1 Societal pressures

Denmark is a rich country, and our consumption and production have increased during the 1990s. This has enhanced pressure on the environment. In many cases, technological development can mitigate the environmental impacts. The sectors that most affect nature and the environment are agriculture, transport and energy production.

Photo: NERI/Jørn Pagh Bertelsen

1.1 Introduction

The pressures on the environment are the result of both economic/technological development and consumer behaviour. Growth in the economy is the result of a higher level of business activity and greater consumption. This potentially also increases the impact on the environment. Nowadays, technological development is increasingly contributing to mitigation of the environmental impacts caused by economic growth, for example through increased energy efficiency, catalytic converters on cars and energy supply based on renewable energy sources such as wind turbines.

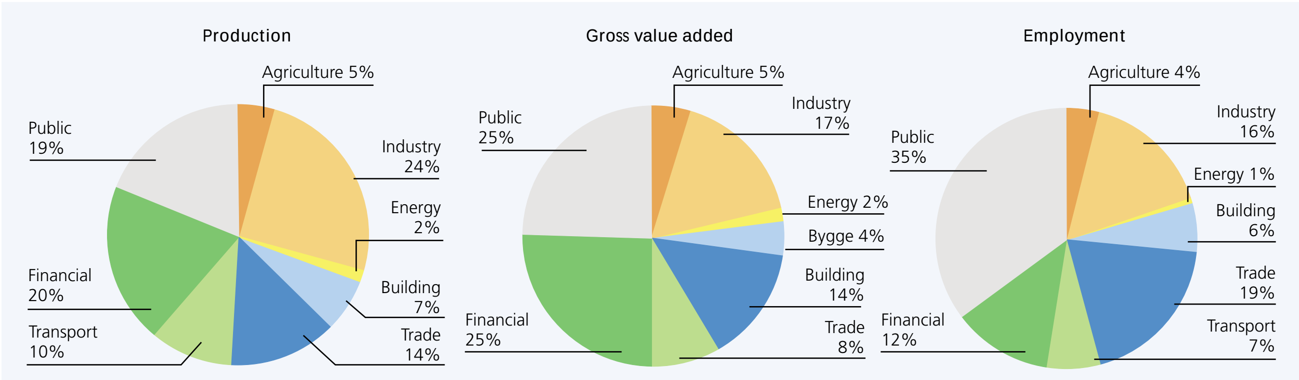
The national economy and the parameters used to describe the overall economic trend are subdivided into societal sectors. This makes it easier to obtain an overall impression of the economy, as well as an insight into some of the factors of greatest significance for the economic trend.

In the national statistics, the economy is subdivided into eight sectors:

1 Agriculture, fishery and raw materials
2 Industry
3 Energy and water supply
4 Building and construction
5 Trade, hotels and resturants
6 Transport, post and telecommunications
7 Financial services
8 Public and private services

Production, gross value added and the number of employed persons are three parameters commonly used to describe the interdependence of the sectors at the economic level (*Figure 1.1.1*).

Figure 1.1.1
Production, gross value added and number of employed persons apportioned by sector in 2000. (Source: Statistics Denmark, 2001a).



The public sector accounts for approx. 20–35% of the economy. Of the private sectors, industry, financial services and trade are the largest. The agricultural sector accounts for 4–5%. The proportion of the economy accounted for by each of the various sectors changes slightly over the course of time. During the past 10 years, industry's share of the economy has decreased slightly, while trade and transport have gained ground. These relative shifts are less than 2–3% in magnitude, however.

The individual sectors affect the environment to very different degrees, and in very different ways. Moreover, some of the sectors (e.g. agriculture and fishery) are very dependent on a clean environment. Direct coupling between the environmental consequences of the economy and its development is not simple, but is possible for some key parameters. Sector apportionment of for example CO_2 emissions reveals a somewhat different picture than sector apportionment of the economy (*Figure 1.1.2*). Apart from the energy sector, which accounts for 60%, the sectors contributing most to CO_2 emissions are transport (11%), industry (13%) and agriculture (9%). With other environmental parameters, the picture differs.

When examining the environmental consequences of economic activity, it is advantageous to subdivide into other sectors than those applied to the national economy. From an environmental point of view, for example, it is relevant to separate agriculture, fishery and forestry. Trade, financial services, post and telecommunications are often pooled as a so-called "service" sector since from the environmental point of view, there is little difference between the shops and the banks that comprise a large part of this sector. Finally, three areas are considered as sectors from the environmental point of view because they are each of special significance for the environment and particularly for nature, namely tourism and outdoor life, raw materials extraction and waste.

In general, the environmentally most important sectors are agriculture, energy and transport. Their environmental consequences are described in three separate sections of this chapter. The other sectors are described together in one section. The section on agriculture contains a theme entitled "From producer to resource manager" that examines the changes in the agricultural sector's role through the ages. The section on energy contains a theme entitled "Environmental consequences of liberalizing the electricity markets" that examines the liberalized electricity market and its potential significance for the environment.

Chemicals are used in all corners of society and are therefore mentioned in many different parts of this report. It is a very complex subject. A separate section of this chapter describes the consumption of chemicals in different sectors. The occurrence of chemicals in the environment is summarized with reference to more detailed descriptions of the various aspects of the issue in other parts of the report.

The final section of this chapter outlines the main trends in the Danish society of relevance to the state of the environment. The section on societal trends also includes a theme entitled "Outlook", concerning projections and forecasts for key sectors and the associated environmental impacts.

Figure 1.1.2
CO_2 emissions apportioned by sector in 1998.
(Source: Statistics Denmark, 2000).

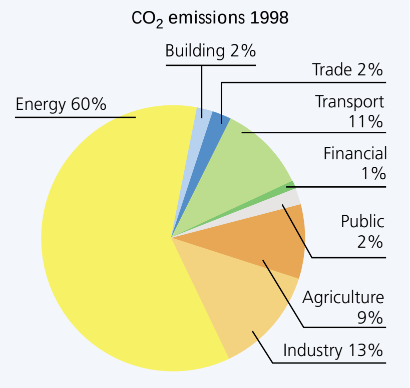


Photo: CDanmark

Photo: NERI/Jørn Pagh Bertelsen

1.2 Agriculture

1.2.1 Environmental impact of the agricultural sector

Price developments in the agricultural sector affect earnings in the sector and hence also affect the way earnings are apportioned between the individual production activities. Prices are therefore an important determinant of the need to rationalize farm operations and of the development and size of the individual production branches (crop, cattle and pig farming). Both these factors influence the interaction between agriculture and nature and the environment, as examined in the themes "From producer to resource manager" (*Section 1.2.2*), "Midterm evaluation of Action Plan on the Aquatic Environment II" (*Section 3.8*) and "Pesticides" (*Section 4.5*).

From 1985 to the present day, sales prices of agricultural produce have fallen by an average of 30% in real terms. Costs for raw materials and ancillary substances have remained largely constant during this period, while labour costs have increased by approx. 80% (*Figure 1.2.1*). It has therefore been necessary to increase agricultural production and productivity in order to maintain the level of earnings.

An indication of this is that total agricultural production has increased by almost 20% during the period (*Figure 1.2.2*), while consumption of commercial fertilizer and pesticides has decreased during the same period. The trend has differed considerably between production forms, however. Thus cattle production has fallen by approx. 10% since 1985, while pig production and crop production have increased by 55% and 10%, respectively.

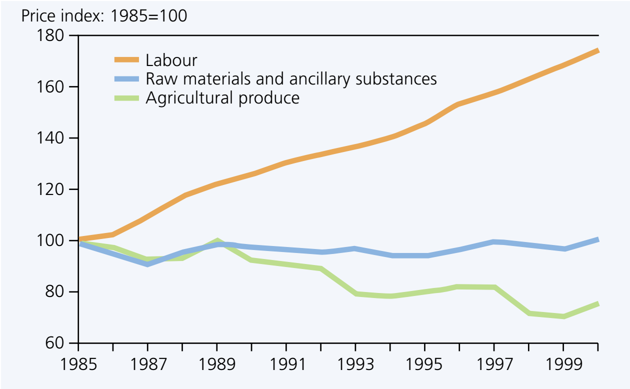


Figure 1.2.1
Price trends for agricultural produce, materials and labour. (Source: Statistics Denmark, 1986–2001).

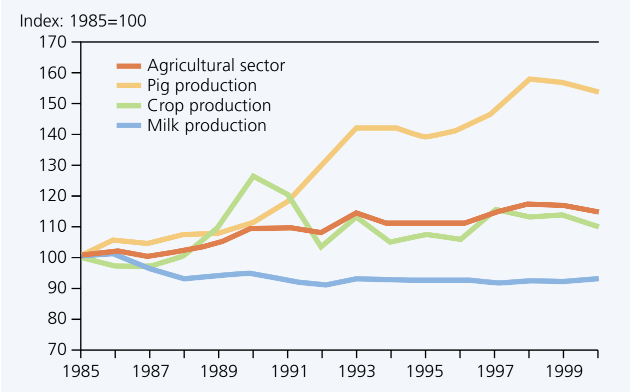


Figure 1.2.2
Indexed trend in agricultural production volume. (Source: Statistics Denmark, 1986–2001).

Structural development

The economically driven need for more effective agricultural production has affected structural development of the sector. During the period 1985–2000, the number of holdings smaller than 50 ha has decreased, the number of holdings in the size group 50–100 ha has remained largely unchanged, and the number of holdings larger than 100 ha has more than doubled (*Figure 1.2.3*).

During the same period, the total number of farms has decreased from around 92,000 to 55,000. Increasing effectiveness is also reflected in increased specialization of the farms (*Figure 1.2.4*). The percentage of purely crop holdings and purely cattle holdings is thus increasing. In contrast, the percentage of mixed cattle and pig holdings is decreasing. The percentage of purely pig holdings is also decreasing, although this is partly attributable to a marked increase in herd size on pig holdings.

The extent of organic farming has been separately recorded since 1988 (*Figure 1.2.5*). Since the mid 1990s, considerable growth has taken place in both the number of organic holdings and the organically farmed acreage. Thus there were almost 3,000 organic holdings in 2000 representing a total of just under 160,000 ha organically farmed acreage. Compared with the beginning of the period, not only has the extent of organic farming increased, but the size of the holdings has tended to increase (from 26.9 to 47.3 ha per holding). As a consequence, the average size of organic holdings is now slightly greater than that of conventional holdings (46.2 ha per holding).

Land use

From the trends in land use over the period 1985–2000 (*Figure 1.2.6*) it is apparent that winter cereals acreage has increased, largely at the expense of spring cereals acreage. The acreage of root crops (e.g. beets) and pulses (e.g. rape and peas) is decreasing, as is the acreage of permanent pasture. There has also been a marked general decrease in total arable acreage, which has been reduced by approx. 190,000 ha during the period. To this should be added the EU set-aside scheme, which was introduced at the beginning of the 1990s to reduce crop production. The decreasing total acreage combined with the increasing production underlines the enhanced pressure on arable land resulting from increased agricultural efficiency.

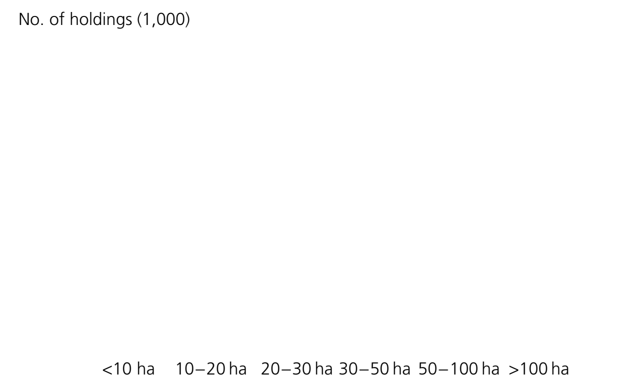


Figure 1.2.3

Agricultural holdings apportioned by acreage.

(Source: Statistics Denmark, 1986–2001).

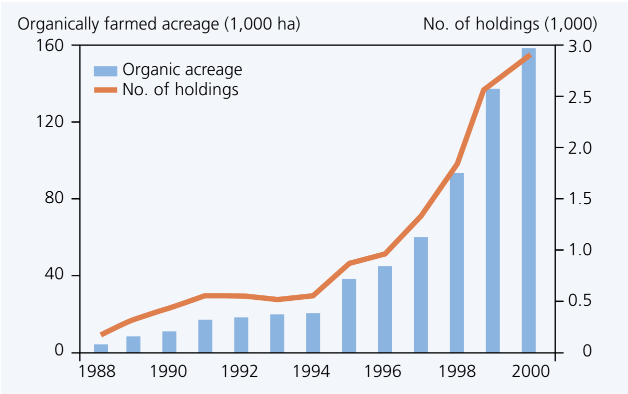


Figure 1.2.5

Number of organic holdings and organically farmed acreage.

(Source: Danish Plant Directorate, 2000).

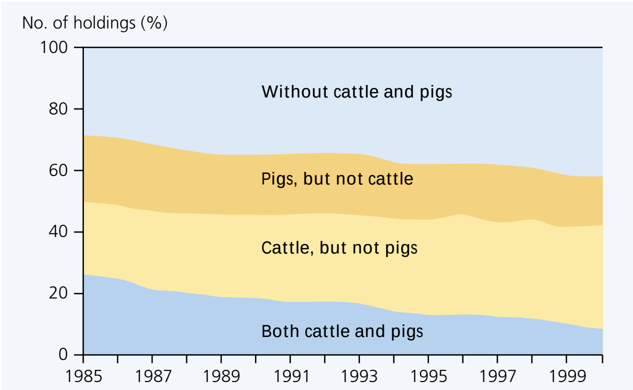


Figure 1.2.4

Relative specialization of the agricultural sector.

(Source: Statistics Denmark, 1986–2001).

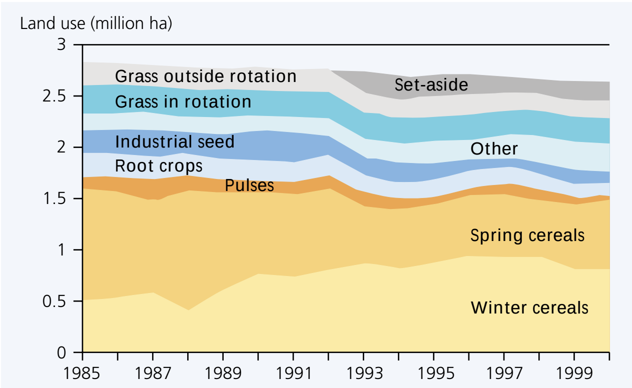


Figure 1.2.6

Land use within the agricultural sector.

(Source: Statistics Denmark, 1986–2001).

Livestock production is characterized by large regional differences. It can be seen from the livestock density on a county basis expressed as the average number of livestock units per hectare arable land that livestock pressure is relatively low on the island part of Denmark and relatively high in Jutland (*Figure 1.2.7*).

Impact on nature and the environment

The impact of agriculture on nature and the environment should be viewed as a complex relationship between natural conditions, cultivation of the land and the use of various ancillary substances in agricultural production. From the environmental point of view, the focus has hitherto been on the use of the nutrients nitrogen and phosphorus, the use of pesticides, and emission of greenhouse gasses (methane and nitrous oxide). Physical intervention in nature, for example drainage, can also significantly affect the quality of nature and the environment, however. Similarly, regionalization of the cattle herd has resulted in local losses of extensively managed pastures.

Agriculture also has a number of positive effects such as forming the landscape, though. Moreover, a number of valuable habitat types are dependent on continued extensive farming.

The level of livestock production in Danish agriculture is high, with cereals and imported feed being used to fatten the animals. This generates large amounts of manure. On the livestock holdings, ammonia volatilizes from livestock housing and slurry tanks and from fields spread with manure. Ammonia negatively affects the forests and natural habitats, thus entailing the risk that vulnerable habitat types will change in character (*see Section 2.4.2*). The agricultural sector also emits the greenhouse gasses methane and nitrous oxide, accounting for around 18% of total Danish greenhouse gas emissions (expressed in terms of CO_2 equivalents) (*see Section 2.2*).

In crop farming, manure and commercial fertilizer are used to satisfy crop needs for nutrients, and pesticides are used to combat weeds, fungal infections and pests. The plants can only use part of the nutrients applied to the fields via fertilizer. Some of the surplus nitrogen and phosphorus leach to the groundwater, watercourses, lakes and coastal waters and negatively affect their environmental quality. Pesticides can leach to the groundwater and affect non-target animals and plants (*see Section 4.5*).

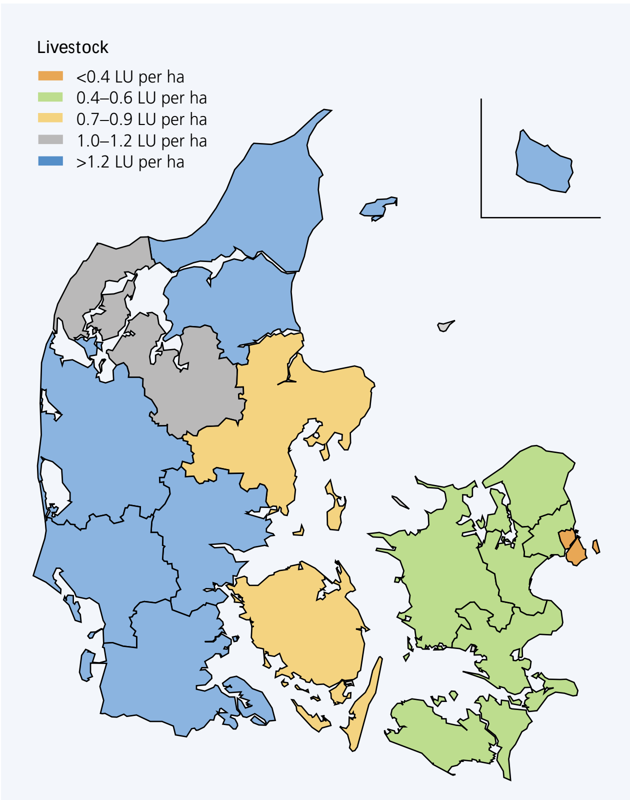


Figure 1.2.7
Livestock density at county level in 1999. (Source: Statistics Denmark, 1986–2001).

Intensification of agriculture over the past 50 years has resulted in impoverishment of the field flora and fauna. The merger of holdings and fields has resulted in the loss of small biotopes, and fertilization has had a negative impact on the small biotopes and permanent grasslands. On the other hand, intensification and structural development have also resulted in more rational farming practice and hence in more efficient use of nutrients and pesticides.

The intensity of livestock farming is of significance to such things as nutrient input to arable land (*Figure 1.2.8*). Overall, nitrogen input has decreased from just over 225 kg per ha in 1985 to just under 200 kg per ha in 1999, largely due to a decrease in the consumption of commercial nitrogen fertilizer. Nitrogen input in the form of manure has remained largely unchanged. The trend is also reflected in the agricultural nitrogen balance, which reveals the total input (feed, commercial fertilizer, etc.) and output (cash products) of nitrogen (*Figure 1.2.9*). During the period in which nitrogen output increased as a result of increased production, input decreased. Overall, this has reduced the nitrogen surplus by 20%. This shows that nitrogen efficiency in agriculture has increased, which is attributable to the above-mentioned increased effectiveness of farming practice together with the initiatives in the various environmental action plans aimed at reducing the impact of agriculture on nature and the environment (*Box 1.2.1*).

Phosphorus input per hectare has remained fairly constant (*Figure 1.2.10*). However, this hides a decrease in the input of commercial fertilizer and an increase in phosphorus input in the form of manure. At the same time, phosphorus input in the form of sewage sludge and industrial waste has become significant. In 1999, sewage sludge and industrial waste accounted for 8% of total phosphorus input.

As total arable acreage has decreased

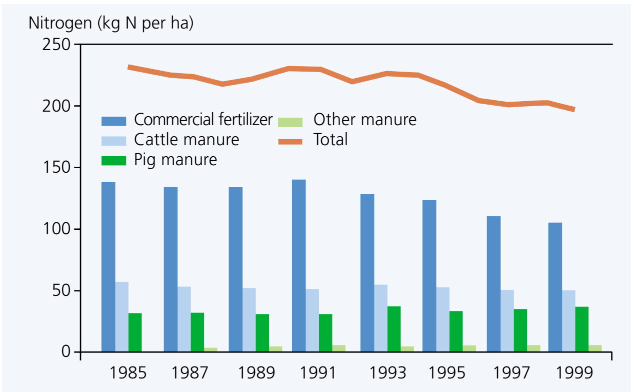


Figure 1.2.8

Nitrogen input to arable land apportioned by type of fertilizer. (Source: Andersen et al., 2001).

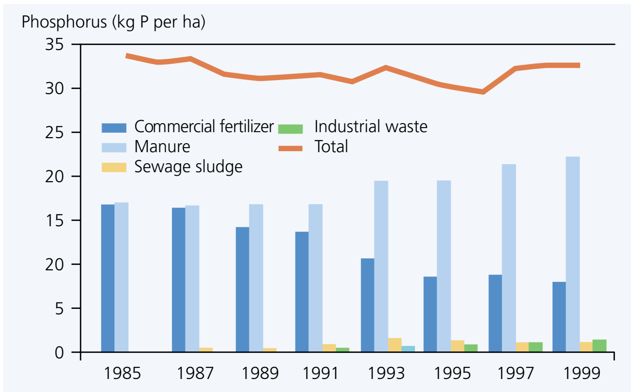


Figure 1.2.10

Phosphorus input to arable land apportioned by type of fertilizer. (Source: Grant et al., 2000).

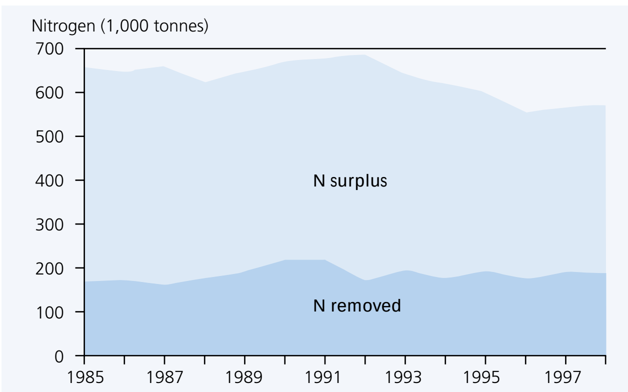


Figure 1.2.9

Total nitrogen (N) input to and output from agriculture. (Source: Kyllingsbæk, A., 2000).

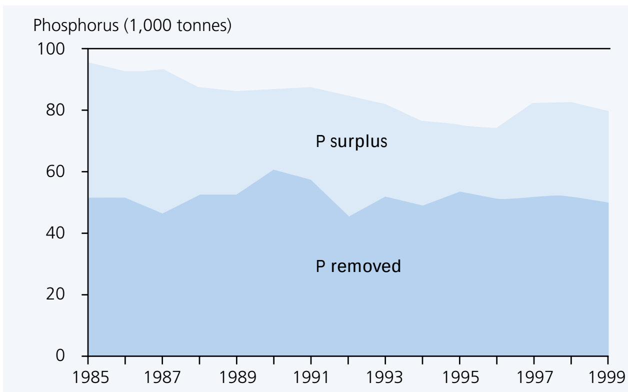


Figure 1.2.11

Total phosphorus (P) input to and output from agriculture. (Source: Grant et al., 2000).

during the period, total input of phosphorus has fallen (*Figure 1.2.11*). In contrast, total output of phosphorus has remained fairly constant. On average, the phosphorus surplus has decreased by 1,200 tonnes P per year. In recent years the reduction has stagnated, however.

As with the use of nitrogen, agricultural consumption of pesticides has also decreased, though to a more limited extent. Pesticide consumption is calculated at the national level using two measures: The amount of active substance and the application frequency. The former is a measure of the total amount of all active substances in the pesticides sold and does not take into account their efficacy on the target organisms. The application frequency is an indicator of the treatment effect of the pesticides used. The treatment frequency expresses how many times on average a plot of Danish arable land is sprayed with pesticides in the recommended dose each year, and is calculated from the national figures for pesticide sales and the recommended doses. Expressed in terms of the amount of active substance, pesticide consumption has decreased considerably since the mid 1980s, whereas the reduction in treatment frequency is somewhat less (*Figure 1.2.12*). It can be seen that the amount of active substance is far less than the target set in the first Pesticide Action Plan (*Box 1.2.2*). In the revised Pesticide Action Plan II this target has been dropped, although it is still of relevance in relation to the risk of leaching in connection with pesticide use.

The application frequency is thus the primary target parameter in pesticide policy. The application frequency for 2000 fulfilled the target for 2002 (*Figure 1.2.12 and Box 1.2.2*). Pesticide use by the agricultural sector is examined in detail in the theme "Pesticides" (*Section 4.5*).

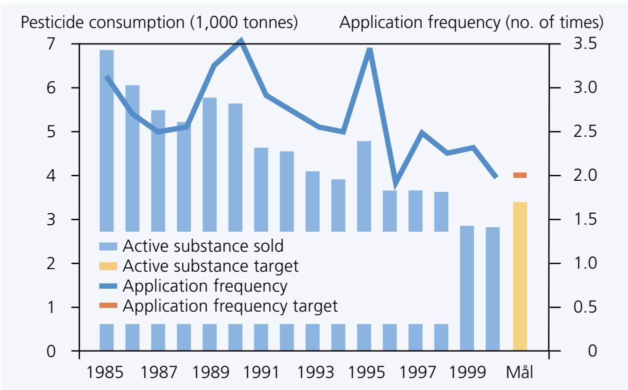


Figure 1.2.12
Agricultural pesticide consumption (amount of active substance sold) and application frequency.
(Source: Statistics Denmark, 2001b).

Photo: Danish Institute of Agricultural Sciences/Henny Rasmussen

Objectives and measures

A number of action plans have been drawn up over the years aimed at reducing nutrient and pesticide pollution from agricultural sources. Danish initiatives to regulate nutrient losses and the use of pesticides during the period 1986–2000 are summarized in *Box 1.2.1* and *Box 1.2.2*. The situation is followed regularly by evaluating the results of the action plans, thus enabling the measures to be adjusted where necessary. A midterm evaluation and revision of Action Plan on the Aquatic Environment II was carried out at the end of 2000 (*see Section 3.8*).

Box 1.2.1

Summary of initiatives aimed at reducing nutrient losses from agricultural sources 1986-2000.

Action plans	Objectives and measures
NPo Action Plan (1986)	**Objective:** To reduce pollution with nutrients and organic matter **Measures:** • Minimum of 6 months manure storage capacity • Ban on manure spreading from harvest to 15 October/1 November and ban on the spreading of manure on frozen ground • Manure to be ploughed down within 24 hours, livestock density requirement of 2 LU/ha and green subsidies in connection with improvement of storage capacity
Action Plan on the Aquatic Environment (1987)	**Objective:** To reduce agricultural nitrogen losses from 260,000 tonnes N/year to 133,000 tonnes N/year and reduce phosphorus losses by 4,000 tonnes P/year **Measures:** • Minimum of 9 months manure storage capacity, with exemption down to 6 months permitted • Obligatory crop rotation and fertilization plans; 65% green cover • Manure to be ploughed down within 12 hours
Action Plan for Sustainable Agriculture (1991)	**Objective:** To fulfil the objective of the Action Plan on the Aquatic Environment by 2000 **Measures:** • Obligatory crop rotation and fertilization plans and fertilization budgets • Minimum requirements as to utilization of manure nitrogen content. Storage capacity must be sufficient to meet the requirement as to utilization of manure nitrogen content • Ban on spreading manure in the autumn and on frozen ground • Designation of Environmentally Sensitive Areas (ESAs) with subsidies to reduce fertilization • Tightened fertilization budget requirements
Agricultural Holdings Act (1994)	Acreage requirements governing the permitted herd size on individual holdings and requirements as to the percentage of the required acreage that livestock holdings must own themselves. The acreage requirements represent tightening of the livestock density requirements
Action Plan on the Aquatic Environment II (1998)	**Objective:** To fulfil the objective of the Action Plan on the Aquatic Environment by 2003 **Measures:** • Establishment of wetlands, Environmentally Sensitive Areas (ESAs) and afforestation • Expected improvements in utilization of livestock feed nitrogen content • Improved utilization of manure nitrogen content • More organic farming • Greater area planted with catch crops • 10% reduction in the economically optimal nitrogen norm

Box 1.2.2
Summary of initiatives aimed at reducing agricultural use of pesticides 1986-2000.

Action plans	Objectives and measures
Pesticide Action Plan (1986)	**Objective:** To halve consumption of pesticides before the end of 1996. This applies to both application frequency and the amount of active substances sold **Measures:** • Voluntary reductions in accordance with the objective. 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 (see the 10-point Programme). The amendment was 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 to attain the objectives of the Pesticide Action Plan. The pesticide levy was incraised to an average of 30% of the wholesale price in 1998.
Action Plan for Sustainable Agriculture (1991)	**Objective:** The Action Plan reiterates the objectives of the Pesticide Action Plan **Measures:** Requirements as to training of spraying personnel and spraying accounts
10-point Programme for Protection of Groundwater and Drinking Water (Groundwater strategy) (1994)	**Programme items of significance for pesticide use:** • Ban on particularly harmful pesticides • Promotion of organic farming • Protection of particularly vulnerable groundwater abstraction areas • Improved monitoring of groundwater and drinking water
Pesticide Action Plan II (2000)	**Objective:** To reduce the application frequency as much as possible; subgoal: Reduction to 2.0 before the end of 2002; new subgoal every third year. Protection of certain areas, including areas alongside watercourses and lakes exceeding 100 m^2 for which quality objectives have been stipulated in the Regional Plan. To increase organically farmed acreage. Revision of pesticide approval scheme. **Measures:** Enhanced guidance on how to reduce pesticide use (experience groups, warning systems, training, reduction targets at crop level, etc.). Establishment of border zones by means of set-aside and agri-environmental measure schemes stimulated through increased guidance and information. Research in organic farming, product development and sale. Regular evaluation and expansion of the approval procedure.

Photo: CDanmark

1.2.2 Theme – From producer to resource manager

The intention of this theme is to illustrate how agricultural policy contributes to setting the framework for the farmers' use and management of nature and the environment. Market, technological and institutional conditions and policy together comprise the driving forces that set the framework for development in agricultural production, and also exert a varying influence upon it. The theme focuses on agricultural development and resource management since the beginning of the 20th century in the light of contemporary agricultural policy. The purpose is to illustrate how the farmer's role as a resource manager has changed over the years from an individual precondition for production at farm level to a societal priority.

Agricultural development in the 20th century

The agricultural sector has developed considerably over the past 100 years. In view of the large area of Denmark used for agricultural production, this development has considerably affected the environment, nature and the landscape. In the second half of the 20th century, though, factors such as urban and industrial development and road infrastructure have become important determinants. This is underlined by the fact that the total agricultural acreage has decreased from approx. 3.3 million ha in the mid 1930s to 2.7 million ha at present. This almost 20% reduction in agricultural acreage has had considerable, irreversible effects on the landscape and nature, and has also contributed to enhanced awareness about the state of nature and the environment on present-day farmland.

At the level of individual holdings, the potential and basis for production have changed markedly. Previously the farm was partly self-sufficient as regards foods and especially as regards the factors needed to produce foods. Diverse production and long-term management of nutrients were therefore necessary preconditions. Over the past 100 years, however, a marked shift has occurred. It became possible to import nutrients and energy to the farms in the form of commercial fertilizer and fossil fuels. As a result of technological development, consumption of electricity and fuel doubled from the Second World War to 1970. Total consumption fell in the 1980s, but in the mid

1990s increased again to the level of 1970. After the Second World War, consumption of commercial fertilizer and pesticide increased (*Figure 1.2.13*). Since the end of the 1980s, consumption of commercial nitrogen fertilizer and pesticides has decreased as a result of implementation of the Action Plan on the Aquatic Environment and the Pesticide Action Plan. In the case of phosphorus, the reduction began earlier in the 1970s, primarily due to increased awareness within the agricultural sector about overfertilization with phosphorus and the increasing fertilizer prices. Together with the use of pesticides and technological development in general, the possibility to import nutrients has raised crop and livestock yields. Total nutrient turnover in agriculture has consequently increased considerably. At the same time, crop and livestock production have been decoupled to some extent, and regional specialization has gradually increased.

Changes in the basis and level of production have resulted in development in agricultural land use and production technologies as well as in holding structure. Arable land outside crop rotation (primarily permanent pasture) decreased from a peak of just over 18% of the total agricultural acreage in 1937 to 7% in 1993. At the present time, approx. 11% of agricultural acreage is outside crop rotation. During the same period, holding size has increased markedly from an average of approx. 15 ha to just over 45 ha. This change has affected the agricultural landscape mosaic as well as the environmental impact of the sector.

The contribution of the agricultural sector to the Danish economy has also changed from one of dominance as regards employment and gross domestic product to one of relatively limited significance. Thus the agricultural sector's share of gross domestic product at factor cost has fallen from 16% in 1940 to 3–4% today, and the number of full-time employees has fallen from 504,000 to 71,000. It should be noted, though, that agricultural production results in considerable activity in associated sectors, and that the considerable export share contributes to the balance of payments. In 2000, agricultural produce accounted for approx. 11% of all Danish exports.

The above account reflects a sector that has experienced considerable advances in production and technological development, but which has concomitantly become less important for the Danish economy. At the same time, considerable environmental and nature problems have arisen – problems that are largely attributable to the development in resource use by the agricultural sector.

The significance of agricultural policy

At the beginning of the 20th century the smallholder movement had grown strong, and the number of smallholdings increased markedly through the first half of the century as a result of the 1899 Smallholdings Act and the 1919 State Smallholdings Act. At the same time, though, numerous smallholdings of less than 5 ha disappeared. Average holding size did not change much up to the 1950s. The smallholdings could be used for intensive livestock production with the produce being sold to the many newly established cooperative societies, and were therefore well suited for livestock farming during that change-over.

From the point of view of agricultural policy, the 1919 Act emphasized the establishment of new smallholdings of a size that could support a family. In addition, general preservation of rural properties as active farms was promoted through a 1925 amendment of the Agricultural Holdings Act requiring owners to maintain farms. These measures paved the way for the mixed farms that existed until the 1960s, and which were dominated by smallholdings of 5–10 ha and small farms of 15–30 ha. The structural design of the landscape was thus undercast political regulation aimed during much of the 20th century at preserving family holdings, ensuring user ownership and promoting rational farming practice.

During the period 1920–1940, total agricultural acreage still continued to expand. As the overall trend was towards intensification of agricultural production, however, areal productivity increased. This development was primarily based on intensive fertilization practice, especially using manure, but also with increasing use of commercial fertilizer.

From 1950, human labour and horse power were replaced by fossil fuels, and manure by commercial fertilizer. The need for extensively managed farmland decreased dramatically, and the farmers no longer needed to preserve nutrients within the agro-ecosystem. This enabled them to focus on optimizing the productivity of the land by importing fertilizer, etc. Due to worries about the lax regulations governing such things as the abolishment and merger of farms, the Agricultural Holdings Act was revised in 1949. The intention of preserving the family smallholding was thereby maintained and strengthened.

Figure 1.2.13
Indexed consumption of commercial nitrogen and phosphorus fertilizer and amount of pesticide active substance expressed per hectare under crop rotation.
(Source: National Environmental Research Institute).

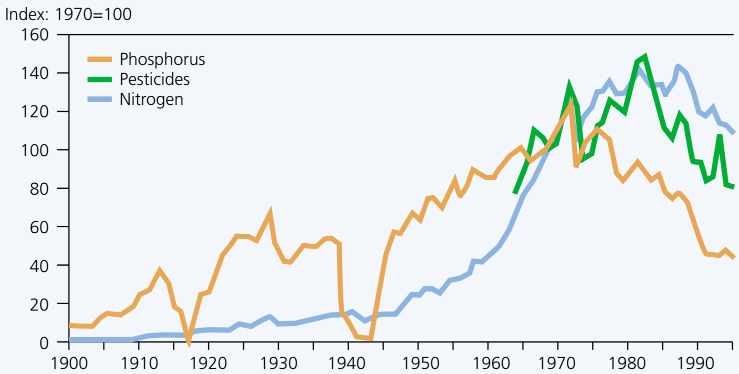



Photo: Highlights

The mechanization and intensification resulted in a need for structural changes, however, not least because agricultural profits continually deteriorated. At the beginning of the 1960s the spatial planning legislation was liberalized, and the basis established for the present agricultural structure. At the same time, agricultural price support was introduced in order to ensure agricultural earnings during the period preceding possible membership of the planned European Community.

The limits on holding size and the duration of mergers, joint operation and tenancy agreements were amended several times during the 1960s and 1970s. The changes were intended to help maximize productivity through mechanization and other types of intensification.

Danish society underwent tremendous changes in the 1960s whereby urbanization, road construction, etc. reduced agricultural acreage by 12,000 ha per year. In 1967, the Agricultural Holdings Act was revised again taking into account the significance of the urbanization processes for labour and land prices and the needs for structural adaptation that had arisen as a consequence of mechanization, etc. While the fundamental intentions of the Act such as the preservation of as great a number of holdings as possible were still maintained, the restrictions on mergers and joint operation were eased to meet the need for them. In 1978, some secondary considerations were incorporated into the legislation, including protection of the landscape values associated with arable land. In continuation of this, several subsequent revisions thus emphasized that the authorities could oppose the reassignment of arable land on the basis of recreational and landscape considerations.

However, structural development led to general deterioration in conditions for the nature associated with the extensively utilized areas and small biotopes such as hedgerows and ponds.

With Denmark's entry into the EC in 1972, the agricultural sector became subject to the Common Agricultural Policy, the overall aim of which was to enhance agricultural productivity to ensure supply security in the region, to ensure the standard of living of the farming community and to stabilize the markets and ensure reasonable food prices. The main means of achieving this has been production support, which led to a highly capital-intensive production system primarily controlled by technological development and the Common Agricultural Policy. As a consequence, the market lost any direct influence on agricultural sector organization and resource management since the EU screened the agricultural sector from the world market. In the mid 1980s, the situation arose where production far exceeded demand. Surplus produce accumulated to an extent that could no longer justify continued agricultural price support at the contemporary level. Moreover, the actors on the world market began to protest against EC agricultural price support in connection with the negotiations under GATT and subsequently under the WTO.

A strategy for marginal land was published in Denmark in 1987. This was founded on the assumption that a major part of Danish arable land would be taken out of production in the years to follow. In continuation of the 1992 Agricultural Reform, attempts were made to predict how much land would be taken out of production as a consequence of various scenarios for the phase-out of agricultural price support. However, actual marginalization of arable land in Denmark was overtaken by an increased need for land within crop rotation, among other reasons because of the livestock density requirements and area-related schemes aimed at improving the environment and nature. Set-aside in connection with the area payments schemes resulted in land being taken out of crop rotation, though.

Overall, this has counteracted marginalization, albeit some of the land uses such as afforestation and the establishment of wetlands must be considered as extensification of agricultural land. They do not follow an actual marginalization process, however, but rather a political prioritization of land use.

Internally within the EC an exodus from agriculture took place that had a significant regional component in that the agricultural systems and cultural landscapes they support were threatened by collapse in certain mountain regions. Since the mid 1970s a "Less-Favoured Areas" programme has existed within the EC/EU that supports agriculture in these regions. This programme was not relevant in Denmark, where the environmental problems associated with agriculture were more associated with intensification and specialization of production than with marginalization of large agricultural regions.

A parallel problem is posed by the overgrowing of open natural habitats that have been taken out of production as a consequence of structural development, which has resulted in a greater percentage of livestock being confined to livestock housing as well as in regional concentration of grazing livestock.

Environmental action plans and reforms of EU agricultural policy

The first environment-related agricultural policy at EU level was introduced in 1985 with the intention of establishing national structural policies incorporating environmental objectives focussed on environmentally sensitive areas (ESAs). Since 1987 these policies have also been supported financially. In Denmark, this was implemented through an ESA scheme and the subsequent agri-environmental measures scheme (*Box 1.2.4*).

Marginal land

Marginalization of arable land is the process whereby the land is taken out of production for one reason or another. Expressed simply, it can be said that marginalization takes place when it is no longer profitable to cultivate the land. In an historical perspective, land having low fertility or other undesirable physical characteristics (e.g. slopes that are too steep for agricultural equipment) has moved in and out of crop rotation depending on prices and technological developments, including irrigation and drainage.

In the mid 1980s, the prices of traditional agricultural products were expected to fall so much that a large proportion of arable land would be taken out of production. Among other things, these expectations were based on the GATT negotiations to draw up the framework for development of EU Common Agricultural Policy for the coming years. Model calculations of a mild and a severe GATT scenario reflecting a moderate and a radical reduction in EU agricultural subsidies, respectively, predicted that between 184,000 ha and 372,000 ha would be marginalized during the period 1990–2004. Part of this was conditional on the payment of a set-aside premium. In the context of Danish environmental policy, there was therefore considerable expectation that this marginalization would represent a positive contribution to nature and environmental policy.

The total area of agricultural land decreased by 130,000 ha between 1989 and 1999 as a result of expansion of other types of land use. During the same period, the area under crop rotation decreased by 253,000 ha such that the area outside crop rotation has increased by a net 123,000 ha between 1989 and 1999.

However, this trend veils a marked increase following the introduction of set-aside subsidies in 1993: Thus the area of permanent grassland increased by 186,000 ha between 1993 and 1996 alone, whereafter it decreased again by approx. 40,000 ha up to 1999.

Agricultural development is complex and difficult to predict. Thus whereas it was once predicted that large areas of arable land would be marginalized, a number of factors have counteracted this development. The expected reduction in agricultural support has not materialized, and instead there has been a switch from price-based support to support given as area payments and livestock payments. In addition, the livestock density criteria have been tightened. As a consequence, the value of livestock production is capitalized in land prices, thereby increasing the value of the potential marginal land. In the same way, arable land has been converted to other purposes such as urban development, afforestation, etc. This has increased pressure on the remaining arable land.

Box 1.2.3
Marginal land – trend in agricultural acreage.

In Denmark, consideration for the environment was specifically incorporated in the Agricultural Holdings Act in 1986, when balancing of the economic interests of the sector against consideration for the environment was incorporated into the objects clause. A number of contemporary environmental measures were also increasingly aimed at the agricultural area, including the NPo Action Plan and subsequent aquatic environment and pesticide action plans.

Revisions of the Agricultural Holdings Act at the end of the 1980s liberalized the operating regulations again in order to satisfy the need for structural development, one of the goals of which was a self-sufficient agricultural sector. Thereafter the provisions governing farm mergers and joint operation were relaxed considerably. At the same time, though, the environmental requirements pertaining to farm operation were tightened significantly.

With adoption of the reform of EU Common Agricultural Policy in 1992, the line previously followed was broken. The reform was driven by problems of excessive agricultural expenditure, excess production and a need to better harmonize prices with the world market. Expectations that solution of these problems could be combined with extensification of agriculture to the benefit of nature and the environment paved the way for incorporation of environmental considerations.

Because of the great exodus from the agricultural sector, one of the aims of reforming the Common Agricultural Policy was to ensure that a "sufficient number of farmers" remained in the sector. Farmers were no longer to just be food producers, but also good managers of nature and the environment in agricultural areas. To further this aim, the environmental initiatives that had already been implemented were extended and placed under the reform of the Common Agricultural Policy as agri-environmental measures. In addition, part of EC expenditure on agriculture was switched from price support to area payments – a move expected to lead to some degree of extensification.

Early proposals for the present reform of the Common Agricultural Policy within the framework of Agenda 2000 spawned visions of an integrated rural development policy as the second pillar of the Common

Photo: Highlights

Agricultural Policy. These visions coupled progressive reduction of direct support to increasing support of programmes for rural development, including management of nature and the environment. The final result, though, is a somewhat different reform that does not couple the financing of the two pillars, and which still directs the majority of the support to the most intensively operated parts of agriculture.

Certain new elements will influence resource management, however. For example, the reform opened up the possibility of coupling conditions to the payment of direct support (cross-compliance). Payments can thus be made conditional on compliance with a specific farming practice, for example extensification or set-aside of vulnerable areas.

Multifunctional agriculture

The present section shows that the agricultural sector is characterized by complex trends attributable partly to the need for structural adaptation similar to that in other business sectors, and partly to the political framework to which the sector is subject in the form of Danish environmental action plans and EU agricultural policy.

The marginal land strategy and the agri-environmental measures scheme also show that there is considerable interplay between the political initiatives, and that this leads to the need for coordination of the policies. Moreover, they illustrate a great need to more precisely formulate the intended effects of (environmental) policy and of implementation of the measures that are to bring these about.

In continuation of the WTO negotiations, the discussion is focusing on the "multifunctionality" of the agricultural sector, i.e. societal benefits produced by the agricultural sector in the form of the landscape, environment, jobs, etc. In the longer term, the WTO negotiations in the agricultural area will probably result in further phase-out of price support and possibly to extension of support for valuable activities that improve nature and the environment in agricultural areas. The multifunctionality of the agricultural sector is characterized by a situation where the sector over and above being a producer of foods and non-food crops is assigned or accepts a number of other activities such as management of various natural resources (environment, nature and biodiversity) as means of enhancing settlement and employment in rural areas, preserving cultural landscapes and ensuring pure groundwater aquifers (for the drinking water supply). This indicates that the measures should be more specifically directed at the agricultural sector,

Agricultural support schemes

Support for agri-environmental measures was introduced as part of EU agricultural policy at the end of the 1980s. Between 1989 and 1992, farmers were able to obtain support for environment-friendly management of so-called Environmentally Sensitive Areas (ESAs). As part of the 1992 EU common agricultural reform, the ESA schemes were replaced by the current agri-environmental measures. From 2000, the agri-environmental measures have been part of the support scheme under the EU Rural District Programme.

The agri-environmental measures were initially primarily aimed at improving the aquatic environment. Today, however, they are also intended to improve and conserve nature. The agri-environmental measures underwent their latest revision in 1996, at which the possibility to provide support for nature management was incorporated. Since the introduction of the agri-environmental measures the available funds have generally been increased, and the measures have therefore become more attractive.


Photo: Highlights

The currently existing agri-environmental measures are:

- Reduction of nitrogen input levels to 60% of the requirement
- Cultivation without the use of plant protection products
- Establishing pesticide-free border zones
- Environment-friendly farming of permanent grassland
- Management of grassland and natural countryside by grazing
- Management of grassland and natural countryside by clearing
- Management of grassland and natural countryside by haymaking
- Undersowing of cereals with rye-grass, etc.
- Set-aside of arable land
- Set-aside of permanent grassland
- Modified drainage
- Demonstration projects of relevance to agri-environmental measures and organic farming

With the exception of the demonstration projects it is presently only possible to draw up agreements on the above-mentioned agri-environmental measures for designated Environmentally Sensitive Areas (ESAs). The ESAs are designated with the clear objective of possibly also suggesting a greater role for the farmer as a resource manager. Sustainable agricultural production is a precondition if agriculture is to fulfil its multifunctional role. Part of current EU support for agriculture is given on the premise that the sector manages the environment and nature and supports the rural districts and therefore requires special treatment, especially in areas where no effective market exists. Areas may also exist, however, where the objectives are met more efficiently by actors other than the agricultural sector.

Focused regulation and geographic differentiation

Questions are currently being raised as to whether focusing regulatory efforts enhances their effects in relation to pressure on the environment and conservation of nature. At the same time, the agricultural sector is calling for simplification of the regulations. The sector is administered by several different authorities, each with their own administrative foundation. A proposal by the agricultural sector, the Counties and the Municipalities calls for more differentiated regulation of the agricultural sector based on local needs.

Present environmental regulation of agriculture mainly takes place at a general level. The sector is regulated uniformly, with little heed being taken of local needs, among other things as far as concerns livestock density requirements, nitrogen norms in relation to classification of the soil, pesticide application frequency, etc. However, there are some indications of a change in the direction of differentiated regulation. Support for agri-environmental measures is presently largely restricted to the ESAs, which are designated locally. A groundwater protection initiative entailing implementation of action plans in selected areas is being planned. In addition, the EU Water Framework Directive will lead to differentiated efforts in relation to the individual water bodies.

A shift towards more differentiated regulation necessitates assigning greater priority to area designation as a management tool. Designation of priority areas can help focus the available financial resources on the desired considerations for the environment and conservation of nature. In order for area designation to be an effective management and prioritization tool, it has to be possible to identify a clear benefit to nature and the environment of focusing the efforts on specific areas. An example is the designation of the ESAs. There is generally little overlap between the ESAs and the areas encompassed by Section 3 of the Protection of Nature Act in that the ESAs are largely intended to

restricting agri-environmental measure agreements to those areas where there is a special need for them. For example, all cultivation-free border zones alongside watercourses for which a quality objective is stipulated in the Regional Plan are designated as ESAs in order to ensure that the measures can be used. Designation of the ESAs is the responsibility of the Counties. In 1998, a total of 370,000 ha of arable land had been designated as ESAs. In connection with Action Plan on the Aquatic Environment II the Counties designated a further 88,000 ha of ESAs as well as areas suitable for the re-establishment of wetlands.

The specific objectives for the individual areas together encompass environmental protection (nitrogen, pesticides, ochre), nature and landscape protection or improvements (valuable semi-cultural and landscape entities), and improvement of recreational possibilities.

Until 1996 it was possible to obtain support for agri-environmental measures to reduce nitrogen input and to establish pesticide-free border zones even if the areas lay outside the ESAs. Current restriction of the support solely to land within the ESAs has both advantages and disadvantages. The advantages include the possibility to prioritize the efforts, while the disadvantages are the increasing overlap with other designations of land for other purposes.

When the agri-environmental measures started in 1993, it was expected that they would be applied on approx. 160,000 ha. Due to lack of interest, however, this target is far from being met. The target is still approx. 160,000 ha, and it is expected to be attained by 2003. At the end of 1999, agreements had been entered into encompassing 64,100 ha, corresponding to just over 40% of the target. If the expectations regarding agri-environmental agreements within the ESAs are to be met, the area encompassed by such agreements will have to be increased by approx. 98,000 before 2003, i.e. 33,000 ha per year, in addition to maintaining the present area encompassed by agreements. The most popular measure is environment-friendly farming of permanent grassland. Viewed in relation to the objective of fulfilling Action Plan on the Aquatic Environment II, the agri-environmental measures thus have a greater effect on nature quality than on reducing nitrogen losses.

Box 1.2.4
Development in voluntary support schemes – exemplified by the Agri-environmental Measures Scheme.

facilitate attainment of the goals of Action Plan on the Aquatic Environment II. From the point of view of nature, it would generally be best if the ESAs and Section 3 areas overlapped as far as possible. Designation of areas is relatively information-demanding for both farmers and authorities. In addition, designation can cause uncertainty about future possibilities due to doubt about what requirements and limitations the areas will be subject to in the future.

The farmers' role thus changes from primarily encompassing production of food to also encompassing management of the environment and nature and looking after cultural environment, landscape and outdoor interests. The farmers will have to enter into a concrete dialogue with the administration concerning how to achieve the desired environmental protection. Some experience with this already exists from initiatives such as the Varde river valley project and the designation of hunting-free core areas (*Box 1.2.5*), where local public participation was the foundation stone for realization of the projects, but which also led to a number of open conflicts and hence highlighted the need for the development of new planning and development tools. In this context, there is a general need for knowledge of the farmers' own view of the role as resource manager and partner in dialogue. Studies in other European countries indicate a variability in the farmers' perception of and relationship to resource management that could form an important knowledge base for dialogue-oriented regulation.

WTO and expansion of the EU

Under the auspices of the WTO, efforts are being made to enhance liberalization of world trade. Expansion of the EU with a number of East European countries will entail considerable expansion of the inner market. At the same time, the coming expansion of the EU will place pressure on the design of the Common Agricultural Policy. In particular, the 100% EU-financed support schemes will probably be gradually phased out since it will be very costly to continue them in their present form. On the other hand, structural support and subsidies for nature conservation, environmental protection, extensification, afforestation, Less-Favoured Areas, etc., all of which require some degree of national co-financing, and which can continue within the framework of the WTO, will probably be carried on – in other words, the types of subsidy that can support the farmer in the role of resource manager.

Box 1.2.5
Public participation in environmental and nature projects

Public participation


Photo: CDanmark

In the Varde river valley, the Varde Farmers Association, Varde Smallholders Association, the Danish Directorate for Development, the Danish Forest and Nature Agency and Ribe County are presently collaborating on a major agricultural/environmental project to improve environmental and ecosystem conditions in the area while concomitantly preserving agricultural production through changes in drainage, environment-friendly farming of permanent grassland and management of grassland and natural countryside. The project is based on voluntary redistribution of land and allocation of substitute land outside the river valley for landowners unwilling to enter into agreements on agri-environmental measures. Approx. 400 ha were included in the project in 1999. The target is 2,700 ha by 2003, however. In contrast to many other projects, the land in Varde river valley remains privately owned and the individual holdings are responsible for establishment and operation.

In connection with the decision to establish a hunting- and disturbance-free core area for aquatic birds in 46 EC Bird Protection Sites, the Danish Forest and Nature Agency drew up an action plan encompassing plans for implementation, biological assessment, public hearings and establishment of local advisory user groups. The latter was a particularly novel move, but has concomitantly given rise to difficult negotiations. The problems mainly stem from hostility to the establishment of reserves, lack of communication and a local experience of not being considered an equal partner in the discussions. This has not only delayed implementation, but has also resulted in a lack of local acceptance and led to some of the resulting reserves losing much of their biological value.

Even though the idea of public participation has generally gained acceptance by the involved parties, there seem to be a number of areas where there is a need to develop negotiation and conflict solution models in connection with more local and user-based management of nature and the environment. This seems to be particularly true in cases involving broad public usership, as for example with hunting in coastal waters, while conflicts have more rarely arisen in cases involving private ownership (Varde river valley), probably due to the well-defined distribution of rights on the privately owned areas.

Photo: Highlight

1.3 Energy

1.3.1 Environmental impact of the energy sector

The environmental problems associated with energy consumption and production are primarily due to emissions of pollutants and their significance for both the greenhouse effect and acidification of the environment. This description of the energy sector therefore emphasizes the status in relation to the targets for the most important greenhouse gas: carbon dioxide (CO_2), and the acidifying gasses: sulphur dioxide (SO_2) and nitrogen oxides (NO_x). In recent decades, Denmark has developed considerable energy production of its own in the form of oil and natural gas extraction and the expansion of wind power, which also has an impact on the environment.

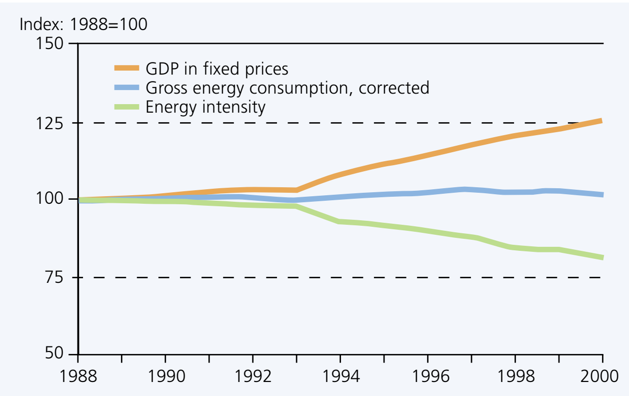


Figure 1.3.1 Denmark's gross domestic product (GDP), energy consumption and energy intensity, 1988–2000. (Source: Danish Energy Agency, 2001).

Gross energy consumption

Despite considerable economic growth, Denmark's gross energy consumption (corrected for climate differences and international trade in electricity) is nearly the same now as in 1972. Denmark's gross domestic product (GDP) has grown by 60% in constant prices since 1972, whereas gross energy consumption has only increased by 2%. Energy intensity (gross energy consumption per unit of GDP) has thus declined by 36% since 1972. Economic activity in Denmark has grown much more rapidly than energy consumption for three reasons: Changes in the structure of the economy, in which the trade and service sectors with low energy intensity (excluding transport) have grown in importance, marked gains in

Photo: Highlight

conversion efficiency in the very energy-intensive generation of electricity and district heating, and more efficient utilization of energy in the various areas of consumption.

While there has been little change in the total gross energy consumption, the fuel mix has changed dramatically (*Figure 1.3.2*). Oil completely dominated energy consumption until the second oil crisis, accounting for 92% of energy consumption in 1972. In 1980, oil accounted for two thirds of total consumption, while coal accounted for 30% and renewable energy and other sources for 3%. One of the most important political objectives since the oil crisis in 1972 has been to minimize Denmark's dependence on oil. This has largely been accomplished through the use of coal instead of oil at power plants and district heating plants. The introduction of natural gas distribution and a political objective of sustainable development subsequently led to the rapidly increasing use of natural gas and renewable energy, etc. This has happened mostly at the expense of coal and, to a lesser extent, oil. The share of coal peaked in 1990 at 40% of total gross energy consumption.

The consumption of renewable energy has increased steadily over the years (*Figure 1.3.3*). Consumption increased from 26 PJ in 1980 to 89 PJ in 2000. In 2000, biomass was the main source of renewable energy followed by waste and wind power. The trend in wind power greatly influences the total amount of energy used since 1 PJ of additional wind power replaces 2.5 PJ of coal in electricity generation. Most of the renewable energy is used to produce electricity and district heating (about two thirds in 2000). The remainder is used directly in businesses and households.

The gross energy consumption minus the final energy consumption (i.e. consumption for transport, production and heating in production sectors, the trade and service sectors and households) comprises the energy used in extraction and refining operations, the heat lost in the generation of electricity and district heating and the network losses in the distribution of energy (*Figure 1.3.4*). Final energy consumption has been increasing since the 1980s and was 8% higher in 1998 than in 1990. In the same period, gross energy consumption only grew by 2.5%, however, because enhanced efficiency of electricity generation and district heating has almost counterbalanced the increase in final energy consumption.

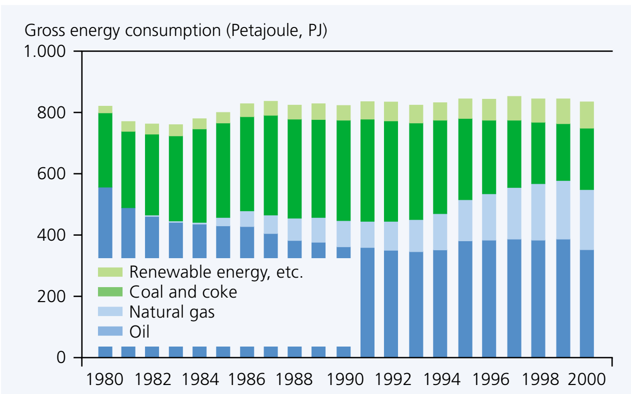


Figure 1.3.2
Denmark's gross energy consumption apportioned by fuel type, 1980–2000.
(Source: Danish Energy Agency, 2001).

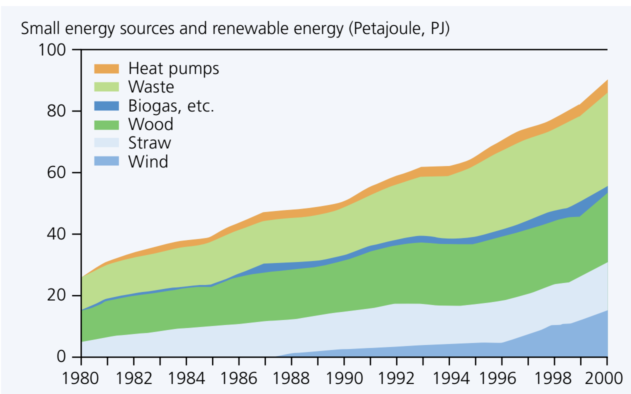


Figure 1.3.3
Small energy sources including renewable energy, 1980–2000.
(Source: Danish Energy Agency, 2001).

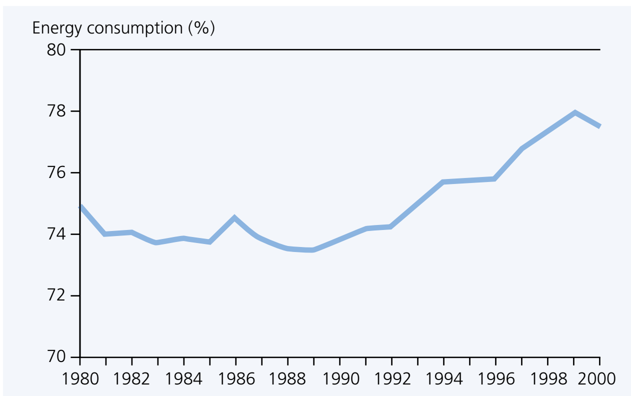


Figure 1.3.4
Denmark's final energy consumption as a percentage of gross energy consumption, 1980–2000.
(Source: Danish Energy Agency, 2001).

Generation of electricity and district heating

Electricity is generated at centralized and decentralized power plants and by wind turbines. The trend in electricity generation varies relative to the domestic supply (*Figure 1.3.5*) due to the fact that Denmark has substantial international trade in electricity. The level of net electricity exports to Norway and Sweden is mainly determined by the variation in precipitation in these countries and therefore fluctuates from year to year.

One of the basic objectives of Denmark's energy policy has been to increase the conversion efficiency of fuel by increasing the cogeneration of electricity and heat. The available technology used in generating electricity at power plants produces large quantities of heat. To convert fuel efficiently, Danish energy policy strongly emphasizes organizing electricity generation in such a way that this heat can be used for space heating purposes. Since 1980, Denmark has therefore vastly expanded its district heating networks, both in major towns with centralized electricity generation and in many small and medium-sized towns that have decentralized combined heat and power plants. In addition, combined heat and power generation has been established in numerous manufacturing enterprises, market gardens, service enterprises, etc. The energy conversion efficiency in electricity generation improved from 1980 to 2000 (*Figure 1.3.6*). The utilization of heat from electricity production for district heating increased and the conversion loss declined correspondingly. The utilization of conversion heat for district heating has mostly replaced heat produced by individual oil-fired boilers.

Denmark's energy policy has strongly emphasized a shift from oil- and coal-based generation of electricity and district heating to plants based on more environmentally sound fuels such as natural gas, renewable energy, etc. Electricity generated using biomass, biogas and waste comprised slightly less than 5% of the total in 2000, while wind energy comprised about 13% of total electricity generation (*Figure 1.3.7*).

Photo: NERI/Britta Munter

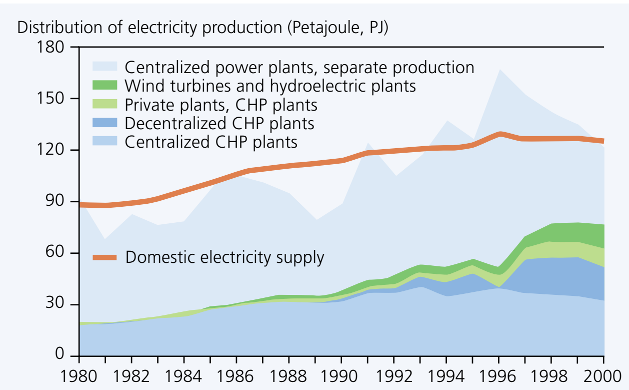
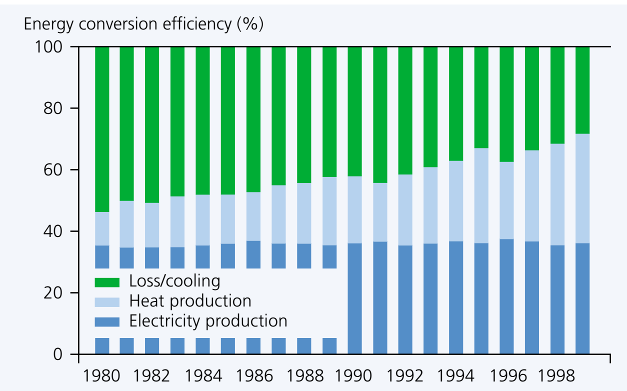


Figure 1.3.5

Electricity production apportioned by type of plant, 1980–2000.

(Source: Danish Energy Agency, 2001).



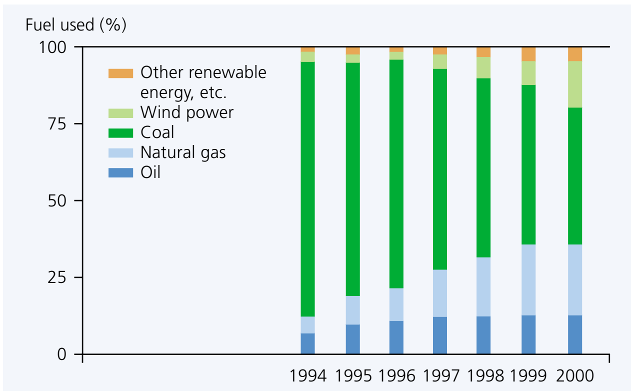


Figure 1.3.6

Energy conversion efficiency in electricity generation as a percentage, 1980–99.

(Source: Danish Energy Agency, 2000).

Figure 1.3.7

Danish electricity production apportioned by fuel type, 1994–2000.

(Source: Danish Energy Agency, 2001).

The fuel mix used by district heating plants that do not generate electricity changed markedly from 1980 to 2000 and heat generation at these plants fell considerably (*Figure 1.3.8*). The main reason is that heat generation based on fossil fuels at these plants has been replaced by combined heat and power generation. The separate generation of district heating in 2000 was mainly based on biomass and waste. The objective is that an increasing proportion of the biomass used in these plants will be redirected to combined heat and power generation. The amount of heat generated per unit of fuel input increased from 1980 to 2000. The main reason is that many plants have installed flue gas condensation, which substantially increases the energy conversion efficiency. In addition, an increasing quantity of industrial surplus heat is being utilized which is not included in these fuel input calculations.

Final energy consumption

The composition of final energy consumption has changed considerably since 1980 (*Figure 1.3.9*). Consumption of oil and town gas has declined in relation to 1980, whereas the consumption of the other types of energy has increased, especially natural gas and electricity. The consumption pattern has only changed slightly in recent years, however. Electricity consumption has now levelled off after many years of growth. Among both businesses and households, electricity as a proportion of total energy consumption rose until the mid 1990s and then stabilized (*Figure 1.3.10*).

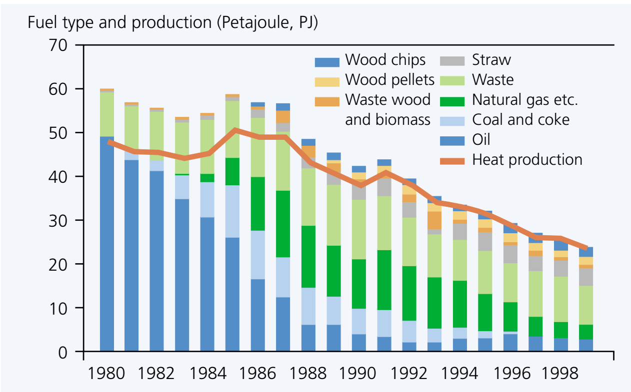
Final energy consumption has grown by 7% since 1990, especially due to the trend in the transport sector (*Figure 1.3.11*). While energy consumption for transport has increased every year, consumption in other areas has only changed slightly. The increasing consumption within transport is attributable to the trends in road transport and, in recent years, particularly to the trend in international air traffic (*see Section 1.4*).

Manufacturing currently accounts for 70% of the final energy consumption by the production sectors. Agriculture, market gardening, fishery and building and construction account for the remaining 30%. Energy consumption in manufacturing declined in the early 1980s because of increases in real energy prices and a subsidy scheme to

Figure 1.3.8

Fuel type and production for district heating plants that do not generate electricity, 1980–99.

(Source: Danish Energy Agency, 2000).



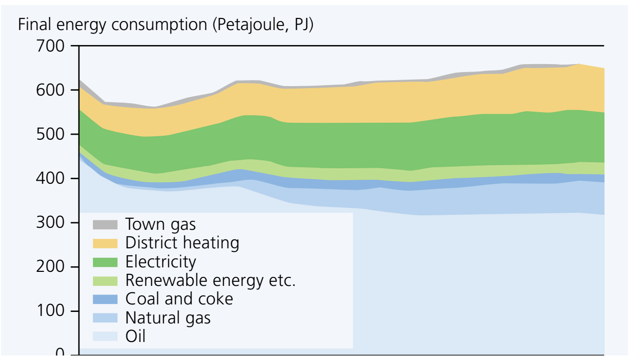


Figure 1.3.9

Final energy consumption apportioned by energy type, 1980–2000.

(Source: Danish Energy Agency, 2001).

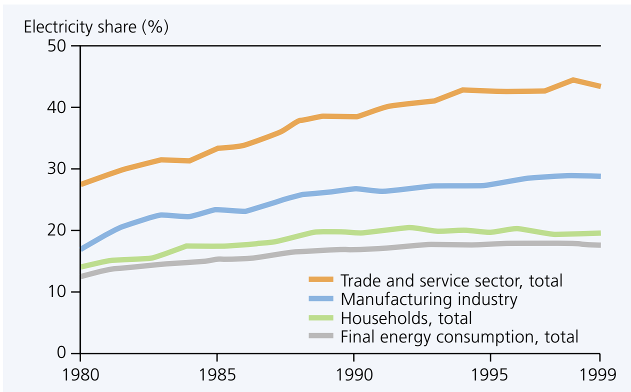


Figure 1.3.10

Proportion of total energy consumption accounted for by electricity, 1980–99.

(Source: Danish Energy Agency, 2000).

promote energy saving. Consumption increased from the mid 1980s to the mid 1990s and then stabilized. A main cause of this is the introduction of a series of environmental taxes and voluntary agreements that have led to increased energy efficiency. The mix of energy types that together account for total energy consumption has changed markedly during the entire period. The increasing consumption of electricity and natural gas has been accompanied by a concomitant decrease in consumption of oil and coal.

Energy consumption in the trade and service sectors combined has remained basically unchanged since 1980 (*see Section 1.5.6*). Household energy consumption declined sharply from 1980 to 1990, increased until 1994, and has since remained nearly constant (*see Section 1.5.7*).

The considerable growth in business activity and in household income has only led to small increases in final energy consumption (except for transport). The main reason is more efficient utilization of energy. The energy intensity of all areas of consumption is considerably lower than in 1980 (*Figure 1.3.12*). This is partly attributable to the change in the proportion of total energy consumption accounted for by the different types of energy. An increased proportion of electricity and district heating at the expense of oil increases the efficiency of fuel utilization. Even though electricity consumption has remained almost constant over the past five years, energy intensity has nevertheless declined.

Environmental impact of energy use

The most important environmental problem associated with energy use is the emission of air pollutants during the combustion of fuel. Combustion converts most of the fuel's content of carbon and sulphur to CO_2 and SO_2, respectively. Moreover, the nitrogen content in the air and fuel further creates nitrogen oxides (NO_x) in amounts determined by the combustion technique used.

The trend in CO_2 emissions is closely coupled to the amount of energy consumed and the fuel mix. Since no technology has yet been found that can remove CO_2 from flue gasses, the CO_2 is emitted directly into the atmosphere. The amount emitted is markedly dependent on the type of fuel used. Thus, natural gas emits 40% less CO_2 per unit of energy than does coal. The biomass-based fuels are considered CO_2 neutral as the amount of CO_2 released upon combustion is equivalent to the amount absorbed by the plants during growth.

Photo: NERI/Mads Hovmand

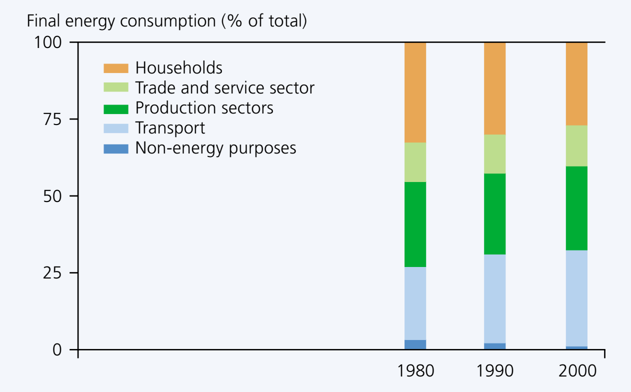


Figure 1.3.11

Final energy consumption apportioned by use in 1980, 1990 and 2000. (Source: Danish Energy Agency, 2001).

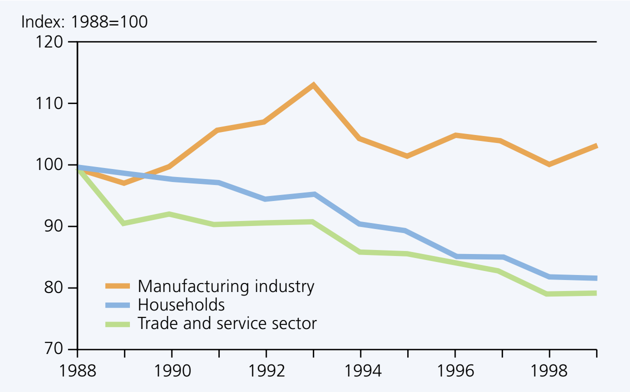


Figure 1.3.12

Energy intensity for industry, households, and the trade and service sectors, 1988–99.

(Source: Danish Energy Agency, 2000).

Both actual and adjusted CO_2 emission inventories are prepared. The latter are corrected for interannual temperature differences and international trade in electricity. The purpose of the adjusted CO_2 emission figures is to provide a more realistic impression of the trend. CO_2 emissions declined markedly in the early 1980s (*Figure 1.3.13*), mostly because of the effects of the second oil crisis. The increase in the mid 1980s was mainly attributable to the economic boom after the economic downturn in the early 1980s. Since the late 1980s, CO_2 emissions have been falling steadily, and by 1999 they had declined by slightly more than 9% relative to 1988. The national target is a 20% decline by 2005.

The main reason for the decline in CO_2 emissions is the previously mentioned shifts in the composition of energy consumption from oil and coal to natural gas and renewable energy, etc. Due to the shift in fuel mix, the amount of CO_2 associated with each unit of fuel has decreased from year to year (*Figure 1.3.14*). Electricity is being generated through the use of increasingly cleaner fuels at power plants and through the growing use of wind power.

Within the UN framework, Denmark is committed to reduce SO_2 emissions by 80% from 1980 to 2000 (*see Section 2.2*). SO_2 emissions have been continually reduced as the result of the declining sulphur content of fuels, desulphurization of flue gasses from power plants and the removal of sulphur during the combustion process itself. The target of 80% reduction was achieved in 1998 (*Figure 1.3.15*).

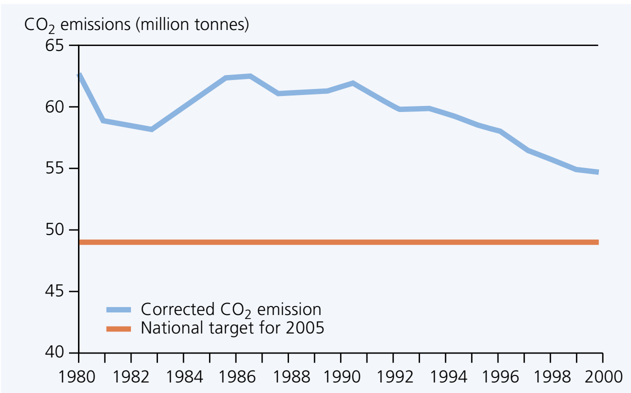
Denmark is similarly committed under the UN framework to reduce NO_x emissions by 30% from 1986 to 1998 (*see Section 2.2*). NO_x emissions have been reduced through "Low-NO_x burners" in large power plants and installations for the denitrification of flue gasses. Emissions have declined considerably in connection with the generation of electricity and district heating, but the trend in the transport sector has counteracted this decline. The target was nearly achieved, as emissions were reduced by 28% from 1986 to 1998 (*Figure 1.3.16*). The emissions of both SO_2 and NO_x from the generation of electricity and district heating have declined considerably in recent years (*Figure 1.3.17*).

Energy use also impacts on the environment in several ways other than

Figure 1.3.13

Trend in CO_2 emissions, 1980–2000.

(Source: Danish Energy Agency, 2001).



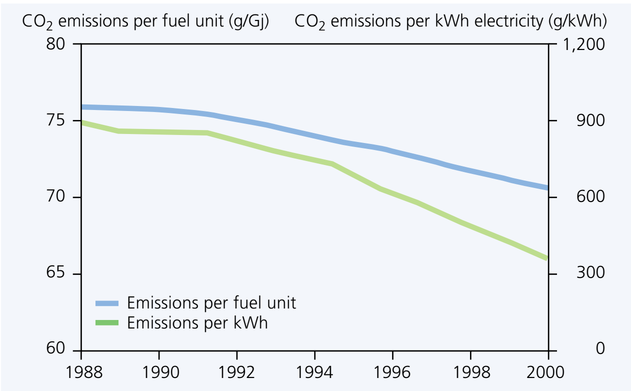


Figure 1.3.14

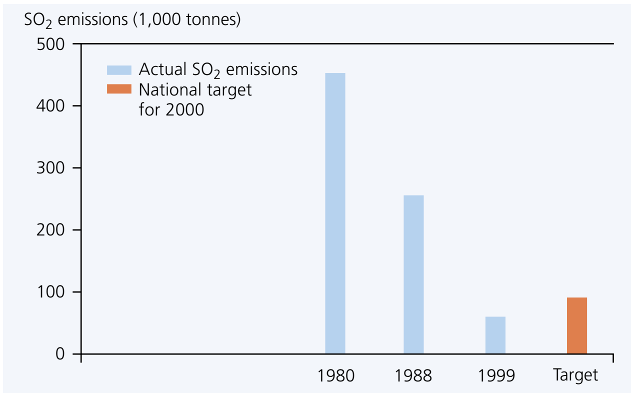
Emission of CO_2 per unit of fuel (g/GJ) and per kilowatt-hour electricity generated (g/kWh), 1980–2000.

(Source: Danish Energy Agency, 2001).

Figure 1.3.15

Total emissions of SO_2.

(Source: National Environmental Research Institute, 2000).



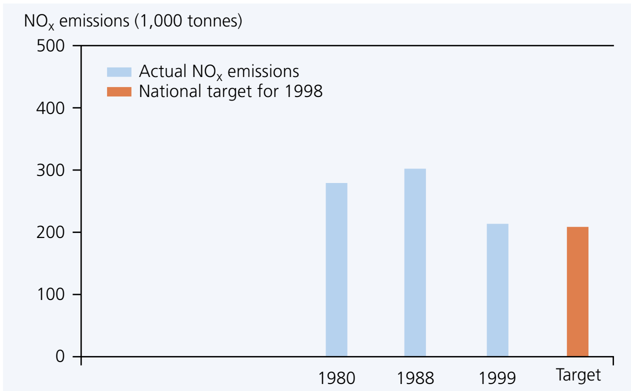


Figure 1.3.16

Total emissions of NO_x in 1980, 1988 and 1999.

(Source: National Environmental Research Institute, 2000).

the emission of air pollutants. Combustion of fuel at power plants, combined heat and power plants and waste incineration plants thus form slag and fly ash that must be disposed of either through landfill or recycling (*see Section 1.5.9*). In addition, energy use leaves its mark on nature and the landscape in the form of oil and natural gas fields, infrastructural installations, land use for wind turbines and biomass crops, etc. Finally, the environment is adversely affected by the transport of fuel, the production of wastewater and emissions of hazardous substances.

Although the majority of environmental problems are associated with the use of fossil fuels, there are also a number of significant environmental problems associated with renewable energy plants. Thus, wind turbines may adversely affect landscapes and can also create noise problems (*Box 1.3.1*).

One discussion topic related to biomass is whether removing straw from fields negatively affects the quality of the soil as a cultivation medium. The straw is removed in order to be used as a biofuel instead of being ploughed down, and this reduces the carbon content of the soil.

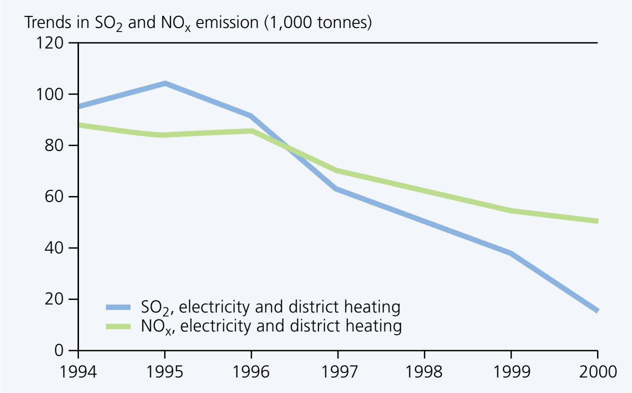


Figure 1.3.17
SO_2 and NO_x emissions from the generation of electricity and district heating, corrected for electricity imports/ exports, 1994–2000. (Source: Danish Energy Agency, 2001).

Box 1.3.1
Environmental assessment of land-based and offshore wind turbines.

Environmental impact of wind turbines

The expansion of wind power entails great environmental benefits as regards reducing the environmental problems associated with conventional power plants based on fossil fuels, especially emissions of CO_2, SO_2 and NO_x. An overall environmental assessment of wind power must also take into account the impact on the landscape, noise, etc.

Assessment of the societal value of wind power includes noise and visual annoyance from wind power. Based on interviews and surveys of house prices in 1995 it was concluded that the value of these annoyances is negligible: Between DKK 0.0004 and 0.01 per kWh. Numerous wind turbines have since been erected, however, especially in Jutland, and it can therefore be assumed that a similar study today would produce a different result.

The erection of land-based wind turbines is regulated by various statutory orders and circulars, one of the aims being to minimize the environmental impact of electricity generation by wind turbines.

Pursuant to Circular No. 100 of 10 June 1999 on planning and rural zone permits for the erection of wind turbines, the location of wind turbines in the landscape has become an integral part of county and municipal spatial planning. Current rules permit wind turbines to be erected solely in specifically designated wind turbine areas. New areas can only be designated through regional planning.

Until the Regional Plan Revision, 2001, however, the County Councils may grant exemptions. Wind turbine clusters and solitary wind turbines must be at least 2.5 km apart. The minimum distance between groups of wind turbine clusters or solitary wind turbines and neighbouring dwellings must be at least four times the wind turbine's total height. These rules are intended to take account of landscape considerations and other factors. Statutory Order No. 304 of 14 May 1991 on noise from wind turbines states that the noise level from wind turbines may not exceed 45 dB(A) for dwellings in the open countryside and 40 dB(A) for housing districts.

An environmental impact assessment (EIA) must be conducted for wind turbines exceeding 80 m in total height and for clusters of more than three wind turbines.

An EIA is always conducted for offshore wind turbines to determine the environmental impact before, during and after erection. In connection with the demonstration offshore wind farms, a programme to monitor the effects on birds, marine mammals, fish and marine biology in general will be established in addition to the formal EIA. The monitoring programme will help establish criteria for environmental impacts before, during and after establishment of offshore wind farms in the future. A panel of independent international experts has been appointed to assess the quality of the monitoring programme.

Photo: NERI/Britta Munter

Environmental impact of Denmark's oil and natural gas production

The environmental problems related to offshore oil and natural gas extraction activities mainly derive from two areas:

1. Ancillary substances, including chemicals, that are discharged in varying quantities in connection with drilling, well stimulation, production, etc.
2. Oil from reservoirs that is discharged into the sea together with production water, displacement water and spillage.

The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) has harmonized the regulation of offshore chemicals, including the integration of Denmark's principles on preliminary studies and substitution of hazardous substances.

The offshore oil industry in the North Sea as a whole accounts for slightly less than one third of the total discharges of oil to the sea from all sources, including land-based sources. Denmark's share of the oil discharges by the offshore oil industry amounts to about 200 tonnes per year, equivalent to 2% of the total discharges by the offshore industry in the North Sea. This trend has been increasing through the 1990s (*Figure 1.3.18*). Spillage comprises non-approved discharges or leakage into the sea or deposition on the sea from offshore oil activities. The quantity of oil discharged in connection with spillage from Danish offshore platforms varies from year to year (*Figure 1.3.18*). From 1991 to 1999, the amount of oil discharged in connection with spillage amounted to between 4.9% and 47.6% of the total discharge of oil to the sea from offshore activities.

Oil discharged with displacement water (water that is pressed out from large storage tanks at the sea floor as oil is extracted and placed in the tanks) has become a new source of oil discharge in the Danish part of the North Sea in recent years. Discharge of oil from this source is thus closely correlated with the total quantity of oil extracted. The OSPAR Convention has adopted an upper limit value of 40 mg of oil per litre of water discharged.

It is not only the visible oil, which can harm birds and sometimes beaches, that is important. The least but most environmentally hazardous part of the oil is dissolved in water, and should be considered on par with other environmentally hazardous substances in the sea. Direct visible effects of these substances are seldom detected, even if the sea in the vicinity of the offshore oil activities is investigated. The substances are not necessarily acutely toxic, but because they degrade slowly and can be taken up by animals and plants, they can spread up the food chain and harm the species at the top of the food chain.

Studies of the sea floor have been conducted in Denmark's part of the North Sea near selected oil-production platforms from 1989 to 1999 in accordance with the applicable Danish guidelines. The main purpose of these studies was to survey changes in the composition of sediment and benthic fauna and to identify the most important factors to which the observed changes can be attributed.

Discharges from wells in the Gorm, Kraka and Harald fields resulted in substantial effects on the sea floor in an area within 250 metres from the platforms. Minor effects could be identified at distances up to 1,500 metres. The effects were expressed as elevated concentrations of such substances as hydrocarbons, barium and heavy metals in the sediment and a reduction in biomass and the number of species of benthic fauna present. The variation in benthic faunal biomass correlated with the sediment concentration of hydrocarbons and barium.

Reduced emissions in connection with cessation of local drilling activities have reduced the adverse effects on the benthic fauna. Certain species, including the brittle star (*Amphiura filiformis*), a common member of the benthic fauna communities in the central part of the North Sea, have still not re-established 2–3 years after cessation of operations, however.

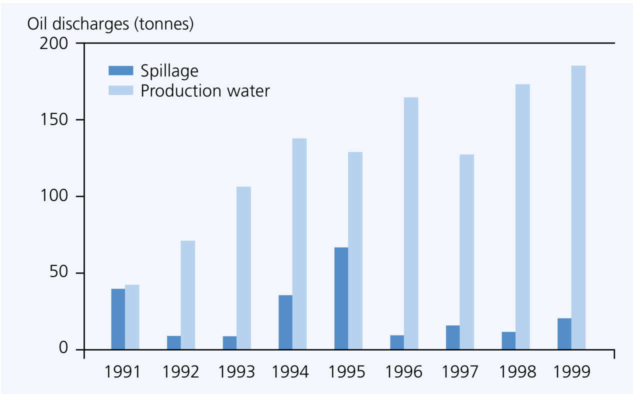


Figure 1.3.18
Discharges of oil to the sea in the form of spillage and production water during the period 1991–99. The 1999 figure for production water (180 tonnes) includes displacement water.
(Source: Danish Environmental Protection Agency, 2000).

The overall environmental objectives and trends in the coming years

The trend in the energy sector over the past decade has been greatly influenced by stipulation of a quantified target for the overall reduction in Danish CO_2 emissions. The target is to reduce emissions by 20% by 2005 relative to the level in 1988. Progress in achieving the national targets is assessed using adjusted figures for CO_2 emissions. Further, the most recent government energy plan, Energy 21, formulated a benchmark for the long-term trend, namely halving CO_2 emissions by 2030 relative to the level in 1990. The subtarget for renewable energy is a 1 annual percentage point increase in the proportion of the total gross energy consumption accounted for by renewable energy.

In 1997, the national CO_2 target was supplemented through an international commitment to reduce greenhouse gas emissions. A meeting in Kyoto under the United Nations Framework Convention on Climate Change adopted an international agreement, the Kyoto Protocol, on reducing the emissions of greenhouse gasses. Specifically, the overall target of the Kyoto Protocol is for the industrialized countries to reduce their emissions of the six most important greenhouse gasses by 5.2% on average in 2008–2012 relative to 1990. This obligation has been distributed among the various countries. In connection with a burden-sharing agreement with the other EU countries, Denmark has pledged to reduce greenhouse gas emissions by 21% relative to the emissions in 1990 adjusted for electricity imports. A precondition for Denmark ratifying the Kyoto Protocol will be that this adjustment of the 1990 level is included in the legal instrument that will form the basis for the overall ratification by the EU.

Whether the targets for CO_2 emissions can be fulfilled depends on the trends in the coming years in the energy sector and the transport sector. Achieving the overall target for greenhouse gas emissions further depends on emissions of nitrous oxide and methane from such sources as waste and agriculture. Another factor is the trend in the consumption and emission of the three industrial greenhouse gasses (*see Section 2.6*).

According to the latest comprehensive assessment from March 2001, it seems that the national CO_2 emission target will be fulfilled through the initiatives already adopted. This estimate is naturally subject to some uncertainty, not least because the trend in final energy consumption has previously proven difficult to predict.

Substantial reductions in CO_2 emissions are expected until 2005 through comprehensive efforts to promote the use of renewable energy, natural gas and district heating and to conserve energy in businesses, households and the public sector. The overall CO_2 emissions will decline despite the expected continuing increase in energy consumption for transport.

Numerous policy instruments have been implemented, especially public subsidy schemes and environmental taxes as well as several informational and administrative instruments. The assessment is that Denmark still needs to reduce emissions of the six greenhouse gasses by 2–3% to achieve its international commitments. The calculation of this gap is based on the previously mentioned need to adjust the base year of 1990 for electricity imports and establishment of a quota for CO_2 emissions from electricity generation corresponding to domestic consumption. It is expected that it will be possible to implement initiatives that will ensure that the commitment is met. A decisive factor for fulfilling the international commitment is to determine the future regulation of CO_2 emissions from electricity generation, including the export of electricity. The present law on CO_2 emission quotas only regulates this until the end of 2003.

In addition to climate, other international agreements have been adopted on the continuing reduction of SO_2 and NO_x emissions. Denmark has pledged to reduce SO_2 emissions by about 30% and NO_x emissions by about 45% in 2010 relative to 1998 (*see Section 2.2*). The target for SO_2 is expected to be met through current initiatives, whereas decisions must be taken on the future regulation of NO_x emissions.

Denmark's goal for extraction of the energy raw materials oil and natural gas is that this should be carried out with the greatest consideration for health and safety at the installations. The oil and natural gas must be produced in a way that minimizes harmful effects on the environment and biodiversity. This applies both locally to the marine environment and to transboundary pollution through the air or via the food chain. To the extent that this is justifiable as regards safety and working environment considerations, efforts will be made to ensure that the use of hazardous chemicals is phased out and that the discharge of oil with production water, etc. will be limited to the greatest extent technically and economically feasible.

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1.3.2 Theme – Environmental effects of liberalizing the electricity markets

Introduction

Two overall political objectives dominate current European energy policy:

- ***The obligations imposed by the Kyoto Protocol on reducing emissions of greenhouse gasses*. The EU countries have jointly pledged to reduce emissions of greenhouse gasses by 8% in 2008–2012 relative to 1990.**
- ***Liberalization of the electricity markets*. Numerous countries, especially in northern Europe, have introduced free competition in the electricity markets. Electricity is increasingly traded across national borders, and the introduction of commercial electricity exchanges and financial trade opportunities is promoting this trade.**

Photo: NERI/Britta Munter

The challenge is to integrate these objectives, which in some cases can be potentially divergent. The goal of reducing greenhouse gas emissions can be inherently difficult to achieve, but many different instruments can be used to achieve reductions in greenhouse gas emissions. These include establishing a market for tradable emission permits to regulate CO_2 emissions from electricity generation and a market for green certificates to promote renewable energy technologies. Both types of market were introduced in Denmark through the Electricity Reform Agreement adopted in 1999.

Renewable energy is planned to have a greater role in reducing emissions of greenhouse gasses, not only in Denmark but also in the EU context. The European Commission's latest strategy and action plan on renewable energy sources lays out the objective that renewable energy resources should account for 12% of total gross energy consumption in the EU in 2010, including 22% of electricity consumption. After biomass, wind energy is expected to be the most important source of renewable energy. The recently adopted EU Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market sets out indicative targets for the expansion of renewable energy in each Member State. Denmark is the clear leader, with a renewable energy target of 29% of total electricity consumption in 2010. Renewable energy is currently being strongly expanded in Denmark and internationally, especially wind power. The global capacity for wind energy has quadrupled within the past 5 years and in 1999, grew by 37% to approx. 13.9 GW. For comparison purposes, the total conventional electricity-generating capacity in Denmark is approx. 8 GW and mainly consists of coal-fired power plants. Countries such as Germany and Spain in particular have substantially increased the number of wind turbines. Denmark's wind power capacity increased by more than 25% in 1999 and is now approx. 2.2 GW.

The background for the successful expansion of wind power in these three countries – Denmark, Germany and Spain – has in all cases been a fixed and very high settlement price for electricity generated from renewable energy. This settlement price includes both a relatively high price for the sale of electricity to the electrical utilities and subsidies per kilowatt-hour. The considerable state expenditure in this connection was part of the background for the comprehensive changes in renewable energy introduced with the Danish Electricity Reform Agreement in spring 1999.

The electricity reform introduces many pioneering elements in relation to electricity. These include a completely free market from 2003 so that all consumers can freely choose an electricity supplier, and the establishment of the two markets for green certificates and tradable CO_2 emission permits.

Denmark's liberalization – the Electricity Reform Agreement

In early 1999 the Danish Parliament adopted legislation reforming the electricity sector – the Electricity Reform Agreement. The purpose of the reform and associated agreement on power utility finances was to ensure supply security and economy viability, to protect the environment and consumers, and to ensure low consumer prices.

The electricity reform establishes a framework for how consumer protection, environmental considerations and supply security are to be ensured in the future liberalized electricity market. The reform also establishes a framework for the CO_2 emissions by the electricity sector and for the expansion of renewable energy until the end of 2003. The electricity reform is intended to contribute to ensuring that Denmark can fulfil its long-term international environmental commitments in 2008–2012. At present, the parties behind the electricity reform are solely bound as regards setting the electricity sector's contribution for the period 2000 to 2003 and for the continued expansion of renewable energy until the end of 2003. The agreement on power company finances establishes the overall economic framework under which they will operate during the transition from "break-even" regulation to market conditions.

The market must be fully opened by the end of 2002 such that all consumers can freely choose an electricity supplier. Opening of the market must be implemented in such a way that all consumers are ensured equal opportunities to take advantage of the free choice of supplier. In order to further promote the competitiveness of Danish trade and industry, however, opening of the market was brought forward for major consumers.

Electricity has become an international commodity. Thus, electricity consumers in both eastern and western Denmark are now part of Nord Pool – the Nordic Power Exchange. Prices on Nord Pool are currently very low, which benefits electricity consumers in Denmark. Electricity consumers cannot cover their entire consumption through purchases on Nord Pool, however. A portion of the electricity must comprise "green electricity". To ensure that Denmark's environmental commitments are fulfilled, all consumers are required to purchase some electricity generated in an environmentally sound manner settled at a higher price than the market price.

The electricity sector plays a key role in fulfilling environmental commitments. Thus, the electricity sector accounts for 40% of all CO_2 emissions and about 33% of the total greenhouse gas emissions. Denmark has implemented a new form of framework management that includes objective approval criteria for establishing new production capacity and quotas for the CO_2 emissions of electricity producers, aimed at ensuring that Denmark can fulfil its international environmental obligations.

Photo: Highlight

An increasing proportion of future electricity consumption will be produced from renewable energy sources. It is therefore important that the future electricity market can utilize more competition-based mechanisms that can ensure cost-effective expansion of renewable energy production. Market mechanisms will therefore be introduced for trade in renewable energy. Thus, a scheme for certifying electricity produced by renewable energy sources (green certificates) is being introduced. All electricity consumers are then bound to purchase green certificates corresponding to an increasing proportion of electricity from renewable energy sources.

The Electricity Reform Agreement presumes that a well-functioning market framework will be established in 2003. The market is intended to allow flexibility in meeting consumer demand for renewable energy exceeding the minimum obligation. Increasing demand is also expected as a result of increasing environmental standards and increasing production costs in conventional electricity generation. The cost of producing renewable energy will also be expected to decline. The Electricity Reform Agreement states that the parties to the agreement are free to choose the framework for further expansion of renewable energy in the period after 2003. The parties agree, however, that the obligation of consumers to purchase renewable energy will help to ensure reasonable rates of return on the investments made prior to 2003, as well as for the period after 2003.

Tradable CO_2 quotas for the electricity sector

From January 2001, a system of tradable emission permits for the electricity sector was introduced in Denmark. An emission permit gives an enterprise the right to emit a certain amount of pollutants to the atmosphere during a given year. Unused permits may be carried forward to subsequent periods. The permits are tradable: Thus enterprises encompassed by the scheme may trade emission permits. Enterprises for whom the cost of reducing emissions is high will benefit from purchasing emission permits, whereas other enterprises will find it profitable to sell permits. This ensures cost-effectiveness, i.e. the greatest environmental benefit for the investment.

Since the public authorities manage the quota, a number of emission permits are allocated each year corresponding to the sector's total maximum permitted emissions. Thus, the public authorities can precisely control the total emission. To avoid imposing a fixed ceiling on electricity generation, a penalty is levied on emissions exceeding the quota rather than imposing an actual ban on further emissions. This ensures flexibility if demand for electricity is great.

The quota scheme imposes a ceiling on the CO_2 emissions by the electrical utilities. A total CO_2 quota for the electricity sector has been set for each year from 2001 to 2003. The previous emissions were considerably higher than these quotas. Thus, the quota for 2003 corresponds to only 66% of the average emissions for the period 1994–1998. If the ceiling is exceeded, a penalty of DKK 40 per tonne of CO_2 emitted is levied. All producers are allocated tradable emission permits corresponding to their quota. The initial allocation of quotas is based on each power company's actual emissions in the period 1994–1998. During this period, the power companies were unaware of the future introduction of quotas as a regulatory instrument and thus have not had the possibility to think "strategically" by raising emissions to ensure a higher quota later. At the end of 2000, the producers were assigned a quota for emissions for the year 2001 after a consultation process. The producers may purchase emission permits if they expect high production, or sell if they do not expect to fully use their emission permits, or save their permits for use in subsequent periods.

Year	Quota
2001	22 million tonnes CO_2
2002	21 million tonnes CO_2
2003	20 million tonnes CO_2

Figure 1.3.1

Total CO_2 quota for the electricity sector (2001–2003).

This scheme includes all power plants except for combined heat and power plants emitting less than 100,000 tonnes of CO_2 per year. The cogeneration of electricity and heat reduces CO_2 emissions. The contribution of heat generation to CO_2 emissions is therefore deducted from the quotas, thereby ensuring a continued incentive for cogeneration.

The implementation of CO_2 quotas in Denmark should especially be viewed in the light of the continuing discussion on international regulation in the environmental area – a discussion on which Denmark would like to leave its mark. The introduction of the quota in Denmark is a good demonstration of the use of a market-based and cost-effective initiative in the environmental field. The desire is that such initiatives will gain in acceptance in Europe and other countries, thereby helping to promote activities at the EU level by demonstrating that economic growth does not necessarily result in increased pollution. The scheme has therefore been designed to be internationally applicable at a later stage.

The parties behind the electricity reform are solely bound until the end of 2003. Before the end of 2001, though, the parties must negotiate the CO_2 emissions of the electricity sector for the period after 2003 based on the overall obligation to reduce emissions in accordance with the Kyoto Protocol. Among other things, this will be based on experience regarding compliance with the existing emission ceilings for the electricity sector, the status for renewable energy and the general trend in energy consumption.

In the negotiations in 2001, the parties are naturally bound by Denmark's international environmental commitments, but this does not mean a predetermined decision on the specific ceiling for CO_2 emissions for the subsequent period. The parties agree, however, that the electrical utilities that have saved up emission permits in the "CO_2 bank" may carry these permits forward to the period after 2003.

A market for green certificates for renewable energy

In accordance with the electricity reform, all electricity is to be sold on the electricity market, including electricity from renewable energy technologies after a transition period. However, even wind turbines still cannot compete on equal terms with conventional power plants. Market mechanisms are therefore being introduced for trade in renewable energy, and transitional schemes are being established in relation to the present system. The renewable energy market is intended to ensure a settlement price surcharge for electricity from renewable energy sources so as to make renewable energy technologies attractive for potential investors. The renewable energy market will thus take over the function of the former fixed settlement price rules and ensure appropriate expansion of renewable energy technologies while concomitantly increasing the competition between the various types of technology.

The Danish model for a green certificate market has two main elements:

- All renewable energy technologies, including wind power, biomass and biogas plants, solar cells, geothermal plants and small hydroelectric plants will be certified for the production of green electricity. This means that they will receive a green certificate for every unit of electricity they generate (for example, per MWh), which they will thereafter be able to sell to electrical utilities or other consumers required to cover part of their electricity consumption with green electricity.
- All electricity consumers in Denmark will be bound to cover a certain percentage of their electricity consumption with electricity produced from renewable sources. Most electricity consumers will delegate this responsibility to their electricity supply utility, which will purchase green certificates on behalf of the consumers. Large enterprises that purchase their electricity directly from abroad will be independently responsible for covering a corresponding portion of their consumption with green electricity.

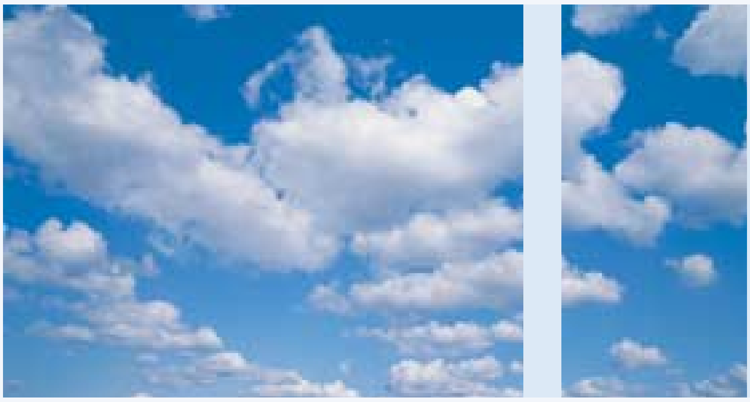


Photo: CDanmark

The demand for green certificates thus derives from electrical utilities and other consumers, who are required to purchase a certain proportion of their electricity turnover or consumption as green electricity on an annual basis. The Danish Energy Agency (or another public authority) will fix this percentage (quota), probably for several years in the future. The supply is determined by the amount of electricity produced by these renewable energy technologies during the year in question. At the end of each year, the consumers must submit to the authorities the number of green certificates corresponding to their quota. According to the electricity reform, 20% of Denmark's electricity consumption must be covered by renewable energy technologies in 2003. In 1999–2000, wind energy accounted for approx. 13% of Denmark's electricity consumption, while 1–2% derived from other renewable energy technologies.

An important characteristic of the market for green certificates is that it functions solely as a financial market – it is totally independent of the physical electricity market. Thus, consumers do not have to think about whether the electricity they use derives from wind turbines or coal-fired power plants. The requirement concerning purchase of a certain proportion of green certificates on an annual basis ensures that a corresponding amount of green electricity has been produced and sold during the year in question.

The green certificates will be based on production from both existing renewable energy plants and new renewable energy plants constructed during the period in question. The key factor as regards the green certificates market is to achieve regulated expansion of new renewable energy capacity. Thus, it is important that the quota be set in such a way that the production capacity of the new plants corresponds to the number of green certificates remaining from the quota after allocation of certificates to the existing plants. The annual increase in the set quota will substantially influence the expected price of green certificates and thus the market expectations of potential investors.

The electricity reform establishes a price range of DKK 0.10 to 0.27 per kWh for the green certificate market, which is thus equivalent to the settlement price surcharge on green electricity. This is derived from a predetermined minimum price for certificates of DKK 0.10 per kWh, corresponding to the existing CO_2 levy on electricity. In addition, consumers are penalized DKK 0.27 per kWh if they do not fulfil their quota. This effectively corresponds to setting a ceiling of DKK 0.27 per kWh since consumers will probably prefer to pay the penalty rather than purchase certificates at a higher price.

Figure 1.3.19 shows how an annual green certificate market will function. The demand for certificates is determined by the set quota. If the certificate price exceeds the maximum price P_{max}, consumers will prefer to pay the latter rather than purchasing certificates. The long-range marginal cost (LRMC) curve is decisive for determining how many new installations will be established in a given year. The LRMC curve is determined by the expected average cost per kWh generated by the renewable energy plant during its entire lifetime. The shape of the curve is determined by the fact that the new and most efficient renewable energy producers are lowest on the curve (are least expensive), whereas the most expensive producers are on top. The LRMC includes all expected costs: Investment, operation, maintenance, fuel, etc. as well as a risk premium justified by the fact that the investor is naturally uncertain what the future prices and costs will be. The long-range equilibrium price will be P_{ex} (*Figure 1.3.19*). At this expected price, a sufficient number of new plants will be built during the period to fulfil the combined quota for certificates.

Photo: NERI/Jonas Teilmann

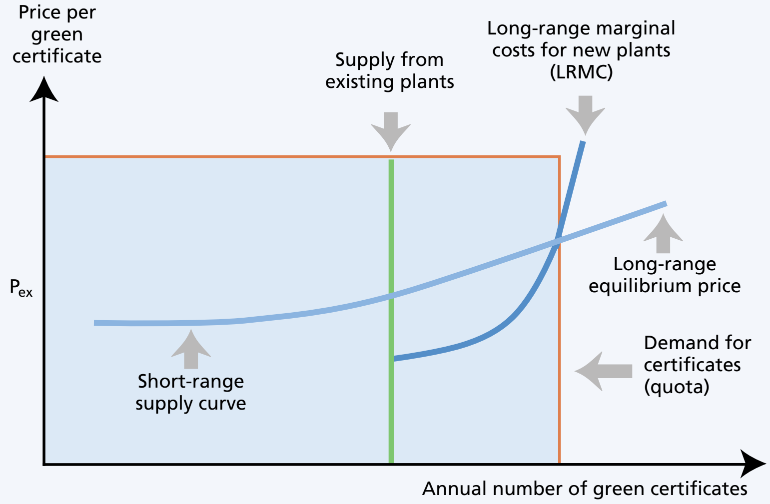


Figure 1.3.19
Price setting and relationship between the short-range and long-range on a green certificate market.
(Source: Morthorst, 2000a).

Since the green certificates will be an important part of the income base for new and existing owners of renewable energy plants, it is important that the pricing of certificates be transparent, realistic and nonvolatile, i.e. that small changes in supply and demand do not lead to large changes in prices. If volatile price fluctuations occur, investors will not know in advance whether they will receive a high or low price for the certificates, which naturally will be an uncertain basis for investing in new plants. It is therefore important that the mechanisms for the green certificate market be arranged in such a way that the risk of volatile pricing is minimized, and that the market otherwise can comprise a credible foundation for potential new investors. The following elements are therefore important to establish for the green certificate market:

- The future quotas must be clearly fixed for several years ahead. An important aspect of achieving the desired expansion of renewable energy is the size of the quota. Achieving steady expansion requires that potential investors be reasonably sure about the future quotas.
- The fact that consumers can save certificates and use them to meet the quota in a future year will help iron out interannual fluctuation in the price of certificates. The same effect could be achieved if producers could borrow green certificates from future renewable energy plants and sell them in a current year. The recently publicized proposal for a green certificate system in England anticipates potential certificate saving of up to 50% of the annual quota and potential borrowing of up to 5%.

A green certificate system will primarily promote the best renewable energy plants on the market. For example, wind energy is expected to achieve a dominant position in Denmark's green certificate market. The development of solar cell technologies is hardly likely to be promoted to any great degree since electricity generation based on solar technologies is still considerably more expensive than wind power. It is therefore expected that other subsidy schemes must be introduced if less commercially viable renewable energy technologies are to be developed.

An international green certificate market

Box 1.3.2
Green certificate markets with an international potential.

Interest for establishing green certificate markets is great not only in Denmark, but also in other countries. Green certificate markets are being implemented in such countries as Italy, England, the Netherlands, Belgium (Flanders) and Australia. The great advantage of an international market is that the renewable energy plants may be localized in the most appropriate countries from the energy and economic points of view. The quota of certificates in each country can then be fulfilled completely or partly through international trade in certificates. As with the national system, a number of factors must be taken into account when developing an international system. This applies not only to developing the system of green certificates itself, but equally to other instruments that can be used to achieve reductions in greenhouse gas emissions in accordance with the commitments under the Kyoto Protocol:

- A green certificate ensures that a certain quantity of electricity has been generated by renewable energy sources. This will reduce the emission of greenhouse gasses since most green electricity will replace electricity generated by fossil fuel-based power plants. But the green certificate does not determine whom should be credited with this reduction since the certificate does not provide any CO_2 credit. This means that international trade in green certificates in a liberalized electricity market will not inherently contribute to fulfilling national greenhouse gas reduction targets under the Kyoto Protocol. CO_2 credit could potentially be linked to the individual certificates, although this is not simple.
- If a green certificate market is combined with an international market for tradable emission permits, individual countries can ensure that they achieve the full environmental benefit of expanding the renewable energy production. Certain conditions still need to be fulfilled, however. In a liberalized electricity market, substantial international exports or imports of electricity can be expected occasionally. If instruments such as a green certificate market and a market for tradable emission permits are to be employed to achieve national emission reductions under such free electricity market conditions, the use of these instruments will have to be coordinated. To obtain the full national benefit of increased expansion of renewable energy it will thus be necessary to reduce the total quota for tradable emission permits in step with expansion of renewable energy. Otherwise, a country that has decided to make great efforts to expand renewable energy risks "giving away" much of the environmental benefits achieved to neighbouring countries.

In addition, the planned national green certificate markets differ from each other in several decisive ways and would not currently be able to serve as the basis for international trade in green certificates. Thus, while international trade in green certificates undoubtedly has great potential, realizing this potential requires coordinating the international expansion of green certificate markets both between individual countries and in relation to the use of other instruments. As mentioned, the interplay between the various instruments is very complex and needs to be thoroughly understood before use of these markets can become more widespread internationally.

Photo: 2. maj/Sonja Iskov

1.4 Transport and mobility

1.4.1 Introduction

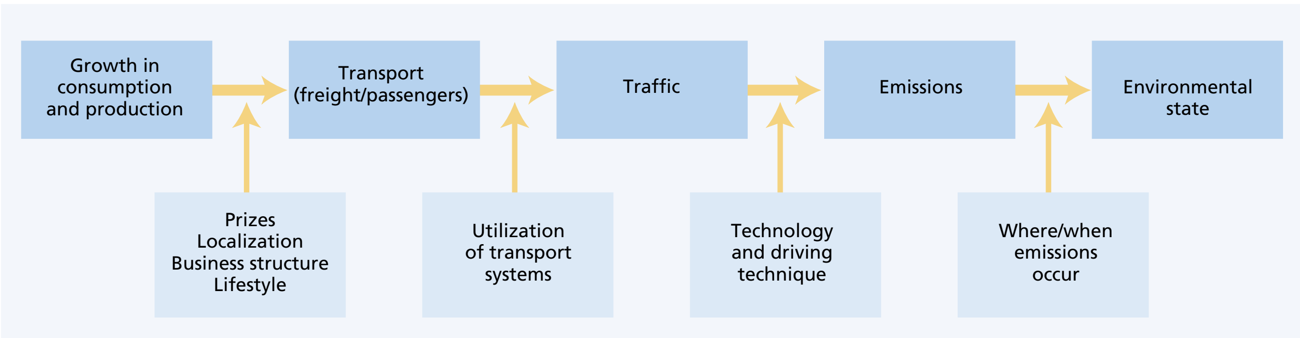
Transport and mobility are important parts of the dynamic development of society, which continues to require substantial physical transport of people and goods despite the rapidly increasing use of the Internet and electronic communication. Increasing globalization contributes to increasing speed and growing turnover. Since 1995, road transport in Denmark has grown by about 10% for passengers and 13% for freight. Transport uses resources and affects the environment both globally and locally. The pressure on nature and the environment is increasing in some areas but decreasing in others as a result of cleaner technology, more efficient transport systems, more environmentally sound behaviour and improved regulatory efforts. The overall situation is a complex interaction of various trends.

The impact of transport on the environment and nature is the combined result of a large number of societal factors or driving forces (*Figure 1.4.1*).

The most important driving forces are:

- **Economic:** Growth, income, structure of the economy and prices
- **Spatial:** Travelling distances between homes, businesses, retail trade outlets, leisure facilities, etc.
- **Sociodemographic:** Age distribution, education, lifestyle, etc.
- **Technical:** Vehicle weight and age, energy consumption and emission standards, etc.

Figure 1.4.1
The impact of transport on the state of the environment is the result of a number of underlying driving forces. The lower boxes indicate some of the mechanisms that can influence the trend.



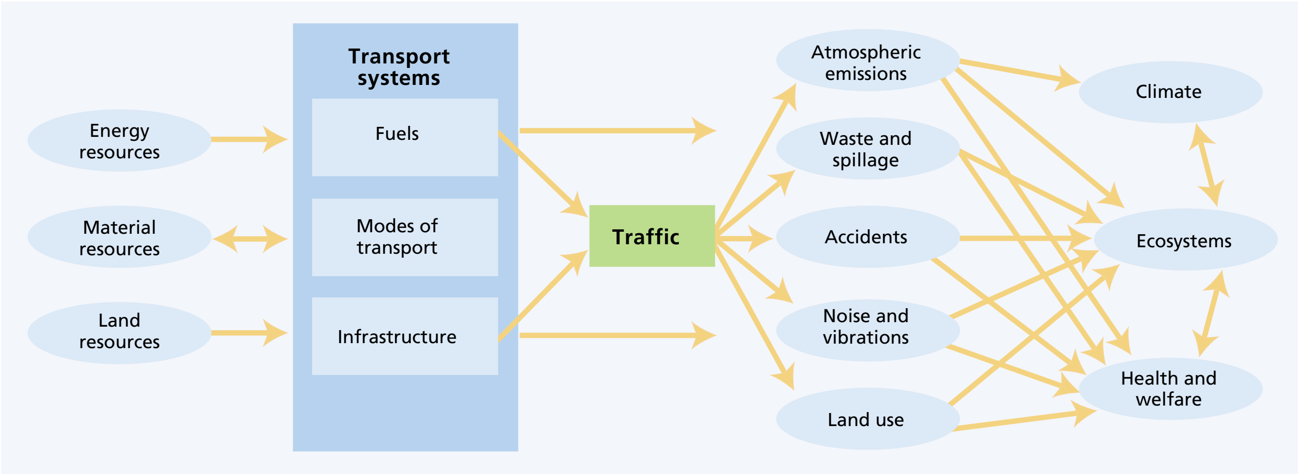


Figure 1.4.2
Examples of nature's "input" to transport systems, and their "output" to the environment. Present-day transport systems are almost 100% dependent on non-renewable resources.

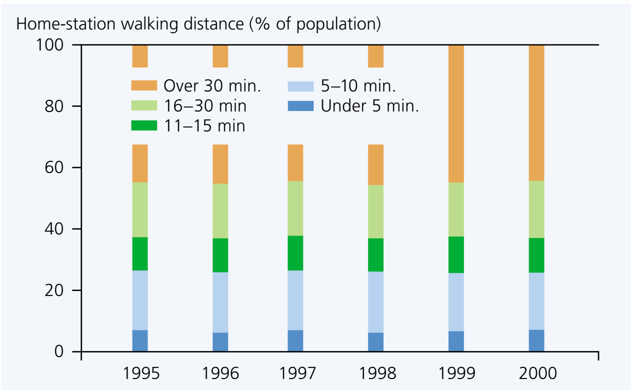
Transport systems and traffic influence nature and the environment in many ways (*Figure 1.4.2*), including both the input of resources (energy, materials and land) to the transport systems and effects such as pollution, noise, intervention in natural ecosystems, accidents, etc. These pressures affect the climate, ecosystems and human health and welfare. Some of the effects occur outside Denmark, for example effects on climate and air pollution (*see Sections 2.4 and 2.6*). In some cases, the contribution of transport to the total environmental impact is known. In many cases, however, only indirect measures or qualitative estimates are available.

1.4.2 Passenger transport

Passenger transport can be expressed in passenger-km, i.e. the number of kilometres a person travels in a day or a year. A second concept is mobility, which also expresses the opportunities people have to transport themselves. Mobility thus depends on access to transport opportunities, for example car ownership or proximity to public transport (*Figure 1.4.3*). A third concept is accessibility, which expresses which objectives in the form of workplaces, shopping opportunities, leisure facilities, etc. people can reach through transport or by other means (e.g. electronically). In modern society, however, mobility and transport are the predominant ways of achieving high accessibility in practice.

Each adult Dane transports himself or herself an average of 36 km per day. Cars are the predominant mode of transport measured in terms of the number of kilometres (*Figure 1.4.4*). The percentage of total transport carried out by car now amounts to about 72% of the total passenger transport for the population as a whole. Since 1995, the volume of passenger transport by car in Denmark has thus grown by about 13% expressed in passenger-km.

A growing Danish car fleet is part of the reason for the increasing proportion of transport carried out by car. From



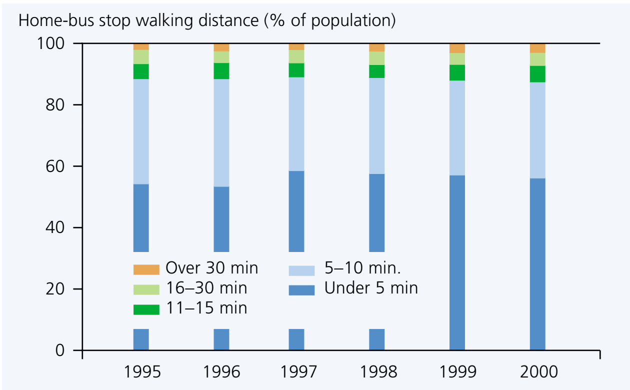


Figure 1.4.3
Over half of the Danish population lives within 5 minutes walking distance of a bus stop while around 8% live more than 15 minutes walking distance from one. On the other hand, almost half of the population lives more than 30 minutes walking distance from the nearest railway station. The general trend over the period 1995–2000 was an increase in proximity to a bus stop and a decrease in proximity to a railway station. (Source: Statistics Denmark's Transport Habits Survey, 2001).

1990 to 2000, the number of cars grew by 15% and is now more than 1.8 million. The growth was especially great in the mid 1990s and levelled off in 2000. In the major cities, half the households still do not have access to a car.

Another factor is the trend in prices (*Figure 1.4.5*). The price of cars and petrol has risen more slowly than the overall consumer price index, whereas the price of bus and train transport has increased considerably more rapidly. In recent years, though, the trends have moved in the direction of an increasing price of petrol (both direct and relative) and a levelling off of the growth of public transport prices.

Most passenger transport (44%) is for various leisure purposes. This is followed by commuting (27%) and errands (including shopping) at 20% (*Figure 1.4.6*). The category "business" mostly comprises transport during working hours. Car drivers drive slightly less for leisure purposes than average, whereas car passengers are transported considerably more to leisure activities. Public transport is used relatively more for commuting (including education). Analyses show that this distribution did not change substantially over the period 1995–2000.

Transport habits surveys show that the growth in motoring is predominantly accounted for by longer rather than more numerous trips, although the variation is minimal. The distance between people's homes and workplaces does not appear to have increased, however (*Figure 1.4.7*). In contrast, the length of car trips for leisure, shopping and especially business purposes all seem to have increased, which has contributed to increasing motoring.

Very recent data (from 2000 onwards) indicate that car traffic in Denmark is now stabilizing. Whereas road traffic grew by an average of 2.8% per year during the 1990s, the increase in 2000 was only 0.3%. Traffic decreased in the first few months of 2001. This does not apply to main roads, however, where traffic has increased.

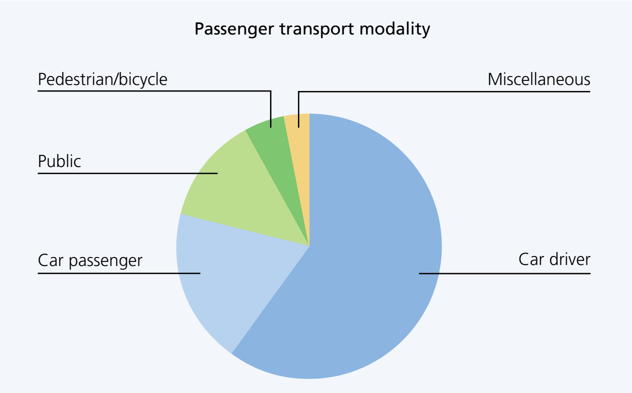


Figure 1.4.4

Passenger transport apportioned according to mode of transport for the Danish population in the age group 16–74 years in 2000.
(Source: Statistics Denmark's Transport Habits Survey, 2001).

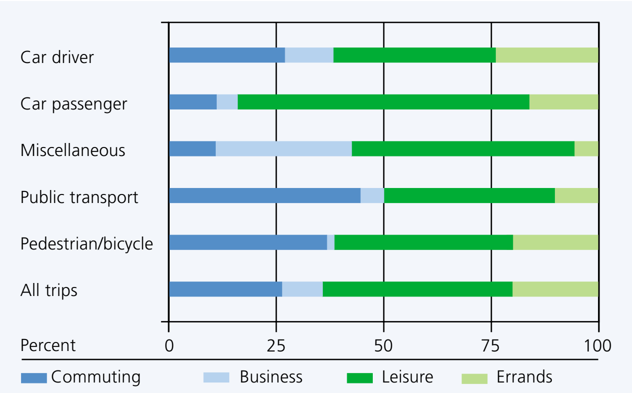


Figure 1.4.6

Daily transport apportioned according to purpose of travel for the Danish population in the age group 16–74 years. Average for the period 1995–2000.
(Source: Statistics Denmark's Transport Habits Survey, 2001).

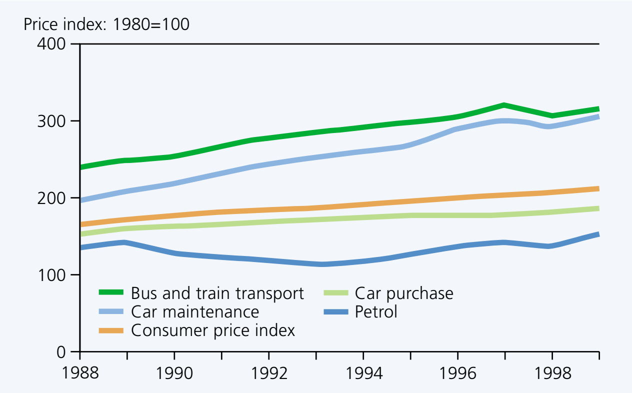


Figure 1.4.5

Trends in transport prices and the overall consumer price index.
(Source: Statistics Denmark, 2000).

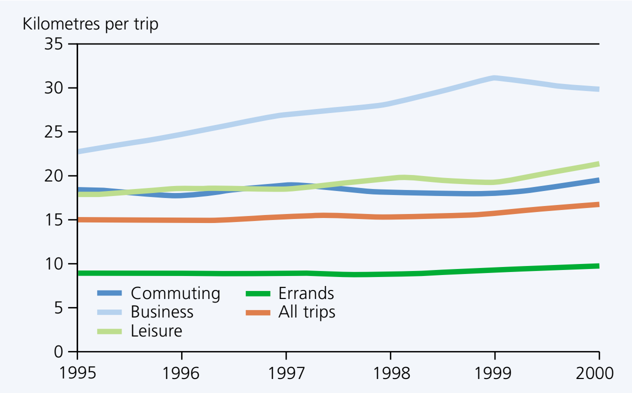


Figure 1.4.7

Average length of car trips for different purposes. The figures for before and after 1997/1998 are not directly comparable.
(Source: Statistics Denmark's Transport Habits Survey, 2001).

The largest increase in 2000 was in traffic across the Great Belt, where car transport increased by 9%. In contrast, traffic declined on numerous urban roads. Reduced traffic in towns benefits the environment. One reason for the levelling off could be pronounced increases in the price of petrol, especially in the first half of 2000. In addition, many cars have been taken off the road because of mandatory periodic inspection. Finally, sales of new cars have declined since 1998, which can contribute to a decline in traffic since new cars are driven considerably more kilometres per year than older models.

The volume of public transport has also increased. Especially travel by coach and by train has grown over the past 10 years (*Figure 1.4.8*). Rail transport has grown by 10% since 1995 alone. Transport by bus has fallen, in contrast, the growth in bus transport being solely attributable to the increase in coach traffic. Domestic air traffic has declined by 25% and ferry traffic by 53% since 1995. This is largely due to opening of the fixed link over the Great Belt. Cycle transport declined by about 15% in the same period. Car transport as a proportion of the total passenger transport has increased by two percentage points since 1995. Taken together, these trends thus do not live up to the intention that cycling and public transport should take over a larger percentage of transport.

Danes are among the EU citizens who travel most, averaging 15,700 passenger-km per year (*Figure 1.4.9*). Despite this, Denmark remains one of the EU countries with the lowest number of cars per inhabitant (*Figure 1.4.9*), although the distance driven annually by each car is relatively great. In addition, Denmark is the EU country with the highest volume of public transport (bus and train) and cycle transport.

One possible explanation for Denmark's high transport volume is that fuel prices in Denmark are relatively low compared with the other EU countries measured in purchasing power parity. The high number of kilometres per car could be due to the relatively high purchase price (including taxes), which provides an incentive to use each car as much as possible. In addition, calculation methods can differ between countries. The official Danish figure of 36 passenger-km per day corresponds to 13,000 passenger-km per year, which is somewhat lower than the EUROSTAT value.

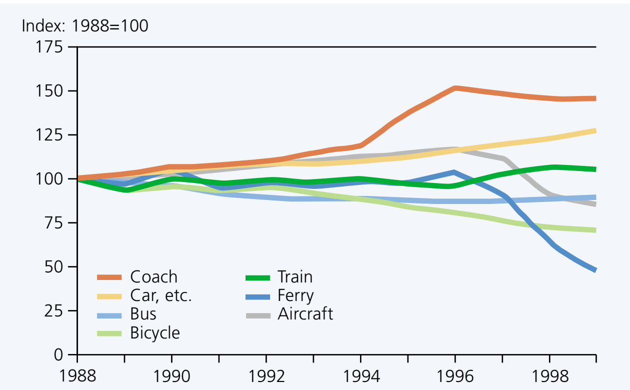
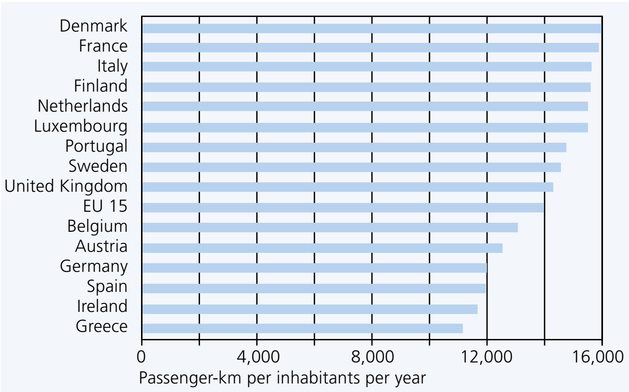


Figure 1.4.8

Indexed trend in passenger transport over the period 1988–99 for different modes of transport. "Cars, etc." encompasses motor cycles and mopeds. (Source: Statistics Denmark, 2000).



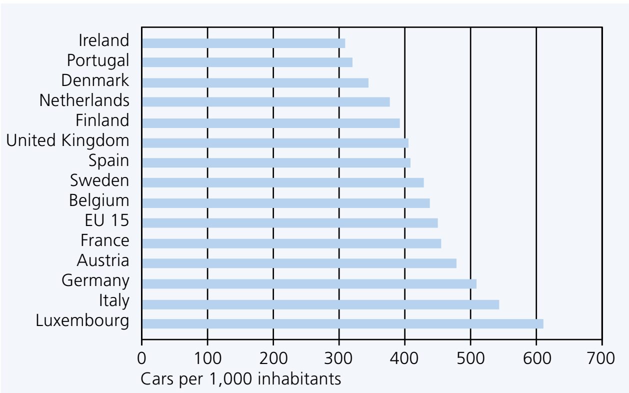


Figure 1.4.9

Passenger-km per inhabitant per year in EU countries (upper panel) and number of cars per 1,000 inhabitants (lower panel). (Source: EUROSTAT, 2001).

1.4.3 Freight transport and international transport

Some of the elements significant for trends in freight transport (*Figure 1.4.10*) include:

- The nature of the goods produced in each sector (goods mix)
- The ratio between value and weight (value density)
- How often the goods are transshipped before reaching their final destination (transshipment factor)
- Who carries out the transport, e.g. in-house transport or haulier (conveyor)
- The average load
- The average haul length.

These elements are naturally influenced by trends in the underlying structural factors. The number of times goods are transshipped is influenced by such factors as the quantity of suppliers and of storage capacity combined with, for example, just-in-time deliveries. Changes in transport conditions can similarly influence the structure. For example, if transport becomes relatively less expensive, the number of suppliers will increase, the distance between the production location and the recipient will increase, and the vehicle load factor will fall. The influence of, for example, the price of transport on the structural factors is a long-term process and is therefore not necessarily reflected in the annual changes in either the transshipment factor or the average haul length.

Freight transport can be expressed as freight lifted, i.e. the total amount of goods in tonnes. Of greater environmental significance, though, is freight transport expressed as freight traffic in vehicle-km with various types of vehicles. Finally, freight transport can be expressed as freight moved in tonne-km, i.e. freight lifted times the distance transported. The total freight traffic carried out by Danish lorries in Denmark in 1999 amounted to approx. 6.4 billion vehicle-kilometres, a 13% increase relative to 1995. In contrast, the increase in freight lifted is negligible. Goods are transported further now, and freight moved (tonne-km) is therefore increasing. For example, food is transported nearly twice as far as it was 20 years ago (*Figure 1.4.11*).

Vans and small lorries account for a large proportion of the traffic (*Figure 1.4.12*). Their share of the freight traffic increased from approx. 77% in 1980 to approx. 81% in 1998. There are several reasons for this. Small lorries transport smaller quantities on more trips relative to large lorries. More importantly, these vehicles are used for work-related

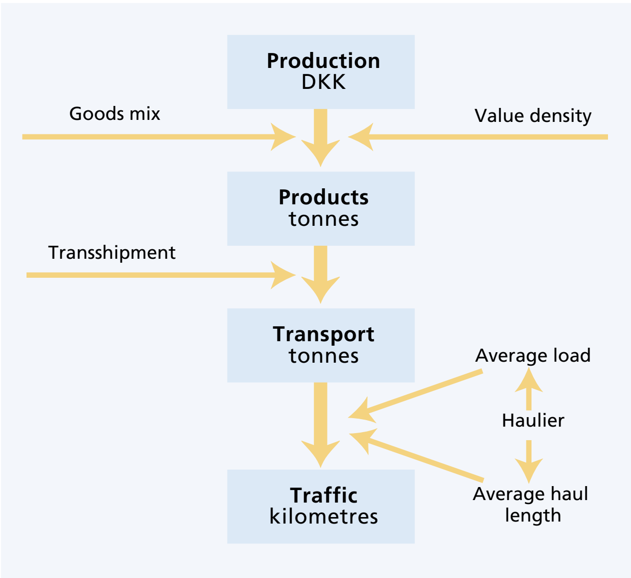


Figure 1.4.10

Summary of some central elements of freight transport. (Source: Kveiborg, 2001).

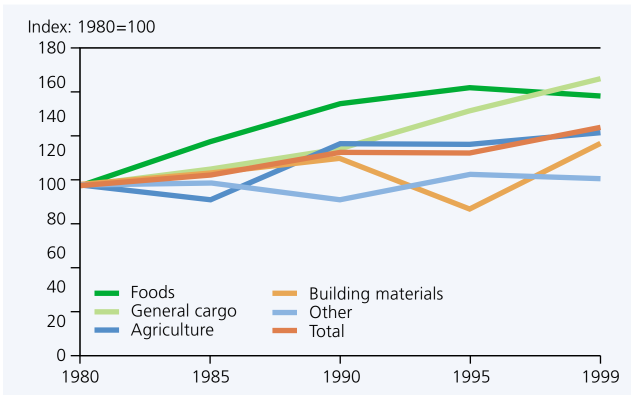


Figure 1.4.11

Indexed trend in freight transport expressed as freight moved (tonne-km) for different types of goods. (Source: Transport Council, 2001).

transport in which both goods and passengers are transported. According to Statistics Denmark, only about 26% of van traffic is actual freight transport.

As regards freight moved, small vans and lorries between 2 and 6 tonnes account for a small but increasing share (*Figure 1.4.12*). An increasing proportion of freight moved in Denmark is accounted for by large lorries, and the environmental impact is consequently increasing.

Most freight transport is generated by the production sectors and the building and construction sector (*Figure 1.4.13*). In particular the food-processing, agricultural and energy sectors contribute to the freight transport.

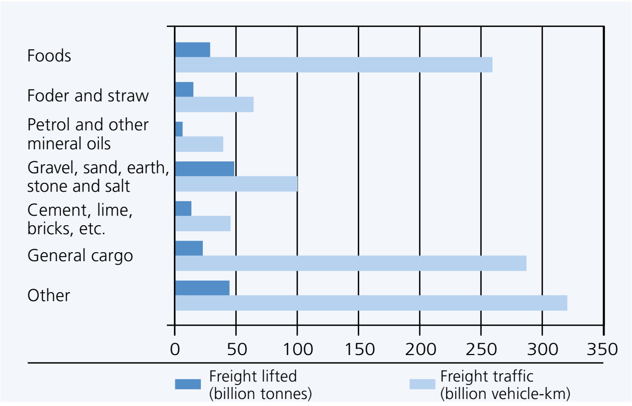
The transport demands associated with the various categories of goods differ considerably. Not surprisingly, food is the category requiring the most transport, followed by building materials and livestock feed (*Figure 1.4.13*). General cargo cannot be apportioned among the traditional categories of goods. This category is very transport-heavy, among other reasons because it is comprised of individual items that are to be transported on the last leg of their journey to the end user.

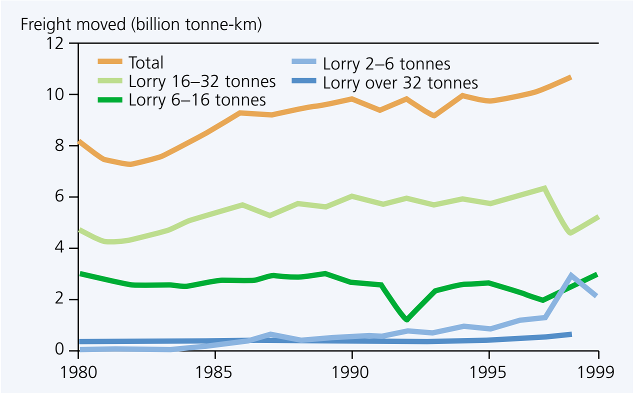
Haul length, transshipment factor and several other factors of significance to the trend in freight transport depend on the types of vehicle used and on the proportion of in-house (company vehicle) versus externally purchased transport (haulier). Differences are apparent in both the average haul length

Table 1.4.1
Average haul load and haul length for vehicles over and under 16 tonnes gross weight for haulier and company vehicles.
(Source: Statistics Denmark's Freight Transport Database).

		Average load (tonnes)		Average haul length (km)	
		1980	1999	1980	1999
Haulier	Lorries under 16 tonnes	4.18	7.63	27.65	78.36
	Lorries over 16 tonnes	9.68	18.49	54.62	89.01
	All	**10.30**	**13.31**	**42.37**	**81.32**
Company	Lorries under 16 tonnes	3.54	6.41	36.06	57.94
	Lorries over 16 tonnes	10.10	17.69	54.57	82.65
	All	**6.65**	**9.02**	**42.07**	**63.40**

Figure 1.4.13
Freight lifted and freight traffic for different categories of goods in 1997.
(Source: Kveiborg, 2001).





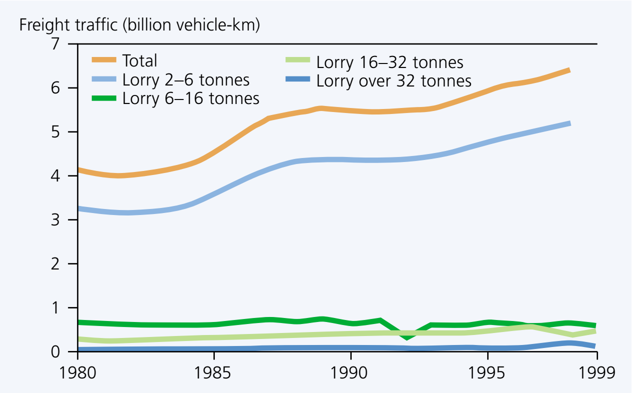


Figure 1.4.12
Trend in national freight transport by road expressed as freight moved (left) and freight traffic (right) apportioned by vehicle size.

(Source: Statistics Denmark's Freight Transport Database and Danish Road Directorate, 2001b).

and average load (*Table 1.4.1*). Company vehicles drive slightly less per trip and have a slightly lower load factor.

It is particularly important to note that the average haul length grew considerably over the period 1980–1999. The fact that the average load has increased concomitantly with a decrease in load factor from approx. 70% in 1984 to approx. 48% in 1999 means that the overall trend is towards an increasing environmental impact. This can partly explain the lower degree of decoupling between transport trends and emissions in freight transport as compared with passenger transport (*Figure 1.4.20*). As yet there is no sign that this trend will change.

International transport

National inventories of transport, energy consumption and environmental impact do not usually account for the transport carried out outside the borders of the country. International transport is growing. For example, the amount of freight transported between Denmark and other countries increased by 20% from 1990 to 1999. Shipping traffic through Danish straits increased by 46% during the same period. The number of international flight operations (take-offs and landings) at Danish airports has grown by 63%. Only part of the air pollution, etc. from international transport affects the environment in Denmark.

1.4.4 Resource consumption in the transport sector

Transport systems use energy, materials and chemical substances.

The transport sector accounts for about 24% of Denmark's gross energy consumption and an even greater percentage of gross oil consumption (52%). In both cases the trend is towards an increase. In the former case, this is attributable to the increase in road transport, and more recently also to the increase in international air traffic (*Figure 1.4.14*).

Transport infrastructure takes up space and impinges upon natural ecosystems by using land and fragmenting the landscape. The total land area used for transport purposes in Denmark is estimated to be 1,276 km^2, equivalent to approx. 3% of the country or an area the size of Lolland. Of this, the majority – approx. three-quarters – is used for the road network. The temporal trend is not known precisely. The total area used for urban purposes, including roads, etc., has been increasing steadily, however, and is expected to grow a further 10% over the next 25 years.

The size, location and density of transport infrastructure influences ecosystems and fauna, including the ability of wildlife to roam within the landscape. According to an EU survey (1997 figures), Denmark is among the countries whose landscape is the most fragmented by large transport infrastructure. The size of unfragmented land units between transport infrastructure averages about 42 km^2. This corresponds to the situation in the Netherlands, whereas the EU average is 130 km^2.

A considerable proportion of the world's metals and minerals is used to manufacture means of transport (vehicles, trains, ships and aircraft). In the United States, for example, this accounts for about 15% of steel consumption, 25% of copper consumption and 75% of lead consumption (for items such as accumulators). A large proportion of the metal is recycled. Thus, about 75% of all waste from scrapped vehicles is recycled in Denmark.

Large quantities of material are used to construct and maintain transport infrastructure (*see Section 1.5.9*). About 3 million tonnes of asphalt is used each year in Denmark, with a slight decline throughout the 1990s (*see Section 1.5.9*). The materials used for the road transport system as a whole (including roads, vehicles and fuel) are estimated at around 8 million tonnes or 6% of Denmark's total annual resource input.

Numerous chemicals are used to "lubricate" the transport systems, including de-icing agents used on roads (*Figure 1.4.15*), herbicides used alongside roads and railroads (*see Section 4.5*) and tin compounds used in antifouling paints on ship hulls (*see Section 3.8*). The very diverse chemical substances can have negative and to some extent unknown effects on the environment.

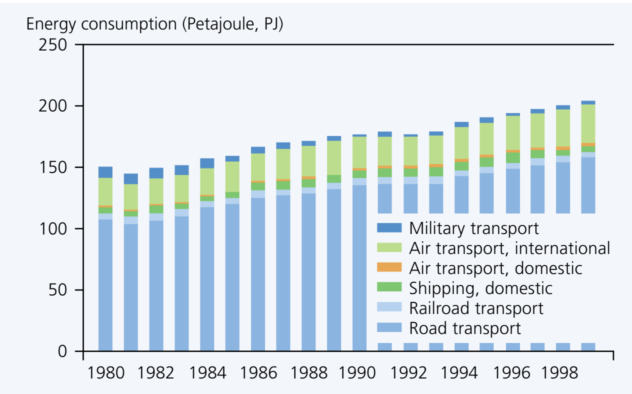


Figure 1.4.14

Energy consumption by different categories of transport over the period 1980–99.

(Source: Danish Energy Agency, 2000a).

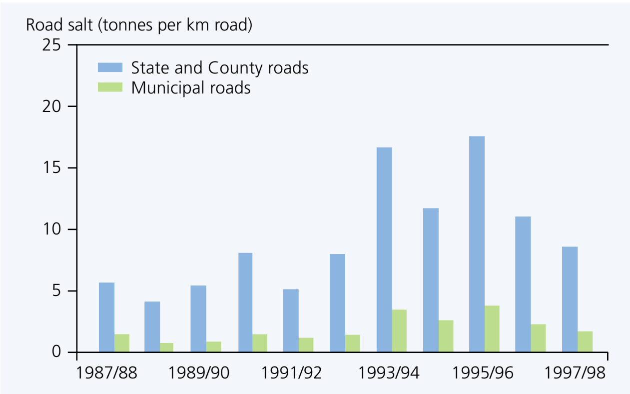


Figure 1.4.15

Consumption of road salt (tonnes per km road) is greatest on the main road network.

(Source: Danish Road Directorate, 1999b).

1.4.5 The environmental impact of transport

Transport causes pollution, noise, accidents, etc. that adversely affect nature and human health.

Emissions to the air

Transport emits a number of substances to the air that influence the climate, ecosystems and human health, including carbon dioxide (CO_2), nitrogen oxides (NO_x), hydrocarbons and particulates. Road traffic is generally the predominant source, but this differs for the individual pollutants. Passenger transport, especially by car, accounts for the largest proportion of CO_2 emissions (*Figure 1.4.16*). Emissions of NO_x are about equally divided between passenger and freight transport, while vans and lorries are the overwhelming source of particulate emissions.

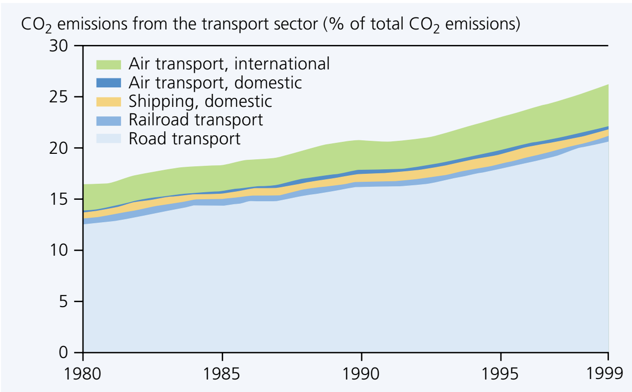
CO_2 emissions from transport correlate relatively closely to energy consumption and in 1999 accounted for 26% of Denmark's total CO_2 emissions (including international air traffic) (*Figure 1.4.17*). Emissions from road transport are the predominant source, comprising 78%, while international air traffic accounted for approx. 16% (*Figure 1.4.18*). Transport accounts for a smaller share of total emissions of greenhouse gasses than of CO_2, however. This is attributable to the fact that greenhouse gas emissions by transport consist almost entirely of CO_2 (approx. 96%), whereas Denmark's greenhouse gas emissions as a whole include other greenhouse gasses in addition to CO_2 (*see Section 2.2*).

From 1988 to 1999, CO_2 emissions from international air traffic increased by about 22% (*Figure 1.4.19*). The increase has been greatest since 1993, which correlates with the economic growth in that period. Energy consumption for international air traffic in that period increased by 5.5% per year on average, whereas energy consumption for road transport "only" grew by an average of 2.4% per year. In addition to the increase in energy consumption and emissions (*Figure 1.4.19*), the latest climate research shows that the emissions of CO_2 by aircraft at great height have about three times the effect on the climate as corresponding CO_2 emissions at the Earth's surface. If this trend continues, the contribution of air traffic to climate change could eventually exceed that of road transport.

The share of Denmark's NO_x emissions accounted for by transport in-

Figure 1.4.17

The transport sector's share of total CO_2 emissions has been growing. (Incl. international air transport; excl. emissions from military transport and emissions associated with the use of electrically powered trains). (Source: Danish Energy Agency, 2000a).



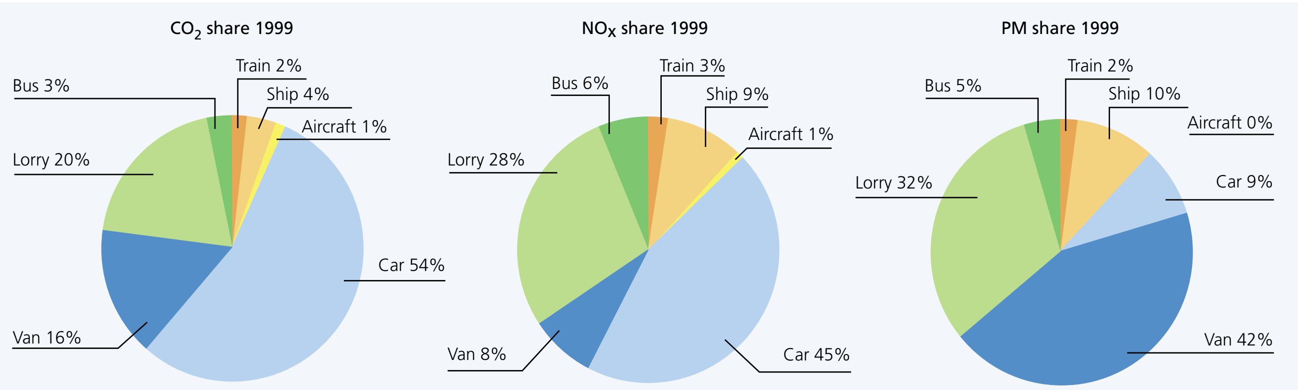


Figure 1.4.16

Transport sector emissions (domestic) of carbon dioxide (CO_2), nitrogen oxides (NO_x) and particulates (PM) apportioned by mode of transport. "Train" does not include emissions associated with the use of electrically powered trains. "Car" also includes 2-wheeled vehicles. (Source: National Environmental Research Institute, 2000).

creased from 51% in 1988 to 61% in 1999. Emissions of NO_x from transport have declined, however, largely due to the increasing proportion of cars equipped with catalytic converters (*Figure 1.4.18*). The proportion of the total emission of hydrocarbons accounted for by transport has declined slightly, from 51% to 47%. Transport emissions of both hydrocarbons and particulates have been declining since around 1991.

New research indicates that particulate air pollution can pose a considerable health risk and cause increased mortality, and that it is the concentration of fine and especially ultrafine particles that is of significance for health. Diesel vehicles emit slightly more ultrafine particles than do petrol vehicles. Ultrafine particles with a diameter of less than 0.1 µm penetrate into the smallest bronchioles, where they can remain for many months before being excreted from the lungs. The current level of particulate pollution is considered to exacerbate illness, especially among people with respiratory disorders and diseases, and to enhance mortality among the general population (*see Section 2.3.2*).

Marine transport is the most energy-efficient form of transport, and the contribution of shipping to global warming is therefore relatively limited. Energy consumption by shipping results in substantial emissions of other air pollutants, however. New inventories thus show that ships in Danish marine waters emitted 133,000 tonnes of sulphur dioxide (SO_2) in 1999–2000. This is twice as much as all the combined land-based sources in Denmark, including heating, road transport and energy production.

This figure includes all (not just Danish) ships in marine waters between 6°E and 16°E and bordered (from north to south) by Norway-the Netherlands and Sweden-Poland. Freight ships account for more than 95% of the SO_2, 76% of the CO_2 and 86% of the NO_x emitted by these ships. The percentage accounted for by ferry traffic is therefore very small. Emissions of SO_2 and NO_x lead to acidification of both terrestrial ecosystems and water bodies throughout the Nordic countries. The problem is greater in Norway and Sweden than in Denmark, however.

An overall environmental policy objective is to decouple the growth in transport from the growth in the environmental effects of transport. This can be illustrated by comparing the trend in transport sector emissions since 1988

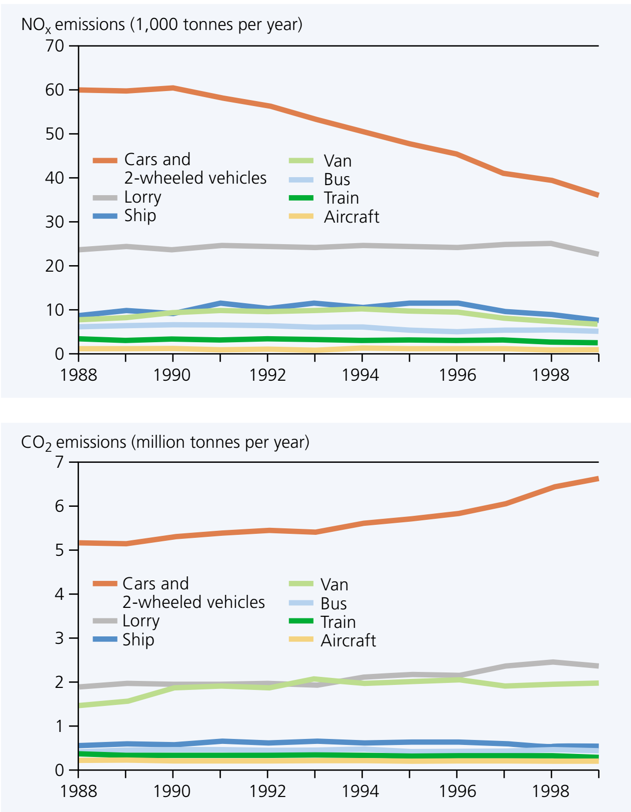


Figure 1.4.18

Trends in NO_x (upper panel) and CO_2 emissions (lower panel) for different modes of transport over the period 1988–99. (Source: National Environmental Research Institute, 2000).

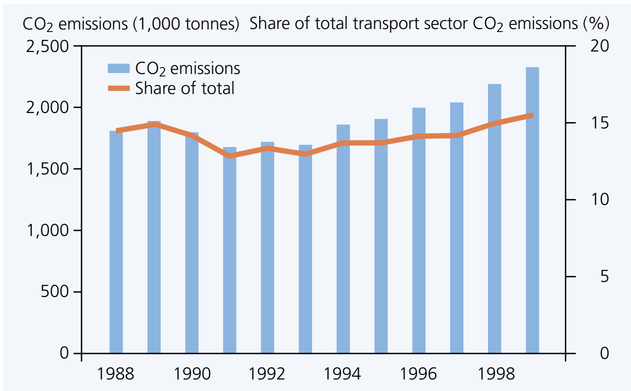


Figure 1.4.19

CO_2 emissions from international air transport. (Source: Danish Energy Agency, 2000a).

with the trend in passenger transport and freight transport (*Figure 1.4.20*). Both passenger and freight transport have grown steadily. Emissions of NO_x, volatile organic compounds and to some extent particulates are declining markedly. It should be noted, though, that the figures for particulates are based solely on the total particulate mass. As mentioned previously, it is especially the ultrafine particles that cause health problems. The trend in emissions of this fraction of particulates is unknown.

Overall, it seems that growth in transport has been decoupled from the emission of these pollutants. The decoupling began in about 1991 for passenger transport and somewhat later, and to a lesser extent, for freight transport, among other reasons because of differences in the environmental standards applied to cars and lorries.

In contrast, such decoupling has not been achieved for CO_2, neither for passenger nor for freight transport. For passenger transport, the growth in passenger-km is very closely accompanied by an increase in CO_2 emissions. Among other reasons, this is because the energy efficiency of the means of transport has not improved substantially despite technical progress. For freight transport, the relative trend in CO_2 emissions was actually higher than the growth in transport during part of the period, i.e. negative decoupling.

The levelling off of car transport will probably lead to a reduction in environmental impact if the trend continues. The environmental impact also depends on several trends pertaining to the car fleet, however:

- The composition of the car fleet by weight class. The average new car is heavier than it was a decade ago. Cars weighing from 1.0 to 1.5 tonnes comprise 44% of the car fleet today versus 22% in 1990. The increased average weight tends to increase energy consumption and CO_2 emissions.
- The composition of the car fleet by type. The proportion of diesel cars is increasing. Diesel cars typically use less energy and emit less CO_2 than do comparable petrol cars. On the other hand, diesel cars lacking particulate filters emit more particulates and NO_x. The number of diesel cars increased by 33% from 1997 to 2001. They still only comprise 6% of the car fleet, however.
- The energy efficiency of new cars. The average energy efficiency of new cars increased slightly during the 1980s, but levelled off in the 1990s. New standardized measurement methods were introduced in 1997. Despite the increased weight, the average fuel efficiency of new cars has increased from approx. 13 to 14 km per litre, with the greatest increase among diesel cars. Energy consumption by vehicle accessories such as air conditioning units is not included, though.
- Age composition of the car fleet. The age composition in 2000 roughly corresponded to that in 1990. In both years, 38% of the cars were less than 5 years old, 24–28% were between 5 and 9 years old and 34–37% were 10 years old or more. As a result of the gradual tightening of emission standards, new cars emit less of such air pollutants as NO_x and hydrocarbons than older cars. About 50% of the emissions of these pollutants derive from that part of the car fleet originating from prior to 1988, i.e. cars that are not fitted with catalytic converters.

The overall significance of these trends for the emissions from car transport is related to the amount driven, which has increased up to 2000. As an overall result of both technical and behavioural changes, CO_2 emission from car transport has been increasing, whereas other emissions have decreased (*Figure 1.4.18*).

Soil and groundwater

Transport systems contribute to contamination of soil and groundwater. Petrol filling stations can pose a risk of contaminating the groundwater and cause problems with subsequent use of the sites. For example, ground-

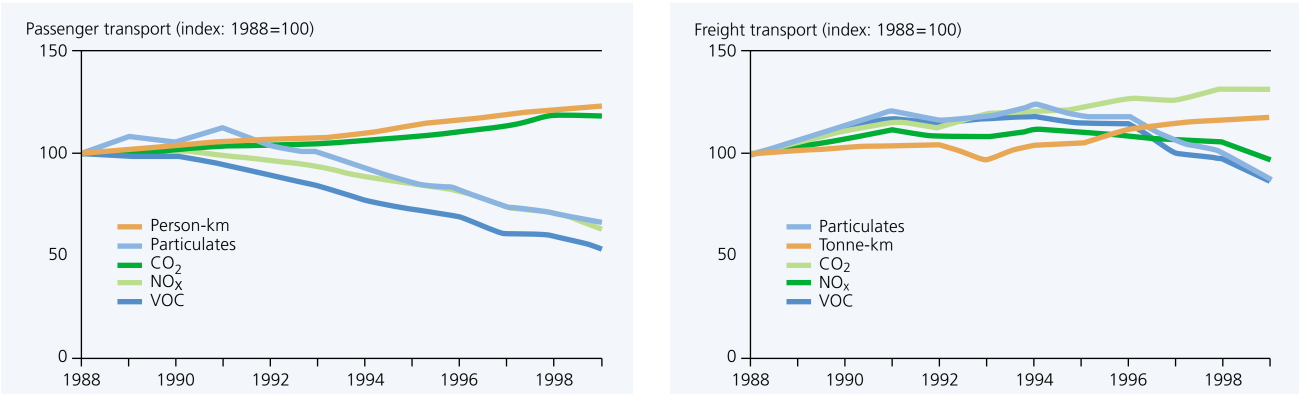


Figure 1.4.20

Indexed trends in passenger transport and freight transport and selected emissions over the period 1988–99. Left: Passenger transport. Right: Freight transport. Passenger and freight transport are measured in passenger-km and tonne-km, respectively.
(Source: National Environmental Research Institute, 2000).

water may be contaminated with MTBE (methyl tertiary-butyl ether), which is used to increase the octane rating of petrol. The groundwater beneath 479 filling station sites was investigated, and MTBE was detected at 102 of them.

Noise

Transport, and especially road traffic, is the most important source of noise. According to the latest estimates, 500,000 Danish homes are exposed to road traffic noise exceeding 55 dB(A), which is the Danish EPA's limit value. Of these, approx. 130,000 are exposed to noise exceeding 65 dB(A). The great majority of these homes are located in large towns, with more than half in Greater Copenhagen. Noise abatement measures implemented by the Danish National Railway Agency have reduced the number of homes exposed to rail traffic noise exceeding 65 dB(A) to approx. 7,000. The phasing out of the noisiest aircraft has reduced the number of homes exposed to aircraft noise exceeding 65 dB(A) to about 1,500. Lower levels of noise may also be a nuisance for wildlife and recreational areas, but no limit values have been set for these (*see Section 5.3.4*).

Road deaths

In 2000, 500 people died in road accidents in Denmark and 10,000 were injured (*Figure 1.4.21*). The number of people killed and injured has declined by about 30% since 1986. In the past 3 years, the number has fluctuated around the same level but was lower in 2000 than in 1999, which could be due to the levelling off of traffic growth. Detailed studies show that the official statistics only capture a small proportion of the total injuries. The number of road deaths is considered to be more reliable. Compared with other EU countries, Denmark has relatively few road deaths per 100,000 inhabitants.

An estimated 5 to 10 million wild animals are killed on the roads in Denmark each year. With some species, road deaths can influence the population and thereby biological diversity. A working group under the Danish Road Directorate found that the following species were particularly vulnerable: Amphibians, of which certain local populations may have been wiped out by road traffic; hares, of which so many are killed that this can limit the spring breeding population; and otters, of which road deaths are one of the major causes of death.

1.4.6 Objectives and initiatives

A number of action plans and targets have been adopted in Denmark and internationally to reduce the environmental impact of transport. The general aim is that the transport sector should contribute to sustainable development. One aspect of this is to promote decoupling of growth in the adverse effects of transport on the environment and human health and the growth in the economy. This must also entail limiting the negative effects of transport in the long term to what man and nature can tolerate.

Denmark has adopted specific targets for reducing transport emissions of CO_2 and the "regulated" emissions of NO_x, hydrocarbons and particulates. Targets have also been set for reducing the number of noise-plagued homes. These targets were set in the Government's 1990 transport action plan and reiterated in the 1993 action plan "Transport 2005" (*Table 1.4.2*) as well as in the national strategy for sustainable development. Future initiatives to reduce particulate emissions will focus more on the fine and ultrafine particles rather than on merely reducing the total particulate mass.

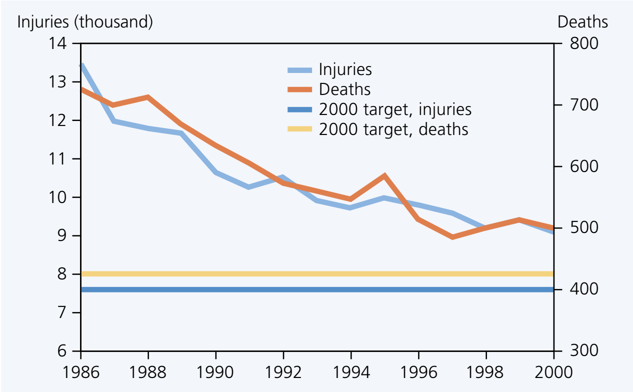


Figure 1.4.21

Number of road injuries and road deaths compared with the Traffic Safety Commission targets for the year 2000.
(Source: Statistics Denmark, 2001a).

The CO_2 reduction targets were revised in 2001 in the Government's action plan for limiting CO_2 emissions from the transport sector (*Table 1.4.3*). A further target is to achieve 85% recycling of scrapped motor cars and vans.

As regards the "regulated" emissions and noise, the trend is towards attainment of the targets, e.g. for NO_x. The overwhelming majority of this reduction derives from cars (*Figure 1.4.18*). This is due to the introduction of mandatory catalytic converters. With the other modes of transport both the share of NO_x emissions and the reductions are much smaller. The next largest share derives from lorries, for which the reduction did not begin until around 1999. The trends for hydrocarbons and particulates (total mass) are also approaching the targets. As regards noise, the impact on the most noise-plagued homes has also been reduced considerably. Achieving the target of reducing the number of homes subjected to noise levels exceeding 65 dB(A) to 50,000 by the year 2010 will require increased efforts in several areas, however.

The target for CO_2 emissions in the transport sector stipulated in the previous action plans was stabilization of CO_2 emissions at the 1988 level by 2005 (*Table 1.4.2*). It has not been possible to approach the adopted targets, though. Reassessment of the transport sector CO_2 emission targets and the means of achieving them was therefore initiated in 1999. The target for 2030 is a 25% reduction relative to the 1988 level.

The new targets were launched in an action plan published in April 2001. The original target for 2005 has been abandoned and replaced by new targets:

- The increase in the CO_2 emissions from transport is to be stopped
- Emissions are to be stabilized at the 2003 level in 2005
- Emissions in 2010 are to be reduced by 7% relative to the "business-as-usual" trend. This corresponds to a level approx. 22% above the 1988 level
- The long-term target of reducing transport emissions by 25% in 2030 has been maintained.

The action plan describes the specific initiatives and instruments to be implemented to achieve the new targets (*Table 1.4.3*). The expected future trend in transport sector emissions relative to the current targets is described in *Section 1.7.2* (Outlook).

Table 1.4.2
Current reduction targets for transport sector emissions and noise nuisance relative to 1988. The CO_2 targets are formulated differently than those of the other parameters, but entail an increase of 22% relative to 1988 (see text). The target for particulates applies to urban areas and encompasses total particulate mass.

1988 Baseline	CO_2	NO_x	HC	PM	Noise
2000		- 40%	- 40%		
2005	see text				
2010	(22%)	- 60%	- 60%	- 50%	max 50,000 homes >65dB(A)
2030	**- 25%**				

Table 1.4.3.
Initiatives to curtail the growth in CO_2 emissions by the transport sector. (Danish Government, 2001).

Strategy	Initiatives and concerted actions	Expected effect (percent) 2005	2010
Make energy consumption more efficient	• Information campaigns about fuel consumption of new cars	0.5	1.0
	• Energy-sound driving techniques	0.5	1.0
	• Promotion of speed limit compliance	0.5	1.0
	• Working group on tax and levy policy instruments to make energy consumption in the transport sector more efficient		ca. 2.0
Make transport more efficient	• Promotion of bicycle traffic	0.5	0.5
	• Promotion of green freight transport	0.5	ca. 1.0
	• Promotion of transport plans		0.5
Total		**ca. 2.5**	**ca. 7.0**