for example, to nutrient loading of the aquatic environment, pollution of the groundwater and changes in the chemical composition of the atmosphere and the resultant climate problems. To this physical reaction time has to be added the reaction time required by plants and animals to adapt to the new conditions. While these reaction times are very long from a societal point of view, in an evolutionary perspective they are very short. The ecosystems have difficulty in adapting to the new conditions in such a short time and there is therefore the risk that their stability will lessen. Similar conditions apply in relation to the changes in the landscape resulting from man's use of the land.

There are also a number of important temporal perspectives associated with the technological risks. Thus because the so-called persistent organic pollutants slowly accumulate in certain parts of the environment and in the food chains, decades can pass from their release into the environment until they become detectable. In addition, the biological reaction to the pressures is also often delayed. Chemical effects on the hormone system during the foetal stage will thus often not yield visible effects until after puberty. Similarly, the effects of carcinogenic substances may first become apparent 20-30 years after exposure. In relation to genetically modified organisms, dispersal of viable species into the environment could cause irreversible changes in nature. These temporal delays entail an extra uncertainty factor in the assessment of the environmental effects.

Thus while many years may often pass before an environmental pressure can be recorded as an unwanted effect in the environment, it will also take a corresponding period for environmental measures to yield visible improvements. As a number of the central environmental problems are deeply rooted in some of society's fundamental structures, which take a long time to change, it is clear that environmental policy is characterized by a time horizon that is fundamentally different from the majority of other policy areas.

The international dimension

As mentioned earlier, environmental problems are transboundary in character from two points of view: On one hand, a large number of environmental problems are regional and global in their impact. On the other hand, a number of the pressures on the environment are driven by societal development, which is becoming increasingly international.

The increasing internationalization of the economy means - not least for a small country like Denmark - that a growing part of our consumption consists of commodities produced abroad. The environmental impact of the production of those commodities thus lies abroad. Conversely, much of the environmental pressure in Denmark is associated with the production of commodities that are consumed in other parts of the world. A purely national examination of environmental state, environmental pressures and environmental initiatives is therefore inadequate and needs to be supplemented with an overview of this import/export of environmental impacts. This is a difficult task, however, and cannot presently be undertaken because the necessary data are not available. Nevertheless, it is reasonable to suppose that as a country poor in raw materials with a high level of consumption, Denmark gives rise to considerable environmental impacts abroad. Studies of the Netherlands' import/export of environmental problems confirm this.

Such a broader international perspective on Denmark's impact on the environment and environmental initiatives is a central feature of the ideas on "sustainable development" propounded in the Bruntland Commission's 1987 report, which introduced the idea "think globally and act locally". In international research circles there has subsequently been fierce debate on whether internationalization of the economies is advantageous or detrimental to the environment.

In support of the first view, it is suggested that internationalization contributes to an effective exploitation of resources, to the transfer of environmentally friendly technology between countries, and to the promotion of growth in the poorer countries, which is considered a precondition if they are to accord higher priority to environmental protection.

In support of the second view, it is conversely suggested that internationalization contributes to strengthening economic growth beyond the bounds of environmental sustainability, that it emphasizes economic competitiveness and hence favours countries with low environmental standards, and that there are no international institutions able to enforce consideration for the environment in the face of the far stronger economic interests.

Another aspect of the international environmental discussion is the question of the distribution of the consumption of the world's natural resources that lies behind the concept of the "ecological carrying capacity". The philosophy behind this term is that there is a certain upper limit for how much of nature's resources the population of the world can exploit in a sustainable manner. In addition, the term encompasses considerations on even distribution of these resources between the individual countries weighted according to the size of their populations. The resultant figures are an expression of the countries' "ecological carrying capacity". This concept entails that countries such as Denmark shall reduce their consumption of natural resources.

In parallel with internationalization of the economy, more and more environmental problems have become global in nature and cannot be solved through purely national efforts. There is an increasing need to be able to analyse the relationships between economy and the environment at the global level - irrespective of how the development of these two aspects is coupled. The problem is that while the global economy is currently an effective reality, it is a more complex matter to perceive ecology in a global context.

As these international aspects and perspectives in the environmental debate are not the basis for the present report, they have only been examined briefly above.

This applies in relation to nutrient discharges from agriculture, CO_2 emissions from the energy production, especially in relation to transport, as well as to the increasing amounts of waste.

The agricultural sector is thus far from meeting the 50% reduction target for nitrogen losses stipulated in the Action Plan on the Aquatic Environment. With respect to phosphorus, moreover, it is estimated that diffuse loading from agricultural land makes a major contribution to the continued poor quality of the water in our lakes. CO_2 emissions from traffic are expected to be at least 16% higher than the target of stabilizing emissions at the 1988 level by the year 2005. Partly for this reason, it is estimated that the goal of a 20% reduction in total CO_2 emissions by the year 2005 relative to 1988 will be difficult to achieve through the measures hitherto implemented. In addition, the growing amounts of waste mean that the goal of stabilization of waste levels will not be achieved.

In relation to the other areas, where achievement of the environmental objectives is partly based on more resource-effective technologies, it needs to be emphasized that there are upper technical limits for what can be achieved by these means.

With time, a continued increase in societal production and consumption will therefore neutralize the benefits of improved efficiency. Within the transport area, growth in the amount of transport in the preceding period has thus markedly exceeded the improvements in vehicular fuel efficiency. In the energy area, more effective exploitation of heat and more effective energy supply systems have led to a 4% fall in CO_2 emissions, but these improvements in efficiency have now largely been outweighed and will not be able to compensate for further growth in final energy consumption. Similarly, continued growth in agricultural production will neutralize the increased efficiency in the utilization of livestock manure in future. In these areas, it will therefore be necessary to supplement increased efficiency in resource use with other technical measures as well as behavioural changes.

4.4 Land use

Man's use of land for production and consumption is another important aspect of anthropogenic pressure on nature and the environment. Land use alters the physical and geographical structure of the landscape and hence the distribution between and the conditions for the various ecosystems and habitat types that have developed as a function of these conditions. The pressures depend partly on the size of the area used by man and partly on the intensity with which it is used.

In the present century, land use has mainly been characterized by increasing urbanization and, from the end of the 1950s, also by growth in holiday cottage districts and tourist facilities along the coast. There has been a slight decline in land use for agriculture while the amount of natural countryside has declined considerably. The changes in overall land use have been closely accompanied by major changes in the landscape.

The countryside has been dominated by agricultural development and the transition to more intensive and specialized agricultural practices that have characterized this development. In the first half of the century, this led to widespread regulation of the hydrological cycle and attempts at the cultivation of marginal land, especially in western Jutland. The drained agricultural area thus increased by about 110% between 1900 and 1980, and 85% of all watercourses in the country are currently channelized. At the same time, habitat types such as heaths and raised bogs have been reduced to less than 10% of the area they occupied in the previous century. In the second half of the century, development has been characterized by agricultural mechanization, specialization and concentration. Over the last 20-30 years, farms have thus specialized in the direction of pure crop, pig or cattle/dairy farms and at the same time, have become larger. From the geographical point of view, the cattle farms have concentrated in Jutland while the crop farms have concentrated on the island part of Denmark. The pig farms tend also to be concentrated in certain areas of Jutland. As a result of this regionalization of agricultural land use, nutrient and organic matter cycling in the agricultural sector has become more open. Among other things, this has led to problems with respect to the utilization of livestock manure. Nearly half of the pig farms produce more livestock manure than can lawfully be applied to the farm's land according to current livestock density limits. Conversely, there are crop farms where no livestock manure is ever applied to the land. Specialization, regionalization and the trend towards larger farms also lead to a less varied landscape and in many places, to the elimination of borders, hedgerows and small biotopes.

The tendency towards specialization and regionalization is also seen within urban commerce. Different parts of industry congregate in different regions. The retail trade congregate in the form of large stores that are primarily sited in association with the medium-sized and larger towns. Urban activities become functionally divided and dispersed. Tourism mainly concentrates in the coastal areas, especially along the west coast of Jutland. For households, this spreading of society's production and service activities combined with the increasing participation in the labour market means that the geographic radius of action has increased markedly over the past 10-20 years. Each adult Dane now travels an average of 35 km per day.

The overall effect of these trends in localization and land use has been extensive expansion of the infrastructure within the transport, energy supply, water supply, waste water treatment and waste management sectors. This leaves an indelible mark on the landscape and exerts considerable pressure on a number of natural ecosystems. For example, marked expansion of the road net has led to severe fragmentation of the landscape and created barriers for the natural migration of certain animals in the landscape.

All in all, this societal development entails more intensive land use and hence increased pressure on nature and the environment. On the other hand, a number of initiatives have been implemented to try to protect nature and the environment from this pressure of land use. Preservation orders are placed on natural ecosystems and historical monuments, the restricted-building zone along the coast has been widened, protective border zones have been established along watercourses, and more gentle watercourse maintenance has been introduced. The county authorities have been required to identify areas where the groundwater is threatened in order to protect these areas against intensive use.

Nature restoration projects and afforestation have been undertaken, and in the towns, attempts have been made to regulate the retail trade and preserve historical environments. The pressure on nature and the environment is still high, however, and a long-term effort will be required if noticeable reductions are to be achieved.

4.5 Technological risks

In addition to the major pressures on nature and the environment from land use and the major natural cycles, pressure is placed on the biological processes through the introduction of environmentally hazardous substances and modification of the genetic characteristics of plants and animals.

In contrast to the pressures associated with the major natural cycles and land use, what is involved here is man's development of new substances and organisms which do not have any known biological function and which are foreign to the ecosystems generated by evolution. These pressures and the resultant effects are termed *technological risks* in this report.

Concern about the environmentally hazardous substances was formerly directed towards their acute and chronic toxicity. In the last 10-20 years, attention has increasingly focused on more complicated health and ecotoxicological effects such as allergies, cancer, reproductive damage and reduced fertility. Genetic change and modification of plants and animals have been undertaken for many years, partly through routine breeding work and partly through intentional or unintentional introduction of foreign species to the country. By means of genetic engineering, however, it is now possible to introduce completely new types of hereditary characteristics into plants and animals that it has not been possible to achieve through the methods previously available.

With respect to the above mentioned technological risks, no unambiguous picture can be drawn of the overall societal development. The tendency towards increased specialization and knowledge-based production generally means that the production processes and products become increasingly refined. The possibilities are therefore greater to optimize both production and products from the environmental point of view, and we have also seen many examples of more primitive and environmentally harmful technologies being replaced by more refined and environmentally friendly technologies: The ozone layer depleting CFCs have been phased out, the use of heavy metals such as lead, mercury and cadmium has been reduced, a number of chlorinated organic solvents have been phased out, and the general use and emissions of volatile organic compounds (VOCs) have been reduced. In addition, a large number of pesticides have been prohibited and pesticide consumption in terms of amount of active substance has been reduced. Finally, emissions of environmentally hazardous substances from a number of point sources have been reduced through improved treatment measures at commercial enterprises, municipal sewage treatment works, power stations and waste incineration plants.

On the other hand, due to this same specialization and development of knowledge-based production, technological development becomes far more difficult to oversee, and it becomes more difficult to control the use and spread of these technologies in soci-

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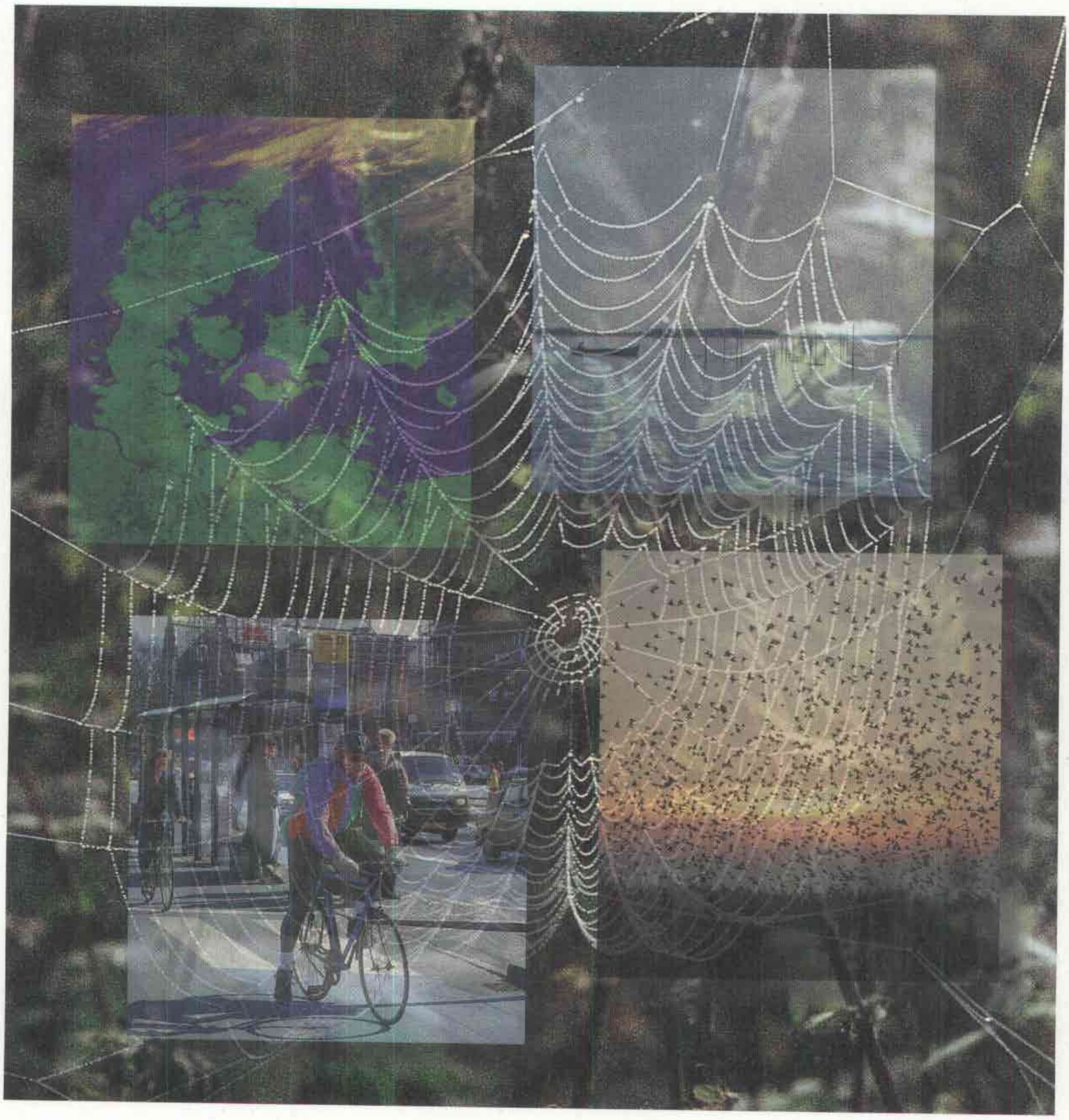

2 State of the environment

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The report summarizes existing knowledge of central developmental tendencies in the state of the Danish environment. In addition, it describes development in some of the sectors of society that contribute most to pressure on the environment and examines the relationship between societal trends and environmental development.

The report divides societal pressure on the environment into three categories: Pressures related to societal turnover of resources, pressures associated with land use and pressures associated with man's development of new technologies.

This is the second comprehensive Danish State of the Environment Report prepared by the National Environmental Research Institute in close collaboration with other parts of the Ministry of Environment and Energy. The first report was published in 1993.

Ministry of Environment and Energy