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The Little Country that Could: Danish Energy Policy and Practice

Chandra L. Meek
Western Washington University

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Bellingham, Washington 98225-9089
(360) 650-3034

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The Little Country that Could:
Danish Energy Policy and Practice

Two BONUS 450 kW wind turbines at Kegnæs Ende, Sydals, Denmark

Huxley and Honors Senior Thesis

Chanda Meek

Spring Quarter, 1996

Outline and Table of Contents

INTRODUCTION

Danish Environmental History

Over the past 25 years, Denmark has made a transition away from an industrial society with a large agricultural sector towards a service economy. Rapid growth in production volumes has resulted in a higher level of resource consumption and pressures on the environment. This development has influenced Denmark's environmental policy, which has grown and diversified over the years. The following statement is indicative of the Danish commitment to the environment and the realization that Denmark is one of the world's leaders in sustainable development:

> The most environmentally conscious countries must therefore be prepared to act as front-runners in the international debate as well as in their own restructuring of production and consumption. At the same time, they must support the poor countries financially and technologically in their restructuring process (Ministry of Environment and Energy, 1995).

The average Dane is conscious of national environmental aims and policies, which transcend many sector boundaries and impose strict demands on virtually all activities in both industry and households. As of early 1995, concrete action plans had been enacted for energy, transport, and agricultural sectors of the Danish economy. Denmark has a unique federal system, combining a strong central government with a broad range of local municipality decision-making. Regulatory actions are frequently based on the precautionary principle, the idea that prioritization of environmental concerns must be based on well-founded documentation but prevention of pollution is given the highest priority. Environmental considerations, even at the planning stage, are integrated into all central government decisions which impact the environment. Citizen involvement is also an integral characteristic of Danish environmental history. Organizations and interest groups are frequently consulted, and a system of public review is in place for significant actions.

The use of management tools has also changed over the years from strict control through prohibitions, orders, authorizations and monitoring to a

situation in which this management system is increasingly coupled with information, agreements, and financial tools (i.e.. taxes and grants) (Ministry of Environment and Energy, 1995).

Agenda 21 and Denmark

Prior to the 1992 United Nations Conference on Environment and Development, the Folketing (Danish parliament) enacted a plan for a 20% reduction of CO_2 emissions by the year 2000. This plan was enacted two years before Denmark became a signatory to Agenda 21, the United Nations (UN) program of action for sustainable development; the Rio Declaration on Environment and Development; and the UN Framework Convention on Climate Change among others. Denmark has taken its commitment to the reduction of greenhouse gases seriously, and is one of only five countries who have implemented CO_2 reduction strategies (Ministry of Foreign Affairs, 1995).

Following the Rio conference, the Folketing moved to increase Danish international assistance for environmental protection and disaster relief to 0.5% of gross domestic product by the year 2002. Some of these funds are earmarked for developing countries and the Arctic region and are administered by the Ministry of Environment and Energy through the Danish agency, DANCED, Danish Cooperation for Environment and Development, started in 1993 to further Agenda 21. The Folketing appropriated 300 million DKK (approx. 60 million USD) in 1995 towards technology and expertise transfers to southern Africa, South-East Asia, China, and other nations (Ministry of Environment and Energy, 1995).

DANISH ENERGY POLICY

Energy 2000

As a commitment to global climate policy, Folketing enacted an action plan in 1990 for the reduction of CO_2 entitled "Energy 2000". The overall objective outlined in Energy 2000 was a 20% reduction in 1988 CO_2 levels before the year 2005. By 1993, however, the Ministry of the Environment published a report showing that CO_2 levels had actually increased because the plan had not been fully implemented and relied on overestimates of energy reductions in certain sectors. A number of assumptions about

electrical consumption have not transpired, and as of 1993, use was expected to increase. The majority of the initiatives are implemented in the energy and transport sectors. The Danish government has realized that the energy sector must be encouraged as well as taxed and regulated because the energy sector represents an important area for Danish technological development and economy. In addition, growth in the energy area also benefits the private sector by providing energy alternatives and efficiency research. A policy follow-up was published in 1993, and further initiatives were outlined to reorient towards the goals put forth in Energy 2000 (Ministry of Environment and Energy, 1993).

Energy 2000 follow-up

Four themes. The main directive of the follow-up is to advance energy savings in the energy and transport sectors. The following four themes are emphasized: economic considerations, international considerations, long term goal-making, and popular support. A well-organized effort in energy efficiency by the business community is expected to bring a number of both short-term and long-term industrial benefits, including economic incentives from developing marketable solutions for resource scarcity. Overall, externalities are projected to decrease, lessening economic loss from pollution. During the short term, the realization of energy objectives will have a certain price; however, the government is aware that the initiatives must not impair competitiveness while keeping in mind the longer-term possibilities of economic gain inherent in technological development.

The environmental effects of greenhouse gases are cross-boundary. Denmark learned this lesson early with acid rain problems in the 70's and 80's. Danish efforts to make energy consumption and supply more efficient are also a firm basis upon which Denmark can put pressure on the EC and global community to ensure that the environmental agreements and international protocols are met. Since 1990, environmental problems have gained prominence in world politics. International energy cooperation increasingly emphasizes market orientation and the lowering of national barriers in the energy sector; however, it is Denmark's contention that this trade liberalization tendency be seen in the context of environmental objectives and that it is implemented so as to not undermine environmental

policies in individual countries, hence Denmark's hesitancy to join the European Union (EU). Renewable energy aid collaboration for Eastern Europe and the former Soviet Union has intensified in recent years; the Danes are particularly interested in reducing Russia's dependency on nuclear energy, given its unpredictable safety precautions. Denmark's proximity to former communistic societies such as Russia and Poland engender unease about nuclear accidents. For these reasons, the Danish Government perceives the duty of established environmentally-aware countries is to contribute support and technology for sustainable development elsewhere. In addition to financial assistance, Denmark has exceptionally valuable expertise to offer in terms of energy efficient solutions.

The third theme of the follow-up is long-term considerations. Energy initiatives must be organized with long-term goals in mind. The objective of 20% reduction of CO_2 emissions must be coupled with decisions about next century's development, and the initiatives in the present will most definitely affect the course of that development. One basic long-term consideration is the international trend in rising electrical consumption. The Bruntland report, which began the modern international environmental era, recommends that industrialized countries halve their energy consumption per inhabitant over the next 40-50 years.

The fourth theme centers on popular support. In order to realize a significant reduction in energy consumption and the environmental impacts associated with it, an effort must be made over a broad front and involve every Danish household. Consequently, the Danish government seeks to find solutions and measures that promote and uphold broad popular support behind the necessary tools. The government will place an emphasis on market-oriented and administratively simple solutions. Although strict regulatory action may accomplish a greater environmental effect for the investment, the government has decided to emphasize voluntary agreements and subsidies.

Goals. The goals outlined in the Energy 2000 follow-up fall into the following six categories: energy conservation, planning, energy supply, renewable energy, research and development, and international relations. Under the conservation heading, the Ministry has identified avenues for energy savings in both the public and private sectors, including conservation of heat. For instance, building regulations for total maximum energy

consumption were made more stringent in 1994. These regulations included a change in the subsidy scheme for improvements in apartment complexes to provide for individual metering for electricity, gas, water, etc. and requirements for new buildings to be serviced with district heating. Another efficiency measure is the Government's Bill on standards for energy efficiency in electrical equipment, including household appliances. The law is intended to authorize the Energy Agency to create binding efficiency standards for appliances. In addition to these regulations, a strong information campaign was intended to inform the Danish market of energy conservation, including energy labeling, informative electricity bills, and campaigns for replacing inefficient appliances.

In the public sector, a plan was to be implemented which requires energy management in all local government bodies, and energy standards monitored in the purchase of equipment. In the industrial sector, a number of measures have been started, including the introduction of the CO_2 tax, subsidies for energy savings, committee discussions with trade organizations on the introduction of green taxes without hindering competitiveness, and voluntary agreements on energy efficiency with industries.

Today the total gross energy consumption in Denmark is approximately at the same level as in 1971 (Danish Energy Agency, 1995). The Danish plan for future electrical supply and demand centers on co-generation of heat and power (CHP) plants. The idea behind CHP is simple, electrical power companies produce a fair amount of excess (waste) heat which is released into waterways in many countries and consequently act as a form of pollution on water plants or animals. CHP plants transport steam or water waste heat through insulated, underground pipes into surrounding residential communities and businesses, serving as a district heating network. This heat source reduces the amount of electricity or natural gas a home uses. CHP plants burn a variety of fuels including biomass, straw, natural gas, coal, and oil. The Government anticipates that the power companies will substantially contribute to realizing energy policy objectives and reducing environmental impacts. To this end, the Government has begun a series of environmental planning projects to guide the Danish utilities into the 21st century.

The energy supply network, the method for heating and powering Danish households and businesses, will be systematically updated.

Several measures have been introduced to increase energy efficiency, including a bill for amending the Heat Supply Act which requires residences and businesses within a central heating district to utilize the system instead of converting to electric heat. Conversion to electric heat generally causes consumption of more energy than heat based on natural gas or CHP and makes later connection to district heating supply more difficult. Another element of the supply network plan is expand CHP production and change steam-based heat networks to water-based district heating.

The Government's commitment to renewable energy is considerable. A committee has been established to promote municipal wind turbine planning and a large-scale information campaign to municipalities about the benefits of wind technology. Another initiative has been drawn up to promote the replacement of less efficient wind turbines with the latest technologies. Yet another committee has begun to evaluate further off-shore wind development possibilities. Small wind turbines have also been promoted for private businesses and municipalities.

Biomass is another form of renewable energy Denmark has been steadily developing. An agreement was formed on June 14, 1993 between the Government and the 3 leading opposition parties on the increased use of biomass in energy supply. The agreement plans for large power stations to increase their use of biomass so that by the year 2000 there is an input of 1.2 million tons of straw and 0.2 million tons of wood chips in use. Concurrently, technical problems associated with the inputs of biomass and residual products will be researched. Additional research has been initiated into the feasibility of using biomass outside of collectively supplied districts, the increased use of biogas from disposal sites, use of biogas for transport, and a biomass development project on the small, agricultural-based island of Bornholm. Development financing for Bornholm projects has been guaranteed at approximately DKK 50-75 million.

Technological research and development in solar technology has progressed due to a concerted effort by the Government to increase alternative energy resource use. Solar heat prices have fallen by about 35% in the Netherlands through large-scale production by power plants and district heating plants who receive state subsidies for solar heating. The transfer of such a subsidy scheme is an interest to the Danish government.

Overall energy research and development is a strong component in Energy 2000 and the subsequent follow-up. The Government aims to continue funding and promotion, including alternative financing schemes for trade and industry involvement. A coordinated effort is to be made for marketing transferable renewable technologies to Eastern and Central Europe, and assisting with developing efficient technologies in those countries. The Government is especially interested in strengthening the export of biomass technology.

In terms of international initiatives, the Danish government has designed and implemented Energy 2000 to follow up the Rio Climate Convention. The Government will pressure and encourage international organizations such as the Organization for Economic Development and Cooperation (OECD) to be actively involved in setting and achieving CO_2 reduction goals. In addition, Denmark is playing an active role in the overall climate change strategy for reducing total EC CO_2 emissions before the year 2000, as well as promoting CO_2 monitoring and green taxes throughout the EC. Denmark has made a firm committment to sustainable development worldwide through its international development aid agencies (Ministry of Environment and Energy, 1993).

Projected benefits. Denmark is experiencing a rising trend in total energy consumption and it is the purpose of the follow-up to curb this rise. Without the follow-up initiatives, total consumption of energy is expected to rise by over 16% between 1992 and 2005, this rise concentrated primarily in the manufacturing and service sector. Electricity consumed by households is projected to stabilize. The original estimate of household electrical use in Energy 2000 was much lower than current levels, leading to a re-evaluation of energy strategies. Household use is targeted in the follow-up in order to achieve this stabilization with combined heating districts, energy-efficient appliances, and energy taxes.

It is assumed that 75% of electrically-heated buildings will convert to natural gas or district heating as a result of regulations and incentives. In addition, an expansion of wind turbines should average above 40 MW per year. Connections to district heating, natural gas networks, and biomass plants will increase. CHP will be promoted, leading to significant efficiency improvements in the energy supply. Further expansion of power plants will utilize natural gas, coal, or other fuels. An overall reduction of 20% in CO_2

emissions will be achieved by a transition away from fossil fuels towards renewable energy sources (figure 1).

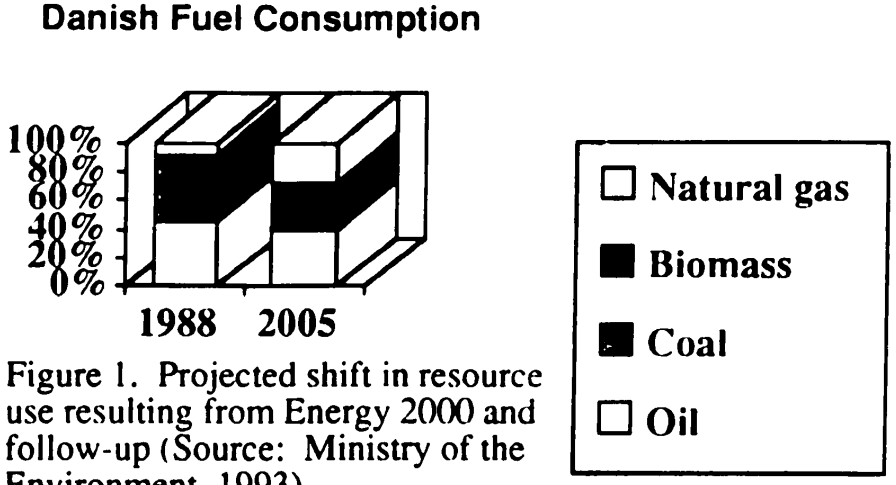

Figure 1. Projected shift in resource use resulting from Energy 2000 and follow-up (Source: Ministry of the Environment, 1993).

Projected costs. The Energy Agency's calculations on net cost of CO_2 reduction show that the initiatives will mean net costs during the first 15 years. After this period, the Agency anticipates a rising profit from exported technology and efficiency savings to achieve a net neutrality. The Danish Economic Council published in 1993 a survey of the costs involved in a 20% reduction of CO_2 emissions using a macro-economic model. The Council found that the target reduction would be the result of an overall tax of DKK 300 per ton of CO_2. This drop in emissions is caused by a change in the efficiency of energy production and the use of more expensive fuels with less environmental impact. If wages are flexible, this assumed tax level will result in an approximate private energy consumption decrease of 1% by 2005. According to their calculations, the costs of reducing a ton of CO_2 are approximately equal to the assumed tax of DKK 300 per ton CO_2 emitted.

Investments made in energy efficiency are estimated to be cheaper at the present time than attempting to retro-fit existing operations in the future. All of the independent assessments of Energy 2000's costs concede that a considerable uncertainty exists concerning the development of both technological and economic parameters. However, most economists predict an overall rise in fuel prices as resources become depleted. This development would no doubt be beneficial to Denmark's alternative energy

production sector, which is also problematic to quantify in an economic model.

ENERGY INITIATIVES

Public sphere

Aesnæs power plant. Aesnæs power station, with a production capacity of 1500 MW, is Denmark's largest power plant, supplying 60% of the demand in Eastern Denmark (where most population is concentrated). The plant supplies electricity to the island of Zealand, district heat to the local municipality of Kalundborg and process steam to neighbor companies. The plant is coal-fired but is in a transition stage to burn a new type of fossil fuel called Orimulsion, from the Orinoco River in Venezuela. The River is a natural bitumen reservoir, and water is a carrier of bitumen so it is easy to extract. In addition, Orimulsion is both cheaper than either heavy fuel oil or coal and produces less CO_2 when burned (Asnæs Power Station, 1995).

Fuel	Price ($/ton)	Reduction of CO_2 (compared to heavy oil)
Orimulsion	30	40
Heavy oil	70	-
Natural gas	n/a	17
Straw	n/a	100

Table 1. Cost and CO2 savings from Orimulsion as compared to other fuels (Source: SK Power, 1995).

The Asnæs power plant also forms the core of an experimental networking of businesses to recycle waste products called the Kalundborg Industrial Symbiosis, which will be discussed later.

Biogas. Denmark has been using biogas from methanization of sewage sludge for motor fuel used in electrical production for more than 50 years. In response to the energy crisis of the 70's, Danish engineers began to develop technologies to collect biogas from farm wastes. Biogas plants digest 70-90% animal manure and 10-30% pure organic wastes from slaughterhouses or food industries to make both biogas and fertilizers. The

plants are said to benefit small farmers economically, improve utilization of fertilizers, reduce greenhouse emissions, and encourage environmentally sound waste recycling (Danish Energy Agency, 1994) Initially, small plants on farms were developed. However, a number of large scale plants have been developed for marketable energy. Presently, 10 farm plants and 9 industrial plants operate in Denmark. Seven of the large-scale plants provide both heat and power production, while three of the plants provide only district heating (Ministry of Energy, 1992). The annual potential for biogas production in Denmark is estimated at 25-30 PJ which is 3.1 to 3.8 % of the total energy consumption (Danish Energy Agency, 1994).

Biogas plants are environmentally attractive as an alternative to fossil fuel combustion, because they emit less CO_2. Farmers have also begun to supply biogas plants with manure as a sound waste management solution. This practice is reinforced by environmental regulations for the storage of manure which have tightened in both Denmark and the EC as a whole. Farmers reap financial advantages from biogas plants in terms of fertilizer quality. The fertilizer returned to the farmer is a mix of high potassium cattle manure and high phosphorous pig manure which, when digested, becomes a highly concentrated chemical-free fertilizer, reducing nutrient runoff and pollution. The farmers save an estimated DKK 4-5 (USD 0.60-0.70) per m^3 of slurry due to the savings on fertilizers, waste storage, and slurry spreading (Tafdrup, 1995).

Sønderborg is a small municipality located on the Danish peninsula, Jutland. This small town is home to a combined gas fired combined cycle CHP plant. The plant is constructed to achieve a thermal efficiency of 86% from the burning of 30 million m^3 Danish natural gas and 55,000 tons of refuse per year in order to suppply 183,000 MWh/s of electric power and 221,000 MWh/s of hot water for district heating. Integrated into the design of the flue gas cleaning plant is a scrubber which uses 40,000 m^3 per year of wastewater from a nearby municipal sewage treatment plant. The plant was built and will be operated by an umbrella group composed of local power, district heating, and refuse treatment companies (Ramsgaard-Neilsen, 1994).

Windfarms. The use of wind for energy purposes has a long tradition in Denmark, beginning in the middle ages as a main source of energy for small farms. During the second half of the 19th century, 3000 commercial

windmills supplied the population with mechanical energy. In the first decades of this century approximately 30,000 farm mills were added to the power structure, for a total approximate wattage of 150-200 MW. Modern wind turbine production took off in the 1980's, increasing the available energy to an average of 155 kW/windmill. As of 1991, the total number of grid-connected wind turbines, privately or utility-owned, was 3,218 units, with a total energy capacity of 418 MW. The power generation during this year was 740 GWh, corresponding to 2.3% of the Danish electrical consumption (Danish Energy Agency, 1992). A premier Danish wind tubine producer, Vestas A/S, has built and supplied 4000 wind turbines to projects in 19 countries, including India, the US, and Greece, with a combined energy capacity of 490 MW (Danish Energy Agency, 1992).

Since 1984 many wind turbines have been installed in windfarms, most of which are owned by the electric utilities. The development of private, small scale wind turbines is no longer promoted by installation subsidies. Reasonable payback rates for excess production and exemption from electricity taxes is the main economic incentive, which has remained popular among farmers and small communities. Several agreements have been reached over the years between utility companies and the Danish government to install 200 MW in windfarms since 1985. These agreements are characteristic of many Danish energy policies; they are not mandated by legislation or regulatory requirements.

The majority of Danish voters are reported to favor renewable energy, and this favor is reflected in the fact that all parties in parliament except for one support strict environmental protection. With this disposition in mind, the utilities prefer to negotiate with the government than to adapt to new legislation. The cost of wind energy in Denmark has fallen approximately 75% since 1980. Further decreases are expected as the installation of larger and more efficient turbines continues. For machines with a power capacity of about 500 MW, the costs of energy are illustrated in table 2 (Nielsen, 1994).

The Danes have begun experimenting with off-shore wind farms. October 1991 saw the first such farm inaugurated at Vindeby, north of the island of Lolland. The project has received funding from the European Community (EC) and has a total budget of more than 80 mill. DKK (approx. 12.3 mill USD). The wind farm is composed of 11 wind turbines sited in two

rows with a combined rated power of 450 kW. The specific output is expected to be approximately 60% higher than for average onshore sites or

Year	Cost (kWh/DKK)	Cost (kWh/USD)
1987-1989	0.50 - 0.60 DKK	0.078 - 0.094 USD
1990 - 1992	0.38 - 0.45 DKK	0.059 - 0.070 USD
1993 (projected)	0.30 - 0.40 DKK	0.047 - 0.063 USD

Table 2. Comparitive yearly cost (kWh/DKK and USD) of wind turbine electricity in the ELSAM area, Denmark. US dollars based on 1993 exchange rate (Nielsen, 1994).

1130 versus 700 kWh per year per m^2 of swept rotor area. However, the cost of energy produced by this prototype is estimated to be 50% higher than for average inland sites because of its high installation and maintenance costs (Nielsen, 1994).

Two environmental problems associated with windfarms, noise and disruption of bird habitat have been leading reasons for resistance by Danish municipalities to construct more windfarms. To this end, a statutory order was issued by the Ministry of the Environment and Energy in 1991 requiring the owner of wind turbines to prove to municipal officials compliance to noise standards. The impact of wind turbines on bird life has been studied in relation to two utility windfarms built near bird sanctuaries. Radar observations at one site indicated that birds are generally able to detect and avoid the turbines. In addition, the risks are comparable to the impacts of nearby road and vehicle noise. Wind turbine construction noise and other physical disturbance are the most intense impacts (Nielsen, 1994).

Solar Technology. During the last 25 years, approximately 16,000 solar heating systems have been installed in Denmark, the majority being sold since the 1980's. Most active solar systems are used for the production of domestic hot water for single-family houses, multi-story dwellings, and institutions. Other uses include systems for both space heating and production of domestic hot water, as well as various larger plants. Denmark has provided a state subsidy of the establishment of solar systems since 1979. During 1994, support was given to 2,500 systems. The Danish Energy Agency's subsidy scheme is divided among the following sectors:

CHP and district heating 20%, natural gas 43%, and individual heating systems 37% (Danish Energy Agency, 1995). The energy savings as a result of both active solar heating systems and building-integrated and passive solar heating systems are estimated to correspond to 0.25% of the total heating and domestic hot water energy consumption.

The Danish solar plan of action, begun in 1992, has been updated every two years. The plan of action from 1992 to 1994 has recently been evaluated by the Solar Energy Committee. The principle goal of this period's plan was to promote active solar heat. Two other dominant goals involve building-integrated passive solar in the form of glass extensions, glazed balconies, and solar walls as well as the promotion of solar cells, which directly convert solar energy into electricity. Projects from this period include the following: improvement of the quality of solar systems and their installation, research and development, improvement of cost effectiveness, and increasing the turnover of solar systems from 200 installed in 1987 to 2500 systems in 1994. The principle goal was to increase the installations to 4-6000 systems per year, which still has not been met (Danish Energy Agency, 1995).

The committee recommends that all three goals must be integrated in order to make active solar systems attractive to the marketplace and to achieve a turnover of 4-6000 systems per year. The committee anticipates reaching this goal by a vigorous public information and marketing campaign, research and development to create more efficient systems, and gradual subsidy reductions in order to increase competition. 1992-1994 did not achieve the 4-6000 system installation goal for several reasons. The committee reports that the subsidy for active solar heating systems was increased against their recommendation as part of a non-related housing bill. The committee's intention was to spur competition in order to reduce prices through marketplace incentives. Prices did not fall even though additional manufacturers entered the market, partially due to the high subsidies. However, information campaigns have been successful in motivating and educating the public. The quality of solar systems has also been dramatically improved during this period (Danish Energy Agency, 1995).

The first period of the plan brought about a "breeding ground" for further development and cooperation from the utilities (electricity, natural gas, and district heating) in the promotion and use of solar heating. Towards the end

of the plan, it is anticipated that the solar heat trade will be self-supporting so that the subsidies can be phased down in order to maintain the agency's solar budget of DKK 30 million annually. The target for years 1995-1997 is to maintain and increase the total development of active and passive systems, solar cells, and building-integrated systems. The plan has been extended towards 2030, with a final solar exploitation goal of 41 PJ/annually. The plan anticipates that solar cell collecting systems will become competitive after the year 2000, when the installment of decentralised CHP is completed across Denmark. At this time, the tentative assumption is that electrical production from solar energy will approximate 300 GWH annually, 1% of the annual consumption of electricity. By the year 2030, the agency anticipates solar will supply up to 3000 GWh annually, 10% of the total consumption.

The committee also evaluated the economic impact of expanding solar technology. The increased use of solar energy for heating homes and businesses is estimated to cost DKK 25,000 (USD 5000) per system. The oil savings is estimated at 400-600 litres so it would take the average consumer 10 years to receive a return on the investment. The committee would like to see the prices halved, in order to achieve a 5 year return rate. In addition, the spread of solar systems are anticipated to create jobs, reduce greenhouse gas emissions, and reduce dependency on foreign oil. For the installation of 10,000 systems over the next 20 years, a total cost of DKK 300 million and an average reduction of 120 TJ of oil usage should result in the following gains: approximately 500 man-years of employment, reduced emissions of 220 tons SO_2, 120 tons NOx and 180,000 tons CO_2, and a reduced oil trade deficit of DKK 30 million (Danish Energy Agency, 1995).

Private Sector

Novo Nordisk. Internationally reknown for its progressive environmental policies, Novo Nordisk is the largest producer of insulin in the world. The company is headquarted in Denmark but also has factories located in the US, Brazil, and China. Novo Nordisk is a two billion dollar company which has emerged as a leader in "green chemistry" -- using enzymes to replace synthetic chemicals in manufacturing processes.

The hazards of disposing of genetically modified organisms is still under debate, but Novo Nordisk has maintained an effort to minimize risks and maximize their green image. The company has begun to diversify its product base, as the insulin market is not large enough for economic growth. The business of industrial enzymes is growing by 40 to 45% per year because enzymes are biodegradable and since they work best in mild conditions, require up to a third less energy to use than many synthetic chemicals. Two prominent Novo enzymes include pulpzyme, which boosts the effect of chlorine in bleaching pulp and paper and therefore reduces chlorine use and alkaline cellulase, which replaces pumice stone to create stone-washed jeans without as much energy waste (Flynn, 1994).

In continuation of a more than twenty year old corporate environmental policy, Novo Nordisk signed the International Chamber of Commerce's 'Business Charter for Sustainable Development' in 1991 and has prioritized the following goals:

1. seek to minimize the impact of operations on the environment by developing more environmentally sound processes and minimizing emissions, consumption of raw materials and energy

2. strive to set high standards of environmental performance

3. educate and motivate employees to comply with policy

4. seek cooperation of all suppliers and contractors to ensure that the goods and services they supply are environmentally sound

5. communicate openly - both internally and externally - about environmental responsibilities, and report on environmental performance annually (Novo Nordisk, 1994).

In order to set a standard for environmental performance, Novo Nordisk has formulated an "Eco-Productivity Index" which relates the ratio of product sold to the following inputs consumed: raw materials, water, energy, and packaging materials. The figures are tracked and validated by an environmental accounting firm, SustainAbility Ltd, London (Novo, 1994). The following figure shows the eco-productivity index for energy use.

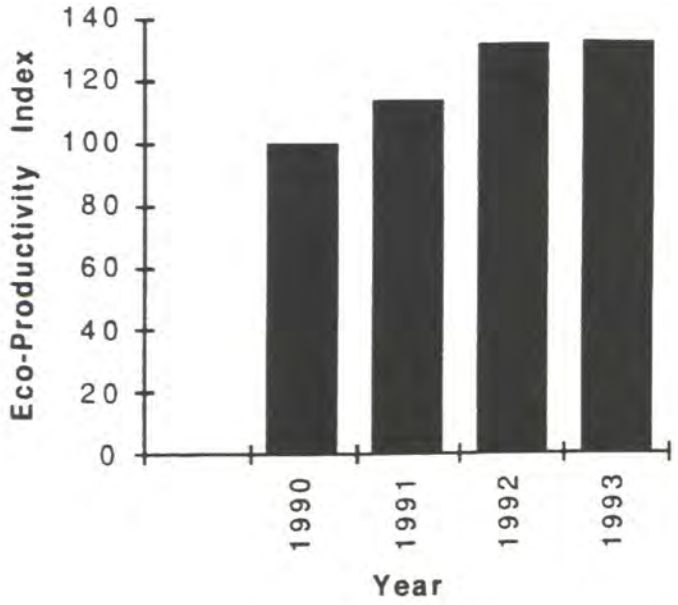

Fig 2. Novo Nordisk's Energy Eco-productivity Index: the ratio of product sold to energy consumed from 1990-1993. Source: Novo Nordisk, 1994

The figures indicate Novo Nordisk's ability to increase production while minimizing energy use, but the company increased its energy use overall under the goal of economic growth.

Kalundborg Industrial Symbiosis. Denmark's largest power plant, Asnæs power station, lies at the heart of what is known as the Kalundborg Industrial Symbiosis, a dynamic cluster of businesses which utilize each others' waste products (figure 3, next page). The symbiosis is composed of the following companies: Asnæs Power Station, a coal and gas-fired utility company; Gyproc, a plasterboard company; Novo Nordisk, Statoil Refinery and the Municipality of Kalundborg. The utilization of residual products reduces total resource consumption and pollution within this alternative industrial park. Asnæs Power Station forms the network core, supplying district heat to the town of Kalundborg and process steam to both Statoil and Novo Nordisk. Co-generation of both heat and electricity means better fuel utilization and cheaper heat than customers can produce themselves. The amount of waste heat discharged into surrounding waters is also

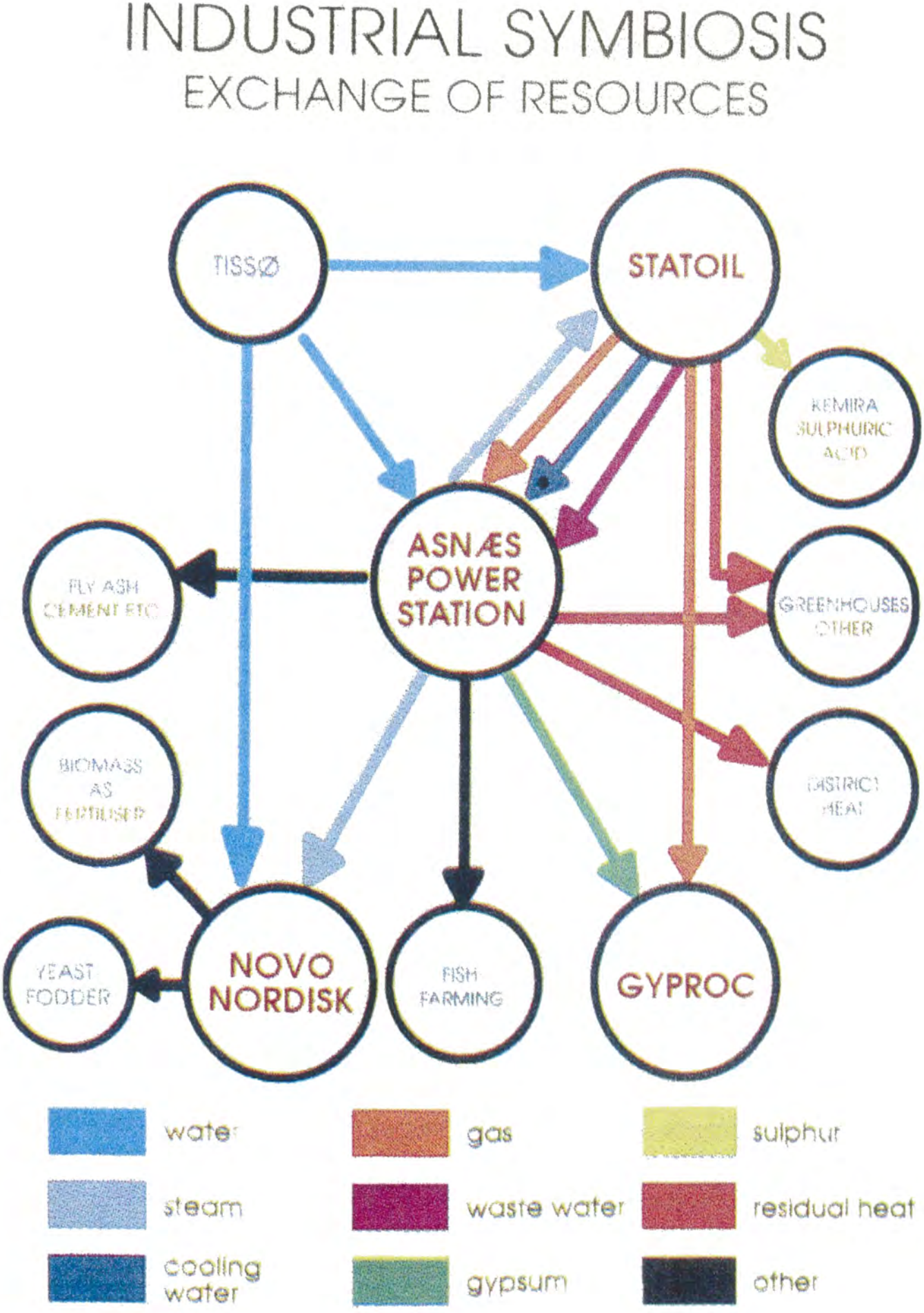

Figure 3. Flow diagram of Kalundborg Industrial Symbiosis (SK Power, 1995).

reduced. Residual heat is also utilized in an adjoining fish farm producing 200 tons of trout per year. Completing the cycle, sludge from the fish farm's waste water treatment plant is used as fertilizer on nearby farms, as part of a larger agricultural fertilizer agreement coordinated by Novo Nordisk (SK Power, 1994).

Asnæs' desulphurization unit produces approximately 100,000 tons of gypsum per year. This gypsum is sold under contract to Gyproc, which produces plasterboard products for the building industry. In 1990 Statoil commissioned a new sulphur recovery unit which produces about 3,000 tons of pure sulfur a year, which is used in the company Kemira's production of sulfuric acid. As a benefit, the refinery's flue gas is almost completely free of sulfur. Statoil has also reduced its emissions of surplus gas in its flare because both Gyproc and Asnæs buy refinery gas to replace oil and coal. The use of gas at Asnæs has replaced approximately 30,000 tons of coal per year (SK Power, 1994).

In addition to the aforementioned benefits, the close proximity of the plants allows for reduced packaging, transport, and marketing costs associated with the sale of residual products. However rosy the Kalundborg Industrial symbiosis may seem, it is nevertheless in jeopardy. Asnæs Power Station presently supplies 50% of the energy demand on the island of Zealand. However, the municipality of Copenhagen has intentions of building a new power plant which would supply district heating as well as electricity. District heating is regarded by the Danish government as an integral part of its energy savings initiatives. However, if this new power plant comes on line, the demand for energy from Kalundborg will plummet. Asnæs is on the west coast of Zealand; Copenhagen lies on the east. Asnæs will not be able to supply district heating to the majority of Zealand's population. In this case, Kalundborg must either halve its production or shut down completely, which will also remove the heart of the industrial symbiosis (SK Power, personal comm., 1995).

Confederation of Danish Industries. A large number of Danish companies are organized into unions or umbrella working groups. The Confederation of Danish Industries (CDI) is one such group that negotiates employee benefits and salaries, determines environmental policies for member industries, and lobbies the Folketing for industrial interests. The CDI's environmental department is in charge of occupational safety, pollution

prevention and energy policy lobbying. The CDI is also involved with cooperation and negotiation of environmental agreements. The CDI accredits the following "greening forces" for driving Danish industries to invest in cleaner technologies:

1. consumer preference
2. industrial buyers request cleaner supplies
3. industrial users demand recycled products
4. investors and bankers restrict funding of 'dirty' production
5. employees press for environmental reform, either within the company or through unions
6. industrialists regard 'greening' as profitable and/or morally needed
7. eco-taxes punish waste and emissions
8. legislation prohibits the use of outdated production methods

The above list is adapted from Tony Leighton's report, "Ten Trends". CDI emphasizes that a company can suffer if it is either too slow or too fast in modifying or updating its production equipment. They believe the time to invest in cleaner equipment is when it can be coordinated with other needs for renewal and updating. If the process moves too fast, frequently the company cannot afford to replace existing equipment or cannot find financing to do so. In this case, the company may choose a cheaper end-of-pipe solution over a more long-term solution such as more efficient production. This investment may remove the company's ability to install cleaner technology in the future (Gram, 1995).

THE DANISH ACHIEVEMENT

Social Democracy

Living in a social democracy. Denmark is often considered a model welfare state, with cradle-to-grave security provided to its citizens. This security is provided at a high cost, however, with approximately a 50% personal income tax, combined with a 22% sales tax on top of various green taxes on the consumption of energy. This high tax rate gives the Danes an excellent educational system, universal health care, disability and retirement pensions, many local and national government institutions and a

small defense department. Students must compete for advanced educational opportunities, as only 50% of most applicants are accepted. Most Danes, however, go on to pursue higher education in either universities or trade school. Education often continues into adulthood, with community based night classes on everything from public policy to hobbies. University and trade school students receive tuition and are eligible for housing and supplies subsidies. This educational system is partly responsible for the highly literate and politically active Danish character.

Unlike the British parliamentary system, the Danish Folketing only has one chamber. Parties which receive two percent or more of the popular vote win a seat. As a result, there are many political parties and it is rare for any one party to hold a majority. Governments are formed by a coalitiion of smaller parties. Most legislation is formed by consensus and compromise. Compared to many Western countries, the political spectrum runs from the center of the left to the ultra-left. Danish conservatives have been likened to liberal Democrats in the United States, in part because of their continued committment to universal education and health care, environmental efficiency, and retirement benefits (Nye, 1992).

Public involvement. Denmark has a long-standing tradition of actively involving individuals, nongovernmental organizations and businesses formally and informally in the formulation and implementation of environmental policies and agreements. The Folketing drafts legislation which is administered locally by Denmark's 14 counties and 275 municipalities. Trade organizations such as the Danish Confederation of Employers, the Danish Confederation of Trade Unions, the Federation of Danish Industries and many agricultural co-ops have established strong ties to officials at all levels of government, and are instrumental in drafting and implementing legislation. Voluntary agreements are also often used in lieu of impending legislation in order to achieve a high rate of compliance among industry within a reasonable time frame. The Government also collaborates with environmental groups such as the Danish Society for the Conservation of Nature and the World Wide Fund for Nature (Royal Danish, 1995). Consensus building is an important aspect in the success of Danish environmental policy. Environmental impact hearings are open to the general public and any individual or organization has the right to appeal decisions or issue complaints.

The existence of a long-standing alternative political culture also paved the way for environmentalism to catch on the the early 70's. The rural, agricultural - based social movements of the nineteenth century have grown into the modern Danish state, with an emphasis on decentralized decision making in local governments and wide cooperation among sectors. The environmental era was sparked by a student group called NOAH in the late 60's. NOAH is still active in Denmark, and is credited for framing the environmental debate as an existential one, focusing on individual consciousness and responsibility instead of state protection of nature, as in neighboring Sweden (Jamison et al., 1990). Therefore, the environmental issue was seen as a matter of national priority as well as a symbol of Danish nationalism.

This ideal has grown even more strongly, in the Danish opposition to EU environmental policies, since the Danes wish to retain the strength of their regulations as well as their sovereignty and identity. Technologically, the Danes have been able to succeed because of the small scale of their economy and private investment in alternative energy technology. The Danish government wishes to maintain a high level of public debate on environmental issues which, due to green taxes, now affect every sector of Danish life from large corporations to individual households. The majority of the public is estimated to have a broad knowledge of environmental problems and policies filtered through personal experience, information campaigns, the media, and higher education.

Education. The Danish government has made a concerted effort to include environmental education in the public schools and other educational institutions. The Danish Minister for Education has promoted the following plan: all ministerial orders must analyze their "green component", environmental aspects must be incorporated into the teaching of all subjects as outlined in the Danish Primary and Lower Secondary Education Act, and grants must be allocated for the development and alteration of existing educational programs so that environmental consciousness is "an essential criterion" (Ministry of Environment and Energy, 1995). As a corollary to the above recommendations, the Ministry of Labor has begun a series of environmental courses for a large variety of sectors and training levels, including the following: environmental management, waste sorting (ie. recycling and incineration), contamination, urban ecology, clean technology,

and product life cycle analyses. These courses are intended to inform both management and employees about "greening forces" in the work place (Ministry of Environment and Energy, 1995).

Environmental economics

Economic base. Over the past century, Denmark has transformed itself from a predominantly agricultural state into a modern service-based economic state with an extremely high GDP per capita among industrial nations (US Commerce Dept., 1994). Denmark has achieved this through the development of high-tech agriculture and energy systems, modern small-scale businesses and industries, and a high dependence on foreign trade. Its chief exports include meat and meat products, dairy products, shipbuilding equipment, fish, chemicals, and industrial machinery. Denmark's main trade partners lie within the EC. Because of its small size and limited natural resources, Denmark imports petroleum, machinery and equipment, chemicals, grains and other foods, paper, and automobiles (Ministry of Environment and Energy, 1995). Current environmental concerns involve nitrogen and phosphorous pollution of the North sea, anoxia in the Baltic sea, transboundary and domestic air pollution, and surface water pollution. The agricultural industry has begun to make significant changes in its use of fertilizers, in order to combat nutrient pollution. Denmark's shipping industry

Parameter	Denmark	United States
Tax revenues (% of GDP)	48.3	29.8
Tax revenues (per capita)	12,219	6,550
% GDP spent on military	2	5
Official development assistance to Third World (per capita)	233	45
Health Expenditures (% GDP)	6.5	13.4
Health Expenditures (per capita)	1,151	2,867
Energy consumed (kg coal equivalent per capita)	5,084	10,798

Table 3. A comparison between selected Danish and American economic parameters. All per capita sums in 1991 USD. Source: US Dept. of Commerce, 1994.

has resisted environmental restrictions, even though the state is a party to several international marine agreements. In order to illustrate Denmark's economic situation, the table 3 compares tax revenues and spending patterns of the Danish government and/or population.

Denmark has an exceptionally high tax base to draw upon for subsidies, grants, and assistance to other countries. The government has been able to hold down costs such as healthcare and energy use while still providing universal care and affording its citizens a high standard of living. These revenues and savings allow Denmark to invest in efficient, forward-looking technology.

The fastest and most often used environmental management tools are regulations involving licenses, bans, and standards. However, the last decade has seen growth in the use of economic instruments -- taxes, charges, and tradeable pemits. These management tools have the ability to shape environmental policy through market practices and economic policy, which is highly prioritized. The OECD has officially recommended the use of economic instruments for its member countries since adopting a Resolution of Ministers in 1991 (Barde, 1994). These tools are intended to act as incentives for change in consumption and efficiency as well as a complement to regulations and standards. Denmark has become a leader in this field, especially with the use of green taxes.

Green taxes. Taxes on environmentally disruptive practices can work to incorporate extemalities of production and consumption into market prices. These "green taxes" contribute to environmental goals and shift the tax burden from labor and income towards resource use and environmental pressures. Prices on taxable goods will change to better reflect the total macro-economic costs of production so that the burden of environmental goals is fairly distributed. The Danish government has investigated and issued several green taxes, while keeping in mind the competitiveness of Danish businesses in the global market. Towards this end, Denmark has agressively lobbied for a common CO_2 tax across the European Community as well as in other international forums. Two recent tax reforms have begun the process of greening the tax code.

The Folketing launched a tax reform in 1993 which raised a number of green taxes on consumers while lowering the income tax rate. This

legislation entered into effect in January of 1994. Most of the taxes were directed at household energy use. The following is a sample of taxes levied:

- electricity/coal tax raised
- diesel and gasoline
- registration taxes on trucks and buses (except commercial transportation)
- water tax
- waste tax raised with an exemption for waste used for heat or power production
- wastewater (to be introduced in 1997)
- grocery bags/shopping bags

A later tax reform was directed towards industry in 1995. These taxes were designed so that they would not have a detrimental effect on competitiveness. In addition to the following taxes, several voluntary agreements have been concluded in lieu of regulations with various industry sectors, especially those with energy-intensive production. The revenue from industry green taxes is refunded in a system of subsidies to maintain the companies' incentives to improve their environmental profiles. The revenue from other green taxes is also earmarked for return schemes to secure recycling and waste reduction programs. Examples of industy taxes include:

- taxes on and regulations of the collection of lead batteries
- nickel-cadmium batteries (tax aimed to promote the sale of less hazardous alternatives)
- amendments to statutes on CO_2 tax and energy tax on mineral oil products
- sulfur tax (will be phased in with the Sulphur Tax Act)

The Minister for Environment and Energy has concluded an agreement under the Danish Environmental Protection Act (which allows for such voluntary agreements in lieu of mandates) with the Association for Collection of Lead

Batteries in Denmark (ReturBat) to promote collection. Regulations will be drafted on collection of lead batteries, subsidies for industrial collection, collection for refuse, and lead battery taxes to finance the return programs. When such agreements are concluded, the Minister agrees to refrain from implementing the provisions of the legislation as long as the other parties voluntarily comply with the agreements. The tax on the nickel-cadmium batteries will also be refunded to industry to promote collection and recycling. The CO_2 and SO_2 taxes will also be refunded as revenue to be used in direct investment for energy savings and workers' pensions (Danish Ministry of Environment and Energy, 1995).

Subsidies. The Danish government uses a system of subsidies in the forms of recycling of tax revenues, grants, and reduction of taxes for certain users. Additional revenue from the introduction of taxes on room heating and CO_2 (as well as others) are recycled back to energy-conscious businesses in the private sector. The revenue often offsets labor taxes employers pay which creates incentives to limit energy consumption and pollution. Grants have also been used to further Energy 2000's goals. The years 1996 - 99 should see an increase in grants for energy efficiency technology up to DKK 1.8 billion, allocated as part of the 1992 Danish Energy Package's CO_2 goals. These grants will support energy efficiency and conservation measures in private companies as well as the reduction of CO_2 and other greenhouse gases from the private sector. Another significant grant is for the conversion from electric heat to district heating or natural gas. This conversion is considered to be a relatively cheap method for reducing the electrical utilities' CO_2 emissions. The grants will be directed at individual homeowners and apartment buildings in areas without district heating. Utilitiy companies are also expected to offer incentives for hookup to district heating in areas where the opportunity exists. Investment grants are scheduled to be discontinued in 2000. Overall, 30% of tax revenues from CO_2 and energy taxes will be directed back in the form of investment grants (Danish Energy Agency, 1995).

Political entrepreneurs

Denmark has made a place for itself in the international community as a leader in the development of renewable energy resources. It has accomplished this role through acts of political entrepreneurship, tactics used

to persuade other countries to act in a certain way. These tactics include the following: new research to show a compelling interest among other nations, development of new technologies, hosting international conferences, and unilateral symbolic acts. Denmark has utilized all four of these approaches in order to influence international environmental debate.

Danish environmental consciousness

The average Danish family has a strong conservation ethic. Along with the rest of Europe, only 20% of the Danish population owns energy intensive home appliances like clothes driers or dishwashers. The appliances available have strict efficiency standards. Danish houses are often well-insulated and optimize passive solar energy to increase home temperatures during the winter. Most homes in municipalities are connected to a central heating facility, which provides heat through insulated pipes to individual houses. Even the floors are warmed, as well as built-in towl racks.

Organic foods have become extremely popular in Denmark, and show up regularly in grocery stores, which are most always centrally located in connection with commuter or regional train stations, to discourage driving. Denmark has fewer kilometers of freeways than railways, and due to green taxes on petroleum use as well as automobile taxes, few families own more than one car. Shopping and entertainment districts are also centered around public transportation routes. Parking is discouraged, and various alternatives abound. Biking is a popular form of transportation as well as a sport. Bike lanes follow most coastlines and highways. Copenhagen has many bike lanes and even some street lights specifically directed towards bikes. Public transportation is convenient and effective. Several bus schedules and trains are coordinated to match ferry, plane, long-distance bus, and train schedules.

The Danish environmental experience is exemplified by the Danish word, "hyggeligt" which roughly translates into "coziness" in English. Houses are snug, warm, lit with candlelight, and focused around energy efficiency and family life. Neighborhoods are fairly uniform and centrally planned to coincide with the city center and transportation routes. Historic preservation is also evident in many areas. This homogeneous country has worked diligently and effectively to carry out its environmental goals.

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