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Institut für angewandte Ökologie e.V.
Institute for applied ecology
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A New Energy Policy for Sweden:

Key elements of a sustainable energy future

- Summary Report -

prepared

by

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Introduction

This study presents a **new energy scenario for Sweden** wherein a phaseout of nuclear power plants is assumed: starting in 1998 with the shut-down of the first reactor, the phase-out continues until 2008, when the last reactors are taken out of service.

The scenario addresses especially issues concerning the environment, economy, and jobs in Sweden. The underlying study was carried out in close collaboration by a team of Swedish[1] and German[2] researchers.

The results of the study presented here are meant to stimulate the political discussions and debates in Sweden with respect to the nuclear phaseout policy, energy efficiency programs and biomass-based cogeneration as **key elements of a sustainable energy future** with reduces environmental risks, global warming, and creates new and stable jobs in the Swedish economy. The ECO scenario is the only scenario presented at this time that addresses all the necessary measures for developing a sustainable energy system.

The ECO scenario indicates that some short term increase in natural gas demand might be the results with the studied time table for the nuclear phaseout and the economic growth laid out by the Swedish Energy Commission.

1 The Scenario Approach

In the study, the new energy scenario for Sweden was created using computer-based models for the energy, emission, and economic developments.

The new energy scenario called the **Eco-Wise Case** (ECO in short), was modelled by the Swedish/German research team.

To allow a comparison of the new scenario with previous work and „traditional“ projections of the Swedish energy future, a **Reference Case** (REF in short) was also created which is based on the 1995 NUTEK reference scenario for the Swedish Energy Commission.

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1 Eje Sandberg (ATON Consultants) and Dennis Pamlin with good advices from Deborah Wilson Cornland (the Stockholm Environment Institute)

2 The Öko-Institut (Institute for applied ecology) is a non-governmental, non-profit environmental research institution based in Germany.

3 The work was jointly sponsored by Greenpeace Sweden and Greenpeace Germany as an energy research project.

It is important to note that the economic and social assumptions for both scenarios **are the same**: the growth of energy services in the industry, commercial and residential sectors, as well as the services in the transport sector assumed by NUTEK for the Reference scenario have not been changed for the ECO scenario[4]:

Annual growth rates, REF + ECO	1995-2020
GNP	2.0 %/a
Private consumption	2.2%/a
Public service	0.6%/a
Industry production	2.4%/a
Private service	2.4%/a

Similarly, the development of energy prices and taxes were assumed to be identical[5].

2 The Eco-Wise Scenario

The Eco-Wise Scenario is orientated towards a sound mix of **eco**logical and **eco**nomic goals: to phase-out nuclear power plants without compromising other environmental targets like reducing greenhouse-gas emissions, and without increasing energy costs for the customer collective more than in the reference case. The Eco-Wise Case is not a genuine ecological scenario as it is based on the reference socio-economic growth figures given by the Energy Commission to allow a fair comparison. In this way it is more of a „semi"-ecological scenario, but it will be called ECO scenario for short. The ECO scenario is meant also to analyse the overall economic effects of a more sustainable energy policy in Sweden.

The key elements of ECO (the Eco-Wise scenario) are:

- increased use of energy efficiency technologies on the demand-side in all sectors
- replacing electric heating with biomass, especially in the residential sector, and in district heating plants
- promotion of district heating, and extension of cogeneration to supply district heat
- increasing the share of biomass in cogeneration plants, and application of small- and medium-sized biomass gasification technologies to supply cogeneration facilities
- massive introduction of on- and offshore wind energy systems, and slow but steady development of solar photovoltic (PV) electricity generation

The scenario is developed from the energy use pattern in the base year (1993), from which the future developments of the energy demand is computed. To do so, the growth assumptions of the Reference Case (see Section 4) were used for all sectors[6].

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4 It would have been beyond the scope of this study to do so. Still, one should keep in mind that NUTEK's economic assumptions especially for the industry and transport sectors seem rather optimistic, and do not reflect **any** consideration of a more sustainable society.

5 This does not mean that the costs to the customers are the same: In the Eco scenario, energy costs are lower than in the Reference case (see Section on Economic and Job Impacts).

6 For a detailed listing of all growth assumptions (i.e., population, households, new buildings and equipment, industrial and commercial production, transport services etc.), see the Technical Report.

In the ECO scenario, a significant **shift from electric heating** to biomass and district heating (DH) is assumed especially for the residential and commercial buildings, starting in 1998 with the substitution of switchable electric heaters in residential buildings and DH boilers, so that electricity is immediately replaced by heating oil. In the longer run, the share of DH is also increased, thereby replacing oil heating[7].

For the direct biomass heating, the use of small pellet boilers is assumed in the residential and commercial sector, while in industry, conventional biomass boilers replace mainly oil.

In addition, the energy efficiency is drastically improved for electric appliances in the residential and commercial buildings: here, state-of-the-art technologies for dish-washers, washing machines, refrigeration, etc. will replace existing equipment over time. In the industry, especially electric end-uses are improved also (e.g. motors, fans). The combined effect in 2020 is a drop in electricity demand well below the 1993 level.

Furthermore, a combination of thermal insulation and „smart windows“ are assumed for new residential and commercial buildings, so that their heating demand is reduced also.

In the transport sector, more efficient cars[8], improved logistics, and some shift in the modal-split for passenger and freight transport (from cars to buses/trains and bikes, and from trucks to trains/ships) illustrates possible steps in the traffic sector to be taken. Here the experiences from German studies have been used and transformed to the Swedish transport sector. The calculations are not based on specific Swedish bottom up studies and the German figures therefore are used with much precaution.

The overall effect of the energy efficiency measures on the end-use demand by the Swedish sectors are shown in the following table. The difference to the REF Case are significant especially for the transport sector.

Table A Sectoral End-Use Demand in the ECO Scenario and 2020 for the REF Case. (TWh)

	1993	**2000**	**2020**	***2020 REF***
Transport	83	76	65	*114*
Industry	136	149	149	*170*
Residential & Commercial*	162	162	132	*162*
Total	**382**	**388**	**345**	***446***

*= incl. others

The changes in the fuels use of all sectors in Sweden are shown in the next table.

Here, the significant decrease of electricity and oil primarily from efficiency improvements but also from fuel switching to biomass and biomass-based district heating can be seen.

7 The efficiency of all heating systems is assumed to be the same as in the REF scenario (see Section 4).

8 The average fleet of private cars in 2020 will consume only 3.5 l/100 km.

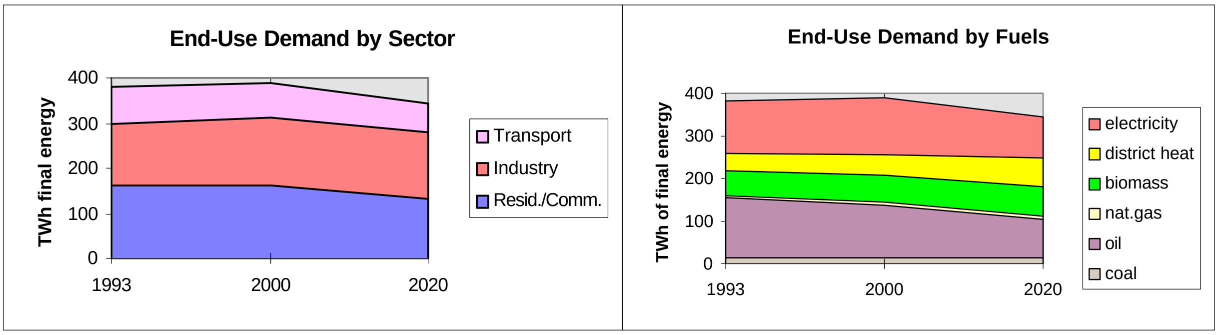
Table B End-Use Demand for Fuels in the ECO Scenario (in TWh)

	1993	2000	2020
electricity	123	133	98
district heat	41	49	65
biomass	58	63	71
natural gas	5	6	8
oil	139	121	89
coal	16	15	14
Total	**382**	**388**	**345**

The **total** effect of all measures is that despite the growing demands for heated floor space, industrial products, and transport services, the overall amount of final energy consumption will **de**crease: energy efficiency is now a major player, providing approx. 100 TWh of DSM[9] more than the REF scenario.

This is shown in the following graphs.

Fig. A End-use Demand in the ECO Scenario



On the supply-side of the scenario, the delivery of the fuels is determined by the mix of electricity and district heating generation.

In ECO scenario, the supply of both electricity and district heat is changed dramatically:

A **phase-out** of nuclear power plants is assumed, starting in 1998 with the shut-down of the first reactor, and ending in 2008 with the closing of all remaining nuclear systems in Sweden[10].

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9 DSM is the acronym for demand-side management, a term used to describe measures which increase energy efficiency on the customer (=demand) side.

10 For the timing of the phase-out, the identifiable reactor and year is not in focus. The nuclear plants are shut down in order of what is possible within the ECO scenario reconstruction of the energy system. The time limit set up was 2010 and if possible 2008 as it gives a two year reserve (if 2007 - 2008 will turn up as dry years).

The reduced nuclear generation is compensated by a mix of existing condensing power plants, minor imports some years during the phase out period, a rapid modernisation of cogeneration systems (re-powering), the doubling of biomass use and some expansion of wind energy (although four times as much as in the reference case).

Gas-fired combined-cycle plants are built only to a very small amount compared to the reference case and only used as a temporary supply source for a 11 year period.

The supply of district heat is also changed: Here, the share of cogeneration, and the use of biomass is increased significantly.

The initial drop of hydro power is because the figure for 1993 is the power that was produced. 1993 was a wet year. The scenarios are based on average hydro production figures.

The overall data are given in the following table and graphs.

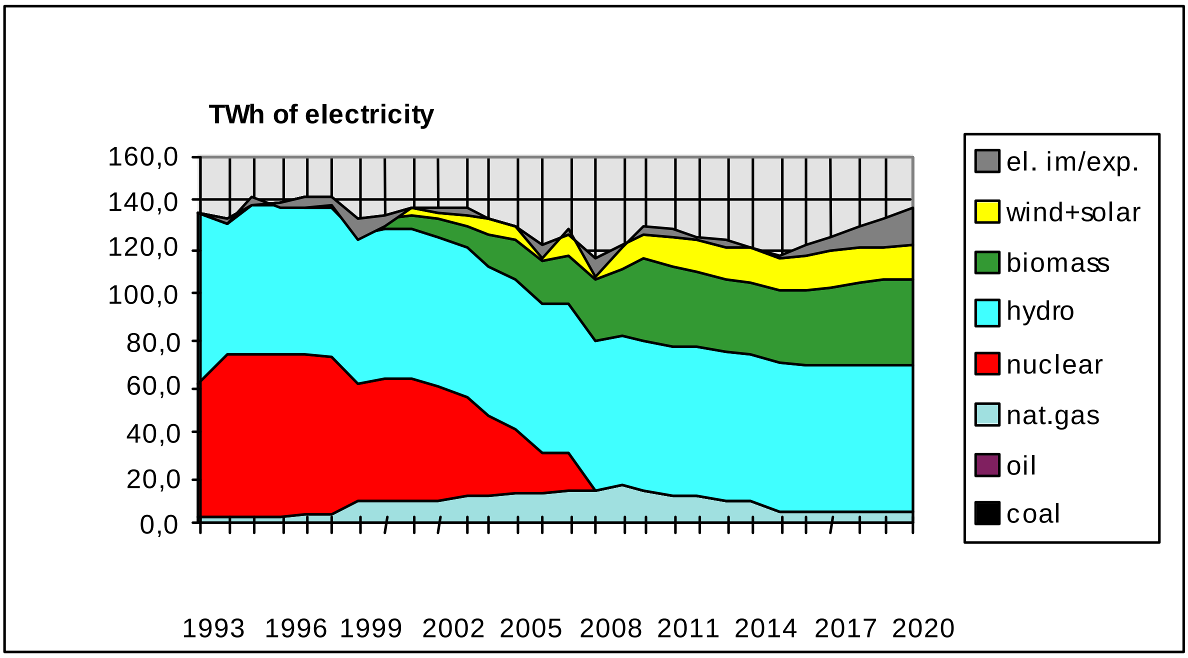
Table C Electricity Generation Mix in the ECO Scenario (in TWh)

	1993	**2000**	**2005**	**2010**	**2015**	**2020**
oil	0,7	1,1	0,9	0,0	0,0	0,0
natural gas	1,3	8,9	11,5	15,3	5,4	4,1
nuclear	58,9	51,7	29,0	0,0	0,0	0,0
hydro	73,3	64,5	64,5	64,5	64,5	64,5
biomass	0,3	4,9	15,6	34,1	30,3	36,7
wind+solar	0,0	2,0	7,0	12,0	15,1	15,1
total	**134,4**	**133,1**	**128,6**	**126,0**	**115,2**	**120,4**
el. im/export [1)]	-0,5	4,0	-0,6	-1,6	-1,0	-16,1

[1)] Imports are given positive values and exports negative.

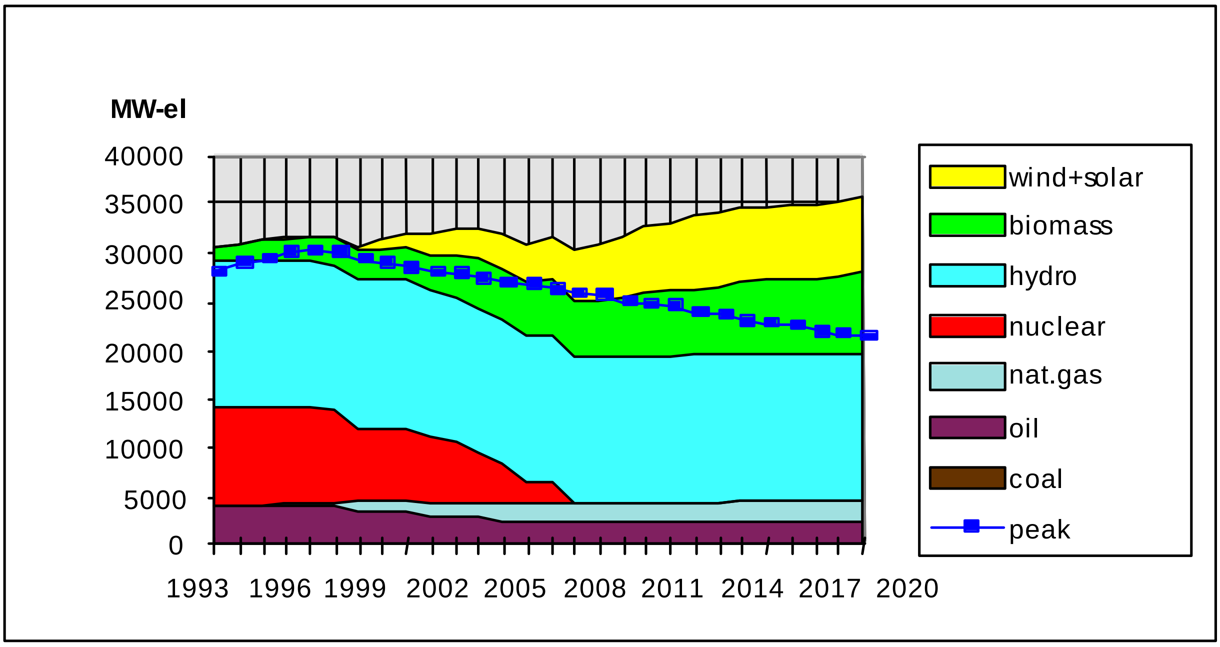
The **import-export structure of electricity** is changed drastically in the end of the scenario: Until 2010, some electricity is imported from the European network, while after that, exports of electricity are increased to some 16 TWh per year.

Fig. B Electricity Generation Mix in the ECO Scenario



The import figures are negative in figure 2 and will illusively hide the area for wind&solar some of the years.

Fig.C Electricity Generation Capacity in the ECO Scenario



As can be seen, the development of the renewable generation sources increases the available capacity in the power system significantly. The firm share of the PV and wind is smaller than for conventional power plants however, due to the intermittent availability of the energy source. Therefore, hydro power is used as a „backup“ for wind and PV in the ECO scenario.

Based on the end-use demand, and the electricity/district heating generation mix, the primary energy demand is determined.

For that, the conversion efficiencies of power plants, cogenerators, and boilers (for district heating) are slightly improved compared to the Reference Case[11].

The data are given in the following table and figure. The table also includes the figures for 2020 in the Reference case.

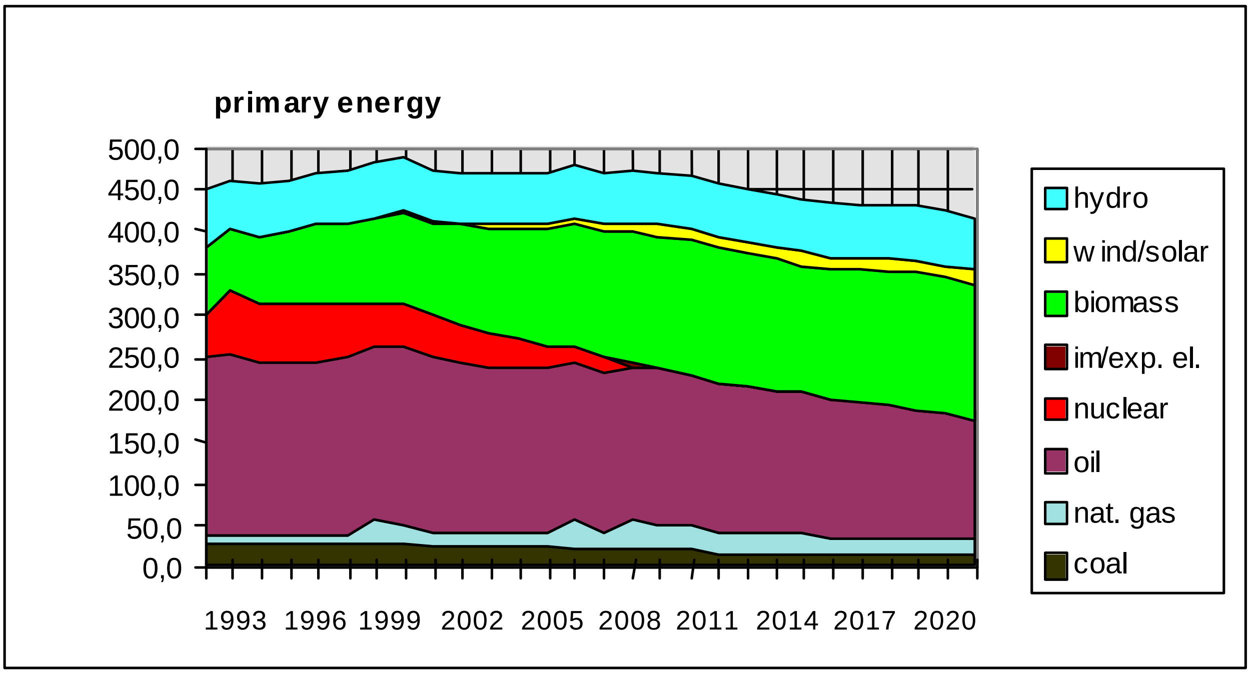
Table D Primary Energy Demand 2000 and 2020 in the ECO Scenario and 2020 for the REF Case. (TWh)

	1993	**2000**	**2020**	***2020 Ref.***
coal	24	23	14	*23*
natural gas	9	26	21	*89*
oil	197	197	150	*239*
nuclear	59	52	0	*43*
hydro	73	65	65	*66*
biomass	75	91	161	*91*
wind/solar	0	2	15	*4*
total	**438**	**455**	**424**	***555***
non-renewable	*290*	*297*	*184*	*393*
renewable	**148**	**158**	**240**	***161***
im/export el.	*0*	*4*	*-16*	*-3*

This development in the ECO scenario is shown graphically in the following figure.

[11] The ECO scenario assumes the same conversion efficiencies of refineries, and the same amount of fuel use for non-energy purposes, and oil exports, as the REF scenario.

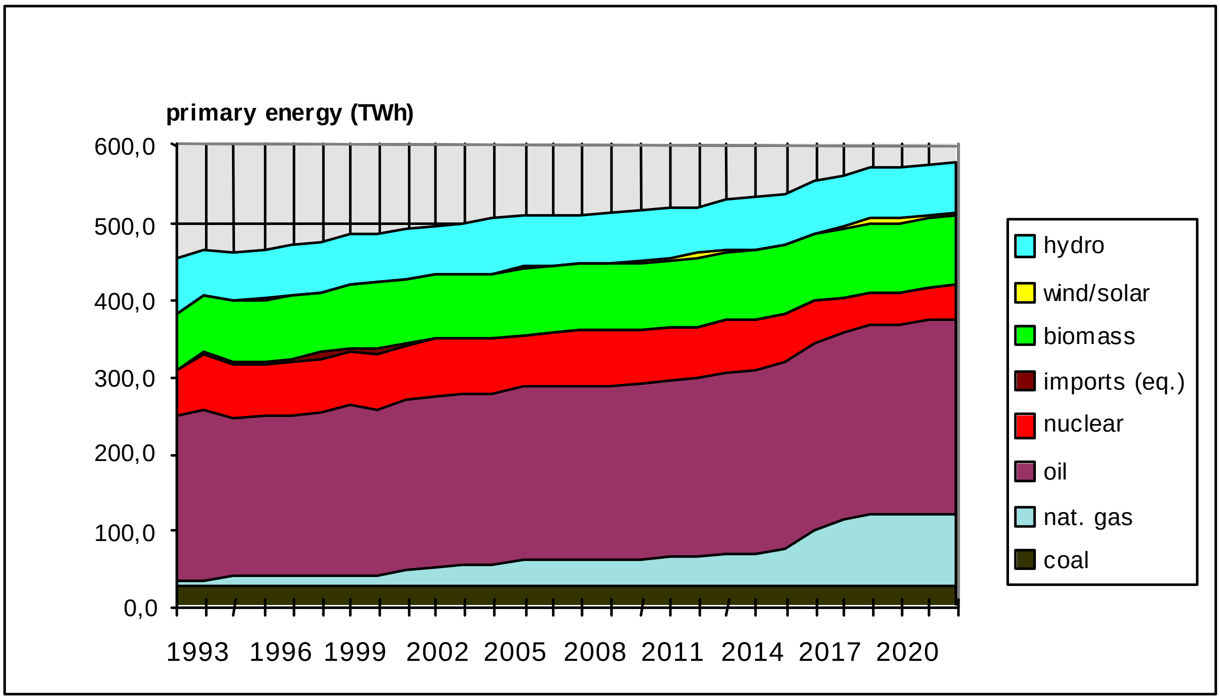
Fig. D Primary Energy Demand in the ECO Scenario



In the **Reference Case** the electricity generation is based on the philosophy to reduce nuclear only partially - nuclear plants are assumed to be operated for 40 years of lifetime. Due to this assumption, the generation mix will not change much, renewables play a minor role only. Natural gas will become more important after the year 2000, when new combined-cycle power plants are built to replace retired nuclear plants. The overall mix of the primary energy demand will not change much. The share of non-renewable energy sources will **increase** from approx. 65% in 1993 to some 71% in 2020. The use of renewable energy sources will grow only marginally. The overall energy demand will increase by some 30%, compared to the 1993 level, while the CO_2 emissions (see Section 2.2) will drastically increase by some 50%, as compared to the 1993 level. This is shown in table 4 and in the figure 5.

Therefore, this „reference“ development is not **sustainable** and is not in accordance with Swedish commitments under the UNFCCC.

Fig. E Primary Energy Demand in the REF Scenario



3 Carbon dioxide effects of the ECO Scenario

Based on the primary energy use of the phaseout scenario, the CO_2 emissions from energy use in Sweden were determined, and compared to those of the Reference Case[12].

The calculation used CO_2 emission factors from the GEMIS model[13] which can include also the effects of exporting and importing energy carriers[14]. The following table shows the overall CO_2 emissions from energy use in Sweden in both scenarios.

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12 For details of the REF scenario, see Section 4.

13 Futher information regarding the German version of the Emission Model for Integrated Systems can be found in the Internet: http://www.oeko.de/service/gemis (in German) and http://www.oeko.de/service/temis (in English)

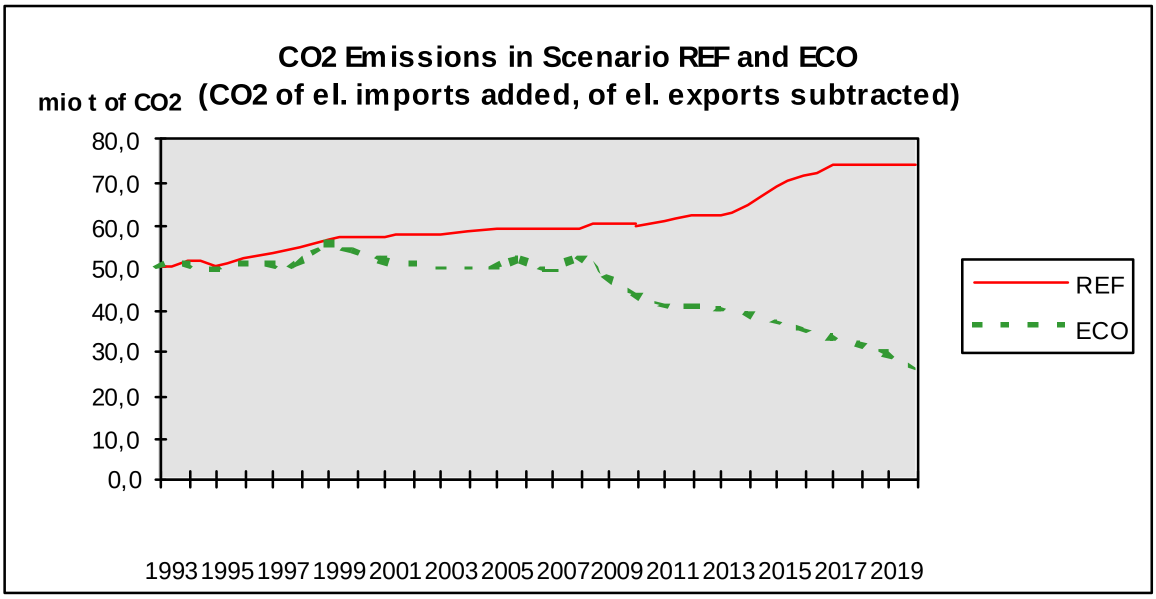
14 For the CO_2 emissions from imports of electricity, it was conservatively assumed that the generation is a mix of coal, natural gas, and hydro. This reflects a possible mix of imports from Denmark, Germany, and Norway. For electricity exports from Sweden, a CO_2 credit is assumed based on the same generation mix as for the imports.

Table E CO_2 Emissions from Energy Use in the Scenarios (incl. el. import/export)

	Emissions (mio t)		**change ECO**	**change relative to 1993**	
year	**REF**	**ECO**	**relative to REF**	**REF**	**ECO**
1993	50,1	50,1	0%		
2005	58,6	49,7	-15%	+17%	-1%
2010	60,0	43,4	-28%	+20%	-14%
2020	74,1	25,9	-65%	+48%	-48%

The following figure shows this development graphically.

Fig. F Annual CO_2 Emissions from Energy Use in the Scenarios (incl. el. import/export)



As can be seen, the CO_2 emissions in the ECO scenario will significantly decrease, while in the REF Case, the emissions will increase, although here half of the nuclear power plants are assumed to continue operation.

The alternative policy in the ECO scenario can quickly bring down national CO_2 emissions - only in the years 1999 and 2000 the emissions of ECO are slightly higher than in REF due to replacing nuclear power with some domestic fossil generation. The CO2 emission figure illustrates the short term problems in both phasing out the nuclear power (50% of Swedish production) and reducing CO2 emissions in this one scenario. In long terms both goals will be fulfilled. The scenario is not optimised (all nuclear plants are phased out at year 2008 and four reactors are closed during 1998) and it is linked to the reference case economic structures and figures. Also, if major imports will be from Norway the three importing years in the period 2005 -2010, instead of Denmark, the CO2 emission peaks will be reduced.

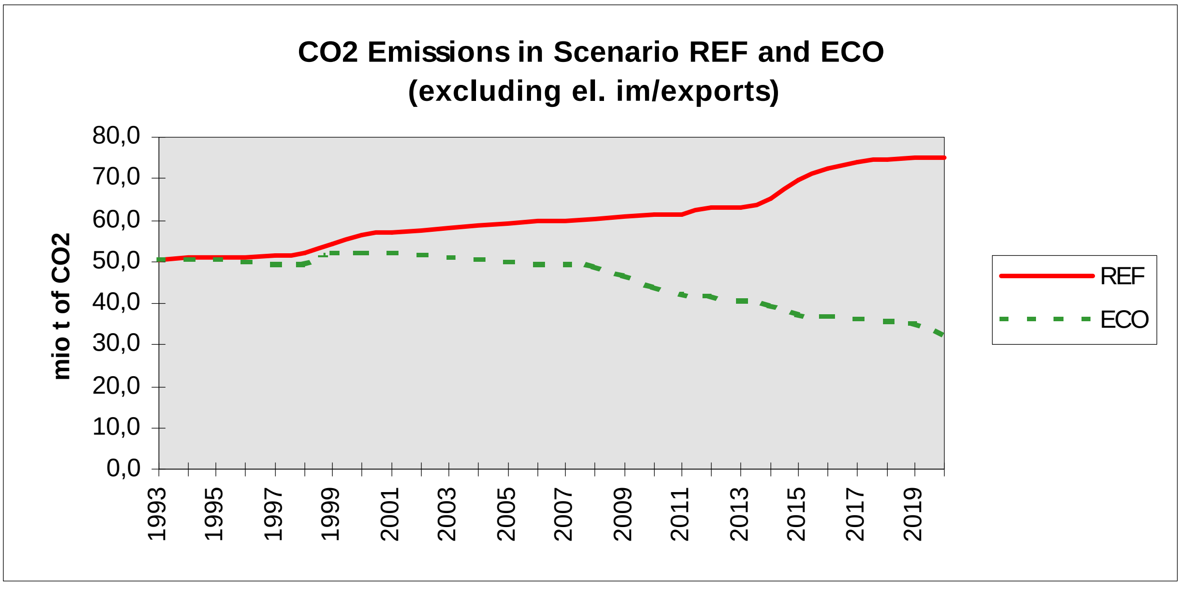
If the balance of CO_2 from imports and exports of electricity **are ignored**, the following development will occur[15]:

Table F CO_2 Emissions from Energy Use in the Scenarios (excl. el. import/export)

	Emissions (mio t)		**change ECO**	**change relative to 1993**	
year	**REF**	**ECO**	**relative to REF**	**REF**	**ECO**
1993	50,3	50,3	0%	**-**	**-**
2005	59,0	50,0	-15%	+17%	-1%
2010	61,2	44,0	-28%	+22%	-13%
2020	75,3	32,5	-57%	+50%	-35%

This is shown graphically in the following figure.

Fig. G Annual CO_2 Emissions from Energy Use in the Scenarios (excl. el. import/export)



15 This procedure of accounting is consistent with the reporting of greenhouse-gas emissions under the Framework Convention for Climate Change, where only the direct emissions from the territory of a country are included.

4 Economic and Employment Effects of the ECO Scenario

In addition to the overall energy balance, and the CO_2 emissions, the study also analysed economic effects of the scenarios. When creating a new energy policy, important effects are

- changes in ex- and imports balances
- changes in investment structures
- changes in employment.

Factions who perceive themselves as potential losers of an alternative energy policy often argue that changes in energy supply and consumption would endanger competitiveness, and ultimately result in lost jobs.

Quite opposite to that, a variety of studies in different countries show that changes to an energy policy which stresses energy conservation, efficiency, and renewable energy sources will result in a net increase of jobs. Though it is true that some jobs in the fossil and nuclear industry will be lost, in return, there will be other jobs created in other sectors.

The analysis in this study determined which sectors would be effected negatively, and which sectors would grow (losers and winners) if the ECO scenario would be implemented instead of the Reference Case. Important for the impact on employment and the economy are the differences in both end energy demand and fuel demand for electricity and heat generation as well as the differences in the investment in energy supply technologies. Using price scenarios, the change in physical demand can be valued in monetary terms.

The resulting vectors are the input variables for a macro-economic analysis with an open and static input-output-model (IOM) that identifies both the direct and the indirect impacts of different demand structures. The indirect impacts are caused by the induced changes in demand of the companies that have to supply the additional or reduced demand. If, as an example, bioenergy use increase it will increase the economical activities (and jobs) not only in forestry but also in manufacturing as more machines and tools will be requested in the forestry productions.

The result of this analysis (sectoral changes in gross production) are then combined with the employment intensity per sector. As a result, the net job balance (growth/loss) as well as the job developments within the sectors can be identified. In this study we have excluded the transport sector from the job analyses.

The main results of these calculations are:

- On the supply side the demand for all fossil fuels and uranium is lower in the ECO scenario, while the demand for biomass and for supply side technologies (as wind power and combined cogeneration plants based on gasified biomass fuels) is higher. In total, the annual expenditure for technologies and fuels is about 3,5 billion SKr higher in ECO than in Reference scenario. This expenditure is an annual average for the whole period 1997 - 2020.
- On the demand side, the annual expenditure of the industry and residential & commerce sectors for end-energy is approx. 21 billion SKr lower in the ECO scenario due to more efficient energy use and due to a shift from higher priced electricity and fuels like oil to district heating and biomass. Especially the demand for electricity will decrease, though in parallel, district heat will increase.

- The 3,5 billion SKr higher expenditure on the supply side has to be financed by the consumers of end-energy. Hence there has to be a „virtual" transfer of money from the demand side which saves money to the supply side which requires more money.[16] Over 17,5 billion SKr would annually remain on the demand side to invest in energy saving technologies. This means that for the period of 23 years the model permits a 400 billion SKr extra investments in ECO-scenario demand side. The model assumes that all these money will be spent for fuel switching, choosing more efficient equipment, etc. on the demand side. It is a balanced model. The extra investments for more efficient equipment might as well be less than here assumed (indications from the NUTEK experiences) but then the extra number of jobs would be less than calculated.

The total differential demand for supply side investment and for energy saving technologies is distributed to the individual sectors. of the Swedish economy by the structure of total investment[17]. Based on this, the overall results of the employment effects are shown in the figure below. The model, based on historic economic data applied on a 23 year period ahead[18], can only give a rough calculation that mainly indicates the direction of the possible changes. Nevertheless the results give strong hints for the potential acceptance of a phase out strategy.

In total, the Swedish economy would gain in order of 45.000 additional jobs as an annual average. There are mainly two reasons for this result:

- The demand is shifted from sectors with a low to sectors with a high labour intensity, e.g. from electricity generation and distribution to forestry or construction.
- The import of fossil resources is substituted by domestic resources like know how for energy saving, solar energy, or biomass.

The sector faced with the biggest job „losses" is - not unexpectedly - the energy supply sector (SCB sector „electricity, gas, and water supply"). Half of these „losses" are future jobs not existing today. However, these losses are more than compensated by the job gains in the construction, agriculture & forestry, wholesale, and manufacturing sectors. As this is a result of a model, not taking into account a shift from less labour intensive nuclear plants to more labour intensive municipal cogeneration plants, it probably overestimates the job losses in the energy supply sector. The electricity demand will be less, but not the number of customers. But, as already commented, the model gives us hints of the directions for different sectors.

And even the companies of the energy sector can avoid job losses - they have to change their focus from energy supply to energy services. If they start to change their business strategies to the new required fields like energy saving, renewables etc., they could create new jobs within the companies for these people who would lose their job in the energy supply.

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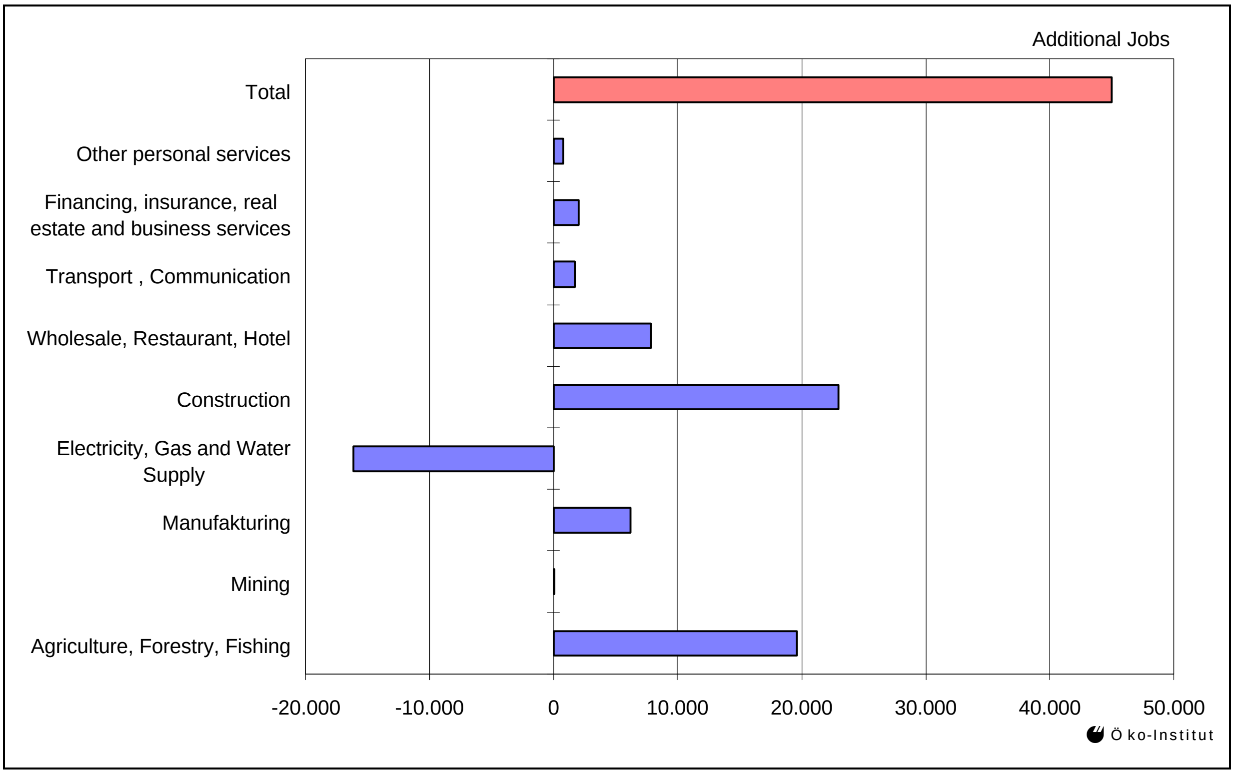
16 How this transfer is organized - e.g. by a specific tax or by other instruments - can not be answered in this study.

17 The input-output based employment-model is based on input-output-tables and production and employment tables of Statistics Sweden (SCB 1992, 1995).

18 This is the draw back it shares with other economic based models applied on long term scenarios.

Fig. H Sectoral Employment Effects of the ECO Scenario as Compared to the REF Case



5 Implementing the ECO Scenario: The first Years

To move beyond mere modelling, the Swedish energy system must be changed in the next years - to achieve the Eco-Wise scenario, a variety of activities are needed.

The following list indicates at least some of the relevant policies and activities:

- A phase-out program for the nuclear plants.
- The technology procurement program with all its linked activities, now conducted by NUTEK, has to continue in all sectors, but expand its activities for the industry sector.
- A new program for promoting the conversion from electrical heat to other heating options through measures such as technology procurement, regional and local planning activities, financing supports etc. For investments in conversion to district heating, bidding for least cost conversions will minimise needed subsidies and procure the most economical measures.
- An upgrading of the Swedish Building Regulations, taking new building technology into consideration, and using primary energy needs as the appropriate indicator of performance and strict limits for using electricity for heating purposes.
- A new program for small-scale biomass heating including technology procurement, biomass fuel infrastructure measures, information activities, financing aid etc.
- A multi-billion demonstration program for full-scale biogasification cogeneration plants.

- A short-term program for small-scale cogeneration plants (internal combustion engines, gas turbines) based on conventional technology, but planned for later upgrading with biogasification units when commercially available.
- A hundred-million demonstration program for off-shore wind power plants.
- A general wind-power financing program (including necessary subsidies) for the needed investment level.
- Legal and economical measures to get the process going, especially regarding a revised (extended) eco-tax scheme, and road-pricing.
- A Swedish contribution to a joint programme of EU car manufacturers to market high-efficiency cars
- A regionalized investment programme to extend the railroads and light-rail systems in and around densely populated areas
- A regionalized programme to establish „cargo management centres“ for advanced freight logistics
- Revised tax policies to favour freight transport by train, and to de-favour truck transports, especially for bulk products

6 Some Answers to Important Questions

In addition to the summary of the results, this section deals with some of the key questions arising from the study.

- **Are the technologies assumed in the ECO Scenario already available ?**

Yes, they are. On the demand side, all energy efficiency technologies are already on the market, although not yet all in Sweden. On the **supply-side**, the upgrading of existing cogeneration plants is well proven (and has started already in Denmark, and East Germany).

For the biomass gasification plants, some small-scale systems are operating already throughout the European Union, while for the medium-sized systems, a pilot plant is operating in Sweden. The further development (cost reduction, efficiency increase) of this technology is assumed until 2005, when the large scale investments in biomass cogeneration starts.

For on- and offshore wind power, experiences in Denmark, Germany and the Netherlands clearly show the proven status, and the competitiveness for good sites, especially offshore.

- **Which first steps are to be taken to implement the ECO Scenario ?**

The most important short-term steps are: To **actively market** energy efficiency technologies, to support the extension of district heating and cogeneration re-powering, and to fuel-switch away from electric heating. Furthermore, the market introduction of both small- and medium-sized biomass gasification systems in Sweden is needed (large scale state financing will be necessary), and the development of energy-efficient cars for the Swedish market.

- **Why building gas-fired power plants, and where will the gas come from ?**

In the ECO scenario, 900 MW of new gas-fired combined-cycle power plants are assumed to be built[19] - they are needed to partially compensate for the shut-down of the first reactors in 1998 and 1999. In the later years, they are used as flexible generation options which can „back-up“ wind energy, and they replace existing oil-fired gas turbines for peaking service.

The gas fuel can be delivered through the **existing** pipeline system when increasing its pressure, so that no additional investments are needed for the fuel supply.

- **Will the ECO scenario work in a „dry year“ ?**

The scenario runs for both the ECO and the REF cases assume the „normal“ hydro year, i.e. the average electricity generation from hydro plants. If a „dry“ year occurs (i.e., few rain and snow to fill the reservoirs), the assumed generation might drop by some 10 TWh. On the other hand, a „wet“ year will increase the output of the existing hydro capacity by the same amount.

In both scenarios, we have assumed that the „dry years“ can be balanced by imports from the European network, and that in „wet“ years, increased exports will compensate the imports.

During dry years, imports would not be possible from Norway (assuming Norwegian hydro reservoirs to be low also), but must come from Denmark, Germany, or other countries with excess capacity to export (e.g., Austria, Switzerland). The associated CO_2 emissions from the imported electricity could be balanced by the Swedish exports during „wet“ years.

Still, as an alternative, the use of domestic Swedish generation resources would be possible also: The existing thermal condensing capacity in Sweden based on oil, coal, and some gas could generate additional 10 TWh - and more, if gas turbines are included. Here, the costs would be higher than for imports from abroad, but on the other hand, the available capacity in Sweden would be better used, so that there is some attraction to this option as well. The phaseout time table, 2008, permits a postponing of the last nuclear aggregates for a year or two if 2007 - 2009 turns up as very dry years.

- **Will Sweden lose its competitive edge when phasing-out nuclear ?**

Clearly not - it will be the opposite: as the economic analysis shows, the shift towards energy efficiency, cogeneration, and renewables will boost new markets, and will shift money spent on imported energy carriers towards domestic energy **services**.

Relying more prominently on domestic energies (biomass, wind, efficiency) will help to stabilise the Swedish economy by creating local income, and reducing tax money spent on unemployment.

Reducing the share of imported fuels also reduces economic risks associated with changes in the dollar-exchange-rate, and the expected increase of oil and gas prices after the year 2000.

The nuclear industry itself cannot give any advantage to the Swedish economy: there is no market for exporting nuclear technologies, and the possible technology spin-offs are extremely small.

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[19] The fact that the ECO case includes gas-fired power plants and some gas-fired cogeneration does not mean that the authors recommend gas-fired power plants in general. In ECO the gas-fired power capacity is needed temporarily, in order to enable the nuclear phaseout to 2008. This fossil gas acceptance is all linked to the complete scenario with a stringent early phase out of four reactors.

- **Can’t Sweden go for the ECO Scenario, but maintain the nuclear plants, and export their electricity abroad Europe ?**

In theory, yes - but not in practice: The internal energy market in the European Union is characterised by a **surplus** of cheap electricity, and the main possible candidate for Swedish exports is Germany .

As the French nuclear electricity exports to Italy, Portugal, Spain and the UK have shown, there is quite a barrier to increase exports far beyond today’s levels: Costs for additional transmission capacity, and competition from domestic generation must be faced.

In Germany, imports of - even cheap - nuclear electricity are unlikely, because the German supply system is „overstocked“ also. Access to world-market coal, and short-term low-cost gas contracts allow German utilities to easily compete with foreign generation, as the French example shows. Furthermore, the liberalisation of the electricity markets will lead to an increase of industrial cogeneration (as seen in East Germany already). Export options for Swedish electricity can arise only for „green“ electricity - which nuclear clearly is not.

- **Why not delaying the phase-out until energy efficiency, and renewables are „ready“ ?**

There are two answers to this question:

First, the alternatives to nuclear power are available already - no need to wait, but a clear need to start their marketing (see Questions 1+2). To do so, investments must be made - and who will invest if the existing nuclear generation can easily undercut even cost-effective new generation ? This „domestic competition“ between the existing nuclear and ALL alternatives is the first answer - if you wait, you will wait very long.

Second, the continued operation of nuclear will not only delay the introduction of the alternatives, but also increase risks: from 1000 MW of nuclear capacity, about 30 tonnes of high-level nuclear wastes are generated annually which have to be taken care of - and no final repository is available for even one single tonne, and nobody can tell today what the „safe“ disposal will ultimately cost.

The operation of nuclear power plants also causes the risk of severe accidents - even the best safety management can fail, and the welfare losses associated with a Swedish core meltdown would shake the foundations not only of the Swedish society, but of neighbouring countries as well.

- **Impacts on the marginal cost of electricity production ?**

In the IO model analysis of the employment effects, the energy prices for the customer in ECO-scenario are assumed to be equal with the REF-case. In the short term the ECO scenario will probably give somewhat higher production costs. What the actual prices will be for the customers are a highly political question. Taxes and environmental fees are important measures in the field of energy politics. The production costs for marginal production plants in Sweden will be set by off shore wind power technology and cogeneration plants based on biomass gasification. The future production costs from these plants will be in the interval of 300 - 400 Skr/MWh when mature commercial technology. The introduction costs not included (1-3 billion SKr demo costs with the timetable as in the ECO scenario). In the REF-case the production costs will increase from 290 SKr/MWh 2010 to 320 SKr/MWh 2020 (NUTEK assumptions). The REF cost (natural gas price) is calculated on the assumption there will be no CO_2 -taxation. Any significant CO_2 taxation would rise the production cost in the REF case. Also a full scale fuel shifting from coal in condense plants to less „harmful" natural gas on the European level probably will effect the natural gas market rising the gas price. If this will occur, we don't know nor how much that would effect the marginal cost in the REF case.

- **What are the costs of the nuclear phase-out, and who will pay ?**

Closing existing nuclear plants definitely has a cost: money lost from potential electricity sales, and some sunk capital. It was beyond the scope of this study to determine the net costs of the phaseout. For that, a detailed accounting of the economic value of the existing nuclear plants would be needed, an estimate of the future cost of retrofits to maintain the plants, and a fair accounting of the cost effects of the final disposal of spent nuclear fuels. The availability of these data is highly questionable.

Still, one can do some reasoning: When continuing to operate the nuclear plants as in the Reference case, their value will mainly consist of „avoided electricity imports" or avoided alternative generation. If these alternatives cost equal or even less, the societal value of the nuclear plants is zero, or even negative.

Still, the private owners will have to get compensated for the „stranded investment" - but the amount also will depend on the economic value of the continued operation. It is important to understand that **profits** in electricity generation can be **made with alternative sources also** - but to do so, one has to invest first.

The only practical way to determine the „private" costs of a phaseout is to compare the short-term marginal costs of nuclear generation with the short-term marginal costs of imported electricity for which (nearly) no investments are needed.

On the EU spot market, the private cost of electricity is in the range of 150-200 SKr/MWh (incl. transmission), while the short-term nuclear generation costs (excluding capital cost and risk premiums for disposal) are around 100-150 SKr/MWh. If one assumes a cost difference of 50 SKr/MWh, the profit (after taxes) would be around 35 SKr/MWh - totalled over time until 2020 this would be around 0,01 SKr/kWh of all electricity generated in the ECO Scenario.

But when discussing the **private** costs of the phaseout, one has to consider the **societal gains** of the alternative: the approx. 45,000 jobs which can be created in the ECO scenario (see Section 2.3) have a value, too - and they are „lost" if the nuclear plants continue to operate.

Tax revenue from the wages would be around 3 billion SKr per year, and avoided unemployment costs would add another 3 billion SKr per year. Totalled over time this would be approx. 0,04 SKr/kWh of all electricity in the ECO Scenario. So one can argue that the societal „loss“ associated with the continued nuclear operation exceeds the expected private loss.

Sweden would be better off paying a compensation for the phaseout, thereby increasing the tax revenue from additional jobs, and reducing unemployment costs.