Energy Planning in Denmark--Methodology and Process

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The paper describes the methodology and process behind the latest energy plan of action for Denmark, "Energy 2000".

"Energy 2000" took the need for energy services as a starting point, whereas earlier planning primarily had been oriented towards supply. The possibilities for fulfilling the need for energy services given the overall goal of reducing the gross energy consumption and CO2 emissions were analyzed in sectorial as well as total analyses using the integrated-resources/least-cost-planning concept on a national level.

The technical data used in the analyses were either worked out by working groups, where most of the technical expertise in Denmark was represented, or on a consultancy basis by relevant experts. The results were submitted at hearings to other relevant experts or bodies in order to obtain a high degree of consensus on the basic technical data.

One result of the analyses was a ranking of the different measures--efficiency in end uses, efficiency in energy production and cleaner fuels--corresponding to the marginal costs of reducing CO2 emissions. The analyses also showed, that no single measure was sufficient to achieve CO2 targets on its own, therefore an effort has to be made in several areas. With the efficiency initiatives already undertaken in Denmark for heating in buildings the most cost efficient CO2-reduction measures proved to be electricity savings in the residential and commercial sectors. But small- to medium-scale cogeneration plants and other measures are also important.

Introduction

In the spring of 1990 the Danish Government presented a new national energy plan, "Energy 2000" (Danish Ministry of Energy 1990), containing an Energy Action Program. The plan shows that a 20% reduction of CO2 emissions before 2005, as recommended in the Toronto declaration, is indeed possible for Denmark. A further reduction to about 45% of present emissions seems possible before 2030.

"Energy 2000" covered energy use in all sectors except transport. But a similar plan for the transport sector was launched simultaneously. This reflects the general intent of the Danish Government to gradually obtain sustainable development in all sectors as recommended by the World Commission on Environment and Development.

The gross energy consumption in Denmark in 1988, which is the base year for "Energy 2000", was approximately 770 PJ. Roughly 30% of the energy was used for heating and 20% for electrical appliances in the household and commercial sectors, 30% was used in the production sector, and 20% in the transportation sector. For 1990 the figures are approximately the same.

The following presentation deals with the energy sector exclusive of transportation.

Background

Energy supply security and cost minimization were the primary objectives of Danish energy policy from 1974, when energy planning started, up to the "Energy 2000". Main emphasis was placed on the reduction of oil use and energy consumption--especially in space heating. Since the beginning of the seventies both the gross and net energy used for heating have decreased. Gross energy consumption per heated m2 has decreased by about 45%.

Heat requirement was reduced substantially through the use of policy measures of different categories and combinations, i.e. economic measures--energy taxes and subsidy schemes--information, regulations and building codes, research and development and organizational changes.

Increased efficiency in overall supply and oil substitution was achieved through expansion of district heating, combined heat and power production and the introduction of natural gas through a new natural gas grid.

Unnecessary competition between collective supply systems was dampened through heat planning, legislated in the Heat Supply Act from 1979.

Many changes in the Danish energy system can be attributed to the existence of our special energy planning system, characterized by a strong public involvement that is fairly exceptional in an international context. The heat planning system is based on the awareness of the fact that market forces alone would not bring about a realization of the radical changes in the energy system decided in 1979.

In accordance with the Heat Supply Act all major decisions must involve participation of local and relevant regional authorities, the energy supply companies and the citizens in the relevant area. The comprehensive planning system incorporates elements of centralized planning, making possible a reinforcement of national policy, as well as a strong local influence on plan contents.

The main role of the planning process may be described as providing a platform for resolving conflicts between competing areas of interest. The process does not obviate conflicts, but ensures that various options are compared fairly, including evaluation of consequences in a socio-economic and environmental context. A comprehensive program for research, development, demonstration and market creation through subsidies has pushed technological innovation with special priority given to fuel substitution (e.g. program for substituting oil by coal in the electricity production), energy conservation (e.g. development of low-energy houses) and renewable energy (e.g. wind, straw and biogas). Focus has been concentrated on high-risk and long-term projects and technologies, which industry would find too risky without support.

Limitation of the environmental effects of energy production always was and increasingly is being seen as an important objective of the energy policy.

Energy 2000--The Planning

The Energy Action Program in "Energy 2000" is based upon two basic assumptions. (1) Growth in gross national product is estimated to be about 1.9% per year for the period 1990-2010 and 1.22% per year for the period 2010-2030. (2) Overall CO2 objectives are to be met without reductions in the development of service and comfort of the population. Eventually the latter assumption might be reconsidered if necessary.

Compared to previous energy plans much more emphasis was placed on the expected development for energy services and how to supply these services with efficient appliances, technologies etc. (It might be compared to using the integrated-resources/least-cost planning ideas on national level, but not carrying it through in detail.)

The Analyses

As a part of the work with the energy plan there was developed a scenario model (Halsnaes and Morthorst 1990). The main characteristics of the model can be summed up as follows. It is a long-term simulation model looking to 2030, split into different sectors of energy demand and supply, although these sectors are integrated to give a comprehensive tool. Energy demand and the development of energy production capacity are driven from the demand side, and it is possible to choose different savings options as well as energy conversion technologies. The main results of the model are gross energy consumption split into different fuels, emissions of CO2, SO2 and NOx and the socio-economic costs[1].

A base scenario was prepared illustrating the development in a "business-as-usual" situation. Included in the base scenario is a certain technological development and a certain development in the level or intensity of energy services corresponding to developments in recent years.

To evaluate in particular the socio-economic consequences of possible developments in the energy system, projections of the socio-economic prices of fuel[2] up to 2030 have been made. Evaluation of future developments in prices is subject to very great uncertainty, and especially in the long term it is extremely hard to be sure of their possible tendencies. (Danish energy Agency 1990).

Sectorial Analyses. First a series of sectorial analyses focusing on the technical options that exist within separate parts of the energy system were carried out. The effects of an increased use of known technologies and of potential new technologies were evaluated.

To evaluate the effects of the technological possibilities, the development of the energy sector must be analyzed in a long-term time perspective. Descriptions and analyses therefore covered the period up to 2030. As there are obvious uncertainties attending such a long perspective, the analyses are only indicative of how things might develop if the structure of society remains more or less the same and no completely new technologies appear other than those that seem realistic at present. Especially in the long term, the compilation of the economic effects is most uncertain, in part because the costs relating to new consumption technologies are themselves uncertain.

This account of present and future technical possibilities is based on a number of studies that evaluate and summarize existing knowledge of technologies for potential savings from end uses, new and more efficient supply technologies and renewable sources of energy (Danish Ministry of Energy, background reports (1)-(5) 1990). Paragraph 4.2. includes some of the results for the building sector.

The purpose was primarily to throw light on the various long-term technical possibilities of reducing the environmental impact of the energy sector, and on the socio-economic effects involved. In evaluating the socio-economic consequences, most weight has been placed on developments in fuel costs, operating and maintenance costs and investments.

For technical conservation possibilities the compilations include only the increased costs, e.g. extra insulation of houses and the marginal costs of low-energy appliances. Thus the extra cost of the measures necessary to realize the savings has not been included, such as disseminating information, providing consultancy services and establishing efficiency standards.

Sectorial analyses have been made for the different areas mentioned above. In brief the analyses show that end-use energy savings can contribute significantly to reducing energy consumption and its environmental impact but savings alone cannot ensure reductions corresponding to the goals mentioned. Neither would it be sufficient merely to rely on changes in the supply system. Thus, several initiatives have to be taken.

Average socio-economic costs in connection with a reduction of CO2 emissions in 2030 by means of different measures are sketched out in Table 1. The negative cost of a number of measures is due to the fact that they imply lower costs than the base scenario.

It must be emphasized that these are the average costs when realizing the total technical potential in the individual areas. In a number of cases the first steps will be significantly cheaper and the later steps more expensive. This applies, for example, to heat conservation in existing buildings and to the extended use of renewable energy.

The table also shows the size of the reduction in CO2 emission in 2030 that the individual measure can bring about in relation to the base scenario. As the measures are not independent and exclude one another in several cases, the potentials cannot be summed up.

The various measures also have a number of positive socio-economic effects, i.e. for the balance of payments and employment.

The analyses of the residential and commercial sectors showed that:

Table 1. Average Socio-Economic Cost in Connection with a Reduction of CO2 Emissions in 2030 and Potential for Reduction (% of CO2 emission in the base scenario)

Measure	Costs DKK0.01/kg CO2	Potential %
Heat conservation		
in existing buildings	85	11
in new buildings	33	2
Electricity savings		
in dwellings and commercial	-66	12
Savings in production	-38	12
Increased CHP--natural gas	-55	13
More effective electricity production	15	29
Maximum connection to natural gas	-43	4
Increased CHP--biomass	-17	19
Renewable energy	5	26

- In the base scenario net heat demand will rise about 11% by 2030; electricity consumption in the residential sector will rise by about 13% and in the commercial sector by 100% by 2030.

- Full realization of the technical potential for heat savings up to 2030 in all existing residential and commercial buildings would mean a reduction of more than 50% in net heat demand and a rise of about 15-30% in socio-economic costs compared to the base scenario figures. Extensive previous efforts in this field now mean high costs for further improvements.

- If the entire potential for heat savings in new construction were realized, total net heat consumption would be reduced by about 7% up to 2030. This would incur small extra socio-economic costs.

- For the development in electricity consumption it seems technically possible to halve electricity consumption in households up to 2030. For the commercial sector energy saving measures could reduce the rise to only about 40% compared to the 100% foreseen in the base scenario.

Realizing the entire potential for electricity savings in households and the commercial sector means that electricity consumption in 2030 would be about 40% lower than in the base scenario, and socio-economic costs would be about 10% lower.

Comprehensive Analyses. Besides these sectorial analyses comprehensive development scenarios for the energy sector as a whole with different technological options combined were prepared. The aim was to identify and consider the more fundamental choices of development paths.

The scenarios chosen were a supply scenario, where efforts consist primarily in changing the supply structure and the use of fuel, an environmental scenario, with main emphasis on the reduction of the environmental impact (especially CO_2 emission) and therefore with a high priority of energy savings, and finally an economy scenario, where priorities were based on socio-economic considerations. The scenarios chosen do not mean that the development can follow only these; rather they reflect different priorities.

The analyses showed that by using the technologies known today and the technologies that are expected to be commercially available in the future, it is technically possible to fulfill the increasing demand of society for energy services and at the same time achieve significant reductions in consumption and environmental impacts including the emission of CO_2.

The Technical Possibilities

In connection with the preparation of the energy action plan data for the technical possibilities for energy conservation in the different end-use sectors were collected as well as data for new and more efficient supply and production technologies and for cleaner energy sources, especially biomass.

For each area the future technical possibilities were estimated along with their costs, the necessary research and development initiatives, the industrial development implications and eventual barriers. The evaluations were, due to the short deadline, based on the existing facts available. The estimates were made for the years 2000, 2015 and 2030.

The collection of data was organized in two ways. For the building sector--including the residential and the commercial sector--and the biomass resources the data were worked out by working groups, where most of the professional expertise in Denmark was represented. For the production sector and the energy supply and production possibilities the work was carried out by Risoe National Laboratory or the two Danish power companies Elkraft and Elsam. Afterwards the results were submitted to hearings among other relevant experts and interested parties.

The above mentioned procedure for procuring data was used in order to secure a common agreement on the technical possibilities in order to eliminate further discussions on purely technical matters, and instead concentrate the debate on the political aspects: which way to go and how far. The results are summarized in five reports (Danish Ministry of Energy, background reports (1)-(5) 1990).

The following examples will only deal with the building sector.

Heating. In spite of previous aggressive efforts there is still a fairly large potential for further savings in the existing buildings using only traditional methods of additional insulation of attics, walls and floors and by improving and draught-proofing windows (Working Group on Energy Consumptions in Buildings 1990). The potential is up to 75% for buildings built before 1979 and up to 50% for newer existing buildings.

Table 2 shows the estimated correspondence between saving possibilities in existing buildings and the corresponding average costs. About half of these costs are

Table 2. Investment Costs (DKK/m2 Gross Area) for Traditional Reduction of the Heating Demand (excl. of hot water) for Existing Buildings

	Typical Heat Demand GJ/100m2	Investment (DKK/m2) for a Reduction of 25%	50%	75%
Buildings Built Before 1979				
non-insulated	100-200	100-150	250-400	600-900
insulated	50- 70	150-250	350-500	800-1200
Buildings Built After 1979	30- 40	150-250	700-900	> 1200

costs of materials. The actual costs for remedies described will depend on how and how fast the energy savings are to be obtained. E.g., if the remedies are applied in combination with maintenance and renovation, the costs might be only a little more than the costs of the materials.

There are further possibilities for reducing the heat demand by use of passive solar heating, low-temperature heating systems and more efficient boilers.

In future construction, net heat demands can be reduced through the use of extra insulation, use of passive solar heat, changes in building designs and use of new materials, for example various kinds of transparent insulation. The working group estimated that it is technically possible to reduce net heat demand by 60% to 70% from the present level. The marginal costs were estimated to be at most those for using greater volumes of materials.

Electrical appliances. Consumption of electricity in the household sector exclusive of electricity for heating was in 1988 about 25% of the total use of electricity in Denmark, and another 30% was used in the commercial sector. For 1990 the figures are approximately the same.

The technical potential for energy savings in appliances was estimated for different kinds of equipment based on a very detailed knowledge of the stock of electric appliances in the household sector. For the commercial sector--the private as well as the public--the knowledge of the stock of equipment is less detailed, and the saving potentials have therefore been estimated for different end-use areas, e.g. lighting, ventilation, refrigeration and freezing. (Working Group on Energy Consumption in Buildings 1990).

The potential for savings in household equipment was estimated in the way that the average appliance in year 2030 will be as efficient as, or a little better than, the most efficient equipment today. But it is at the same time recognized, that it will be possible to have even more efficient equipment. Figure 1 shows the average electricity consumption by a 200 litres refrigerators in 1973 and 1988 and the most efficient technology in 1988, 2000 and 2015.

Figure 2 shows the estimated prices of some common household costs per appliance for the average and the most energy-efficient appliances. It is seen from the figure

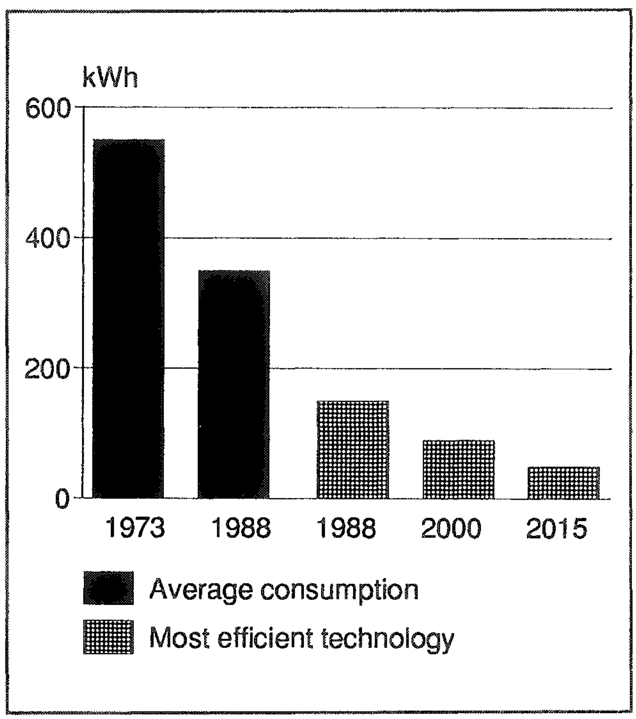

Figure 1. Development in Electricity Consumption by Refrigerators, in kWh/Year

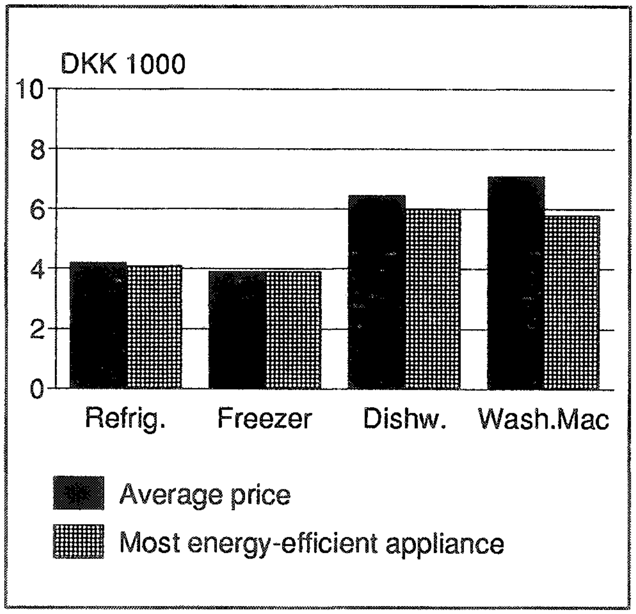

Figure 2. Average Price of Household Appliances Compared with Prices of the Most Energy-Efficient Appliance. (Source: the report division of the Association of Danish Electric Utilities, DEF)

that the average price and the price of the most efficient appliance is practically the same.

In the commercial sector the technical saving potential was, as mentioned above, only estimated for different end-use areas. In general the potential is subject to an evolution over time, but at the same time there is an upper limit for the saving possibilities. So the potential is expected to grow over the period, but more and more slowly. Table 3 shows the estimated technical saving potential in the private and public commercial sector. The savings are expressed as a percentage of expected consumption in the "business-as-usual" situation, allowing for those savings that are expected to be realized "automatically". As can be seen from the table the largest potential is within lighting and ventilation.

The average additional costs of obtaining these savings were estimated as the costs per saved kWh exclusive of the value of the saved electricity. A rough estimate of the costs of obtaining the 1st, the 2nd and the 3rd third of the potential in the different years is shown in Table 4. As can be seen from the table the costs were estimated to vary between -0.10 and +0.35 DKK per kWh (the socio-economic costs of 1 kWh was in 1988 about 0.35 DKK).

Table 3. Remaining Technical Conservation Possibilities Above What is Realized Automatically (% of consumption in base scenario) in Private and Public Service Sector

	Remaining conservation possibilities (%)		
	1988-	2000-	2015-
Private Sector			
Lighting	50	53	51
Ventilation	45	47	46
Cool/Freeze	35	37	34
Others	30	25	22
Total	40	39	36
Public Sector			
Lighting	52	58	60
Ventilation	48	57	62
Cooking/washing etc.	24	33	39
Electronics	31	49	75
Pumping	52	56	59
Others	29	26	30
Total	44	48	53

Table 4. Average Expenses for Conservations Inside the Private and Public Service Sector

	1st Third	2nd Third	3rd Third
	of the Technical Possibilities		
Private Sector			
Lighting	-10	0	15
Ventilation	0	15	35
Cool/Freeze	0	10	30
Others	5	5	20
Public Sector			
Lighting	-10	0	15
Ventilation	0	15	35
Cooking/washing etc.	0	10	25
Electronics	-10	0	15
Pumping	0	10	25
Others	0	5	20

The price for saving the 1st third of the potential for lighting was estimated to be negative due to expected savings in e.g. manpower used to change light bulbs, as compact flourescent lamps have an expected lifetime which is about 8 times the lifetime of an ordinary bulb.

Energy 2000--The Action Program

The plan of action contains measures to be taken within four key areas: energy end uses, restructure of the supply system, utilization of environmentally more acceptable energy sources and research and development.

Compared with 1988 levels, the plan of action is expected to reduce gross energy consumption by just under 15% up to 2005 (see Figure 3). This should be compared with about 9% rise of the base scenario. The decrease is due to energy savings in the end use sectors and a more efficient energy supply system.

The growth in power consumption up to 2005 will be reduced to a third of the growth in the base scenario. In the action plan the electricity consumption is expected to increase mainly in the period up to 2000 until efficiency standards etc. take full effect.

Trends in emissions (see Figure 4) are estimated to include a decrease of nearly 30% in CO2 emissions before 2005, thanks in part to the reduced energy consumption by savings and increased efficiency, and in part to the switch to cleaner fuels such as natural gas, biomass and other renewable energy sources. In the base scenario CO2 emissions increase by about 4% up to 2005.

In addition, by 2005, SO2 and NOx emissions will fall considerably.

The action program is estimated to call for increased investments up to 2005 compared to the base scenario, but these are expected to be offset by drops in socio-economic fuel costs and operating and maintenance costs. As a whole the action program is therefore not seen as a greater burden on the economy than the development assumed in the base scenario (see Figure 5).

Evaluating the total effect is subject to a good deal of uncertainty, particularly for savings in households and the commercial and manufacturing areas. Some of the methods have never before been applied in a Danish context, some background data are incomplete, and collating the impact of each of several measures launched simultaneously is difficult.

The listed results should be regarded merely as a qualified estimate of the total impact of the plan of action. In working out detailed formulations of the methods, uncertainty can often be reduced, especially if the assumed systematic follow-up and evaluation of methods is started without delay.

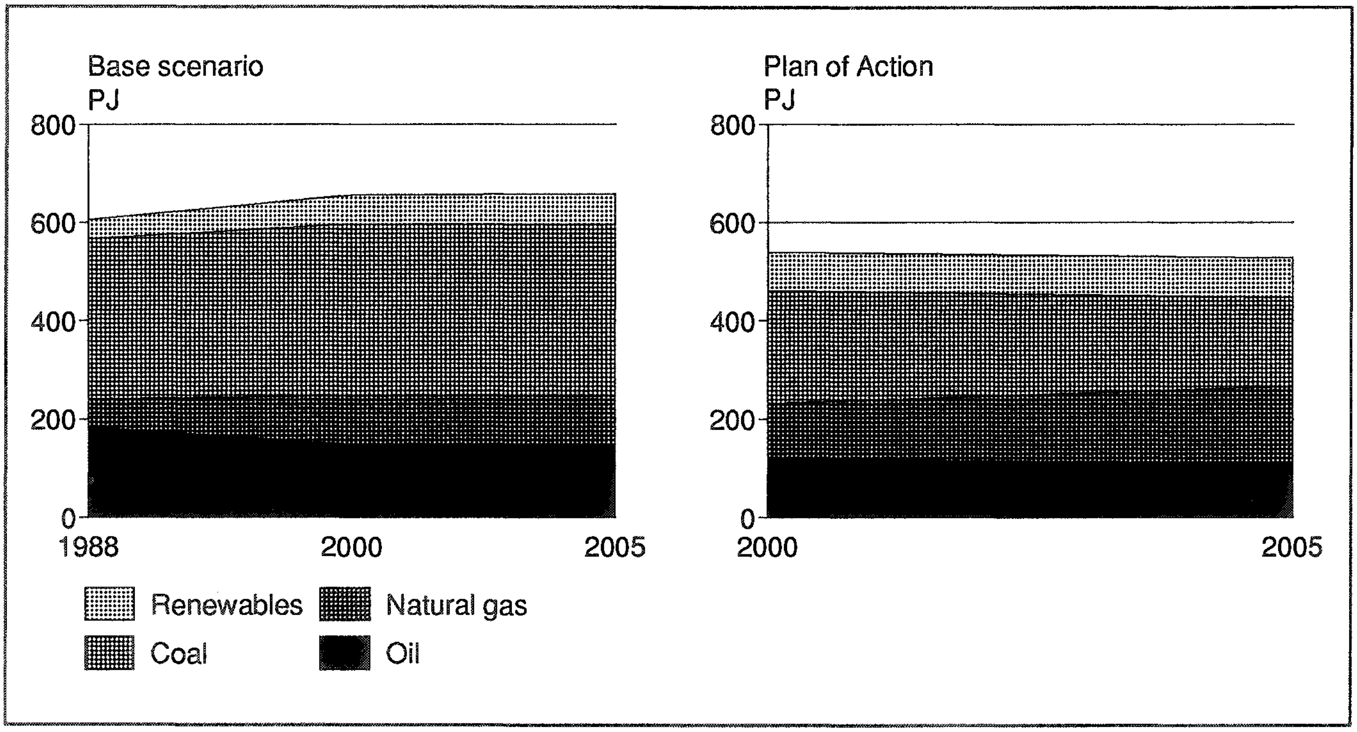

Figure 3. The Development in Gross Energy Consumption and Its Distribution over Fuels in the Plan of Action Compared with the Base Scenario

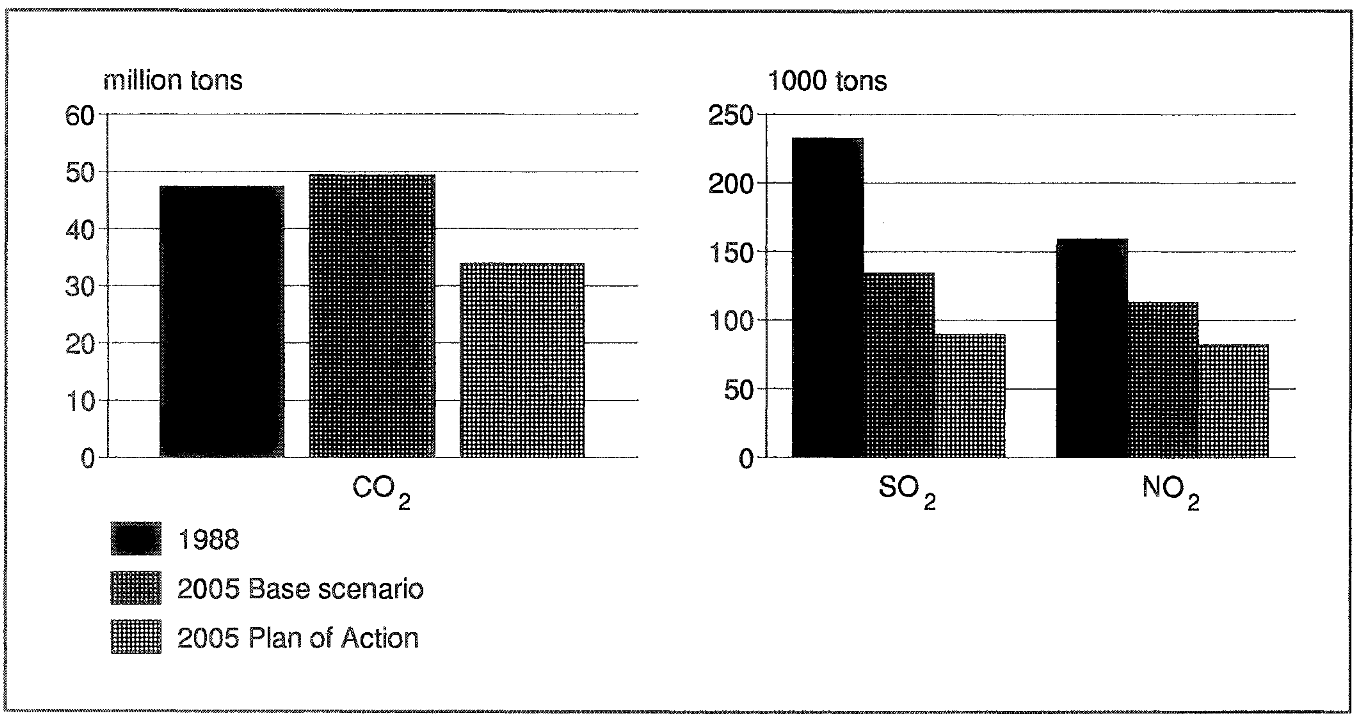

Figure 4. The Development in Emissions of CO2, SO2 and NOx in the Plan of Action in Relation to the Base Scenario

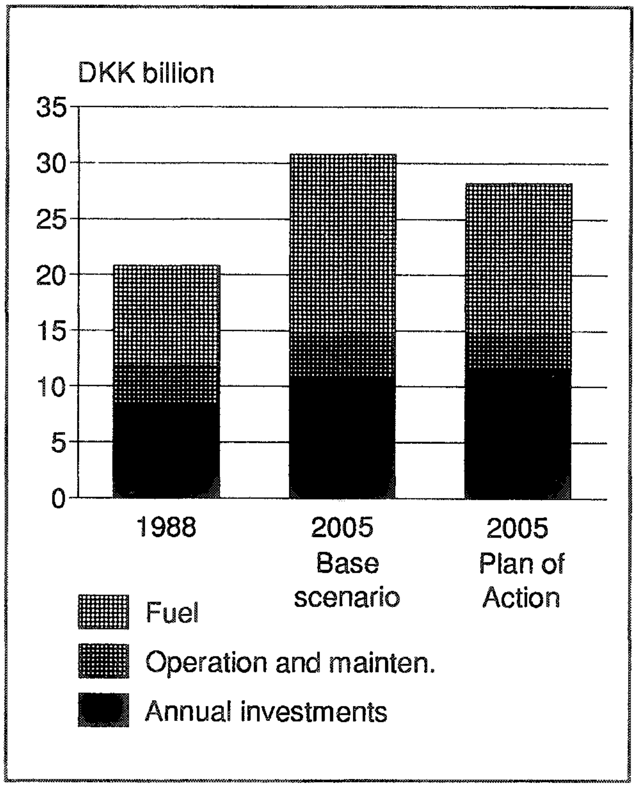

Figure 5. The Socio-Economic Costs in the Plan of Action Compared with the Base Scenario

It was neither possible--nor the point--to look for specific plans for the evolution of the energy sector over the next half century. The overall strategy should be formed through continuous updating of targets and measures. Therefore the action program primarily contains measures that can be implemented now and which will constitute the foundation for continuous adoption and serve as a springboard for continuous updating.

Action Areas

The action program contains 79 specific action areas. It is a very ambitious program and to illustrate the nature of the actions areas some examples from the building sector are given in the following. It is recognized that realizing the potential for energy savings is an immense task as it influences millions of individual consumers.

- Taxes and tariffs are probably the most direct and effective means of control. The Government will seek to modify the system of energy taxes with a view to making it more supportive of long-term energy and environmental targets, although not at the cost of other socio-economic considerations such as Danish competitiveness on the international market. To be considered was i.a. the introduction of environmental taxes on CO_2 and SO_2 coupled with continued use of ordinary energy taxes.

- The Government will work to reduce heat demand in new buildings by 25% by 1993 and by 50% by the year 2000 in relation to the present requirement. Furthermore mandatory standards for maximum electricity consumption for fixed ventilation and lighting installations in new buildings will be introduced. For existing buildings the requirements of heat inspection reports when buildings are sold will be tightened and energy-savings costs will be included in the calculation of special heating benefits to pensioners.

- Also the introduction of electricity and heating billing based on consumption of individual households will be encouraged.

- Labeling schemes and standards for maximum electricity consumption allowed in household appliances will be introduced to promote energy awareness among the consumers in connection with the purchase and use of electrical appliances.

- The Government will introduce energy management, with a consultancy scheme, in state-owned buildings over a three year period and seek to conclude agreements with landlords on energy management in buildings leased to the state.

It is expected that as a result of more stringent building regulations heat consumption in new buildings will be reduced. In existing buildings estimates are of savings of some 10% of heat consumption per m2 up to 2005. Altogether, by 2005 heat consumption is estimated to fall by 10% compared with the base scenario.

For the electricity consumption the action program is expected to realize 35% of the technical potential in households and 50% in the commercial sector corresponding to an electricity saving of about 20% in 2005 compared to the base scenario.

Final Remarks

The Danish energy plan of action shows that it is possible for Denmark to adopt Toronto objectives for reduction of CO_2 emissions. But an effort has to be made in several areas. Up to now the following initiatives have been taken with respect to energy saving in end uses (the ranking is random):

- CO2 taxes and most of the corresponding subsidy schemes have been approved by the EEC.

- New building regulations are under preparation and are expected to be introduced in 1993.

- A campaign for energy efficiency in government buildings will start up in 1992 and is expected to run for three years.

- Labeling schemes have been notified to the EEC. Common EEC labeling schemes are expected in 1993.

- Denmark participates in work concerning standards for the maximum electricity consumption allowed in household appliances--in Nordic and European connection. The EEC are preparing voluntary standards.

- The electricity sector continues their own DSM activities, e.g. energy audits to large customers, arrangements for third party financing, campaigns for compact flourescent lamps, combined programs for scrapping of old appliances/rebates for new energy efficient appliances and publishing manuals on energy auditing and of "energy-arrows", (folders where the efficiency of different household appliances on the market are compared).

Endnotes

1. The socio-economic costs include socio-economic fuel expenses, operation and maintenance costs and investements. The investments have been converted into an annuity on the basis of the lifetime of the individual investments and an estimated social discount rate of 7% per annum. This is called the socio-economic costs in a "narrow" sense.

   Besides this the evalution of the socio-economic effects includes an evaluaion of the effects on foreign exchange expenditure, employment and the environment, i.e. emissions of CO2, SO2 and NOx. Cost estimates of avoided externalities are not included.

2. Socio-economic fuel prices are average prices exclusive of energy taxes and VAT but inclusive of the average costs of transportation, e.g. from the import habour to the user. The prices are expressed in DKK per GJ (fixed costs at 1988 level).

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