A Viable Energy Strategy for the Nordic Countries 2006 - 2030

A viable investment budget for the renewal and consolidation of the energy resource base, the reduction of CO_2 emission, and the phasing out of nuclear power

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Summary

This paper presents the results of the application of a general energy systems analysis method in a study of technological and economic ways and means for the initiation of the transition to a viable Nordic energy system.

The main results are summarised as reductions in fossil fuel consumption and CO_2 *emission obtainable by the implementation of well-coordinated investment programmes in the different parts of the Nordic energy system, comprising Norway, Sweden, Finland, and Denmark.*

Under certain assumptions as to quantitative growth parameters, a fictive "business-as usual" or "baseline" scenario (A) is compared with a viable scenario (B), in which comprehensive investment programmes are implemented in order to meet the Nordic countries' obligations to reduce CO_2 *emission and to phase out nuclear power generation at the same time.*

Economic costs assessments are made under different assumptions as to future fossil fuel prices. The results of these assessments strongly indicate that the renewal and consolidation of the energy resource base required to sustain the Nordic welfare societies does not impose economic costs which restrain other economic activities. On the contrary, there is reason to fear that other economic activities will be severely restrained if the Nordic economy remains strongly dependent on oil and gas supplies until the global production of these fuels can no longer meet the global demand. The CO_2 *emission reduction comes as a corollary to security of energy supply.*

The more efficient utilization of electric power provided by existing hydropower stations and a strongly growing windpower capacity renders nuclear power superfluous in the B-scenario.

The physical reality cannot be ignored in energy policy making. A strategy for the safeguarding of the welfare society's energy resource base and the mitigation of environmental impacts and hazards caused by fossil fuel consumption and nuclear power must rely on consistent information of physically and technologically possible options. Therefore, if the strategy outlined in this paper is dismissed, another feasible strategy which demonstrably meets the political objectives in a least-cost manner must be presented as a better alternative. The laissez-faire argument that "This is not what we want, but we can't concretely specify what is needed - the market will find out" does not express a rational approach to the problems to be solved.

Contents:

All graphs and tables are compiled in section 19, at the beginning of which a list of its contents is found. There are two reasons for this. First, it makes is easier to find graphs and tables to which references are made in several text sections. Second, the documentation provided in the array of graphs and tables shows in the several dimensions the changes taking place from 2005 to 2030 in the scenario (scenario B) described in the text sections and also the main differences between this scenario and the "baseline scenario" (scenario A). Thus, the array of graphs and tables which show the changes taking place in scenario B may be read as the numerical mapping of the transition of the energy system from its presents state towards a future viable state.

The last table (table 19) summarizes the net results in terms of the CO_2 emission reductions obtained in the B-scenario.

1. Introduction

Our economy is based on wasteful segregated energy and transportation systems developed during half a century where cheap oil was in abundant supply and CO_2 emission constraints were non-existent. Now we are confronted with an enormous challenge of technical and social engineering, namely the accomplishing of the transition to an economy based on the efficient utilization of limited and costly energy sources. This study is concerned mainly with ways and means to meet the technical engineering challenge. The social engineering of the proper conditions for the implementation of appropriate technical solutions - in terms of public participation, political consensus, planning and financing - has cultural and ideologic implications concerning the strive for the common good in the longer term as against the mere strive for here-and-now economic growth by any means. Only one of these social issues is addressed, namely in a specific critical note on the electricity market (section 12). However, without the analysis and presentation of feasible technological development strategies, there is no basis for a public discussion of alternative approaches which could lead to political consensus on the establishing of the proper social conditions for the implementation of an appropriate strategy.

Together the Nordic countries have renewable energy potentials unmatched by any other region with a similar population density. Hydropower plants produce about 200 TWh/year and windy coastlines and plateaus make the utilization of windpower on a large scale economically feasible. Moreover, substantial amounts of wood and straw are available on a sustainable basis.

Therefore, if the Nordic welfare societies cannot be sustained on the basis of mainly renewable energy resources there is little hope for the development of sustainable energy resource bases for other industrialised regions.

Presently, the Nordic countries, in addition to hydropower and biomass, use large amounts of coal, oil, natural gas and also nuclear power to sustain the functioning of their societies. The reason for this is that low fuel and electricity prices have allowed a generally inefficient and wasteful use of energy resources. The economy has been optimized under the conditions set by low fuel and electricity prices and the absence of CO_2 emission constraints. Now, however, the optimization criteria change because of growing fuel costs and CO_2 constraints. Moreover, it must be taken into account that it is unlikely that oil and gas will be in ample supply in the next decades. And it is questionable for how long fissionable nuclear fuel will be in ample supply at the present price level.

Under these new economic and environmental optimization criteria the present Nordic energy system is far from optimal. In order to examine ways and means for the transition to a new energy system which approximates an economic and environmental optimum under the new criteria, Nordic Greenpeace commissioned the study presented in this paper.

The study is based on a SESAM[1] model of the Nordic energy system. SESAM is a generic multi-scenario model which facilitates the comparative analysis of a wide spectrum of alternative scenarios for the future development of the energy system in question. The model represents the energy system in the form of a database containing the physical, structural and economic specifications of the components of the system and time-series data which specify alternative future changes in the system properties.

The database for the Nordic energy system was prepared by Greenpeace appointees in collaboration with the author of this paper. Among a series of scenarios examined, one scenario, here called scenario B, was selected for comparison with the fictive "business-as-usual" or "baseline" scenario, scenario A, in which no technological improvements take place except the natural replacement of old electrical appliances by new, more energy-efficient models.

The outcome of the study is presented in commented graphs and tables which summarise the assumptions made and the results which can be achieved by the implementation of the investment programme specified for scenario B. These graphs and tables are arranged in the last section of this paper, section 19. Together they constitute an appropriate framework for the presentation of an energy strategy in the form of a long-term energy investment budget for public discussion and political consideration. Other scenarios can be presented for comparison within the same framework.

Moreover, additional tables and graphs for sensitivity analyses and comparative analyses of alternative strategies can be displayed. For example, table 17 shows the results of a sensitivity analysis based on the comparison of scenario B with scenarios in which 1) electricity consumption, 2) power generation in windmills, and 3) power generation in hydropower stations, respectively, is marginally changed. In table 18, main results of scenario B are compared with main results of a scenario in which a stronger growth in energy consuming hardware takes place.

In the following sections 2 and 3 the physical modelling of the Nordic energy system and the method used for the assessment of economic costs is briefly described. Thereupon, with references to the graphs and tables in section 19, the A-scenario and the particulars of the changes taking place in the B-scenario are commented on in the sections 4 thru 18.

2. The physical modelling of the Nordic energy system

The model consists of a database which contains (a) data common to the system as a whole and (b) four database sections containing data for each of the four countries. Norway and Sweden are subdivided into three climatic zones: south, mid,

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[1] The methodology is described in
Klaus Illum: *SESAM The Sustainable Energy Systems Analysis Model.* Aalborg University Press, 1995.
The application of the SESAM model to the Nordic energy system is described in the compendium: *A SESAM Model of the Nordic Energy System. Methodology and the modelling of the Nordic Energy System.* Greenpeace 2006. By Klaus Illum

north, and Finland is subdivided into a north and a south climatic zone. Denmark is one zone.

Based on the specifications given in the database, the SESAM programs firstly compute the end-use demand for heat and electricity in buildings and industries as well as the motive power needed for transportation by the different means of transport. Thereupon, the energy flows from *1) the system of energy sources* (fossil fuels; biomass fuels; nuclear power stations; hydropower stations; windmills; etc.) through *2) the energy conversion and transmission system* (power and cogeneration plants, some with biogas plants; boilers; electrochemical converters; etc.) to *3) the end-use system* are computed in accordance with the geographic, structural, technical and quantitative specifications given in the database registers. To take into account the climatic and other variations in the annual cycle, the computations are performed month by month and reiterated year by year as the system undergoes structural, technical and behavioural changes. In order to assess the capacities required in the different energy conversion units, energy flow balances are concurrently computed on a diurnal basis with 15 minute intervals.

The SESAM documentation programs provide documentation of results at all levels of detail: Summaries and overviews as well as particular results for any part of the system.

For each zone the database contains a building register specifying the properties of the different types of buildings, the different types of individual and collective energy conversion units presently in use (boilers, cogeneration units, power stations, etc.), and industrial production plants.

Thus, although the degree of detail and accuracy of the data presently available does not warrant the modelling of the Nordic energy system in great detail, the database structure is prepared for the more detailed and accurate specifications of the system properties. As it is, the specifications have been calibrated against the more aggregated data available for each country.

This means that although not all the data contained in the particular database records for buildings, electrical appliances etc. are based on available statistics, and the geographical structuring of district heat supply is not specified in any detail, the calibrated database represents four energy systems with properties which closely resemble those of the four Nordic countries.

Regarding electric power transmission, the Nordic energy systems is modelled as one system in which all power generating units and all consumers are connected to the same grid. The power transmission capacities needed are assessed as described in section 15. Electric power transmission between the Nordic countries and their neighbouring countries is restricted to a small percentage of the power generation within the system, meaning that the Nordic energy system is modelled as a relatively closed system. This is because there is no basis for the assessment of the CO_2 emission effects of a relatively large power transmission across the system boundary.

3. Economic costs

The database contains an economic cost register consisting of "price tags" for the different types of investment items. A "price tag" is a record of specific investment and maintenance costs for a particular type of physical unit - e.g. fuel-fired power generation or cogeneration units of a certain type, a type of boilers, heat pumps, windmills, biogasplants, etc. - or another kind of investment item. In addition to specific costs, a "price tag" specifies the technical lifetime and the interval between major overhauls (re-investments) for the type of investment item referred to.

Costs of energy conversion units and power generating energy sources are specified as per MW of installed capacity. Costs of district heat connections, central heating installations, etc. in buildings are specified as per square metre of floor area for larger and smaller buildings respectively. Costs of reductions of net heat consumption in buildings of a certain category (improved heat insulation, heat recovery, etc.) are specified per square metre of heated floor area as a function of the reduction obtained.

The costs specified in a "price tag" are valuated by market prices (without taxes and duties), assuming that the market prices reflect social costs in terms of labour and natural resources which could alternatively be used for the accomplishing of other activities (the so-called *opportunity costs*)[2].

When, in a particular scenario, the time-series of future physical changes occurring in the system have been computed, the program generates a file of records which specify the time-series of changes in each particular unit or object (e.g. new cogeneration capacity of a particular type of unit; new windpower capacity of a particular type of on-shore or off-shore windmill; reduced heat loss in a particular type of building; etc.). Thereupon, the economic costs are computed year by year by the matching of each of the physical changes to the "price tag" for the particular investment involved, adding the costs of maintenance and re-investments for all the units in operation in each year.

Fuel costs are computed on the basis of the computed fuel consumption and the price specifications for the different types of fuels (see table 12).

It is important to point out that because of the uncertainties of future market price assessments and because it is questionable to which extent the market prices of goods reflect the real opportunity costs, the computed costs should be considered only a measure to be used for the comparison of different scenarios. Considering that the total costs result for a particular scenario is computed as the sum of a large number of cost items, each of which is somewhat inaccurate plus/minus, there is reason to expect that a significant difference between the computed total costs for two scenarios indicates a real significant cost difference, whereas a relatively small difference indicates that the two scenarios are practically equivalent regarding economic costs.

Moreover, the opportunity costs only partly account for the total costs of energy supply and consumption to be borne by the society as a whole. The external costs to

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[2] Social costs of economic activities have two different sets of components: (1) the so-called *opportunity costs*, i.e. the costs in terms of labour and natural resources which could alternatively be used for the accomplishing of other activities; and (2) the so-called *external costs*. These are the costs assigned to any loss of welfare or increase in costs which the activities cause to any individual or firm in the economy, i.e. to the society as whole.

be assigned to environmental degradation, resource depletion and other effects resulting from activities directly or indirectly related to energy supply and consumption cannot be assessed to any degree of accuracy in terms of money. The economic costs of oil depletion are unforeseeable and the costs of irreversible and irreparable environmental degradation are immeasurable.

Figure 3 and table 13 shows the aggregated results of the economic cost computed for the two scenarios A and B. Because external costs are not taken into account, the real differences in costs to be assigned to scenario A and B, respectively, are much higher than shown in figure 3 and table 13. Were the external costs of CO_2 emission and other environmental hazards as well as the external costs of resource depletion estimated in some way and taken into account, the resulting total costs to be borne by the society as a whole would become higher by an order of magnitude in scenario A than in scenario B. Therefore, scenario A is unrealistic.

Finally, it should be noted that the economic costs computed in this manner do not provide a basis for the assessment of end-use consumer prices of electricity and heat. The setting of consumer prices is a matter of cost distribution policies or business preferences regarding the setting of prices for electricity and heat from cogeneration stations.

4. Limits to growth

Continued quantitative growth in the stocks of energy consuming hardware is a risk factor which must be taken into account in the search for an appropriate strategy for the construction of a viable energy system. Continued growth makes the welfare society more and more vulnerable to future restraints in energy supply.

In a finite world with limited energy resources, exponential growth in the quantities of energy consuming hardware can continue only for a limited period of time. And even without energy or other resource constraints, saturation will occur at some point. Surely, billions of people on this planet have good reasons to strive for energy consuming aids which can make life easier, but in the Nordic countries, with stagnating populations, a redoubling of the number of cars or the time spent in cars does not make sense. Neither does a redoubling of the number of electric household appliances or the number of square metres of heated floor area in buildings.

Nevertheless, in the scenarios considered in this paper, it is assumed that the points of saturation have not yet been reached. As shown in section 19, figure 1, the main quantitative factors influencing energy consumption are assumed to continue to grow in the next decades, except transportation volumes, which are assumed to peak around 2020 at a level about 15% higher than in 2005.

To indicate the sensitivity of the B-scenario results to upwards changes in these growth factors, the fossil fuel consumption and CO_2 emission results computed for a scenario identical to the B-scenario but with stronger growth in the main quantitative growth factors are shown in table 18.

5. Future fuel prices

Future fossil fuel prices are unpredictable but considering the looming peak of global oil production capacity they are likely to grow to unprecedented heights. In this study the economic costs are computed in the three fuel price development cases shown in section 19, figure 2 and table 12.

The reason for taking three different fuel price cases into account is only to assess the influence of these prices on the total costs involved in the different scenarios. There are no forecasts involved.

6. The fictive baseline scenario A

The business-as-usual scenario A is a baseline scenario in which no technological or structural changes take place, apart from the replacement of old electrical appliances by new, more energy-efficient models. It is a fictional scenario because changes *will* take place and because fossil fuel consumption and CO_2 emission will be restricted in the next decades.

Comparing scenario A with a viable scenario such as scenario B, only one observation can be made. Namely, that even on another planet where fossil fuels were practically unlimited but becoming more costly and the climate was not influenced by CO_2 emission, the B-scenario would be preferable to the A-scenario in purely economic terms.

7. A viable investment programme. Scenario B

Energy policy and planning is all about the allocation of labour and other resources to particular projects. A political strategy for change is manifested in the form of an investment programme. An investment programme for the initiation of the transition to a viable energy system, namely the investments to be made in scenario B, is presented in section 19, table 1. The main results of the implementation of this investment programme are shown in figure 3, 4 and 5. More detailed country-by-country results are shown in the tables 2 thru 17.

8. Nuclear power

In the A-scenario nuclear power production continues at the 2005 level. In the B-scenario, the nuclear reactors in Sweden as well as in Finland are phased out around 2025.

The total costs of operation and maintenance of nuclear plants over the scenario period are estimated at 28,000 mio. Euro in scenario B (see section 19, table 1) as against 43,000 mio. Euro in scenario A. The costs of operation correspond to about 15 Euro/MWh on the average for all the plants. The total costs of maintenance/refurbishing are estimated at 6,200 mio. Euro in scenario B and 7,600 mio. Euro in scenario A. The costs of decommissioning nuclear plants are not included in the cost computations.

In 2005 the construction of a new reactor, Olkiluoto 3, began in Finland. It is expected to be commissioned in 2010. In the B-scenario, the production from this reactor is not needed in the Nordic energy system. It is, therefore, not taken into account, neither as a power source nor as an economic cost item. However, if the reactor is completed, it allows for the sooner decommissioning of the other reactors in Finland.

Greenpeace envisages that the decommissioning of nuclear reactors in Sweden and Finland could take place as follows:

	Reactor	Capacity MW	Age in 2005 Years	Decommissioned in	at the age of
Sweden:	Oscarshamn 1	445	34	2009	38 years
	Ringhals 1	835	31	2011	37
	Oscarshamn 2	605	31	2012	38
	Ringhals 2	875	31	2013	39
	Forsmark 1	970	25	2015	35
	Ringhals 3	915	25	2016	36
	Forsmark 2	970	24	2018	37
	Ringhals 4	915	23	2020	38
	Oskarshamn 3	1160	20	2022	37
	Forsmark 3	1160	20	2024	39

Finland:

Assuming that the Olkiluoto 3 reactor is not completed:

Reactor	Capacity MW	Age in 2005 Years	Decommissioned in	at the age of
Loviisa 1	488	28	2016	39 years
Loviisa 2	488	25	2019	39
Olkiluoto 1	840	27	2022	44
Olkiluoto 2	840	25	2025-29	45-49

Assuming that the Olkiluoto 3 reactor is completed by 2010:

Reactor	Capacity MW	Age in 2005 Years	Decommissioned in	at the age of
Loviisa 1	488	28	2010	33 years
Olkiluoto 1	840	27	2010	32
Loviisa 2	488	25	2012	32
Olkiluoto 2	840	25	2019	39
Olkiluoto 3	1600		2025-29	15-19

9. Hydropower

No investments in new hydropower capacity take place in either of the two scenarios. In the A-scenario the electricity production in hydropower stations in Norway, Sweden and Finland is the same year by year, equalling the average production in years with “normal” precipitation.

In the B-scenario, the production in 2005 equals the average production in “normal” years. In the following years the production is gradually (linearly) reduced to 85% of the “normal” production by 2030. The reason for this reduction is that computed capacities in cogeneration stations should be sufficient to provide backup power generation capacity in years with lower precipitation than in “normal” years.

Moreover, the CO_2 emission reduction computed under this restraint (see section 19, figure 3 and table 19) should be on the safe side of the margin of uncertainty regarding a moving annual average. Likewise, the computed economic cost benefits of the B-scenario as compared with the A-scenario (see figure 3 and table 13) tend to be underestimated because the economic benefits of the existing hydropower capacity are bigger in the A-scenario than in the B-scenario.

10. Large investments in the end-use sector

The results obtained in the B-scenario strongly depend on the more efficient utilisation of energy resources in the end-use system. Therefore, as shown in section 19, table 1, a large percentage of the investments are to be made in buildings: In Norway almost 80%, in Sweden 60%, in Finland and in Denmark 45%. The higher percentages in Norway and Sweden are mainly due to the replacement of electric radiators by central heating from heat pumps, biomass boilers, and mini-cogeneration units in many buildings, see table 5.

11. Lower utilization of investments in cogeneration stations

The energy conversion and transmission system consist of power and cogeneration stations and boiler stations; facilities for the conversion of electric power to chemical energy for the powering of vehicles; and district heating and gas networks and electric power transmission lines. The system serves to convert and transmit electric power and chemical energy (fuels) from the energy sources to the end-use system at such rates that the end-use demands for electric power, district heating and motive power for transport are continually met. Therefore, the investments needed in the conversion and transmission system in order to make sufficient capacities available and to ensure the energy-efficient functioning of the system are determined mainly by:

1) the development in end-use electricity demand and in heat demand at certain temperatures in the end-use system;
2) the growth in electric power generation in windmills, photovoltaic panels, and, possibly, wave machines;

and by

3) the partial shift from fossil fuels to biomass fuels in collective cogeneration stations.

In particular, the investments needed in cogeneration stations are determined by these factors.

As shown in section 19, table 4, fuel-based power generation in 2030 takes place in collective cogeneration stations and individual cogeneration units only. Most of the electricity generation in the collective cogeneration stations takes place in the winter month (see table 14 and 15: Electricity production in "motors"). Moreover, the power delivered from the stations to the grid must be regulated upwards or downwards in opposition to the power generation in windmills, partly by means of heat pumps connected to the stations' district heating networks. Therefore, the utilization of the investments made in power generation capacity in these stations becomes relatively low (less than 3000 hours/year), corresponding to the utilization of investments in windmills.

In Denmark in particular, the power delivered to the grid from collective cogeneration stations is much smaller in 2030 than in 2005 (see table 4) although the heat production from these stations is about the same as in 2005 (see table 3). This is partly because of fuel-shifts from coal and gas to biomass fuels (see table 6), resulting in a lower power-to-heat ratio, partly because part of the power generated is used in heat pumps (see table 15). In the other countries heat pumps in cogeneration stations play a minor role.

Because of the relatively low utilization, the pay-back time for investments in cogeneration stations, including heat pumps for the regulation of the power to heat output ratio, is much longer than normally accepted for investments in the private sector.

Naturally, the relatively low utilization of investments is a general characteristic of energy systems in which windmills and solar energy sources, whose production fluctuate and vary in the diurnal and annual cycles, play a major role.

12. No separate electricity sector

Because of the dependency of investments in the collective energy conversion stations on the investments made in buildings and new energy sources, the concurrent coordination of the investments made in all sectors of the system is essential. However, under the present electricity market regime this coordination cannot be ensured.

By legislative measures regarding subsidies, taxation, technical standards, and price guaranties, the governments can ensure that private investments in buildings, such as those listed in section 19, table 1, are made. By tendering, the governments can also ensure that investments in windmills on appropriate locations are made. But the government cannot ensure that the investment policies of the big corporate electricity companies operating in the electricity market are in accordance with a strategy laid out in an appropriate investment programme.

For example, for people to shift from electric heating to district heating there must be a district heating network and a cogeneration station at the end of the pipe. But it may not be a lucrative business for private electricity companies to make investment with a long pay-back time in cogeneration stations and thereby eliminate part of their electricity market, unless they can set a high price for the heat from these stations.

The crux of the matter is that in an energy-efficient integrated energy system with an around-the-clock varying interplay between many different energy sources there is no electricity sector which can be singled out from the rest of the system.

Investments in windmills and photovoltaic panels cannot be efficiently utilised unless the system as a whole is designed to make efficient use of their continually varying power generation. And power generation in collective cogeneration stations and individual mini-cogeneration units is tied up with the heat generation required from these stations and units at the different times of the year, partly regulated by the use of electric power in heat pumps. Moreover, a part of the electric power generated in the system must be converted to chemical energy in the form of hydrogen or other chemical potentials for use in vehicles.

Thus, electric power generation in the many different power generating stations and units is an integral part of the functioning of the system as a whole. The electricity market regime, in which an artificial electric power sector is singled out from the system as a whole, is detrimental to the construction of an efficiently operating integrated energy system.

In particular, it should be noted that in cogeneration stations in which electric power transmission to heat pumps or electrochemical converters (electrolyses or other, see section 14) is an integral property of the functioning of the stations, the rate of power transmission at different times should be regulated in such a manner that the overall energy efficiency of the energy system is optimized under the varying conditions regarding electricity consumption, heat consumption, and power generation in windmills and solar devices. In the SESAM model, which represents the physical properties of the energy system, only a power transmission regulation routine which approximates the thermodynamically efficient functioning of the system can be simulated. Any other regulation criteria would be arbitrary. It is highly questionable whether the thermodynamic efficiency criteria can be met under an electricity market pricing regime where the operators of cogeneration plants with heat pumps and electrochemical converters seek to minimize their net production costs.

It should also be noted that in industrial plants there is no rational reason to assign prices to the internal electric power transmission to the plants' production machinery from engines or fuel cells which are integral parts of the plants. Within industrial plants, biogas plants, and other production complexes, electric power transmission is simply an easier and cheaper way than mechanical or hydraulic transmission to transmit power upon which the functioning of the plants depends. And - presumably - noone would assign specific prices to mechanical or hydraulic power transmission.

13. Motive power for transportation

The factors which in the B-scenario determine the changes in fuel consumption and electric power consumption in vehicles are shown in section 19, figure 1 and table 7, 8 and 9. In this scenario these factors are the same for all the four countries:

- First, in figure 1, the changes in transportation volumes.
- Second, in table 7, the distribution of transportation volumes by individual and collective means of transport. (The distribution of collective transport by the different collective means of transport is not shown in this presentation).
- Third, in table 8, the average changes in motive power per person- or ton-kilometre as a result of changes in
  a) the number of people transported in each vehicle (percentage of seats occupied; car-sharing),
  b) the weight and aerodynamics of vehicles, and
  c) the average speed of vehicles.
- Fourth, in table 9, the means and energy-efficiency of motive power generation.

The steep decline in oil consumption in vehicles shown in figure 6 is the result of changes in all these factors so as to improve energy efficiency. In particular the improved efficiency of engines. In 2030 all petrol- and diesel-fuelled vehicles are assumed to be combustion-engine/electric hybrids with recuperation of breaking power.

"Fuel cell" here stands for any kind of electrochemical power device: hydrogen or methanol fuel cells or metal-oxygen cells such as the zinc fuel cell. (See notes to figure 6 and table 11).

14. From electric power to mechanical shaft power in vehicles

As oil consumption is reduced - deliberately or because of global oil production capacity limitations - the mechanical shaft power in vehicles must increasingly be delivered form the electric grid, directly from overhead wires or power rails to trains, trams and trolley busses or indirectly as chemical or electrochemical energy generated by electric power.

The *direct transmission* of electric power to electric motors in vehicles is by far the most energy-efficient way. In this way about 20% of the electric power delivered from power generating units is lost in the grid and in the electric motors.

The *indirect transmission by means of batteries* is less energy-efficient. Because of additional losses in the charging and discharging of batteries the total loss becomes about 40%, probably less when new batteries with lower losses penetrate the market.

The *indirect transmission by chemical potentials* in the form of hydrogen, methanol or a metal (e.g. zinc) is subject to considerably bigger losses. First the losses in the processes in which the chemical is produced. Then - for hydrogen in particular - the losses in storage and recovery. And, finally, the losses occurring in the engines or fuel cells in which the chemical potential is converted to mechanical or electric power. In the case of fuel cells, additional losses occur in the intermediate storage in buffer batteries of some of the electric power from the cell to the electric motor.

If hydrogen is produced in electrolytic converters, stored in high pressure storage tanks or in metalhydrids and reconverted to electric power in PEM fuel cells[3], the total loss on the way from power generating units to the wheels amount to about 80%. Similar energy losses plus large CO_2 emissions take place when hydrogen is produced in coal/water gasification processes or from natural gas.

Hydrogen can be stored and transported in the form of chemical compounds such as magnesium hydrid or ammoniac. In that case additional losses occur in the chemical storage and retrieval processes.

A different kind of fuel cell, rather like a galvanic battery, has been developed in China. In these cells the electric current is generated by the oxidation of zinc plates. The electric power is converted to an electrochemical potential by the reduction of zinc-oxide from the used oxidated zinc-plates. Thus the zinc is recycled in the process: reduction of zinc-oxide by electric power > oxidation of zinc in the power generating cell. As zinc is cheaply available in large quantities and much easier to handle than hydrogen, this technology may prove preferable to hydrogen technologies.

In this study, “Electricity for transport”, as recorded in figure 4 and table 11 a - e, stands for electricity consumption in vehicles driven directly by electric power (trains, trams, trolley busses powered from overhead wires or power rails) *and* consumption in the recharging of batteries used in electric cars.

Electricity consumption in processes in which electric power is converted to a chemical potential (in the form of hydrogen, a chemical compound or an electropositive metal) is called energy consumption for “electrolysis”. Thus “electrolysis” covers any such process. The reason for this is that these converters are larger plants which are assumed to be located at cogeneration stations so that the heat released in the processes can be utilised in district heating networks, see table 3, table 11 a - e and table 14.

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[3] PEM: Proton Exchange Membrane. It should be noted that hydrogen can also be used in specially designed piston engines, attaining an energy efficiency comparable to the PEM fuel cell + intermediate power storage battery + the electric motor. The fuel cell is not necessarily the most efficient power device but surely the most expensive.

15. Electric power transmission between the Nordic countries

As shown in section 19, table 16, electricity export from Norway in the summer months grows to about 9 GW on the average by 2030. About 2 GW goes to Sweden, about 4 GW to Finland, and about 2 GW to Denmark. The reason is that the electricity production in cogeneration stations is much smaller in summer than in winter and that also windmills produce less in summer than in winter. Therefore, to meet the electricity demand in summer and to deliver electric power to processes converting electric power to chemical energy for vehicles (electrolysis or other) at the same time, the production in hydropower stations must be higher than in winter, see table 14. As most of the hydropower capacity is in Norway, these circumstances result in an increase in the electricity export from Norway in the summer month.

In 2030 about 20% of the electric power produced in the Nordic countries in the summer months, corresponding to about 50% of the electricity export from Norway, is converted to chemical energy for use in vehicles. With sufficient storage capacity, this conversion can be regulated according to the diurnal fluctuations in electric power from windmills and photovoltaic panels. Moreover, the charging of batteries for electric cars can likewise be regulated. By these means the fluctuations in power transmission from Norway to the other countries can be levelled out so that the need for transmission capacity will not by far exceed the average of about 9 GW.

In section 11 above it is mentioned that investments with a rather low utilization, in terms of hours of usage per year, is a general characteristics of energy systems designed to make efficient use of many different energy sources with different annual and diurnal production variations and in which cogeneration of power and heat ensure the efficient utilization of fuel resources. The investments in power transmission lines from Norway, needed to make efficient use of the Norwegian hydropower resources, is an example of these low-utilisation investments.

16. CO_2 emission reduction

The annual CO_2 emissions shown in section 19, figure 3, table 11 and table 16 comprise emissions from stationary units (chimneys) and vehicles (exhaust pipes), except emissions from oil refineries, oil platforms in the North Sea and international air carriers.

In scenario B the 2008 - 2012 emission reduction requirements agreed upon in the EU according to the Kyoto protocol are met for the Nordic region as a whole (see table 11a and 19). For Norway, Sweden and Finland the emissions are a little smaller than or equal to the allowed emissions - in total 2.7 mio. tonnes or 2% less than allowed. Correspondingly, the total emission for Denmark is 2.0 mio. tonnes or 2.0% above the allowed.

In order to limit the rise in average global temperatures to 2 degrees above the pre-industrial temperatures, the developed countries should before 2020 reduce their emissions to 70% of their 1990-emission levels. In scenario B this goal is met for the Nordic region as a whole as the emissions from Sweden, Finland and Denmark are substantially reduced, partly because of electricity import from Norway (see table 16). The further reductions achieved by 2030 come close to the 80% reductions set as a goal for the old developed countries by 2050, so as to allow for an increase in the emission from developing countries under the global plus 2 degrees temperature ceiling.

17. No general specific CO_2 emission reduction factors

In the argumentation for or against certain investments, a specific CO_2 emission reduction factor is often quoted as a weighty argument. For example, it is said that one additional PetaJoule of windpower will reduce the CO_2 emission by so many tonnes per year. But in fact there are no such specific reduction factors which are generally applicable. As shown in the examples in section 19, table 17, the factors vary considerably as the energy system undergoes structural changes.

In the scenario B case, the emission factors for total electricity consumption and for electricity generation in windmills and hydropower stations are generally reduced as the system is changed, see table 17. Because the system is a non-linear complex in which changes in any component has an influence on every energy flow in the system, the numerical changes in these factors are not easily explained.

However, regarding electricity consumption, the main reason why the emission factor is reduced in the course of time is that a higher percentage of the electricity generated in cogeneration plants is converted to heat and to chemical energy for use in vehicles. This conversion is accompanied with energy losses in heat pumps and in electrochemical converters. When electricity consumption in the end-use system is increased, less electricity is converted to heat or chemical energy and, therefore, the conversion losses are decreased. Thus, the reductions in fuel consumption and CO_2 emission obtained by a marginal increase in electricity consumption become smaller, even though the amount of chemical energy for vehicles is reduced. But still, it does pay to save electricity in buildings and industries so as to make more electric power available for transportation.

For the same reason, the reductions obtained by a marginal increase in power generation in windmills becomes smaller as conversion of electric power in heat pumps in cogeneration stations and electrochemical converters comes into play, see table 17.

For hydropower the marginal effects on fuel consumption and CO_2 emission of a marginal increase do not change as much as for windpower. The reason for this is that the hydropower production in contrast to windpower is regulated so as to utilize the production efficiently in the annual and diurnal cycles.

In 2010 the marginal effect of an increase in electricity consumption is numerically less than the marginal effect of an increase in power generation in windmills or hydropower stations. One reason for this is that indoor electricity consumption contributes to the heating of buildings. Therefore, when electricity consumption is increased, fuel consumption for heat generation is decreased.

The examples shown in table 17 thus serve to draw attention to the fact that the energy systems analysis is concerned with complex systems the properties of which cannot be quantified by simple linear spread-sheet analyses. Regarding the preparation of consistent information for energy policy decisions, this is an essential observation.

18. In search of a least-cost strategy for the common good

As noted in section 10 above, individual investments in buildings - improved weathering and new heating installations - are essential for the achievement of the B-scenario results. These investments make up a substantial part of the total investment cost. In total they amount to about 130,000 mio. Euro or about 5,000 Euro per capita in the Nordic countries as a whole - about 10,000 Euro per capita in Norway, 5,000 in Sweden, and about 4,000 in Finland and Denmark over the 25 year period from 2005 to 2030. Plus increasing costs of re-investments in and maintenance of heating installations, see section 19, table 1.

Investments in new energy conversion and storage facilities and new energy sources total about 120,000 mio. Euro and the corresponding costs of re-investments and maintenance total about 110,000 mio. Euro. As mentioned in section 11 and 14 above, the annual utilization of many of these investments is relatively low.

The total costs of investments, re-investments and maintenance over the 25 year period is about 470,000 mio. Euro - around 18,000 Euro per capita in Norway, Sweden and Denmark, a little more in Finland. On the average only around 750 Euro per capita per year.

Some of the capital invested in the different kinds of machinery is worn out along the way (is depreciated) but as shown in figure 3, a large portion (the accumulated capital) remains intact in 2030, serving to keep down the annual fuel costs. And as shown in figure 3 and table 13, the economic cost assessments do not indicate any significant benefits of the pursuance of a business-as-usual policy, even if business-as-usual were a possible option.

Notably, investments in new transportation infrastructures are not included in the cost accounts. This is because there is no basis for the assessment of the investment costs before the new infrastructures are more concretely specified, neither for the comparison with the investment costs implied in the pursuance of the business-as-usual approach.

However, assuming for the case of argument that scenario A is a realistic scenario, it could be argued that the savings in annual costs of operation obtained in the B-scenario can pay for large investments in new transportation infrastructures. As shown in figure 3, the annual costs of operation, including maintenance, depreciation and fuel costs (fuel price case 2), in 2020 - 2030 amounts to about 45,000 mio. Euro/year in scenario A and about 32,000 mio. Euro in scenario B - investments in new transportation infrastructures not included. A portion of the annual savings of about 13,000 mio. Euro, for instance 5,000 mio. Euro/year, can pay for long-term investments in the range of 50,000 - 100,000 mio. Euro in new transportation infrastructures.

Or, more to the point, for transport in particular it does not make sense to compare the business-as-usual with a programme for change. Because there is no way that transportation can remain based mainly on oil-driven means of transport of the present kinds. The longer these technologies prevail and expand, the steeper the decline when the global oil production capacity can no longer meet the global oil demand. Therefore, the swifter the present generation of fuel-guzzling cars is replaced by much more energy-efficient models and substantial parts of the transportation of persons and goods are transferred to energy-efficient collective means of transportation, the better the future social economy for the common good.

In conclusion, regarding the social economy for the common good there is no rational reason not to pursue an energy policy aimed at the implementation of comprehensive, well-coordinated investments programmes aimed at the expeditious reduction of fossil fuel consumption and CO_2 emission. Indeed, there is no realistic alternative to the safeguarding of the basic physical functions of the welfare society by the pursuance of such a policy.

Therefore, the conventional economic comparison of a viable scenario with a business-as-usual scenario, as in figure 3 and table 13, is of very limited relevance. What is relevant is the search for a least-cost strategy for the development of a viable energy system comprising transport and all. The B-scenario is a first approximation to such a least-cost strategy.

19. A first approximation to a viable energy strategy for the Nordic countries

This section shows in graphs and tables a path towards a viable Nordic energy system. In the macro-perspective of total economic costs, CO_2 emission and fuel consumption, this path, called scenario B, is compared with the fictive “baseline” scenario A. This comparison strongly indicate the benefits regarding economic costs, resource economy and environmental impacts of the implementation of an investment programme such as the B-scenario programme.

The transition towards a viable energy system along the scenario B path takes place in a multi-dimensional space of interrelated changes in the many parts and sectors of the energy system. Each graph and table show the transition in one or more of the many dimensions. This documentation provides the insight primarily needed for the inspection and subsequent improvement of the contents of the database which constitutes the model.

Graphs and tables:

Figure 1. Quantitative growth rates
Figure 2. Crude oil price scenarios
Table 1. Investments, reinvestments and maintenance costs 2005 - 2030
Figure 3. Economic costs and CO_2 emission for the Nordic energy system as a whole
Figure 4. Consumption and generation of electricity and heat
Figure 5. Total fuel consumption, including oil consumption in vehicles
Figure 6. Fuel consumption in vehicles
Table 2. Room heat and hot water. Net by source
Table 3. District heat production
Table 4. Electric power generation
Table 5. Replacement of electric heating
Table 6. Fuel consumption in stationary units
Table 7. Transportation by means of transport
Table 8. Average motive power in 2030 per person/tons-kilometre
Table 9. Means of motive power generation
Table 10. General quantitative, qualitative and structural development parameters
Table 11a. Summary of physical results. All four countries
Table 11b - e Summary of physical results, country by country
Table 12. Fuel prices
Table 13. Summaries of economic costs. All four countries. Scenario A and B
Table 14. Annual and monthly energy balances in 2030. The four countries as a whole
Table 15. Annual and monthly energy balances in 2030. Denmark
Table 16. Electricity import and export in 2030
Table 17. Marginal changes in CO2 emission as a result of marginal changes in electricity consumption or production
Table 18. Comparison with a stronger-growth scenario
Table 19. CO_2 emission reductions

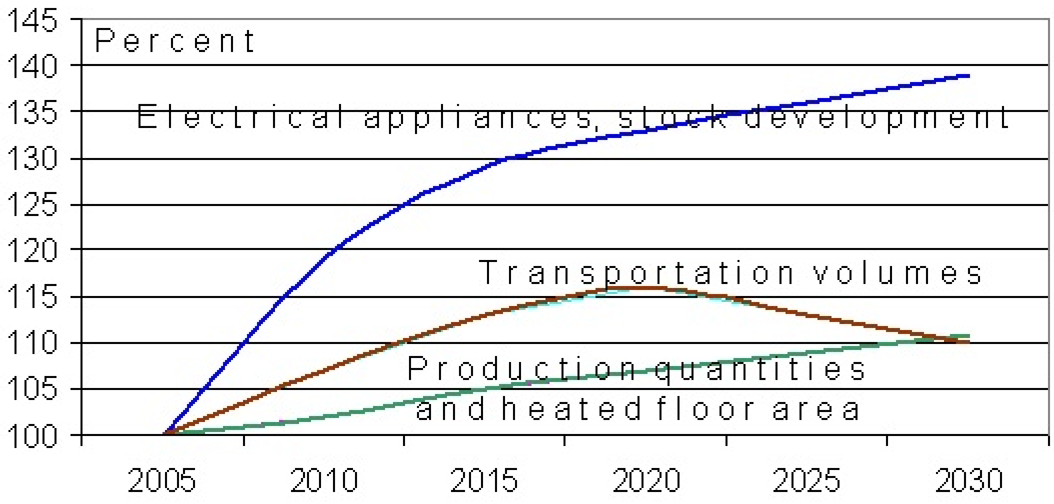

Figure 1. Quantitative growth rates. The same quantitative growth rates are assumed for all the four Nordic countries. For stocks of electrical appliances the growth shown is the weighted average (with respect to annual electricity consumption) for all the different types of appliances. For heated floor area it is the average for all the different building categories. Production quantities are assumed to be the same for all industrial branches. Transportation volumes are measured in person-kilometres and ton-kilometres, respectively.

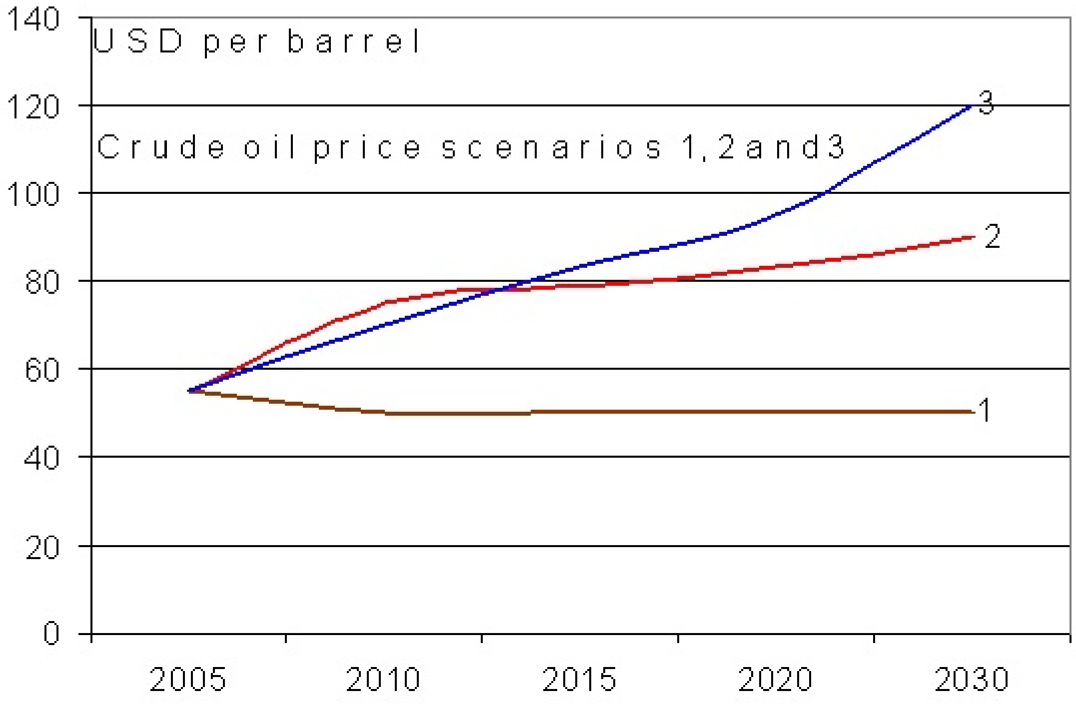

Figure 2. Crude oil price scenarios. The costs of fuel supply are computed in the three cases of future crude oil prices shown. The prices shown are in 2005-USD. The Euro/USD exchange rate is assumed to be constant 1.25 in the whole period. The consumer prices of coal, fuel oil, gas oil, petrol, diesel and natural gas (excl. taxes and VAT) vary with the crude oil price. See table 12.

Naturally, these fuel prices are rather arbitrary projections. They are relevant only for the examination of the sensitivity of the economic costs with respect to fuel prices.

Table 1 Investments, re-investments and maintenance costs 2005 - 2030
1,000 million Euro

	NOR	SWE	FIN	DEN	Total
In buildings:					
Improved heat insulation, heat recovery, etc.	11	24	13	15	63
Average reduction of heat consumption per sq.metre of heated floor area	*34%*	*30%*	*29%*	*30%*	*31%*
Piping, radiators	16	14	5	3	39
Heat pumps	6.6	1.1	0.6	0.5	9
Mini-cogeneration units	1.3	2.5	1.6	2.1	8
Boilers	5.1	2.8	1.0	0.7	10
Solar absorbers	1.1	0.4	0.3	0.7	2
Investments total	41	46	22	22	131
Re-investments and maintenance total	15	31	18	20	84
Total costs	56	77	40	42	215
Collective supply stations (power and heat) and district heating networks. Excl. nuclear power stations					
Investments total	4.4	17	15	15	52
Re-investments and maintenance total	2.7	24	25	21	73
Total cost	6	41	40	36	125
Conversion of electric power to chemical energy for the powering of vehicles (hydrogen or other)					
Investments total					7
Re-investments and maintenance total					3
Total costs					10
Nuclear power stations					
Total operating costs		19	9		28
Windmills *Power generation in 2030* *Installed power MW*	*60 PJ* *5100*	*115 PJ* *9360*	*87 PJ* *7560*	*98 PJ* *9000*	*360 PJ* *31000*
Investments total	6.1	12	9.1	7.6	35
Re-investments and maintenance total	3.5	7.6	4.5	7.8	23
Total costs	10	19	14	16	58
Photovoltaic panels *Power generation in 2030*					*18 PJ*
Investments total					18
Re-investments and maintenance total					4.5
Total costs					22
Solar panels for district heating *Heat generation in 2030*	*2.4 PJ*	*3.9 PJ*	*5.5 PJ*	*12 PJ*	*24 PJ*
Investments total	0.4	0.6	0.8	1.7	3.5
Re-investments and maintenance total	0.1	0.1	0.1	0.3	0.6
Total costs	0.4	0.6	1.0	2.1	4
Biogas plants *Gas production in 2030*		*18 PJ*	*25 PJ*	*20 PJ*	*63 PJ*
Investments total		1.5	2.0	1.3	5
Re-investments and maintenance total		0.9	1.8	1.3	4
Total costs		2.4	3.9	2.6	9
Total costs (Industrial plants not included)	**72**	**159**	**108**	**99**	**471**

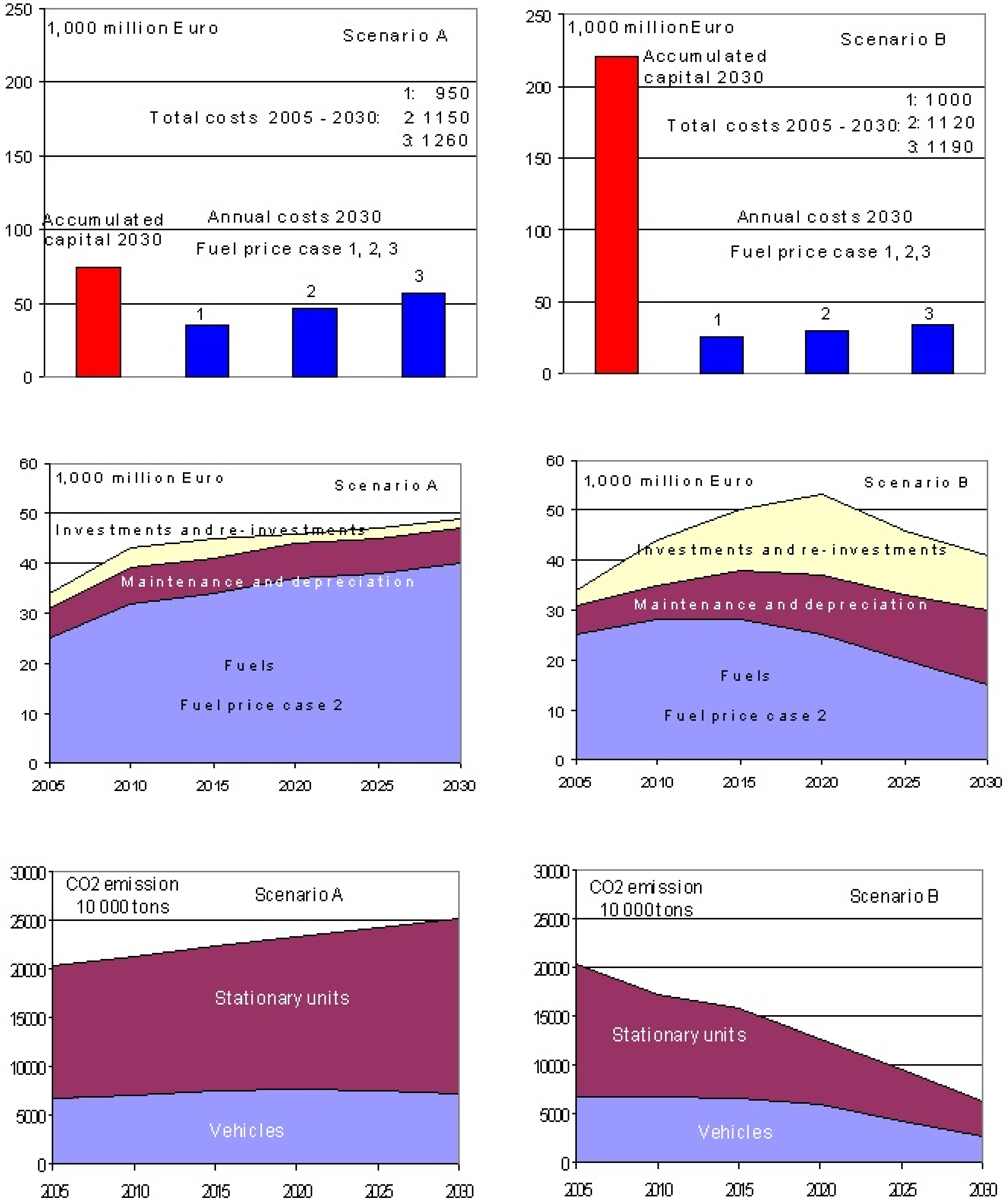

Figure 3. Economic costs and CO_2 emission for the Nordic energy system as a whole.

As a result of the investments made in scenario B (see table 1), the annual CO_2 emission is substantially reduced. Moreover, the total future annual costs in terms of fuel supply, maintenance, and depreciation of capital are substantially reduced in scenario B as compared with scenario A. Regardless of future fossil fuel prices, the total costs, including investments and re-investments, over the period 2005 to 2030 are the same in scenario A and B, within the margin of uncertainty of the cost assessments.

The costs of investments in new transportation infrastructures are not included in the cost accounts for scenario B. However, the future savings in annual costs allow for large investments in new transportation infrastructures without an increase in total annual expenditures of the development and operation of the energy system as a whole as compared with a scenario where oil and gas consumption in vehicles is not substantially reduced.

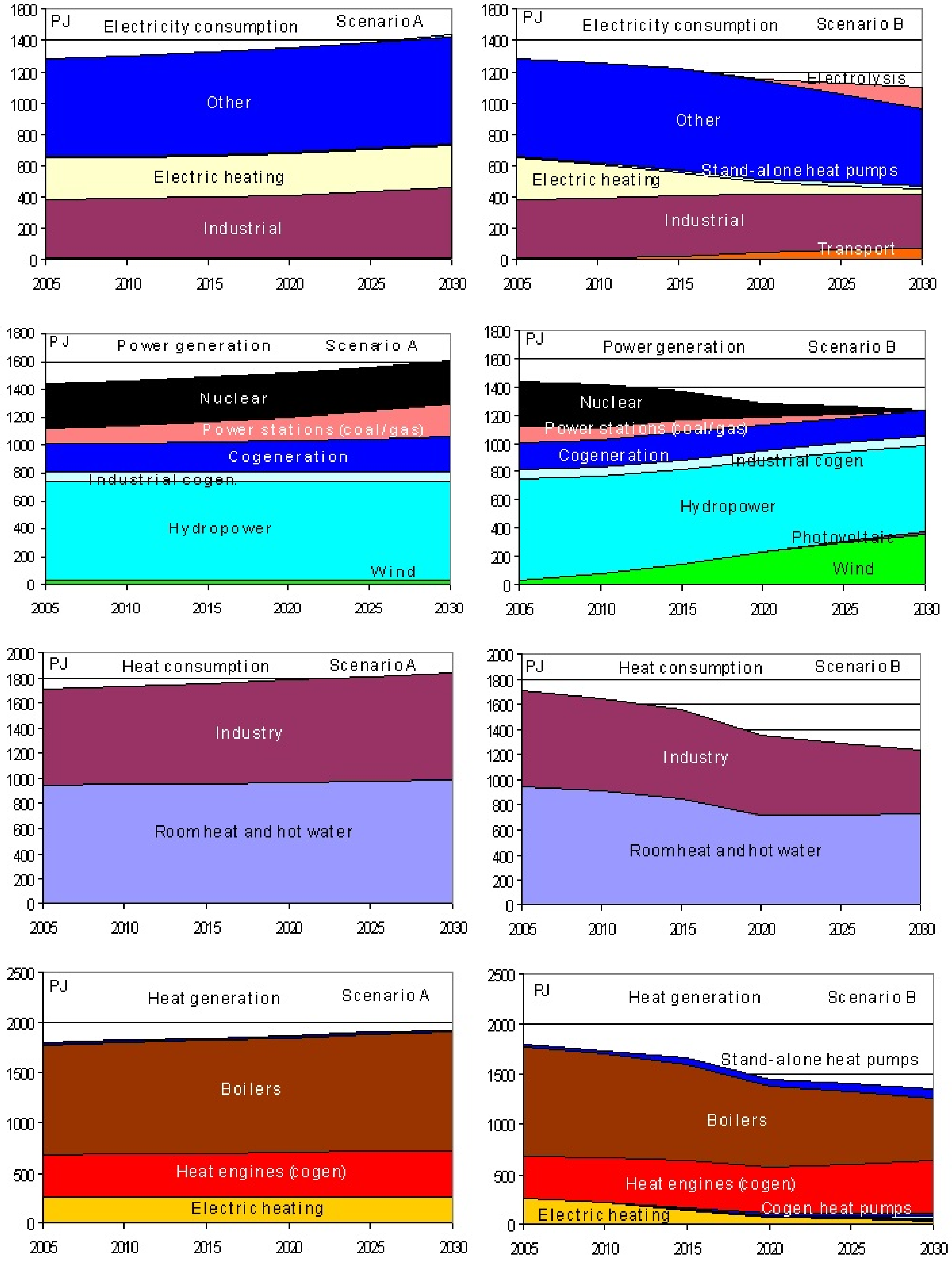

Figure 4. Consumption and generation of electricity and heat. In scenario B nuclear power and power from coal-fired power stations is phased out and electric heating is mostly replaced by other means of heat supply (see table 5). Many fossil-fuel-fired stations are replaced by biomass-fired stations with a lower power to heat ratio (see table 6). Therefore, heat from cogeneration stations grows although electricity generation from these stations is almost constant.

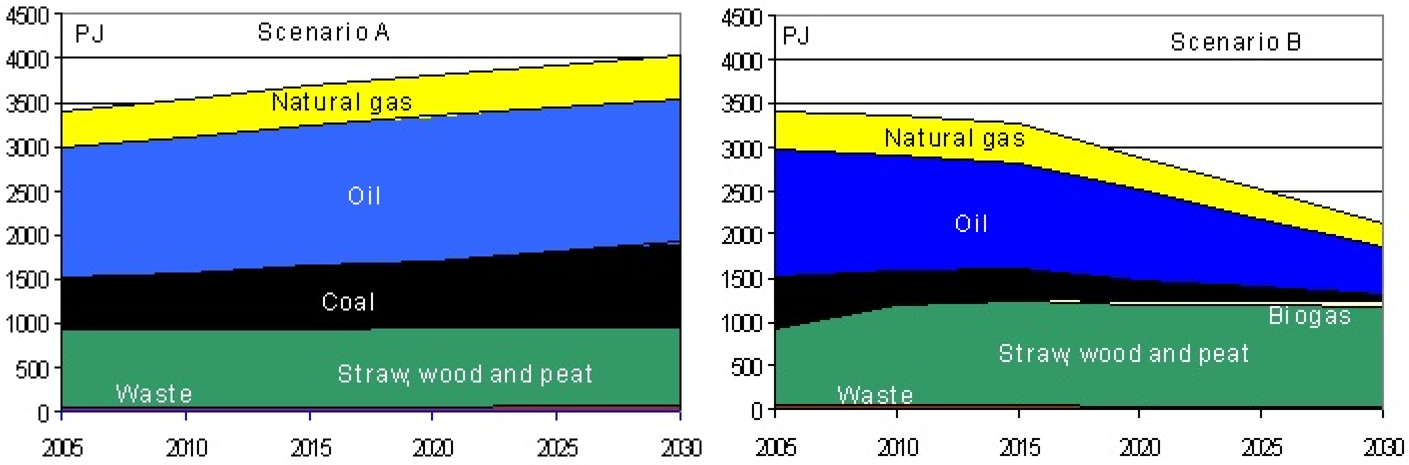

Figure 5. Total fuel consumption, including oil consumption in vehicles. Although nuclear power is phased out and hydropower in 2030 is taken into account by only 85% of the normal-year-production (see figure 4, table 4 and table 11), a substantial decline in fossil fuel consumption is achieved in scenario B.

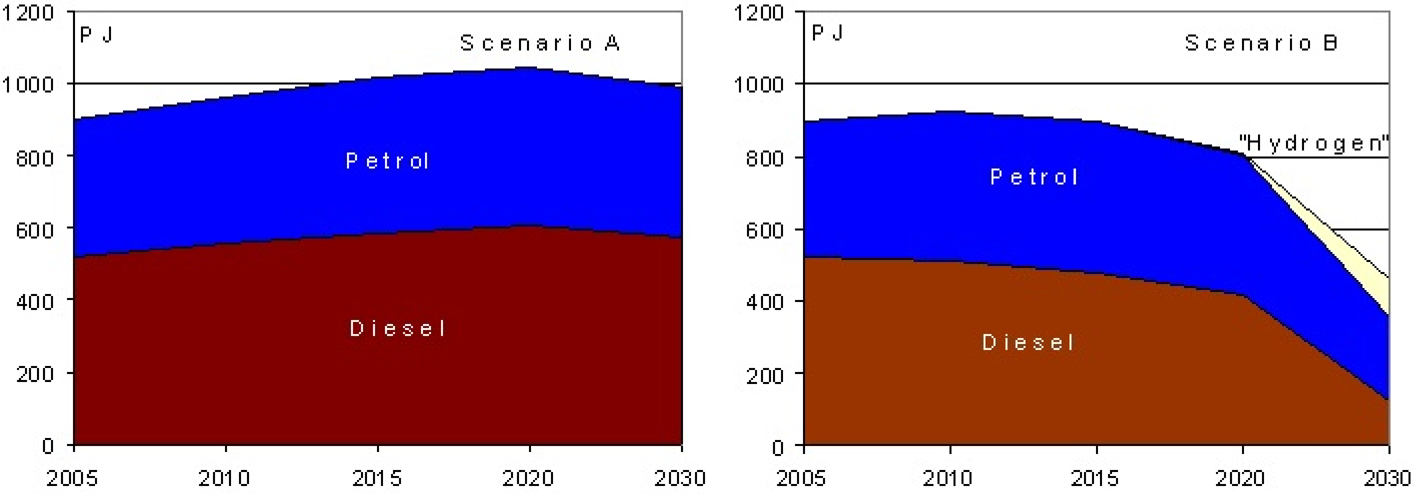

Figure 6. Fuel consumption in vehicles (cars, vans, buses, lorries and trucks, trains and ships). As specified in table 7, 8 and 9, substantial improvements in the energy efficiency in the transport sector is assumed to be achieved in scenario B. Moreover, transportation volumes are assumed to peak around 2020, see figure 1. These changes require that the implementation of a well-planned transition to new, more energy efficient transportation infrastructures as well as the marketing of more energy efficient cars begins well before 2010. Apart from CO_2 reduction requirements, the probability of the peaking of global oil production capacity before 2015 is a compelling reason for the accomplishing of comprehensive efficiency improvements in the transport sector.

“Hydrogen” here stands for any kind of chemical energy generated by the conversion of electric power to chemical energy for use in vehicles. (See section 14).

Table 2 **Room heat and hot water. Net by source. PJ/year**

		Norway		Sweden		Finland		Denmark		Total	
		2005	2030	2005	2030	2005	2030	2005	2030	2005	2030
Cogeneration stations		0	30	95	160	96	115	109	106	300	411
Boiler stations		9	3	63	8	25	7	12	5	109	22
From industrial plants								18	18	18	18
Loss in networks		-1.5	-7.0	-33	-36	-27	-27	-30	-30	-92	-100
District heating total		7	26	125	132	94	94	109	99	335	351
Individual boilers	Oil	17	7	67	14	42	12	34	9	160	42
	Nat.gas			4	1	5	1	31	6	40	8
	Straw, wood etc	25	32	33	51	49	44	12	14	119	141
	Total	42	39	104	66	96	57	77	29	319	191
Individual mini-cogeneration units	Nat.gas				11		6		18		35
	Biomass		10		10		7		2		29
	Total		10		21		13		20		64
Individual solar panels					1		1		2		4
Electric heating		143	12	81	14	28	6	9	2	261	34
Individual heat pumps		3	52	16	23	5	9		3	24	87
Total		195	142	326	257	223	179	195	156	939	734

Table 3 **District heat production PJ/year**

	Norway		Sweden		Finland		Denmark	
	2005	2030	2005	2030	2005	2030	2005	2030
Cogeneration stations: Total:		**30**	**96**	**160**	**96**	**115**	**109**	**106**
Engine and exhaust cooling or condensers		22	89	135	90	93	107	59
Heat pumps		2.4		3.0		4.2		23
Boilers		2.7	6.5	9.0	6.0	6.2	2.4	6.7
From electrolytic converters or alike				8.5		6.0		5.2
Solar absorbers		2.4		3.9		5.5		12
Boilers stations: Total:	**9**	**3.2**	**63**	**8**	**25**	**7**	**12**	**5**
Boilers	7.2	3.2	61	6.5	25	7.1	12	5.3
Heat pumps				1.4				
Electric coils	1.4	0	2.0	0.3				
Average district heating temperatures. Degree Celcius								
January Forward	85	78	85	82	85	82	85	81
Return	35	31	35	33	35	33	35	33
July Forward	75	71	75	73	75	73	75	73
Return	45	38	45	41	45	42	45	41

Table 4 **Electric power generation PJ/year**

	Norway		Sweden		Finland		Denmark		Total	
	2002	2030	2005	2030	2005	2030	2005	2030	2005	2030
Nuclear power stations			240	0	78	0			318	0
Power stations (non-nuclear)					78	0	38	0	116	0
Cogeneration stations (collective) Excl. power used in heat pumps in the stations		10	47	66	59	47	92	33	199	156
Mini-cogeneration units (individual)		5		10		6		11		32
Industrial cogeneration stations			16	16	43	43	7.9	7.9	66	66
Windpower	0.1	61	3.6	115	0.3	87	26	98	30	360
Photovoltaic panels		4.4		4.4		4.4		4.4		18
Hydropower	423	360	244	207	47	40			713	607
Total	423	440	551	418	305	227	164	154	1443	1239

Table 5
Replacement of electric heating.
Percent of electric radiators

		NOR	SWE	FIN	DEN
By heat pumps		52%	16%	10%	10%
By district heating		19%	26%	25%	25%
By biomass boilers		7%	8%	12%	10%
By mini-cogeneration units	Nat. gas		8%	8%	12%
	Biomass	8%	8%	10%	6%
Total replaced		86%	66%	65%	63%

Table 6 **Fuel consumption in stationary units PJ/year**

	2005								2030							
	Coal	Fuel oil	Gas oil	Nat. gas	Straw Wood	Peat	Waste	Bio-gas	Coal	Fuel oil	Gas oil	Nat. gas	Straw Wood	Peat	Waste	Bio-gas
Norway **Total**	70	18	24	13	64		7.6		29	8.3	9.7	42	137		2.6	
Power&cogeneration plants										2.1	0.8	2.6	53		0.9	
District heating boilers		0.5			1.5		7.6			0.6		0.3	1.8		1.7	
Individual boilers and stoves			24		41						8.9		60			
Industrial plants	70	18		13	22				29	5.6		39	23			
Sweden **Total**	79	143	84	54	348	19	14		19	47	18	52	489		6.8	18
Power&cogeneration plants	25	43		6.2	58	19	14			17	0.8	23	218		6.8	18
District heating boilers		27		1.5	45					0.5	17		7.5			
Individual boilers and stoves			84	4.9	55							1.1	99			
Industrial plants	54	72		42	190				19	29		28	165			
Finland **Total**	242	143	48	160	277	92	8.5		13	39	14	63	430		4.4	25
Power&cogeneration plants	217	32		59	38	25	6.2			10		26	128		3.7	25
District heating boilers	0.6	0.8		6.1	11	12	2.2		0.5	0.7		0.5	8.0		0.6	
Individual boilers and stoves			48	5.2	96						14	1.0	86			
Industrial plants	24	109		90	131	54			13	29		36	209			
Denmark **Total**	209	58	41	196	65		28	3.0	5.5	39	11	123	99		9.7	20
Power&cogeneration plants	198	6.1		105	28		8.3	3.0	0.5	9.1		75	46		3.6	20
District heating boilers		2.3		3.1	9.0		1.0			0.4		0.4	5.8		0.4	
Individual boilers and stoves			41	35	21						11	6.7	27			
Industrial plants	11	50		52	6.0		18		5.0	29		40	20		5.6	
Total	600	361	197	424	753	111	58	3.0	67	133	53	281	1156		24	64
Power&cogeneration plants	440	81		170	124	44	29	3.0	0.5	38	2.3	127	445		15	64
District heating boilers	0.6	31		11	67	12	11		0.5	2.2		1.2	23		2.8	
Individual boilers and stoves			197	45	213						50	9.0	272			
Industrial plants	160	250		197	349	54	18		66	92		143	417		5.6	

Table 7

Transportation by means of transport. Percent of person/ton-kilometres

Transport of:	Persons		Goods	
By:	Cars	Collective means of transport	Lorries and trucks	Train and ship
2005	77%	23%	70%	30%
2030	57%	43%	49%	51%

Table 8

Average motive power in 2030 per person/ton-kilometre in percent of motive power used in 2005

Cars	Busses	Trains, persons	Trains, goods	Lorries, trucks
90%	80%	90%	90%	100%

Table 9

Means of motive power generation

			Petrol engine	Diesel engine	Electric motor	Fuel cell
Cars	2005	Percent of motive power	84%	16%		
		Efficiency	0.21	0.25		
	2030	Percent of motive power	36%	10%	17%	37%
		Efficiency	0.30	0.35	0.67	0.32
Busses	2005	Percent of motive power		100%		
		Efficiency		0.27		
	2030	Percent of motive power		55%	45%	
		Efficiency		0.35	0.9	
Trains	2005	Percent of motive power		14%	86%	
		Efficiency		0.26	0.9	
	2030	Percent of motive power		12%	88%	
		Efficiency		0.35	0.9	

Table 10. General quantitative, qualitative and structural development parameters.

The parameters for electrical appliances, heated floor area, industrial production and transportation are the same for all the four countries.

For electrical appliances the values are weighted averages - with respect to annual electricity consumption - for the different types of appliances.

The parameters for net heat consumption in buildings are averages of computed values for the different types of buildings in the four countries.

Scenario B:

Electrical appliances Index 2005=100

	2005	2010	2015	2020	2030
Stock development	100	119	129	133	139
El.consumption devel.	100	103	105	101	78
Efficiency factor	1.00	0.86	0.81	0.76	0.57

Buildings stock Index 2005=100

	2005	2010	2015	2020	2030
Heated floor area	100	102	105	107	111
Net heat consumption	100	97	91	76	77
Consumption per m2	1.00	0.94	0.87	0.71	0.69

Industrial production Index 2005=100

	2005	2010	2015	2020	2030
Production quantities	100	102	105	107	111

Transportation, persons Index 2005=100

	2005	2010	2015	2020	2030
Total	100	107	113	116	110
Cars	0.77	0.77	0.76	0.75	0.57
Public transport	0.23	0.23	0.24	0.25	0.43

Transportation of goods Index 2005=100

	2005	2010	2015	2020	2030
Total	100	107	113	116	110
Vans and trucks	0.70	0.69	0.69	0.67	0.49
Trains and ships	0.30	0.31	0.31	0.33	0.51

Corresponding scenario A values ("business-as-usual" scenario):

Electrical appliances Index 2005=100

	2005	2010	2015	2020	2030
Stock development	100	119	129	133	139
El.consumption devel.	100	103	105	107	110
Efficiency factor	1.00	0.86	0.81	0.80	0.79

Buildings stock Index 2005=100

	2005	2010	2015	2020	2030
Heated floor area	100	102	105	107	111
Net heat consumption	100	101	102	103	105
Consumption per m2	1.00	0.98	0.97	0.96	0.95

Industrial production Index 2005=100

	2005	2010	2015	2020	2030
Production quantities	100	102	105	107	111

Transportation, persons Index 2005=100

	2005	2010	2015	2020	2030
Total	100	107	113	116	110
Cars	0.77	0.77	0.77	0.77	0.77
Public transport	0.23	0.23	0.23	0.23	0.23

Transportation of goods Index 2005=100

	2005	2010	2015	2020	2030
Total	100	107	113	116	110
Vans and trucks	0.70	0.70	0.70	0.70	0.70
Trains and ships	0.30	0.30	0.30	0.30	0.30

Table 11a. Norway Sweden Finland Denmark
Scenario B. Summary of physical results

Note: "Electrolysis, el.consum" stands for the conversion of electric power to any kind of chemical energy for use in vehicles, not necessarily hydrogen. Hence, "Hydrogen" stands for any kind of chemical energy generated by "electrolysis". See section 14.

```
Electricity consumption & export    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            13.3    16.9    25.4    42.0    76.4
 Industrial processes       374     375     381     381     338
 Electric heating           264     217     146    72.1    33.8
 Stand-alone heat pumps    6.79    8.40    16.0    19.0    24.8
 Other                      623     639     652     629     489
 Electrolysis,el.consum    0.00    0.00    0.00    7.15     142
 Export                    0.00   -0.00    0.52    1.96    7.59
  -----------------------------------------------------------------------
                 Total     1282    1257    1222    1152    1112

Electricity generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Windpower                 30.1    74.5     139     228     360
 Photovoltaic panels       0.00    0.98    2.36    5.38    17.6
 Hydropower                 713     695     677     653     607
 Industrial cogenerat.     66.2    66.2    66.2    66.2    66.2
 Cogeneration stations      199     196     201     180     188
 Power stations             116    83.2    86.0    52.5    0.00
 Import                    0.00    0.02    0.00    0.00    0.00
 Nuclear power              318     298     202     105    0.00
  -----------------------------------------------------------------------
                 Total     1443    1414    1373    1291    1239

Net heat consumption    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Room heat&hot water        941     908     853     712     724
 Industrial processes       763     737     710     644     511
  -----------------------------------------------------------------------
                 Total     1704    1645    1563    1356    1235

Heat generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Electric heating           264     217     146    72.1    33.8
 From indiv.solar coll.    0.09    0.05    0.53    2.47    7.17
 Collective solar coll.    0.00    0.00    1.23    9.04    23.5
 Electrolytic converter    0.00    0.00    0.00    1.07    21.4
 Cogeneration heatpumps    0.00    0.00    20.8    32.1    32.5
 Motors                     423     450     474     461     514
 Boilers                   1085    1042     958     810     625
 From seasonstor. to HP    0.00    0.00    0.00    0.50    4.86
 Stand-alone heat pumps    23.4    29.5    57.0    67.9    88.8
  -----------------------------------------------------------------------
                 Total     1795    1738    1658    1456    1351

Fuel consumption Total    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Waste                     58.1    52.1    46.8    39.4    23.6
 Straw+wood                 864    1143    1192    1161    1156
 Biogas                    3.03    9.61    25.4    38.1    63.6
 Coal, int.                 600     385     335     222    66.9
 Oil, int.                 1458    1306    1212    1045     541
 Natural gas, int.          424     458     470     372     281
 Coal, ext.                0.00    0.03   -0.98   -3.68   -14.3
 Oil, ext.                 0.00    0.00    0.00    0.00    0.00
 Natural gas, ext.         0.00    0.01   -0.25   -0.92   -3.57
  -----------------------------------------------------------------------
                 Total     3407    3354    3280    2872    2114

Fuel consumption in vehicles    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
PETROL                      522     511     479     416     125
DIESEL                      378     413     416     386     231
HYDROGEN                   0.00    0.00    0.00    5.19     104
-----------------------------------------------------------------------
                 Total      900     924     895     807     460

CO2 emission, 10,000 tons    10.000 tons  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            6609    6786    6575    5891    2620
 Stationary units, int.   13616   10435    9188    6746    3669
 Stationary units, ext.    0.00    0.32   -10.7   -40.2    -156
  -----------------------------------------------------------------------
                 Total    20225   17221   15752   12597    6133
Kyoto/EU target                   17280
```

Table 11b. Norway
Scenario B. Summary of physical results

Note: “Electrolysis, el.consum” stands for the conversion of electric power to any kind of chemical energy for use in vehicles, not necessarily hydrogen. Hence, “Hydrogen” stands for any kind of chemical energy generated by “electrolysis”. See section 14.

```
Electricity consumption & export    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            2.55    3.16    5.15    9.06    17.2
 Industrial processes       119     118     119     118     101
 Electric heating           144     120    78.9    36.4    12.1
 Stand-alone heat pumps    0.73    1.80    6.32    9.51    13.9
 Other                      107     109     110     107    86.0
 Electrolysis,el.consum    0.00    0.00    0.00    0.41    10.7
 Export                    15.5    37.9    78.4     125     175
  -----------------------------------------------------------------------
                 Total      389     390     398     405     417

Electricity generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Windpower                 0.13    8.46    20.2    31.8    60.7
 Photovoltaic panels       0.00    0.24    0.59    1.35    4.39
 Hydropower                 423     412     401     387     360
 Industrial cogenerat.     0.00    0.00    0.00    0.00    0.00
 Cogeneration stations     0.00    2.06    6.88    11.3    14.7
 Power stations            0.00    0.00    0.00    0.00    0.00
 Import                    0.00    0.00    0.00    0.00    0.00
 Nuclear power             0.00    0.00    0.00    0.00    0.00
  -----------------------------------------------------------------------
                 Total      423     422     428     431     439

Net heat consumption    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Room heat&hot water        195     188     176     145     142
 Industrial processes       101    98.2    95.5    90.9    80.8
  -----------------------------------------------------------------------
                 Total      296     287     272     236     223

Heat generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Electric heating           144     120    78.9    36.4    12.1
 From indiv.solar coll.    0.03    0.02    0.21    1.04    3.38
 Collective solar coll.    0.00    0.00    0.00    0.52    2.38
 Electrolytic converter    0.00    0.00    0.00    0.06    1.61
 Cogeneration heatpumps    0.00    0.00    0.73    1.69    2.44
 Motors                    0.00    4.10    13.9    23.3    31.7
 Boilers                    150     157     156     142     125
 From seasonstor. to HP    0.00    0.00    0.00    0.00    0.40
 Stand-alone heat pumps    2.83    6.87    24.1    35.7    51.8
  -----------------------------------------------------------------------
                 Total      298     288     274     241     231

Fuel consumption Total    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Waste                     7.58    4.77    2.33    3.81    2.66
 Straw+wood                63.6     111     135     134     137
 Biogas                    0.00    0.00    0.00    0.00    0.00
 Coal                      70.3    47.7    43.3    38.4    29.2
 Oil                        277     275     266     240     141
 Natural gas               13.3    29.5    34.8    39.4    42.2
  -----------------------------------------------------------------------
                 Total      432     469     482     456     353

Fuel consumption in vehicles    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
PETROL                      119     117     109    95.9    43.0
DIESEL                      116     128     130     121    80.1
HYDROGEN                   0.00    0.00    0.00    0.30    7.84
-----------------------------------------------------------------------
                 Total      236     245     239     217     131

CO2 emission, 10,000 tons    10.000 tons  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            1732    1800    1760    1596     906
 Stationary units          1060     854     816     766     656
  -----------------------------------------------------------------------
                 Total     2792    2654    2577    2362    1562
Kyoto/EU target                    2730
```

Table 11c. Sweden
Scenario B. Summary of physical results

Note: “Electrolysis, el.consum” stands for the conversion of electric power to any kind of chemical energy for use in vehicles, not necessarily hydrogen. Hence, “Hydrogen” stands for any kind of chemical energy generated by “electrolysis”. See section 14.

```
Electricity consumption & export    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            7.22    7.67    10.7    16.4    27.8
 Industrial processes       119     119     122     122     110
 Electric heating          83.2    66.6    46.2    23.3    13.8
 Stand-alone heat pumps    4.49    4.72    6.84    6.63    7.19
 Other                      268     275     281     270     209
 Electrolysis,el.consum    0.00    0.00    0.00    2.64    56.7
 Export                    9.52    24.8   -0.00   -0.00   -0.00
  ------------------------------------------------------------------------
                Total       491     498     466     442     425

Electricity generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Windpower                 3.56    24.7    41.5    72.4     115
 Photovoltaic panels       0.00    0.24    0.59    1.35    4.39
 Hydropower                 244     238     231     223     207
 Industrial cogenerat.     15.5    15.5    15.5    15.5    15.5
 Cogeneration stations     47.4    57.7    61.7    58.0    75.8
 Power stations            0.00    0.00    0.00    0.00    0.00
 Import                    0.00    0.00    36.7    62.9    53.8
 Nuclear power              240     220     135    60.0    0.00
  ------------------------------------------------------------------------
                Total       550     556     522     493     472

Net heat consumption    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Room heat&hot water        328     316     296     247     256
 Industrial processes       274     264     254     228     178
  ------------------------------------------------------------------------
                Total       601     580     550     475     433

Heat generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Electric heating          83.2    66.6    46.2    23.3    13.8
 From indiv.solar coll.    0.02    0.01    0.10    0.42    1.15
 Collective solar coll.    0.00    0.00    0.00    0.00    3.90
 Electrolytic converter    0.00    0.00    0.00    0.40    8.50
 Cogeneration heatpumps    0.00    0.00    9.03    12.1    2.96
 Motors                     121     140     154     156     190
 Boilers                    414     390     351     296     226
 From seasonstor. to HP    0.00    0.00    0.00    0.00    0.70
 Stand-alone heat pumps    15.7    16.6    23.7    23.0    24.9
  ------------------------------------------------------------------------
                Total       634     613     585     511     472

Fuel consumption Total    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Waste                     14.4    11.4    8.57    8.96    6.79
 Straw+wood                 367     473     480     476     489
 Biogas                    0.00    0.00    6.72    10.1    18.2
 Coal                      79.0    79.7    69.2    44.9    19.3
 Oil                        510     450     413     338     159
 Natural gas               54.5    51.8    56.5    51.4    52.3
  ------------------------------------------------------------------------
                Total      1025    1066    1034     930     745

Fuel consumption in vehicles    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
PETROL                      196     192     180     156    46.1
DIESEL                     87.8     100     101    91.5    48.7
HYDROGEN                   0.00    0.00    0.00    1.92    41.4
------------------------------------------------------------------------
                Total       284     292     280     249     136

CO2 emission, 10,000 tons    10.000 tons  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            2082    2142    2055    1815     697
 Stationary units          3003    2480    2150    1599     979
  ------------------------------------------------------------------------
                Total      5084    4622    4206    3415    1676
Kyoto/EU target                    4800
```

Table 11d. Finland
Scenario B. Summary of physical results

Note: "Electrolysis, el.consum" stands for the conversion of electric power to any kind of chemical energy for use in vehicles, not necessarily hydrogen. Hence, "Hydrogen" stands for any kind of chemical energy generated by "electrolysis". See section 14.

```
Electricity consumption & export    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            2.01    2.75    4.51    7.74    15.1
 Industrial processes       108     109     111     111     100
 Electric heating          27.7    22.4    15.8    9.26    5.89
 Stand-alone heat pumps    1.57    1.74    2.27    2.19    2.81
 Other                      160     164     167     161     125
 Electrolysis,el.consum    0.00    0.00    0.00    2.02    39.8
 Export                   -0.00   -0.00   -0.00   -0.00   -0.00
  -----------------------------------------------------------------------
                 Total      299     299     300     293     289

Electricity generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Windpower                 0.28    6.09    21.8    42.5    87.0
 Photovoltaic panels       0.00    0.24    0.59    1.35    4.39
 Hydropower                47.0    45.9    44.8    43.2    40.1
 Industrial cogenerat.     42.8    42.8    42.8    42.8    42.8
 Cogeneration stations     58.8    58.0    56.8    50.5    52.7
 Power stations            78.3    67.5    69.7    42.6    0.00
 Import                    39.6    45.7    40.3    65.7    98.8
 Nuclear power             78.0    78.0    67.0    45.0    0.00
  -----------------------------------------------------------------------
                 Total      345     344     344     334     326

Net heat consumption    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Room heat&hot water        222     215     202     170     176
 Industrial processes       299     288     277     249     194
  -----------------------------------------------------------------------
                 Total      521     503     480     419     370

Heat generation    PJ   MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Electric heating          27.7    22.4    15.8    9.26    5.89
 From indiv.solar coll.    0.01    0.01    0.09    0.36    1.02
 Collective solar coll.    0.00    0.00    0.00    2.54    5.49
 Electrolytic converter    0.00    0.00    0.00    0.30    5.98
 Cogeneration heatpumps    0.00    0.00    5.37    7.67    4.24
 Motors                     181     185     188     182     198
 Boilers                    335     317     291     239     171
 From seasonstor. to HP    0.00    0.00    0.00    0.00    1.00
 Stand-alone heat pumps    4.88    5.48    7.19    6.88    8.75
  -----------------------------------------------------------------------
                 Total      548     530     508     448     401

Fuel consumption Total    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Waste                     8.49    8.44    7.77    6.28    4.38
 Straw+wood                 369     477     485     451     430
 Biogas                    0.00    5.45    11.9    16.0    25.3
 Coal                       242     163     154    98.9    13.0
 Oil                        374     302     277     237     119
 Natural gas                160     163     157     116    63.5
  -----------------------------------------------------------------------
                 Total     1154    1119    1093     925     655

Fuel consumption in vehicles    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
PETROL                     93.3    91.3    85.5    74.2    7.96
DIESEL                     90.9    98.2    98.7    92.4    57.1
HYDROGEN                   0.00    0.00    0.00    1.47    29.1
-----------------------------------------------------------------------
                 Total      184     190     184     168    94.2

CO2 emission, 10,000 tons    10.000 tons  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            1354    1393    1355    1226     481
 Stationary units          5688    4349    3813    2612     898
  -----------------------------------------------------------------------
                 Total     7042    5742    5167    3838    1379
Kyoto/EU target                    5750
```

Table 11e. Denmark
Scenario B. Summary of physical results

Note: “Electrolysis, el.consum” stands for the conversion of electric power to any kind of chemical energy for use in vehicles, not necessarily hydrogen. Hence, “Hydrogen” stands for any kind of chemical energy generated by “electrolysis”. See section 14.

```
Electricity consumption & export    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            1.51    3.30    5.09    8.79    16.4
 Industrial processes      28.8    28.9    29.5    29.6    26.7
 Electric heating          8.66    7.51    5.49    3.16    1.98
 Stand-alone heat pumps    0.00    0.14    0.54    0.63    0.90
 Other                     88.6    92.1    94.5    91.1    68.7
 Electrolysis,el.consum    0.00    0.00    0.00    2.08    35.2
 Export                    14.7   -0.00   -0.00    5.58   -0.00
  ---------------------------------------------------------------------
                Total       142     132     135     141     150

Electricity generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Windpower                 26.1    35.2    55.5    81.7    97.6
 Photovoltaic panels       0.00    0.24    0.59    1.35    4.39
 Hydropower                0.00    0.00    0.00    0.00    0.00
 Industrial cogenerat.     7.92    7.92    7.92    7.92    7.92
 Cogeneration stations     92.4    78.1    75.8    60.1    44.3
 Power stations            38.1    15.7    16.2    9.90    0.00
 Import                    0.00    17.1    0.80    0.00    15.2
 Nuclear power             0.00    0.00    0.00    0.00    0.00
  ---------------------------------------------------------------------
                Total       165     154     157     161     169

Net heat consumption    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Room heat&hot water        196     189     178     150     151
 Industrial processes      90.0    86.8    83.5    75.1    58.4
  ---------------------------------------------------------------------
                Total       286     276     262     225     209

Heat generation    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Electric heating          8.66    7.51    5.49    3.16    1.98
 From indiv.solar coll.    0.02    0.02    0.14    0.64    1.63
 Collective solar coll.    0.00    0.00    1.23    5.98    11.8
 Electrolytic converter    0.00    0.00    0.00    0.31    5.28
 Cogeneration heatpumps    0.00    0.00    5.67    10.7    22.8
 Motors                     121     120     118     101    94.5
 Boilers                    186     178     160     133     103
 From seasonstor. to HP    0.00    0.00    0.00    0.50    2.75
 Stand-alone heat pumps    0.00    0.53    2.05    2.35    3.34
  ---------------------------------------------------------------------
                Total       316     307     293     257     247

Fuel consumption Total    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Waste                     27.6    27.5    28.2    20.3    9.72
 Straw+wood                64.6    80.7    92.4     100    99.0
 Biogas                    3.03    4.16    6.79    12.0    20.1
 Coal                       209    95.3    67.8    39.4    5.48
 Oil                        296     279     256     229     122
 Natural gas                196     214     222     165     123
  ---------------------------------------------------------------------
                Total       796     701     673     566     379

Fuel consumption in vehicles    PJ  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
PETROL                      113     111     104    90.0    27.7
DIESEL                     83.3    86.5    87.1    80.7    45.1
HYDROGEN                   0.00    0.00    0.00    1.51    25.7
---------------------------------------------------------------------
                Total       196     197     191     172    98.5

CO2 emission, 10,000 tons    10.000 tons  MM: F4H3I1E2L1W3P3S3h1V3
                           2005    2010    2015    2020    2030
 Transportation            1441    1450    1404    1255     536
 Stationary units          3865    2752    2409    1769    1136
  ---------------------------------------------------------------------
                Total      5307    4202    3813    3024    1672
Kyoto/EU target                    4000
```

Table 12. Fuel prices
Consumer prices, excl. taxes and VAT

Fuel price development case 1

		2005	2010	2015	2020	2030
COAL	EUR/ton	37	37	37	37	37
	EUR/GJ	1.5	1.5	1.5	1.5	1.5

		2005	2010	2015	2020	2030
Crude oil	USD/barrel	55	50	50	50	50
1 USD= 0.80 EUR						

		2005	2010	2015	2020	2030
FUELOIL	EUR/1000 ltr	468	443	443	443	443
	EUR/GJ	13.8	13.1	13.1	13.1	13.1
GASOIL	EUR/1000 ltr	497	471	471	471	471
	EUR/GJ	13.9	13.1	13.1	13.1	13.1
PETROL	EUR/1000 ltr	510	483	483	483	483
	EUR/GJ	13.9	13.1	13.1	13.1	13.1
DIESEL	EUR/1000 ltr	497	471	471	471	471
	EUR/GJ	13.9	13.1	13.1	13.1	13.1

		2005	2010	2015	2020	2030
NATUR.GAS	EUR/1000 m3	238	238	238	238	238
	EUR/GJ	6.1	6.1	6.1	6.1	6.1

Fuel price development case 2

		2005	2010	2015	2020	2030
COAL	EUR/ton	37	39	47	54	69
	EUR/GJ	1.5	1.6	1.9	2.1	2.7

		2005	2010	2015	2020	2030
Crude oil	USD/barrel	55	75	79	83	90
1 USD= 0.80 EUR						

		2005	2010	2015	2020	2030
FUELOIL	EUR/1000 ltr	468	566	584	603	639
	EUR/GJ	13.8	16.7	17.2	17.8	18.8
GASOIL	EUR/1000 ltr	497	601	620	639	678
	EUR/GJ	13.9	16.7	17.3	17.8	18.9
PETROL	EUR/1000 ltr	510	616	636	656	696
	EUR/GJ	13.9	16.7	17.3	17.8	18.9
DIESEL	EUR/1000 ltr	497	601	620	639	678
	EUR/GJ	13.9	16.7	17.3	17.8	18.9

		2005	2010	2015	2020	2030
NATUR.GAS	EUR/1000 m3	238	322	336	351	381
	EUR/GJ	6.1	8.2	8.6	9.0	9.8

Fuel price development case 3

		2005	2010	2015	2020	2030
COAL	EUR/ton	37	48	57	66	84
	EUR/GJ	1.5	1.9	2.3	2.6	3.3

		2005	2010	2015	2020	2030
Crude oil	USD/barrel	55	70	83	95	120
1 USD= 0.80 EUR						

		2005	2010	2015	2020	2030
FUELOIL	EUR/1000 ltr	468	541	603	664	786
	EUR/GJ	13.8	16.0	17.8	19.6	23.2
GASOIL	EUR/1000 ltr	497	575	639	704	834
	EUR/GJ	13.9	16.0	17.8	19.6	23.2
PETROL	EUR/1000 ltr	510	590	656	722	855
	EUR/GJ	13.9	16.0	17.8	19.6	23.2
DIESEL	EUR/1000 ltr	497	575	639	704	834
	EUR/GJ	13.9	16.0	17.8	19.6	23.2

		2005	2010	2015	2020	2030
NATUR.GAS	EUR/1000 m3	238	393	426	458	524
	EUR/GJ	6.1	10.1	10.9	11.8	13.4

Table 13. Summaries of economic costs. All four countries total. Scenario A and B

```
r= 0% Summary of costs, year by year
r= 5% Present value, discounted by 5%
```

Fuel prices development case 1:

```
Economic costs  1000 million  EUR
Total                           A       B
          r= 0.0% 2005-2030   943.9   997.5
          r= 5.0% 2005-2030   546.4   590.1
Fossil fuels                    A       B
          r= 0.0% 2005-2030   645.5   440.7
          r= 5.0% 2005-2030   370.6   278.2
Local fuels                     A       B
          r= 0.0% 2005-2030   46.78   59.84
          r= 5.0% 2005-2030   27.04   34.08
El-import/export                A       B
          r= 0.0% 2005-2030   -0.34   -0.38
          r= 5.0% 2005-2030   -0.12   -0.15
Renewable energy sources        A       B
          r= 0.0% 2005-2030    3.82   95.82
          r= 5.0% 2005-2030    2.38   49.04
Supply installations            A       B
          r= 0.0% 2005-2030   248.1   338.6
          r= 5.0% 2005-2030   146.4   194.8
Buildings                       A       B
          r= 0.0% 2005-2030    0.00   63.03
          r= 5.0% 2005-2030    0.00   34.11
```

Fuel prices development case 2:

```
Economic costs  1000 million  EUR
Total                           A       B
          r= 0.0% 2005-2030    1152    1124
          r= 5.0% 2005-2030   650.1   659.2
Fossil fuels                    A       B
          r= 0.0% 2005-2030   857.2   571.7
          r= 5.0% 2005-2030   476.2   349.7
Local fuels                     A       B
          r= 0.0% 2005-2030   43.46   55.52
          r= 5.0% 2005-2030   25.27   31.78
El-import/export                A       B
          r= 0.0% 2005-2030   -0.48   -0.52
          r= 5.0% 2005-2030   -0.16   -0.20
Renewable energy sources        A       B
          r= 0.0% 2005-2030    3.82   95.82
          r= 5.0% 2005-2030    2.38   49.04
Supply installations            A       B
          r= 0.0% 2005-2030   248.1   338.6
          r= 5.0% 2005-2030   146.4   194.8
Buildings                       A       B
          r= 0.0% 2005-2030    0.00   63.03
          r= 5.0% 2005-2030    0.00   34.11
```

Fuel prices development case 3:

```
Economic costs  1000 million  EUR
Total                           A       B
          r= 0.0% 2005-2030    1257    1189
          r= 5.0% 2005-2030   693.8   687.9
Fossil fuels                    A       B
          r= 0.0% 2005-2030   953.8   624.8
          r= 5.0% 2005-2030   515.8   373.1
Local fuels                     A       B
          r= 0.0% 2005-2030   52.50   67.31
          r= 5.0% 2005-2030   29.40   37.17
El-import/export                A       B
          r= 0.0% 2005-2030   -0.84   -0.88
          r= 5.0% 2005-2030   -0.29   -0.33
Renewable energy sources        A       B
          r= 0.0% 2005-2030    3.82   95.82
          r= 5.0% 2005-2030    2.38   49.04
Supply installations            A       B
          r= 0.0% 2005-2030   248.1   338.6
          r= 5.0% 2005-2030   146.4   194.8
Buildings                       A       B
          r= 0.0% 2005-2030    0.00   63.03
          r= 5.0% 2005-2030    0.00   34.11
```

Table 14. The Nordic energy system as a whole.
Annual and monthly energy balances in 2030

Year: Unit: PJ/year. Average monthly rate: Unit: GW

	2030	1	2	3	4	5	6	7	8	9	10	11	12
Net Heat consumpt.:	1235.305	67.961	64.067	51.336	35.024	21.724	19.278	19.210	19.265	22.047	35.615	50.761	63.767
Heatcons.ConvUnits:	5.692	0.192	0.192	0.186	0.173	0.173	0.173	0.173	0.173	0.173	0.180	0.185	0.192
Indiv.Solar coll. :	-7.175	-0.052	-0.114	-0.214	-0.308	-0.383	-0.424	-0.382	-0.340	-0.265	-0.145	-0.064	-0.039
EL heating :	-33.758	-2.446	-2.261	-1.659	-0.896	-0.219	-0.082	-0.081	-0.092	-0.267	-0.902	-1.663	-2.276
Prim.DH net losses:	100.057	3.163	3.163	3.163	3.223	3.223	3.163	3.163	3.163	3.163	3.163	3.163	3.163
DH&centr.heat.cons:	1300.120	68.817	65.047	52.812	37.217	24.519	22.109	22.083	22.168	24.851	37.910	52.381	64.806
Coll.Solar coll. :	23.538	0.166	0.368	0.696	1.005	1.251	1.450	1.248	1.112	0.866	0.472	0.203	0.121
Cogen. Heat pumps :	32.459	2.743	2.508	1.986	0.665	0.166	0.135	0.116	0.124	0.148	1.142	0.897	1.722
Stand-alone H-pump:	88.808	6.060	5.788	4.530	2.571	0.586	0.266	0.256	0.304	0.814	2.353	4.420	5.845
Heat from motors :	513.702	28.518	26.991	21.431	14.607	8.988	7.835	7.565	7.682	8.686	14.898	21.151	27.120
Heat from boilers :	625.093	30.492	28.619	23.518	17.978	13.892	13.012	13.006	13.035	13.967	18.298	23.352	28.690
Heat from el.lysis:	21.367	0.839	0.773	0.652	0.434	0.441	0.554	0.919	0.766	0.897	0.621	0.603	0.632
DH from processes+:	16.014	0.508	0.508	0.508	0.507	0.507	0.508	0.508	0.508	0.508	0.508	0.508	0.508
Process DH surplus:	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DH from processes-:	-16.014	-0.508	-0.508	-0.508	-0.507	-0.507	-0.508	-0.508	-0.508	-0.508	-0.508	-0.508	-0.508
From seasonstorage:	0.010	0.976	0.451	0.118	-0.042	-0.806	-1.143	-1.027	-0.855	-0.527	0.127	1.753	0.979
Seasonstor. to HP :	-4.856	-0.976	-0.451	-0.118	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.303
DH&ctr.heat prod. :	1300.120	68.817	65.047	52.812	37.217	24.519	22.109	22.083	22.168	24.851	37.910	52.381	64.806

Seasonal heat storage capacity, 1000 m3 : 33230

	2030	1	2	3	4	5	6	7	8	9	10	11	12
EL-consumption :	827.371	26.461	26.240	26.335	26.286	26.701	26.929	25.448	26.435	25.973	25.781	25.725	26.514
EL-cons.Conv.Units:	2.648	0.085	0.086	0.086	0.083	0.084	0.086	0.084	0.083	0.082	0.082	0.082	0.085
EL-cons.,DH nets :	28.574	1.316	1.259	1.075	0.841	0.661	0.628	0.628	0.628	0.661	0.858	1.069	1.252
EL-cons.,DHboilers:	20.842	1.068	1.002	0.814	0.600	0.428	0.388	0.387	0.388	0.430	0.615	0.808	1.002
Electric heating :	33.758	2.446	2.261	1.659	0.896	0.219	0.082	0.081	0.092	0.267	0.902	1.663	2.276
St.alone heatpumps:	24.799	1.857	1.750	1.287	0.664	0.130	0.053	0.046	0.057	0.172	0.535	1.159	1.728
Transport :	76.449	2.424	2.424	2.424	2.424	2.424	2.424	2.424	2.424	2.424	2.424	2.424	2.424
EL losses in grid :	74.131	2.595	2.528	2.409	2.219	2.180	2.234	2.300	2.299	2.345	2.274	2.343	2.481
El-export :	7.587	0.268	0.046	0.311	0.084	0.548	0.343	0.317	0.305	0.014	0.269	0.319	0.062
EL-cons., total :	1096.159	38.520	37.595	36.402	34.096	33.375	33.166	31.717	32.711	32.368	33.739	35.593	37.824
EL-prod., motors :	264.390	15.325	14.354	10.886	7.175	4.352	3.780	3.609	3.678	4.148	7.263	11.288	14.748
To cogen.H.pumps :	-10.604	-0.799	-0.872	-0.704	-0.216	-0.049	-0.037	-0.030	-0.033	-0.043	-0.362	-0.310	-0.581
EL-prod.,Windmills:	360.494	14.671	14.216	13.428	10.825	9.858	8.970	9.331	9.331	10.503	11.215	11.844	12.984
EL-prod.photovolt.:	17.575	0.154	0.294	0.522	0.737	0.907	1.045	0.905	0.811	0.640	0.367	0.180	0.124
EL-prod.hydropower:	606.753	14.760	14.760	16.614	18.468	21.248	23.102	24.029	24.029	23.102	19.394	16.614	14.760
EL-cons.,el.lysis :	-142.449	-5.591	-5.156	-4.344	-2.893	-2.942	-3.694	-6.126	-5.105	-5.982	-4.138	-4.023	-4.210
El-prod., total :	1096.159	38.520	37.595	36.402	34.096	33.375	33.166	31.717	32.711	32.368	33.739	35.593	37.824

“motor” stands for any power generation unit (engine, steamturbine, fuel cell, etc.)

“Stand-alone H.pumps” are heat pumps in individual buildings.

Table 15. Denmark
Annual and monthly energy balances in 2030

```
Year: Unit:  PJ/year.  Average monthly rate: Unit: GW

                          2030       1       2       3       4       5       6       7       8       9      10      11      12
Net Heat consumpt.:  209.427  12.480  11.883   9.494   5.612   2.825   2.527   2.527   2.527   2.825   6.210   9.494  11.286
Heatcons.ConvUnits:    1.800   0.060   0.060   0.060   0.054   0.054   0.054   0.054   0.054   0.054   0.060   0.060   0.060
Indiv.Solar coll. :   -1.629  -0.012  -0.026  -0.048  -0.070  -0.087  -0.096  -0.087  -0.077  -0.060  -0.033  -0.015  -0.009
EL heating        :   -1.982  -0.150  -0.141  -0.104  -0.047  -0.005  -0.000  -0.001  -0.001  -0.007  -0.058  -0.107  -0.133
Prim.DH net losses:   30.261   0.957   0.957   0.957   0.975   0.975   0.957   0.957   0.957   0.957   0.957   0.957   0.957
-------------------------------------------------------------------------------------------------------------------------
DH&centr.heat.cons:  237.877  13.335  12.733  10.358   6.525   3.762   3.441   3.450   3.458   3.768   7.135  10.390  12.161

Coll.Solar coll.  :   11.769   0.082   0.183   0.348   0.503   0.626   0.726   0.625   0.557   0.433   0.235   0.101   0.060
Cogen. Heat pumps :   22.818   1.791   1.638   1.318   0.492   0.166   0.135   0.116   0.124   0.147   0.872   0.885   0.998
Stand-alone H-pump:    3.343   0.244   0.232   0.178   0.082   0.010   0.000   0.002   0.004   0.015   0.102   0.184   0.221
Heat from motors  :   94.519   5.843   5.597   4.319   2.498   1.195   1.025   0.992   1.006   1.136   2.725   4.145   5.485
Heat from boilers :  102.891   5.167   4.892   4.035   2.864   2.122   2.036   2.043   2.050   2.140   3.059   4.030   4.713
Heat from el.lysis:    5.279   0.207   0.191   0.161   0.107   0.109   0.137   0.227   0.189   0.222   0.153   0.149   0.156
DH from processes+:   16.014   0.508   0.508   0.508   0.507   0.507   0.508   0.508   0.508   0.508   0.508   0.508   0.508
Process DH surplus:    0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
DH from processes-:  -16.014  -0.508  -0.508  -0.508  -0.507  -0.507  -0.508  -0.508  -0.508  -0.508  -0.508  -0.508  -0.508
From seasonstorage:    0.010   0.496   0.433   0.118  -0.022  -0.466  -0.618  -0.555  -0.471  -0.324  -0.012   0.896   0.528
Seasonstor. to HP :   -2.752  -0.496  -0.433  -0.118   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
-------------------------------------------------------------------------------------------------------------------------
DH&ctr.heat prod. :  237.877  13.335  12.733  10.358   6.525   3.762   3.441   3.450   3.458   3.768   7.135  10.390  12.161

Seasonal heat storage capacity, 1000 m3 : 18803

EL-consumption    :   95.439   3.123   3.073   3.038   2.990   3.031   3.043   2.926   3.041   2.961   2.963   2.988   3.139
EL-cons.Conv.Units:    0.868   0.027   0.028   0.029   0.027   0.028   0.029   0.028   0.027   0.027   0.028   0.027   0.027
EL-cons.,DH nets  :    5.488   0.282   0.271   0.227   0.155   0.104   0.098   0.098   0.098   0.103   0.166   0.227   0.260
EL-cons.,DHboilers:    3.238   0.164   0.156   0.130   0.091   0.064   0.061   0.061   0.061   0.065   0.098   0.131   0.151
Electric heating  :    1.982   0.150   0.141   0.104   0.047   0.005   0.000   0.001   0.001   0.007   0.058   0.107   0.133
St.alone heatpumps:    0.905   0.072   0.067   0.048   0.020   0.002   0.000   0.000   0.001   0.003   0.023   0.047   0.061
Transport         :   16.368   0.519   0.519   0.519   0.519   0.519   0.519   0.519   0.519   0.519   0.519   0.519   0.519
EL losses in grid :    9.971   0.359   0.347   0.323   0.282   0.278   0.290   0.324   0.315   0.325   0.304   0.314   0.333
El-export         :  -15.168   1.108   1.049   0.347  -0.460  -1.131  -1.533  -2.027  -1.894  -1.925  -0.869   0.492   1.071
-------------------------------------------------------------------------------------------------------------------------
EL-cons., total   :  119.092   5.804   5.650   4.765   3.671   2.900   2.506   1.930   2.170   2.084   3.291   4.851   5.695

EL-prod., motors  :   59.634   3.963   3.722   2.624   1.388   0.636   0.531   0.489   0.503   0.565   1.494   2.997   3.781
To cogen.H.pumps  :   -7.380  -0.557  -0.518  -0.442  -0.160  -0.049  -0.037  -0.030  -0.033  -0.042  -0.273  -0.305  -0.360
EL-prod.,Windmills:   97.635   3.741   3.647   3.526   2.974   2.812   2.664   2.758   2.758   2.879   3.001   3.108   3.283
EL-prod.photovolt.:    4.394   0.039   0.074   0.131   0.184   0.227   0.261   0.226   0.203   0.160   0.092   0.045   0.031
EL-prod.hydropower:    0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
EL-cons.,el.lysis :  -35.192  -1.381  -1.274  -1.073  -0.715  -0.727  -0.913  -1.513  -1.261  -1.478  -1.022  -0.994  -1.040
-------------------------------------------------------------------------------------------------------------------------
El-prod., total   :  119.092   5.804   5.650   4.765   3.671   2.900   2.506   1.930   2.170   2.084   3.291   4.851   5.695
```

"motor" stands for any power generation unit (engine, steamturbine, fuel cell, etc.)

"Stand-alone H.pumps" are heat pumps in individual buildings.

Table 16. Electricity import and export in 2030.
Annual totals in PJ.
Monthly average rates in GW

NORWAY	2030	1	2	3	4	5	6	7	8	9	10	11	12
El-consumption	253.235	9.186	9.061	8.663	7.986	7.368	7.347	7.040	7.243	7.327	7.672	8.363	9.104
El-production	428.609	11.197	11.216	12.192	13.160	14.609	15.607	16.004	16.066	15.817	13.742	12.141	11.342
El-export	175.374	2.011	2.155	3.529	5.174	7.242	8.259	8.964	8.823	8.489	6.071	3.778	2.238

SWEDEN	2030	1	2	3	4	5	6	7	8	9	10	11	12
El-consumption	415.150	14.372	14.137	13.679	13.000	12.714	12.778	12.178	12.560	12.361	12.690	13.347	14.156
El-production	361.343	13.435	13.150	12.593	11.346	10.709	10.409	9.774	10.185	9.981	11.014	12.089	12.812
El-export	-53.807	-0.937	-0.987	-1.087	-1.654	-2.005	-2.369	-2.404	-2.375	-2.380	-1.676	-1.258	-1.344

FINLAND	2030	1	2	3	4	5	6	7	8	9	10	11	12
El-consumption	285.928	9.998	9.750	9.330	8.895	8.715	8.658	8.225	8.541	8.657	8.948	9.205	9.879
El-production	187.115	8.085	7.579	6.852	5.919	5.157	4.644	4.009	4.291	4.486	5.691	6.511	7.976
El-export	-98.813	-1.914	-2.171	-2.478	-2.975	-3.558	-4.014	-4.215	-4.250	-4.171	-3.257	-2.694	-1.903

DENMARK	2030	1	2	3	4	5	6	7	8	9	10	11	12
El-consumption	134.260	4.697	4.602	4.418	4.131	4.030	4.039	3.957	4.063	4.009	4.159	4.359	4.624
El-production	119.092	5.804	5.650	4.765	3.671	2.900	2.506	1.930	2.170	2.084	3.291	4.851	5.695
El-export	-15.168	1.108	1.049	0.347	-0.460	-1.131	-1.533	-2.027	-1.894	-1.925	-0.869	0.492	1.071

Nordic region	2030	1	2	3	4	5	6	7	8	9	10	11	12
El-eksport, total	7.586	0.268	0.046	0.311	0.084	0.548	0.343	0.317	0.305	0.014	0.269	0.319	0.062

Table 17. Marginal changes in CO2 emission as a result of marginal changes in electricity consumption or production.

Internal emission is emission from the Nordic countries.

External emission is additional emission (+/-)in other countries because of changes in electricity export from the Nordic countries. Emission assessments in other countries are based on the assumption that additional electricity generation in these countries takes place in a mix of coal-fired and gas-fired steam turbine power plants with certain average efficiencies.
The external emissions are relatively small as compared with the internal emissions because the Nordic energy system is modelled as a relatively closed system (see section 2).

Influence on CO2 emission and fuel consumption of changes in electricity consumption in the end-use system.

Electricity consumption: + 1 PJ

	Fuel consumption PJ	CO2-emission 10.000 tons		
		Total	Internal	External
2010	1.950	19.134	17.797	1.337
Average 2005-2030	1.239	10.116	9.544	0.571
2030	0.888	6.917	6.033	0.885

Influence on CO2 emission and fuel consumption of changes in Windpower

Windpower: + 1 PJ

	Fuel consumption PJ	CO2-emission 10.000 tons		
		Total	Internal	External
2010	-2.347	-19.978	-19.991	0.013
Average 2005-2030	-1.710	-12.389	-11.789	-0.600
2030	-1.203	-6.786	-5.995	-0.791

Influence on CO2 emission and fuel consumption of changes in Hydropower

Hydropower: + 1 PJ

	Fuel consumption PJ	CO2-emission 10.000 tons		
		Total	Internal	External
2010	-2.338	-19.938	-18.399	-1.539
Average 2005-2030	-2.035	-16.072	-14.723	-1.348

Table 18. Comparison with a stronger-growth scenario

Growth and efficiency parameters:

Electrical appliances Index 2005=100					
Scenario B:	2005	2010	2015	2020	2030
Stock development	**100**	**119**	**129**	**133**	**139**
El.consumption devel.	100	103	105	101	78
Efficiency factor	1.00	0.86	0.81	0.76	0.57
Stronger growth:					
Stock development	**100**	**121**	**136**	**148**	**161**
El.consumption devel.	100	104	108	108	90
Efficiency factor	1.00	0.86	0.79	0.72	0.56

Buildings stock Index 2005=100					
Scenario B:	2005	2010	2015	2020	2030
Heated floor area	**100**	**102**	**105**	**107**	**111**
Net heat consumption	100	97	91	76	77
Consumption per m2	1.00	0.94	0.87	0.71	0.69
Stronger growth:					
Heated floor area	**100**	**104**	**108**	**113**	**121**
Net heat consumption	100	98	93	80	83
Consumption per m2	1.00	0.94	0.86	0.70	0.69

Industrial production Index 2005=100					
Scenario B:	2005	2010	2015	2020	2030
Production quantities	**100**	**102**	**105**	**107**	**111**
Stronger growth:					
Production quantities	**100**	**104**	**108**	**113**	**122**

Transportation, persons Index 2005=100					
Scenario B:	2005	2010	2015	2020	2030
Total	**100**	**107**	**113**	**116**	**110**
Cars	0.77	0.77	0.76	0.75	0.57
Public transport	0.23	0.23	0.24	0.25	0.43
Stronger growth:					
Total	**100**	**107**	**113**	**118**	**123**
Cars	0.77	0.77	0.76	0.75	0.57
Public transport	0.23	0.23	0.24	0.25	0.43

Transportation of goods Index 2005=100					
Scenario B:	2005	2010	2015	2020	2030
Total	**100**	**107**	**113**	**116**	**110**
Vans and trucks	0.70	0.69	0.69	0.67	0.49
Trains and ships	0.30	0.31	0.31	0.33	0.51
Stronger growth:					
Total	**100**	**107**	**113**	**118**	**123**
Vans and trucks	0.70	0.69	0.69	0.67	0.49
Trains and ships	0.30	0.31	0.31	0.33	0.51

Summary of fuel and CO2 emisssion results. Total for all four countries

Fossil fuels PJ					
Scenario B:	2005	2010	2015	2020	2030
Coal, int.	600	389	340	225	66.9
Coal, ext.	0.00	0.02	-1.02	-3.80	-14.3
Oil	1458	1306	1212	1045	541
Natural gas, int.	424	456	466	370	281
Natural gas, ext.	0.00	0.01	-0.25	-0.95	-3.57
Total	**2482**	**2151**	**2016**	**1635**	**871**
Stronger growth:					
Coal, int.	600	413	388	305	73.2
Coal, ext.	0.00	-0.01	-0.01	-2.34	-5.59
Oil, int.	1458	1315	1225	1083	683
Natural gas, int.	424	469	499	428	333
Natural gas, ext.	0.00	-0.00	-0.00	-0.59	-1.40
Total	**2482**	**2198**	**2112**	**1814**	**1082**

CO2 emission 10.000 tons					
Scenario B:	2005	2010	2015	2020	2030
Transportation	6609	6786	6575	5891	2620
Stationary units, int.	13616	10455	9211	6765	3669
Stationary units, ext.	0.00	0.27	-11.1	-41.6	-156
Total	**20225**	**17241**	**15775**	**12615**	**6133**
Stronger growth:					
Transportation	6609	6786	6595	6052	3516
Stationary units, int.	13616	10835	9967	8036	4175
Stationary units, ext.	0.00	-0.11	-0.06	-25.6	-61.1
Total	**20225**	**17621**	**16561**	**14062**	**7630**

Table 19. **CO_2 emission reductions in the B-scenario**

	1990 reference emission Mio. tons	Reduction obligation 2008-2012	Allowed emission in 2008-2012 Mio. tons	B-scenario: Emission in 2010 Mio. tons	Emission target for 2020 Mio. tons	B-scenario: Emission in 2020 Mio. tons	B-scenario: Change compared with 1990		
							2010	2020	2030
Norway	27.0	+ 1%	27.3	26.5	18.9	23.6	0%	- 13%	- 42%
Sweden	50.0	- 4%	48.0	46.2	35.0	34.2	- 4%	- 32%	- 67%
Finland	57.5	- 0%	57.5	57.4	40.3	38.4	0%	- 33%	- 76%
Denmark	50.6	- 21%	40.0	42.0	35.4	30.2	- 17%	- 40%	- 67%
Total	185	- 6.7%	173	172	130	126	- 7%	- 32%	- 67%

The emissions shown in table 19 are the total emissions from chimneys and vehicle exhaust pipes, except emissions from oil and gas platforms, oil refineries, and international air transport.

For each of the four countries, the 1990-reference values refer to the country's "Third National Communication on Climate Change".

Although the EU agreements on reduction obligations allow Sweden to increase its emission by 4% by 2008-2012, Sweden has set a 4% national reduction target.

The emission reduction target for 2020 (70% of the 1990 reference emission) refers to the aim to keep the average global temperature increase below a ceiling 2 degrees above the pre-industrial level, see section 15.