Ten Opportunities and Challenges for Nordic Energy

Towards a Sustainable Nordic Energy System

April 2010

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The financiers

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Elforsk is the host of the project.

The researchers

The research group is interdisciplinary and includes researchers from the following universities, institutes and research companies during the second phase of the project:

VTT – Finland's Technological Research Institute in Espoo, Profu in Gothenburg, Sweco in Stockholm, ECON Pöyry in Stavanger and Oslo, Gothenburg School of Business, Economics and Law, Xrgia in Oslo, VATT – The Government Institute for Economic Research in Helsinki, RAM-løse edb in Copenhagen.

The project leader is Profu.

Preface

The Nordic Energy Perspectives project has clarified several economically significant opportunities and challenges for Nordic energy actors. With an interdisciplinary approach, involving research groups from four Nordic countries and different traditions, the opportunities of EU policy and market integration have been explored. The aim of the project is to provide a better basis for decisions on energy and environmental policy at both national and international levels. It is intended to contribute to constructive dialogue between researchers, politicians, authorities and actors in the energy markets. A second phase of the project has been carried out during 2007-2010. This extract summarises important results.

More than 20 organisations financed the second phase of the project. Many of them were represented on the board of directors. The board holds the overall responsibility for the project. The research leaders have led the scientific work. The project managers have been responsible for co-ordination of the project. Together we have striven actively for rapid and extensive dissemination of results. The board can happily note that the researchers have delivered interesting results, meeting expectations as well as time schedules. The research issues of the second phase are related to targets and measures of the EU's energy and climate policy package. Examples of areas that have been analysed are the function and development of the energy markets and infrastructure, effective measures to reduce carbon dioxide emissions – renewable energy and other energy with low CO_2 emissions, together with energy efficiency and resource management – as well as security of supply issues. Core research activities have been the synthesis work of different perspectives, results and models of the research-groups from different countries and scientific disciplines.

Results produced by the project's researchers have been examined and quality-assured. They are not only reviewed by the project directors from a scientific perspective, but also challenged at several conferences and workshops with participating, external experts from relevant fields. The board has not interfered with the scientific freedom of researchers. Thus, the researchers, not the project as such, are accountable for the contents of this report.

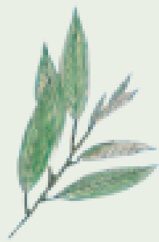
An objective of Nordic Energy Perspectives has been to create a forum for fact-based discussion between politicians, civil servants, industrialists and other energy actors from different disciplines and countries. This forum is active. We are eager that these discussions shall continue on the themes dealt with by Nordic Energy Perspectives. Contact information is found at the project's web site: www.nordicenergyperspectives.org.

We extend warm thanks to the project management as well as to all the researchers who have contributed to the project's second phase. As this is written we look forward to the final seminar and the enlightening discussions we hope will follow!

For the project board in April 2010

Tomas Kåberger
Chairman

THE EU ENERGY AND CLIMATE PACKAGE



On January 23 2008 the EU Commission presented its energy and climate package and in December 2008 an agreement with the EU Parliament was reached. The goal for the policy package is to reduce emissions of greenhouse gases by at least 20 % compared to 1990 and to increase the renewable share in the EU energy mix from 8.5 to 20 % until the year 2020.

The target for CO_2 emissions reduction of 20 % compared to the 1990 level corresponds to a reduction of 14 % compared to the 2005 level. The reduction should be reached partly within the system for emission trading and partly through measures in other sectors. The trading system will be expanded and the number of emission allowances will gradually be reduced in a way that the emissions covered by the system decreases by 21 % until 2020, compared to the 2005 level.

Within the sectors not included in the emission trading system the emissions should, as an average, be reduced by 10 % compared to the 2005 level. For these sectors a burden sharing has been applied, taking each country's specific prerequisites into account.

In order to reach the 20 % target for increased use of renewable energy until 2020 the EU Commission has assigned individual and mandatory targets for all EU countries. The policy package also includes the target that at least 10 % of all fuels in the EU´s transport sector should be biofuels.

The EU's energy and climate package also includes a requirement for energy efficiency improvements of 9 % by 2016, and a proposal for 20 % energy efficiency improvements by 2020.

The EU Commission has also issued new guidelines for governmental support to environmental protection which should help the member states to develop a sustainable European energy and climate policy.

Introduction

Nordic Energy Perspectives (NEP) is an interdisciplinary energy research project with the overall goal of demonstrating means for sustainable growth and development in the Nordic countries. The Nordic energy system is the point of departure, seen from a European and a global perspective.

The second phase of the project has been carried out during 2007-2010.

NEP analyses the national and international political goals, directives, and policy instruments within the energy area, as well as their influence on the Nordic energy sector. The analysis includes the impact on energy markets, energy systems, infrastructures and institutional structures. NEP aims at clarifying to decision-makers the consequences for politicians, energy actors and the public of political and strategic decisions. The project is intended to promote a constructive dialogue among researchers, politicians, authorities and other actors on the energy markets.

This second phase is characterized by:

- The most important market actors have participated
- Experienced researchers involved
- Cross scientific cooperation and process of synthesis
- Professional energy models
- Intense dissemination of results.

Towards a sustainable energy system

A common aspiration in the EU´s and the Nordic countries´ policies is to develop the society in a sustainable direction. The future energy system is an important part of such a society. In the NEP project we have a general view of a sustainable development of the society, but our focus is directed towards the demands such a society will put on the energy system.

Since 2001 the EU has a general strategy for sustainable development. A key element is that environmental protection, social cohesion and economic prosperity must go hand in hand. The strategy should, according to its aims, found a basis for reviews and development of EU policy within different areas during the coming years. The EU´s energy and climate policy package could be seen in this perspective.

The EU´s energy and climate policy package has been viewed as an operational expression of an energy policy for the EU, based on the general strategy for sustainability. The analysis in the project is based on the targets of the package.

Ten Opportunities and Challenges for Nordic Energy

In this extract we briefly present the main findings from the NEP project in the form of *ten opportunities and challenges for Nordic energy*. A more complete and detailed presentation of the results from NEP can be found in the project's final report "Towards a Sustainable Nordic Energy system". The ten opportunities and challenges presented in this extract, which have been derived from a large number of contributions from the whole research group, have the following headlines:

I. The challenge of implementing the EU climate and energy package in the Nordic countries

II. The Nordic renewable energy resources provide opportunities, but also challenges

III. Three energy efficiency challenges

IV. Making Nordic electricity CO_2 free - a challenge which opens for opportunities

V. Finding the balance between politics and markets - a recurring theme in the Nordic Energy Perspectives project

VI. A further integration of the electricity markets in Northern Europe

VII. The district heating challenge – how to remain competitive and contribute to a sustainable development if/when energy demand starts to decline

VIII. Industrial development and future export for Nordic industry – opportunities and challenges

IX. Security of supply challenges in the Nordic countries

X. The challenge to use energy systems modelling in a "wise and appropriate" manner in large multidisciplinary research projects

It has also been a challenge for the project to reach its overall goal of "demonstrating means for stronger and sustainable growth and development in the Nordic countries". By showing all these opportunities we are convinced that the project's results and conclusions can – if they are taken into consideration – contribute to strengthening the development in the Nordic countries and Nordic cooperation.

"It has also been a challenge for the project to reach its overall goal"

Other NEP reports

In addition to this booklet the analyses and results from the NEP project are presented through a number of additional channels:

The final report from the project, in the form of the book *"Towards a sustainable Nordic energy system"*.

A report describing experiences from the extensive use of energy-system models: "*Coordinated use of energy-system models in energy and climate-policy analysis – lessons learned from the NEP project"*.

A number of research reports and presentations from workshops and conferences that can be found on the project's web site: *www.nordicenergyperspectives.org*. These reports provide more comprehensive and detailed descriptions of the project's results and analyses within different areas.

20 perspectives on Nordic Energy

The final report *"Towards a sustainable Nordic energy system"* gives the main findings from the NEP project in the form of short chapters that presents conclusions and syntheses based on the project's results and analyses. We have chosen to call these chapters "20 perspectives on Nordic energy". The twenty perspectives are:

- Significant impact of meeting the EU energy and climate package on Nordic energy markets
- Future options for large-scale stationary energy production with low CO_2 emissions – nuclear in the near future, CCS a long term option
- The EU's renewable target is the main driver for reducing Nordic emissions of CO_2 by 20 %
- Large renewable energy resources in the Nordic region - but the extent to which the use of these resources can be increased varies significantly from country to country
- Energy efficiency measures in the entire energy system leads to synergies
- Large, profitable efficiency improvement potential in end-use – existing programmes and simple measures can result in significant improvements in efficiency
- The development of the Nordic electricity system – towards zero CO_2 emissions?
- Can we expect electricity demand to grow?
- Millions of electric vehicles will have manageable impacts on the Nordic power system
- Huge opportunities for Nordic electricity export in a widened European electricity market
- Scenarios for the Baltic Sea Region
- District heating in the Nordic region – an important part of a sustainable Nordic energy system
- District heating price model – important for future competitiveness
- Proactive strategies for environmental sustainability of municipal energy companies – pathways of sustainable development in the stationary energy system
- Leading indicators in successful facilitation schemes for Clean Tech companies – the case of increasing growth and export volumes in the biomass combustion manufacturing industry
- International climate policy participation critical for Nordic industry competitiveness
- The Nordic forest industry – a temporary dip or the beginning of a structurally driven decline?
- Broader participation required for successful emissions reduction as global energy demand increases
- Global climate challenge – a stimulant for a new Nordic business
- Perspectives on security of supply issues in the Nordic countries
- Is nuclear power a threat to security of supply? – more wind power highlights capacity issues
- Potential effects on the Nordic region of a gas shortage in Europe - increased demand of gas in EU and decreased production gives increased dependence of imports

Main scenarios used in the NEP project

The development of the Nordic energy systems have been analysed through a number of scenarios. The NEP model toolbox has been used for the calculations. A certain focus has been on the EU energy and climate package. The following scenarios have been calculated:

The reference scenario

The reference scenario includes existing policy instruments such as energy and CO_2 taxes and selected support schemes such as the Swedish electricity certificate system and direct subsidies in other Nordic countries. Furthermore, the EU emission trading scheme (EU ETS) is included as an exogenously given EU emission allowance (EUA) price of 25 EUR/t.

The EU policy scenario

The EU policy scenario includes the same policy instruments as the reference scenario but, in addition, a requirement to reach the renewable target defined for Denmark, Finland and Sweden in accordance with the EU energy and climate package, and an assumed target for Norway. The scenario also includes an EU emission reduction target of 20 %, also applied for the Nordic region.

The extended EU policy scenario

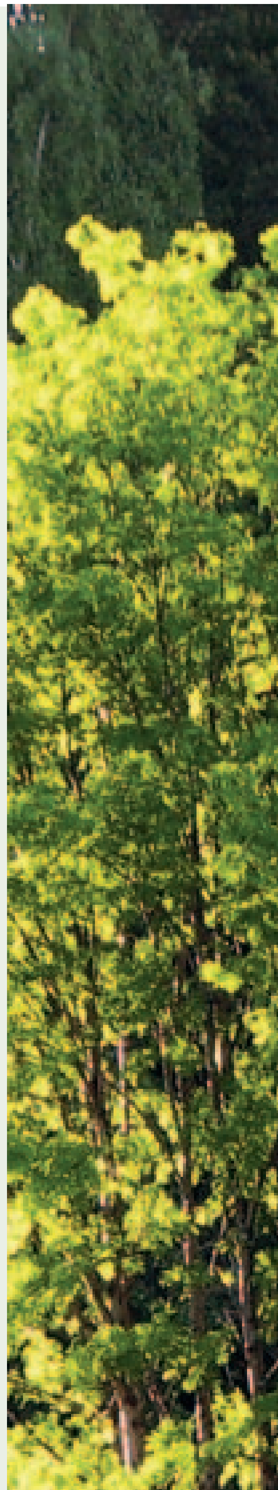
The extended EU policy scenario includes the same policy measurements as the EU policy scenario but, in addition, the target of increasing energy efficiency by 20 % until 2020 adapted to the Nordic countries.

The global policy scenario

The global policy scenario includes a new global climate policy agreement where the EU CO_2 emission reduction target is increased to 30 % and the renewable target is met. The emission reduction target is included both in the form of different global emission reduction targets and in the form of the EU emission trading scheme (EU ETS). The scenario also includes existing policy instruments. (The scenario does not include the increased energy efficiency target.)

Alternative scenarios

A number of additional scenarios are also defined, calculated and analysed. They are designed to illustrate the effect of certain specific factors or situations. These scenarios are explained in the chapters where they are referred to.



I. The challenge of implementing the EU climate and energy package in the Nordic countries

Fulfilling the goals and targets within the energy and climate package of the EU, and the Nordic ambitions within the energy field, has a decisive impact on the development of the energy markets and systems of the Nordic countries. In the NEP analyses it is shown that all sectors and all energy markets are likely to be affected. Such far-reaching changes of the energy systems will present a number of challenges but also opportunities.

It is a challenge in itself to redirect the energy system in order to meet the political requirements at the EU level and at the Nordic level. CO_2 emissions are reduced by 70-80 Mtonne and renewable energy is increased by around 100-150 TWh. Moreover, if energy efficiency also is increased by 20 percent until 2020, primary energy consumption is reduced by up to 200 TWh (compared to the outcome of a "Business-as-usual" scenario).

Identifying synergies is the key to cost-efficient solutions, and opens up for opportunities

Meeting the targets in the energy system is costly but identifying synergies is the key, and an opportunity, to reduce the additional costs. It is, however, a challenge to identify and promote such synergies. This may be achieved through:

- *choosing policy instruments and other political decisions that in a cost-efficient way promote measures that contribute in reaching all three EU goals at the same time*. Wind power is a good example. It is renewable and reduces CO_2 emissions in the Nordic electricity market. At the same time, a shift from e.g. coal power to wind power implies significant efficiency gains at the electricity-supply side.
- *considering policy measures at all levels of the energy system in order to include system effects*. Energy efficiency measures are not only associated with end use but also with the supply side.
- *recognizing a certain degree of flexibility in the commitments of the different parts of the energy system*. This means that sector-specific goals for e.g. renewables should be used with care. Instead, including as many sectors as possible in an overall target reduces compliance costs.
- *international cooperation and trade, for instance among the Nordic countries*. The analysis and results of the NEP project largely comply with a scenario where the Nordic countries initiate a far-stretched cooperation in order to collectively meet the EU energy and climate package.

The EU policy goals affect each other

The analyses carried out by the NEP project frequently show that the various climate and energy targets affect each other. Sometimes, they may even counteract. For instance, the CO_2 reduction target results in a higher electricity price through the EU ETS, while the renewable target may reduce wholesale electricity prices due to investments in renewable capacity, everything else held constant. This makes other non-renewable, but nevertheless lean-carbon, options such as coal-to-gas fuel shift and CCS less viable. If costs for renewable electricity are not incurred on the consumer electricity bills this would also work in the opposite direction of the ambitions of the efficiency target, where demand for energy services is to be dampened.

Figure I.1 below shows the increased use of renewables in the four Nordic countries as a whole for the three policy scenarios. The Directive on the promotion of energy from renewable sources (The "EU Policy" scenario) foresees that the use of renewable energy sources increases by around 160 TWh (incl. transport) by 2020 compared to 2007 levels (specific asssumptions have been made for Norway). At least half of that increase will come from biomass used in different sectors (biomass is mainly supplied through domestic resources but also import is considered if the market price exceeds a certain level). If the energy efficiency target is also achieved ("Extended EU Policy" scenario) the increase in renewables is reduced to around 120 TWh. Specifically, the use of biomass is significantly smaller than in the "EU Policy" scenario, but, of course, larger than in 2007. This is due to lower energy demand but also efficiency measures on the supply side. Biomass use is especially affected by efficiency measures, since biomass is generally associated with lower overall (applied) efficiencies than e.g. heat pumps and wind power, which are also included in the Directive. This is important since, as mentioned earlier, the efficiency target in this study is applied to the entire energy system and to all energy resources. However, the efficiency goal will only affect the use of renewables in their absolute numbers. Since the renewable target is expressed as a relative target (percent of gross demand), it is still being reached by 2020 in the "Extended EU Policy" scenario.

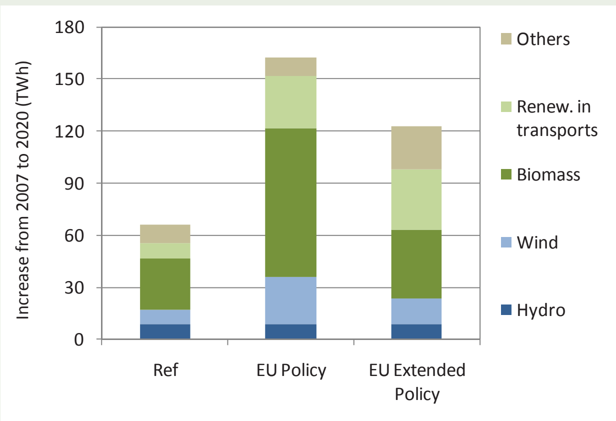


Figure I.1: Increase in use of renewable energy in the Nordic countries in 2020 compared to 2007 for three scenarios investigated.

New technology gives new opportunities

Cost reductions may also be achieved by using a basket of many technological options. The NEP project has shown that the path towards meeting the energy and climate package of the EU involves many measures, options and technologies at all levels of the energy system. Therefore, ruling out specific technological choices out of e.g. political reasons is likely to increase the compliance cost. However, in certain cases climate and economic considerations must be balanced with considerations related to public acceptance (e.g. nuclear power or wind power), other environmental pollutants (e.g. biomass) and so forth. Opening up, and promoting, a wide range of measures in the Nordic countries may create business opportunities for Nordic industry. This may not only involve technological development where the Nordic countries already today are at the very edge within several areas – district heating, biomass, heat pumps, wind power etc - but also within areas related to e.g. systems planning and development, management and markets.

Synergies are also achieved though the encouraging of structural changes of the energy systems where, for instance, grid-distributed energy such as electricity, district heating and gas (e.g. biogas) are made practically CO_2-free and largely renewable, and subsequently become used as "measures" in the development of the energy systems.

Renewables and energy efficiency are the most important CO_2-reduction measures

The significant reduction of CO_2 emissions by 2020 and beyond in the "Extended EU Policy" scenario is achieved mainly through increased use of renewables in all sectors and through energy-efficiency measures at the end-use side as well as at the supply side of the energy system. But also nuclear power plays a significant part in the reduction measures identified through model analyses. This includes a fifth reactor in Finland and repowering and increased availability in Swedish nuclear power plants by 2020. The individual contributions of these measures are shown in Figure I.2 as CO_2 -reduction "wedges". These contributions are estimations related to a trend projection until 2030, based on the years 1990-2007.

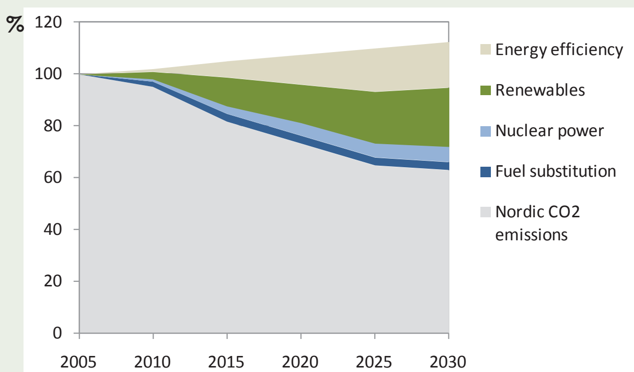


Figure I.2: CO_2-reduction measures in the entire energy system of the Nordic countries in the "Extended EU Policy" scenario put in relation to an assumed trend projection, based on 1990-2007, by 2030.

A large share of the CO_2 reductions is taken by the trading sector

The analyses of the NEP project clearly show that meeting all three energy- and climate-policy goals of the EU implies significant impact on the Nordic energy systems and a reduction of CO_2 emissions by around 30 percent by 2020. The work presented here also shows that a large share of the emission reductions take place in the trading sector of the EU ETS which indicates that the Nordic region may become a net exporter of emission allowances. However, at the same time the reduction commitments applied to the non-trading sector may become tougher to meet without additional policy incentives. This should in particular involve the transport sector.

Measures that transfer the responsibility from the non-trading sector to the trading sector are important

Model analyses of the NEP project have shown that electricity and district-heating supply are only to a small extent still dependent on fossil fuels by 2020 if all three EU targets are met. The European Commission has also formulated a vision of CO_2-free electricity production in Europe by 2050. This means that electricity and district heating, in itself, become important reduction measures in climate-change mitigation. Such measures could, for instance, include switching from oil heating to district heating in dwellings or switching from a gasoline car to an electric car. At the same time, a switch from gasoline to electricity or from oil to district heating means that the reduction responsibility is transferred from the non-trading sector to the trading sector of the EU ETS. The NEP analyses reported in this book indicate that such a transfer of responsibility may account for up to half of the emission reductions set up for the non-trading sectors of the Nordic countries. This is a very important conclusion which may play a decisive role in the fulfillment of the Nordic countries' domestic commitments.

Several of the measures and options that may contribute in transferring the responsibility for emission reductions from the non-trading sector to the trading sector, such as district heating, electricity and electric cars are more thoroughly discussed in other chapters of this report.

Our climate is a very complex system

The Earth's climate system is a complex, interconnected system formed by the atmosphere, the oceans and other bodies of water, land surface, snow and ice cover together with all living organisms, and linked by flows of energy and matter. Changes in the Earth's climate are influenced mainly by changes in the atmospheric composition of gases and particles, but also by changes in solar radiation and surface albedo.

The most important component to influence the atmosphere is CO_2, which stands for 70 % of the global warming potential in the atmosphere. Other gases of great importance are long-lived gases like CH_4 (20 %), N_2O (5 %) and fluor-containing gases like HFC, PFC and SF_6 (5 %). All act on a global scale. Mitigation of greenhouse gases must consider not only CO_2, but also the other long-lived greenhouse gases. (The non-CO_2, gases are included in the commitment of the non-tradable sector).

Measures that reduce more than one greenhouse gas at the same time

It is therefore important to seek measures that may reduce more than one greenhouse gas at the same time. These "synergies" will make the measures much more cost-efficient. Such measures identified by the NEP include for instance:

- waste incineration
- biogas (e.g. from manure).

Scenarios including a reduction of all greenhouse gases are analysed in NEP, and exemplified in short on the next page.

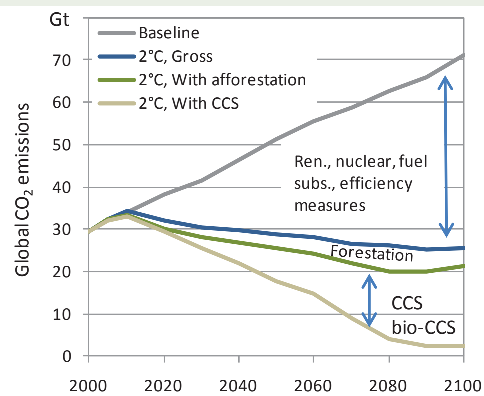
Global climate challenge – a stimulant for a new Nordic business

The EU has agreed to adopt the necessary domestic measures to ensure that global average temperature increases do not exceed pre-industrial levels by more than 2°C. This target was also agreed in Copenhagen Accord at the United Nations Climate Change Conference in 2009. Tackling climate change to a safe level would require from 50 to 80% reductions in global greenhouse gas emissions compared to the present level by 2050, which would need a total change of the existing energy systems and could stimulate a new industrial revolution. Nordic countries have long traditions in developing and using low carbon technologies, like renewable energy technologies and CHP, as well as energy efficient solutions in residential and industrial sectors. Tackling climate change would create huge markets for clean energy technologies, and Nordic industry could take a great advantage on this.

2°C degree target would require zero CO_2 emission levels and radical decrease of all the greenhouse gases ...

The Figure I.3 (left) shows the global CO_2 emissions in the Baseline and global policy scenario with 2 °C mitigation target up to 2100. The scenario results illustrate the required emission reduction level and emission reduction path in the shorter term. The largest share of emission reductions would be realized by conventional technology change, i.e. by increased use of renewables, nuclear and other low carbon fuels, and especially by improvement of energy efficiencies through the whole energy chain. Large share of emission reductions could be realized by investing in carbon capture and storage (CCS) integrated to fossil fuel fired energy plants as well as to industrial processes. Even bio-CCS with "negative" net emissions seems an attractive option, i.e. CCS equipped with co-firing of fossil fuels and biomass or CCS integrated to a pulp industry. It should be noted that in these scenarios it is assumed that deforestation has been stopped and natural sinks have been increased by forestation. The opposite trend would make climate change mitigation even more challenging.

Figure I.3 (right) shows the development of greenhouse-gas emissions in Western Europe (i.e. EU-15, Iceland, Malta, Norway and Switzerland) by 2050 for the CO2 price level of 50 EUR/t with regional climate policies.



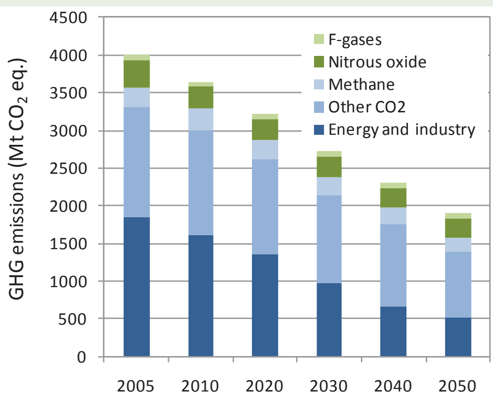


Figure I.3: Global CO_2 emissions in the Baseline and 2 °C mitigation scenarios (figure to the left). Greenhouse-gas emissions in Western Europe (figure to the right). The assumed CO_2 price increases linearly from 20 €/t in 2020 to the indicated price level of 50 €/t in 2040. "Other CO_2" includes transport and residential sectors.

II. The Nordic renewable energy resources provide opportunities
- but also challenges

The EU target for increased use of renewable energy, often referred to as the RES Directive, will be a challenge to meet for many EU member states. It will lead to challenges also for the Nordic countries, but it also creates opportunities here. The RES Directive includes a burden sharing scheme since different countries have different sizes of their renewable energy resources. The Nordic region is unique in the sense that both renewable energy potentials and present renewable energy use is large in an EU perspective.

Investments are, however, still constrained because renewable energy production is still more expensive than conventional production. In some cases, investments are also hampered by immature technologies. Denmark is the only country that has significant wind power use today, but there is excellent potential for substantially increased use of wind power in all countries in the region. The use of biomass in energy production is already high in Finland and Sweden, and this use is expected to grow due to large forest resources. In Denmark, field biomass could also notably contribute to energy production in the future. However, the assessment of future bioenergy production has great uncertainties due to future policies of Nordic countries, which might lead to increased exports of biomass or biofuels to those countries which have higher supports for renewable energy. On the other hand, EU's sustainability regulations could limit import of liquid biofuels to the EU area from South America of South-East Asia, which have large potential to increase their bio-fuel production. The share of hydropower is already above 50% of total electricity production in the Nord Pool area, and the theoretical potential to increase hydropower production is also large.

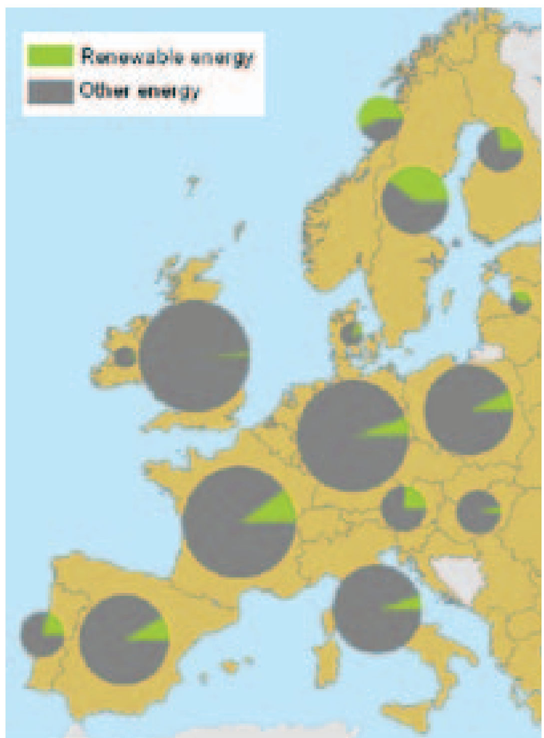


Figure II.1: The present use of renewable energy in relation to total energy use is shown for a selection of European countries.

Hydro power and wind power are naturally directly associated with electricity, whereas biomass could be used for a number of purposes, e.g. electricity production, heat production and production of bio-fuels for the transport sector. Biomass could also be used for non energy purposes, e.g. as a raw material for the pulp and paper industry.

The renewable energy issue highlights a number of opportunities for the Nordic energy systems, but also challenges. The challenges are typically related to the question of making the most effective use of the Nordic renewable energy resources.

Bioenergy and wind power – a large increase due to the EU target

The result of our analysis of what would happen if the RES Directive was implemented in the Nordic countries is shown in the figure below. It turns out that the use of renewable energy in the Nordic region increases substantially. The outcomes for the individual renewable energy technologies vary significantly. The use of hydropower is virtually unaffected, since its expansion is constrained by conditions stipulated in the model. The use of bio-fuel increases considerably. Most of the bio-fuel is used for heat production in industry and district heating systems, often through combined heat and power production. Demand for district heating and industrial process heat places a limit on how much bio-fuel heating can be introduced in a profitable manner. Moreover, the bio-fuel price is described with a "supply stairway", where the bio-fuel range becomes gradually more expensive as the amount used increases. At the same time, the results show that the use of bio-fuel is strongly stimulated by current policy instruments.

The EU's renewable target also leads to more wind power. The growth reaches 30 TWh. Most of the new wind power plants will be built over the next 10-15 years.

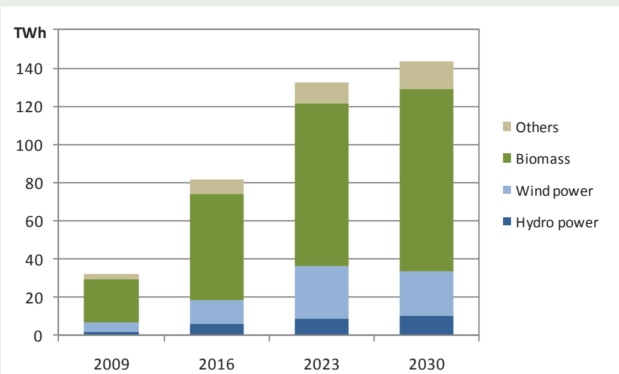


Figure II.2: Increase of renewable energy technologies in the Nordic region relative to 2005, when measures for the EU renewable energy target are applied (also keeping current emission-rights trade and national policy instruments)

Nordic cooperation in order to effectively utilize the renewable resources – within the Nordic region

The first question is where, geographically, the renewable energy resources should be used. Although the RES Directive includes a burden sharing scheme in order to define national targets for renewable energy use that corresponds to the prerequisites of each country, there may still be different marginal costs for the use of renewable energy in different countries. This indicates that it would be cost effective for some countries to utilize more renewables than the national target specifies, while other countries use less. The RES Directive offers such possibilities. This is an opportunity for cooperation between the Nordic countries. The challenge is to find effective ways to implement such cooperation. The proposed Swedish / Norwegian electricity certificate system is in line with this.

Effective use of the Nordic renewable energy resource – the EU perspective

Opportunities for Nordic cooperation in order to effectively utilize the renewable resources are relevant both within the Nordic region and in relation to neighbouring countries. The relatively large resources for renewable energy in the Nordic region will of course provide opportunities in a situation where renewable energy will be an increasingly valuable resource in Europe. Electricity trade between the Nordic region and the rest of EU and how this relates to the RES Directive is discussed in Chapter VI.

Increased renewable electricity production and stagnating electricity use lead to Nordic export

The Nordic targets for renewable energy use probably results in a large increase in renewable electricity production. In combination with stagnating electricity use in the Nordic region this will put pressure on the capabilities to export electricity to other EU countries. This can be seen as another challenge for the Nordic region that is closely related to the opportunity mentioned directly above. In order to facilitate such export it could become necessary to increase capacity in cables to neighbouring countries as well as in the national electricity transmission grid. If the export capability is very limited the described situation would result in low electricity prices in the Nordic region ("supply and demand"). This is further discussed in Chapter VI.

The optimal national mix of where to introduce the renewable energy

A challenge will be to find the optimal national mix of where to introduce the renewable energy that the EU target specifies. The most effective way to find this balance is probably identified by the market itself. Here it is, however, important that the policy instruments that are used in order to get the desired renewable energy use does not distort the balance. In order to mobilize an even larger part of the Nordic renewable energy potential, more powerful policy instruments will have to be implemented. Existing policy instruments will not be powerful enough to reach the EU renewable targets. The balance between policy and market is discussed further in the Chapter V.

A proper balance between different demands for biomass

Finding a proper balance between different demands for the biomass resource can be seen as the next challenge. Since this is a limited resource, both in the Nordic region and globally, not all future demands may be possible to satisfy, at least not at the historical price levels. The increased demand for biomass for energy purposes in the Nordic region, encouraged through different policy instruments, has not only increased the use of felling residues, but also imposed an upward pressure on the price of wood qualities that typically have been used as pulp wood. This may lead to decreased international competitiveness for the Nordic pulp and paper industry if corresponding raw material price increases does not occur in other regions. A balancing factor is here that the pulp and paper industry also could benefit from the renewable energy target, e.g. through combined heat and power (CHP) production based on biomass. The Nordic pulp and paper industry is subject to a number of structural threats and the future of this industry is discussed further in Chapter VIII.

Public acceptance and permitting procedures

Another challenge is related to public acceptance and regulations and permitting procedures for land use. Utilization of parts of the renewable energy resources lead to conflicts with other interests. Hydro power and wind power are examples of this. The theoretical potential to increase hydro power production is large, but public acceptance and political goals limits further development. Much of the increase in hydro power production comes from refurbishment and enlargement of existing hydro power plants. Norway is probably the only country where a significant increase in hydro power production can be expected. (Sweden also has large unexploited hydro power resources, but they are strictly limited through political goals.) Public acceptance and permit procedures are also important issues in connection with wind power development. There are currently large uncertainties as to how these factors will influence the possibility to build large quantities of wind power.

Intermittent electricity production, e.g. wind power, is a challenge for the Nordic electricity market

Increased use of renewable energy often includes significant expansion of wind power. Wind power can be seen as an intermittent production source, since it relies on wind that cannot be stored. (The operation of the Nordic power system with increasing volumes of intermittent power is discussed further in Chapter IV. The introduction of wind power contributes to reduced operation of condensing plants, which will eventually lead to phasing out of such plants due to economical reasons. Although wind power plants will most likely be spread geographically over the entire Nordic region, there will be periods with high demand and unusually low wind generation. This will increase the risk for capacity shortage in the region. To balance this risk can be seen as a security of supply challenge related to renewable energy.

Renewable energy also creates other opportunities for the Nordic region

All in all it is, however, probably correct to look upon the issue of renewable energy more in terms of opportunities than threats. The challenges presented above are often directly associated with opportunities for the Nordic region. Here follows some additional examples of such opportunities:

- Increased use of renewable energy decreases CO_2 emissions in the Nordic region.
- The Nordic renewable resource can contribute to lower CO_2 emissions in other countries, either through export of primary energy or through electricity export. This is valuable for the receiving countries and therefore represents an asset for the Nordic region.
- Increased use of renewable energy reduces Nordic import dependency, especially for fossil fuels.
- Increased use of renewable energy in the Nordic region stimulates development of new technologies and industries that produce equipment related to the utilization of renewable energy. It may also create export opportunities when the demand for such equipment outside the Nordic region grows.
- Improved energy efficiency when electricity production in condensing plants is substituted by CHP production and wind power.

III. Three energy efficiency challenges

In NEP, we have identified a package of energy efficiency improvement measures. This package results in increased efficiency by 20 % and includes the measures that are most cost-effective for the Nordic energy system.

However, it is not obvious that these measures will be the ones that are chosen to be implemented if the EU makes its 20 % target binding. NEP has identified three major challenges for the Nordic and European energy systems that need to be met:

1. Formulate a policy that gives equivalent incentives to increase efficiency in the whole energy system, in energy conversion as well as in end-use, so that the most cost-effective measures are chosen.
2. Balance policy instruments for improved energy efficiency with other policy instruments, including carbon emissions and renewable energy profiting from the synergies that arise from the different targets.
3. State clearly that efficiency measures – especially in end-use – require clear incentives and programmes in order to be carried out. That there is an economic viable efficiency potential is not a guarantee that a measure will be actually carried out.

A cost-effective package of measures to achieve the 20 % target

NEP's analyses show that a cost-effective package of energy efficiency measures designed to achieve the 20% efficiency improvement by 2020, includes approximately equal amounts of energy conversion efficiency measures and end-use measures:

4-5 % is efficiency measures in the large-scale energy conversion., e.g. wind power plants instead of a production in condensing plants. This corresponds to 40-50 TWh primary energy.

6 % is substitution in the building sector and industry, e.g. change from electrical heating to heat pumps in small houses. This corresponds to around 60 TWh.

9-10 % is conservation measures in the building sector and industry, corresponding to 90-100 TWh primary energy.

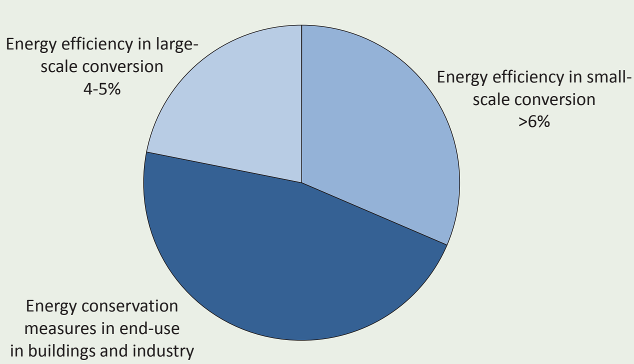


Figure III.1: The "NEP package" of measures to achieve 20 % improved energy efficiency in the Nordic countries.

Choose a policy that gives equivalent incentives to energy efficiency in the entire energy system

A cost-effective implementation of the 20 % energy efficiency improvement by 2020 target in the Nordic energy system should include all parts of the energy system, from supply to end-use. NEP's analyses show that cost-effectiveness is attained with approximately equal amounts of energy conversion efficiency measures and end-use measures. Most of these energy efficiency improvement measures will, in addition to increasing energy efficiency, also reduce greenhouse gas emissions and lead to an increased use of renewable energy sources in the Nordic countries. These synergies will make the measures more cost-effective.

In both Nordic and European energy policy, the reasoning for energy efficiency improvements have traditionally been brought forward by the energy users. The consequence can be seen in the European Commission's document on efficiency, where end-use measures get the most attention. Many cost-effective measures on the supply side are overlooked, resulting in a sub optimization that can be expencive. However, if the EU and the Nordic countries are to achieve a 20 % efficiency improvement in the 10 years until 2020, sub optimization cannot occur.

The choice of policy instruments – finding a good balance

Align energy efficiency policies with other policy instruments

Policy instruments such as the EU's Emission Trading System (ETS), CO_2 emission taxes, green certificates, and feed-in tariffs are examples of policy instruments that are designed to reduce CO_2 emissions and increase the use of renewable energy sources. At the same time, these policy instruments provide incentives to improve energy efficiency, especially through energy conversion measures. An effective approach to improve efficiency through energy conversion could therefore be to strengthen related policy instruments. NEP has not made a detailed analysis on the best way to do this. We merely list a couple of measures that might contribute to energy efficiency:

- Dedicated support for wind power as a complement to existing certificate systems.
- Feed-in-tariffs that are higher than the levels required to meet renewable targets.

Traditional energy efficiency programmes and policy instruments for end-use efficiency are of course also important to use frequently, to reach the 20 % efficiency target.

Large incentives might be required to reach the 20 % target

– especially if the EU places the focus on end-use measures

NEP's analyses show that only a small fraction of all profitable energy efficiency improvement measures are carried out unless specific policy instruments are put in place. Clearly articulated political programs are therefore required if these measures are to be carried out.

Go for the simple measures!

Evaluations of previous efficiency programmes show two types of outcome:

1. Even modest economic incentives give rise to substantial improvements in energy efficiency. This is confirmed by the volontary agreements in Finland and the Enova program in Norway.
2. Significant incentives are required for all measures to be carried out fully. This is confirmed by several Swedish energy efficiency programs from the 1990's.

The NEP project has not had the opportunity to analyze these outcomes further. However, an initial analysis indicates that a strongly focused political program might be required to reach the 20 % energy efficiency target by 2020. Such a program might be necessary despite the fact that current energy and climate policy, which includes a 9 % energy efficiency target, already includes energy efficiency incentives, and despite the fact that many energy efficiency measures give rise to synergies with other programs because they also contribute positively to CO_2 emission reduction and renewable targets.

If the EU decides to focus energy efficiency improvements on end-use while retaining high ambitions for reductions in primary energy use, more expensive measures will be required. We know by experience that strong incentives are required for such measures to be implemented. Compared to a policy in which the most cost-effective measures for the entire energy system, the ones included in the NEP energy efficiency package, are selected, such a restricted policy leads to a higher total cost for reaching the 20 % energy efficiency target.

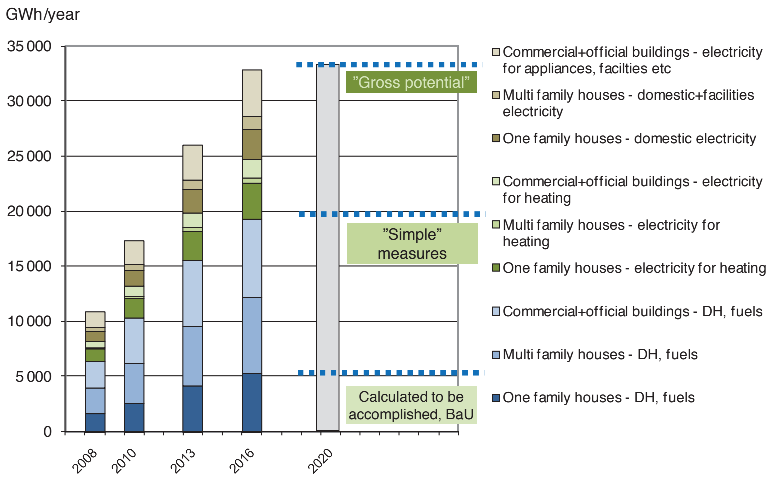
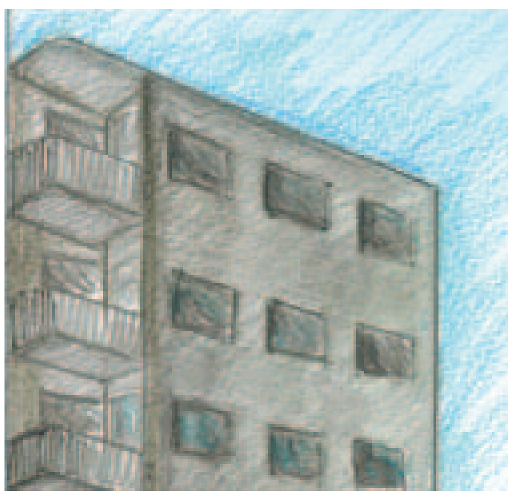


Figure III.2: Calculation of potentials for efficiency improvement. Insulation, appliances etc in the Swedish building sector. Final energy (end use).



Which energy efficiency measures are most important?

A majority of the measures in ”the NEP energy efficiency package” are noteworthy in several ways. Not only do they lead to significant improvements in energy efficiency, they also contribute towards achieving targets for reduced CO_2 emissions and increased use of renewable energy. These synergies improve the cost-effectiveness of implementing the EU's climate change and energy package.

Large-scale energy conversion

Cogeneration and wind power are the most important large-scale energy conversion efficiency measures. Low production efficiencies in older coal- and oil-powered plants lead to high CO_2 emission rates. When these are replaced by biofuel- or gas-fired cogeneration and wind power plants, efficiency is improved. At the same time, CO_2 emissions are reduced and the share of renewable energy is increased.

Small-scale energy conversion

Heat pumps and district heating are two examples of small-scale energy conversion efficiency measures. In the transport sector, a large-scale introduction of electric cars would result in a considerable efficiency increase. However, these measures do not always yield a reduction in primary energy use. Replacing oil-fired boilers by district heating often yields a reduction in primary energy use, and an improvement in efficiency. This improvement is significant if the district heating is produced with a large share of waste heat. Large and clear-cut energy efficiency improvements are also achieved when heat pumps replace electric heating. Heat pumps are included in NEP's efficiency package mostly as a substitute for electric heating.

End-use: useful energy in households, service and industry

The cost-efficient potential for energy efficiency in useful energy is large, but naturally the profitability differs between the different measures. A very large part of the measures are actually quite straightforward to implement, and many of them require no investment. Examples of such measures are:

- Adapting air flows and operation times for ventilation and illumination to the times when premises are used.
- Electricity efficiency in households, buildings and businesses, by using best available technology.
- Insulation of attics.

These simple and inexpensive measures constitute more than half of the gross potential.

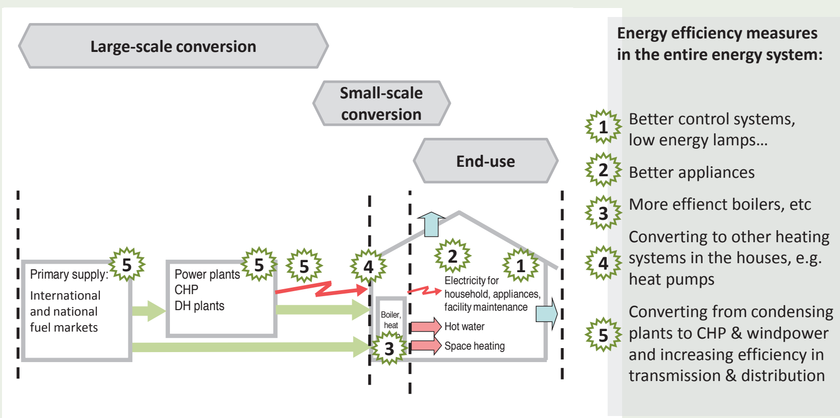


Figure III.3: Energy efficiency measures in the entire energy system

IV. Making Nordic electricity CO_2 free
- a challenge which opens for opportunities

The future electricity system will be shaped by policies, market forces and expectations. The Nordic countries are endowed with significant renewable energy resources, but bringing down CO_2 emissions while sustaining competitive electricity prices is still a challenge. The NEP policy scenarios show to what extent CO_2 emissions from Nordic electricity generation are reduced with different combinations of renewables policies and the emission cap in the EU ETS. CO_2 emissions from Nordic electricity are likely to decline in all scenarios by 2020. The share of renewable generation is found to be the most important factor in reducing emissions, but reductions also depend on the degree to which surplus electricity generation can be exported to Continental markets. Although national renewable energy policies are likely to reduce emissions, the emission cap in the EU ETS and global climate policies are also crucial for CO_2 emissions from the Nordic electricity system. Model results indicate however, that net electricity exports are roughly in line with electricity generation based on fossil fuels in the scenarios with a high share of renewables generation. As such, Nordic electricity consumption can be said to be CO_2 free in the scenarios with a strict climate policy.

Nordic electricity supply almost CO_2 free by 2020

The share of fossil-based (excluding peat) electricity production in the Nordic electricity market currently amounts to around 15 percent. This is a very low figure in an international comparison. Moreover, model calculations indicate that by 2020, this share may shrink to less than 5 percent This result is backed by an expansion of nuclear power (ongoing Swedish capacity increases and a fifth reactor in Finland) along with significant increases in wind and biomass power (CHP). Existing coal power is gradually replaced while gas power is maintained roughly at today's level. The "EU Policy" scenario (see Figure IV.1) results in the largest electricity production and the largest output from renewables in absolute numbers. Combined with a relatively modest increase in electricity demand, this implies that large volumes of electricity may be exported out of the Nordic countries. In the "Extended EU Policy" scenario, a lower demand for electricity and an assumed efficiency pressure on the supply side (in addition to demand-side efficiency measures) gives a relatively smaller total electricity production. Even in this case a significant amount of electricity may be exported due to the lower demand.

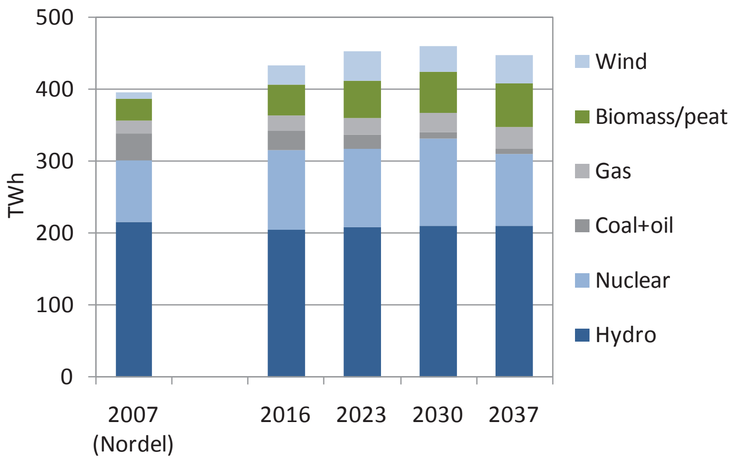
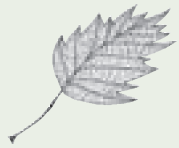


Figure IV.1: Nordic electricity production in the "Extended EU Policy" scenario

Future options for large-scale stationary energy production with low CO_2 emissions

– nuclear in the near future, CCS a new long term option

The renaissance of nuclear power in Finland and Sweden is up for debate. In Finland, a fifth reactor is under construction, and three companies are seeking permission for a new reactor. A sixth and seventh reactor would have similar effects on CO_2 emissions from European electricity production as roughly half of each new nuclear power plant's production might be exported. This means that CO_2 annual emissions in continental Europe could be reduced by approximately 6-7 Mt CO_2 per new nuclear power plant. Nordic emissions would go down relatively less, as nuclear energy would not only replace condensing power production but also combined heat and power (CHP). Besides investments in nuclear power, another option for cutting CO_2 emissions in large-scale energy production is to implement carbon capture and storage (CCS) at condensing power and CHP plants. In theory, CCS can also be implemented in plants using biomass, resulting in "negative net emissions". In the Nordic region, only Norway and Denmark have suitable storage sites for CO_2, which means that international collaboration is a prerequisite for the implementation of CCS in Finland and Sweden. Further, the CCS-technology must be proven to be technically and commercially viable before it can be implemented on a large scale.



Millions of electric vehicles will contribute to reaching the EU targets and will have a manageable impacts on the power system

NEP's analyses show that a large commitment to electric vehicles can make a significant contribution to the Nordic countries reaching the EU's climate and energy targets by 2020:

EVs can markedly *reduce carbon dioxide emissions* in the non-trading sector and can become a decisively important measure for fulfilling national obligations, which would otherwise be difficult to fulfil. Energy conversion is moved to the trading sector, where petrol and diesel consumption is exchanged for electricity production.

Renewable energy sources are well represented in the Nordic power system. Nordic EVs will therefore rely mainly on renewable electricity for power. Since the EU scales up renewable electricity for electric vehicles by a factor of 2.5, the contribution from electric vehicles becomes large.

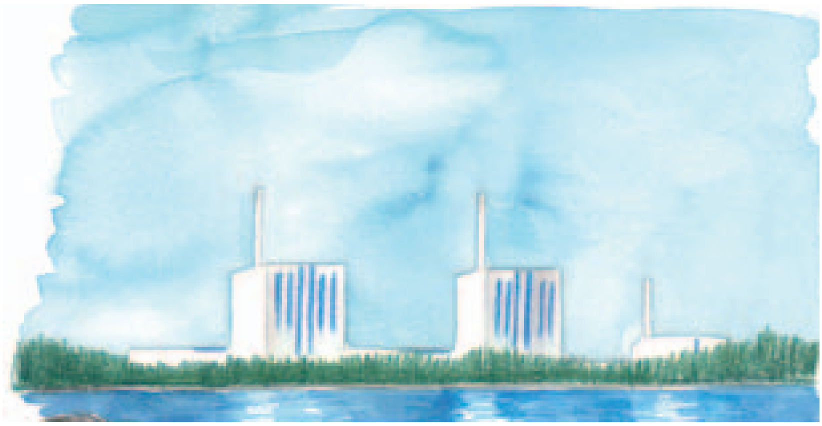
Electric operation makes plug-in hybrids and electric vehicles very energy-efficient. An electric motor converts more than 90 percent of the electrical energy to mechanical energy. A petrol engine can convert only 20-30 percent of the petrol's energy content for propelling the vehicle.

Moving from fossil fuels to electricity in the transport sector increases *security of supply* in the Nordic countries both as a whole and as separate nations.

Is a CO_2 free ambition rational?

From a political perspective it would be positive to be able to claim that the Nordic power sector is CO_2 free. On the other hand this may not be a very rational goal since small quantities of fossil fuel generation can be very profitable to keep in the system as regulatory power, enabling more intermittent power like wind power to be introduced. Fossil fuel generation can bee seen as "lubrication" in an almost CO_2 free electricity system.

The model results from the NEP toolbox indicate that CO_2 emissions in the Nordic region are likely to be substantially reduced in coming decades. However, none of the models yield zero CO_2 emissions from Nordic electricity. This is also the case for the results from the models that include the heat market.



We also know from our work that there will be large unexploited resources of renewable energy in the Nordic area that would be profitable to develop compared to investments in renewable energy in central Europe. With the right economic support for example through common electricity support schemes, there is money to be saved.

The demand for electricity is flattening out

As long as there has been electricity, demand for it has grown. During long periods the demand for electricity in the Nordic region has even grown faster than the economy. This is illustrated in Figure IV.2. A change of economic policy in the 1990's can partly explain why demand for electricity has declined. The devaluations that were so common in the 70's and 80's and that provided an invaluable boost to industries with high exports and low imports – which is the case for the electricity intensive industry - were replaced with among other things, a low inflation policy. Consequently, many electricity intensive industries have faced tougher conditions that have resulted in smaller increases in production and electricity use.

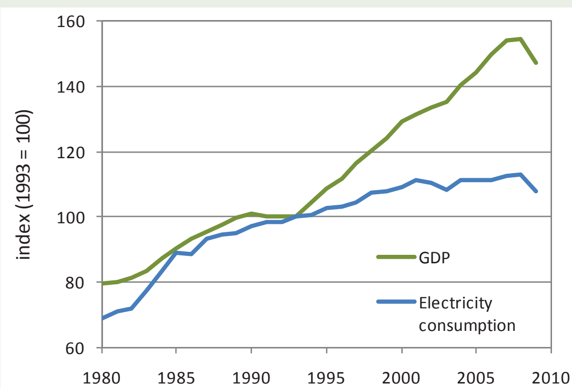


Figure IV.2: Total electricity demand and GDP in Demark, Finland, Norway and Sweden.

A strict marginal perspective

A strict marginal perspective implies that we (the Nordic countries) are exporting our fossil generation and keeping the non fossil for our self?

Increase of renewable generation in combination with more nuclear and a weak demand growth result in large electricity exports from the Nordic countries to Continental markets. Since coal and gas-fueled capacity, which is the generation capacity that emits CO_2, is also the marginal capacity in the Nordic electricity system, it can be argued that it is coal and gas generation which is exported to the Continent: if export opportunities were curbed, Nordic coal and gas generation may be reduced.

However, the perspective on CO_2 emissions from the Nordic power sector should be somewhat broader than on emissions from Nordic power generation alone. If Nordic fossil generation is more competitive than generation on the Continent, even though CO_2 emission costs are the same, exports from the Nordic region replace higher cost and thus lower emission generation on the Continent. Within the framework of a common cap-and-trade system for emission allowances such as the EU ETS, the total CO_2 emissions are not reduced, but the cost of complying with the cap is reduced, contributing positively to the competitiveness of European economies in a carbon-constrained environment.

ELECTRICITY DISCLOSURE AND TRADE IN GUARANTEES OF ORIGIN (GO)

Large quantities of hydro power "attributes" are being exported from the Nordic market to countries in central Europe. This export is carried out through the exchange of certificates, so called guarantees of origin, not physical power. According to the EU legislation for electricity disclosure (2009/28/EC) member States shall ensure that the same unit of energy from renewable sources is taken into account only once (Art 15 §2). This means that disclosure regulation has to take GOs in the account and this regulation has to be coordinated with other countries.

Exports of renewable electricity through guarantees of origin have to be balanced by an equal amount of imports of "attributes". These imported attributes can refer to as specific generation resource, proven by GO (or some other accepted tracking device), or mirror the so called residual mix. If the present trends of exporting GO from the Nordic region will continue - the electricity consumed in the Nordic countries from an electricity disclosure perspective, can deviate a lot from the physical generation mix.

V. The balance between politics and markets

- a recurring theme in the Nordic Energy Perspectives project

The challenges related to coordination of policy incentives and targets, and at the same time providing sufficient room for the market to provide proper price signals, are formidable in the transformation of the energy system to a sustainable, low-carbon world. The balance between markets and politics has been a recurring theme in the Nordic Energy Perspectives project.

Climate policies profoundly changes the energy system

The climate policy focus promises to profoundly restructure the energy system. As we enter the second decade of the 21st century, energy investments are less driven by market signals than perhaps ever since the liberalization of energy markets started. The EU energy and climate policy package, particularly the implementation of the renewables directive, implies that energy investments are set to be determined by policy targets and measures, and not by market prices, in the foreseeable future.

The Nordic electricity market is increasingly policy-driven

Although the policy measures implemented in the Nordic countries, procurement auctions for offshore wind as in Denmark, feed-in premiums as in Finland, investment subsidies as in Norway and green certificates as in Sweden, are linked to the development of power market prices, the overshadowing driver is the political renewables target. Against the background of weak demand growth, the prospect for the Nordic power market is a growing surplus situation with correspondingly declining market prices. The lower the prices, the higher are the needed auction price/investment subsidy/feed-in premium/green certificate price to realize the ambitious renewables targets. The market still plays a role, and aids policies by providing cost efficient solutions within the limits set by policy targets and measures. Nevertheless, the overall market development is policy driven. New types of generation create new challenges for the grid, for existing generation and for consumers. More low cost, but intermittent generation capacity, incentivized by support schemes, creates new system challenges and requires new solutions. A pressing question is whether the market will be made able to deliver in a future system heavily influenced by a mosaic of regulations and policy targets. The strength of the market is to generate and utilize flexibility where it can be found. When policy intervention overrides market adjustments, the necessary flexibility may not be provided.

As markets may have failures in terms of failing to generate efficient solutions, so can policies. The (lack of) balance between different policy targets, e.g. emission abatement, renewable electricity vs. renewable heat or fuel, energy efficiency improvement in an energy surplus situation, are examples of such failures.

The deregulated Nordic electricity market has produced proper price signals

The Nordic electricity markets were deregulated and integrated during the 1990s. At the beginning of the first decade of the 21st century, the Nordic electricity market was commonly regarded as the most well-functioning international power market in the world.

The most prominent characteristic of a well-functioning market is to provide proper price signals. In the power market, market prices should yield proper incentives for demand flexibility and energy conservation, operation of generation capacity and investments in new generation capacity, grid investments, and substitution between electricity and other energy carriers.

During the last decade, market fundamentals have shifted. One implication is that the market is more frequently divided into several price areas, and in some areas there is talk of a looming power "crisis". This development can be seen as a strength – given the cost of infrastructure investments and the variations in generation levels (hydro, but even nuclear) and generation structure (hydro vs thermal systems), and changes in demand (activity fluctuations in industry, cold winters) – prices should differ between market areas (at least from time to time) to provide proper price signals for investments in infrastructure and generation capacity. On the other hand, price differences can be seen as a sign that the market has not been able to generate the proper investments.

Successful deregulation requires adequate reregulation

To provide adequate price signals, most markets must be regulated to correct price formation for so-called market failure, i.e. external effects such as environmental damage from emissions, and natural monopoly, such as the electricity network and transmission lines. Moreover, regulations should ensure a market structure sufficiently decentralized to mitigate market power.

The electricity market is complex and all these concerns, and more, are relevant. Hence, successful deregulation of power market is to a large extent a question of successful reregulation of the markets. The regulations and market design of the power market has been constantly developed over the course of the last decade. At the same time the markets around us have developed, and the Nordic market has become increasingly linked to continental markets through investments in infrastructure and improved market coupling.

The market cannot always be blamed

Sometimes the market is blamed, when in fact it is regulations that should be blamed. When it comes to price differences and possible inadequate investments in infrastructure, these should primarily be blamed on regulations. A one-price policy for a larger area (country) with bottleneck problems will for example obscure price signals and expose the system to erroneous investment signals. In a future where we expect more distributed investments in new generation capacity, adequate locational price signals may prove to be crucial for the cost efficiency of accommodating the targeted volumes of renewable energy.

With a growing Nordic power surplus and increasing market coupling with neighboring market areas, there should be a significant basis for expansion of interconnector capacity. Investments in interconnector capacity are however not purely market based, nor should they be. Although parallel transmission lines may be profitable up to a point, publicly owned TSOs with the objective of maximizing social surplus are prone to make marginal investments that may render privately owned transmission lines unprofitable in the long run. Thus the market is not likely to provide such investments "on its own". New interconnectors are large investments which take time and huge resources to realize. Such investments are moreover subject to regulations in more than one country. Hence, it would be optimistic to assume that interconnector investments can "keep up with" a rapidly changing market based on strong policy measures. On the other hand, infrastructure investments, including new interconnectors, should be taken with a view to the market implications, i.e. the price effects, of such investments. As we also pointed out in the NEP book "Ten Perspectives on Nordic Energy", a coordination between generation and grid development requires a "visible hand" in the market.

VI. A further integration of the electricity markets in Northern Europe

The countries in the Nordic and Baltic regions are diverse with respect to recent history and economic developments, as well as to energy supply technologies and energy resources. Thus, the energy intensity in the new democracies have over the past 20 years been cut to almost half, yet still being twice as large as in the old democracies, leaving room for energy savings. The countries are united through physical infrastructure (electricity transmission lines) as well as trends toward developing a common electricity marked. Moreover, national environmental goals blend with EU targets and regulations, leaving room for co-operation options in their achievement.

The Nordic and Baltic regions together contain large renewable energy sources, including substantial amounts of unexploited hydro, wind and biomass, and hence ambitious targets for reducing CO_2 *and increasing the share of renewable energy can be met with local resources. Shifting from national targets to a common regional target in relation to renewable energy will permit overall savings in achieving the target. Similarly, energy saving will have large impacts on such costs. However, the consequences and benefits will be unevenly distributed between countries and between actors in the markets.*

The NEP project has in various aspects analyzed effects of, and preconditions for, a widening of the North European electricity market. Such a widening includes both increased electricity trade through new interconnectors and a joint effort to meet the renewable targets defined by the EU through e.g. green certificate trading.

Using renewable energy in the Nordic countries in a European context

It is likely that conditions for investing in new renewable electricity are superior in the Nordic counties due to abundant natural resources (potentials for renewable energy in the Nordic countries are further discussed in Chapter II). Therefore, a further integration and increased electricity trade with Continental Europe could increase the exploitation of these resources and provide substantial benefits from electricity (and green certificate) exports, and at the same time reducing the overall cost of fulfilling the EU renewable target. Thus, the exploitation of renewable resources in the Nordic countries is valuable also for other European countries where renewable resources are less abundant.

Some of this has been taken into consideration in the burden-sharing of the renewable goal within the EU but there are reasons to believe that the Nordic region, in a European context, may supply a larger amount of renewables than is domestically required in the burden-sharing agreement. Hence, further integration of electricity provides for important opportunities in the Nordic region. However, such an integration of the North European electricity markets also presents challenges that must be considered.

Intermittency and public acceptance – two decisive issues

Integrating an increased share of intermittent electricity production is a challenge in itself. The Nordic countries are blessed with large amounts of hydro power which may be used for regulating purposes. Nevertheless, a significant expansion of wind power will have impact on the operation of thermal-based electricity generation, e.g. increasing the number of starts and stops.

Renewable electricity production is frequently associated with public resistance when it comes to choosing appropriate sites. This is especially relevant for wind power and hydro power. The question is: will citizens of the Nordic countries quietly accept a massive expansion of renewable electricity from which a large part may be assigned for export?

Investments in cross-border and domestic transmission grids

Model analyses of the NEP project have shown that meeting the EU energy and climate package in a cost-efficient way is likely to involve new interconnector capacity between the countries in Northern Europe. This would be further amplified if a common trade regime for e.g. green certificates (TGC) were to be launched. As can be seen in Figure VI.1 results based on (European) Econ Classic Classic model runs and calculations in the Eureno model – a model for long term European renewable energy sources (RES) generation potentials and costs, the market balances in the Nordics are almost reversed compared to 2007 (modelled). Denmark becomes a net electricity importer, while Norway and Sweden become large exporters in 2020. Finland is also a net exporter to the Nordics (imports from Russia and Estonia are not included in the figure). The results indicate that in a common TGC market, Nordic RES potentials and costs are competitive compared to potentials and costs in the rest of Europe, and hence the Nordics become net exporters of TGCs in a

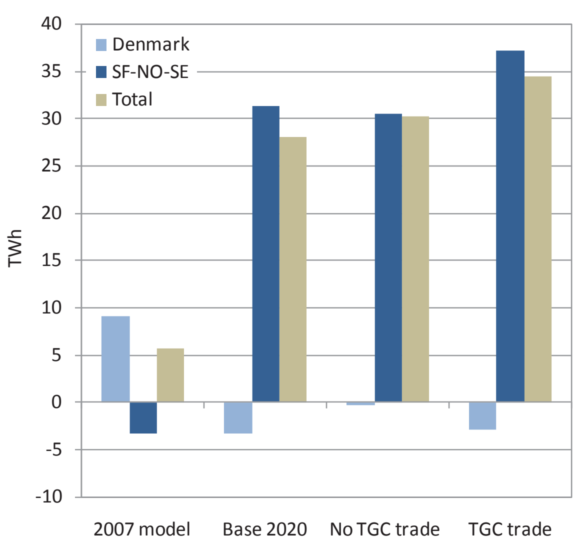


Figure VI.1: Results from the European Econ Classic model, showing <u>net</u> exports to Germany, Netherlands and Poland in 2020 for three different TGC-scenarios. Both existing and new interconnectors are utilized

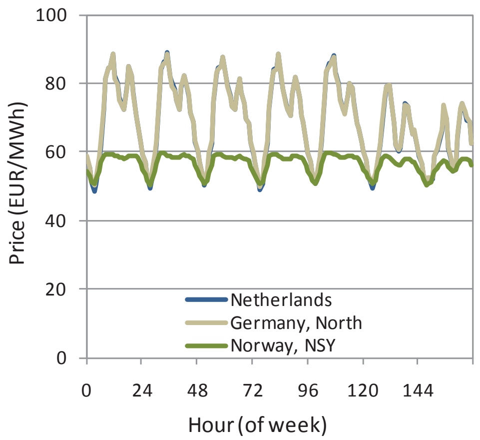


Figure VI.2: Average weekly price structure for South Norway, North Germany and Netherlands, European Policy scenario 2030.

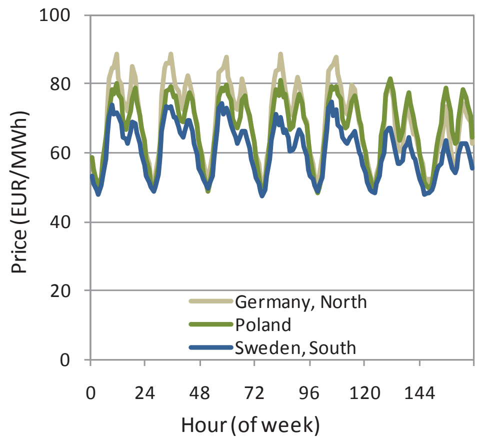


Figure VI.3: Average weekly price structure for South Sweden, North Germany and Poland, European Policy scenario 2030.

common market. Nordic net electricity exports to Continental Europe become significantly larger than today, around 35 TWh if unrestricted TGC trade is assumed. The common TGC price in the TGC Trade scenario is estimated by the model to around 65 EUR/MWh.

Massive investments in renewable electricity generation and large investments in new interconnectors will change electricity flows within the Nordic region. More frequent and new internal bottleneck situations may be the result, and the electricity market may more frequently become divided into several price areas. Regions close to the interconnectors may experience prices more equal to the prices on the other side of the interconnector (border).

This also indicates that significant investments in both cross-border and domestic transmission grids are likely to be needed. One such indicator for regional differences in electricity-price structure is found in Figures VI.2 and VI.3. Nordic electricity prices are generally much flatter (and lower) than prices on the Continent, at least for some Nordic regions (Figure VI.2). For other Nordic regions situated geographically closer to Continental Europe, e.g. Southern Sweden, electricity-price patterns resemble much more of the ones on the Continent (Figure VI.3).

Increased exposure of differences in national policy measures

Further market integration is likely to further expose differences in national policy measures. For instance, investing in renewable electricity is not only a question of where natural conditions are favourable but also where national support schemes generate the highest incomes or profits. From an electricity-system operational point of view, there might even exist a third consideration: to balance the location of wind power over a larger region with respect to wind availability, thereby reducing the risk of having high or low wind situations simultaneously.

Market considerations

What happens with electricity demand in Northern Europe? The energy-efficiency target of the EU may actually lead into two, equally possible, but opposite directions. More efficient energy use may result in increased electricity use, e.g. in transportation (this is, among others, discussed in Chapter I). However, a future decrease in electricity demand is also a possible outcome of a general increase in energy efficiency in e.g. industries (prospects for electricity demand are elaborated on in Chapter IV). If demand is reduced significantly during the coming years, Northern Europe may face a significant "oversupply" of generation capacity partly initiated by the renewable targets of the EU. Such a situation would imply relatively low wholesale electricity prices in the Nordic market if the export possibilities were limited due to bottlenecks in interconnector capacity.

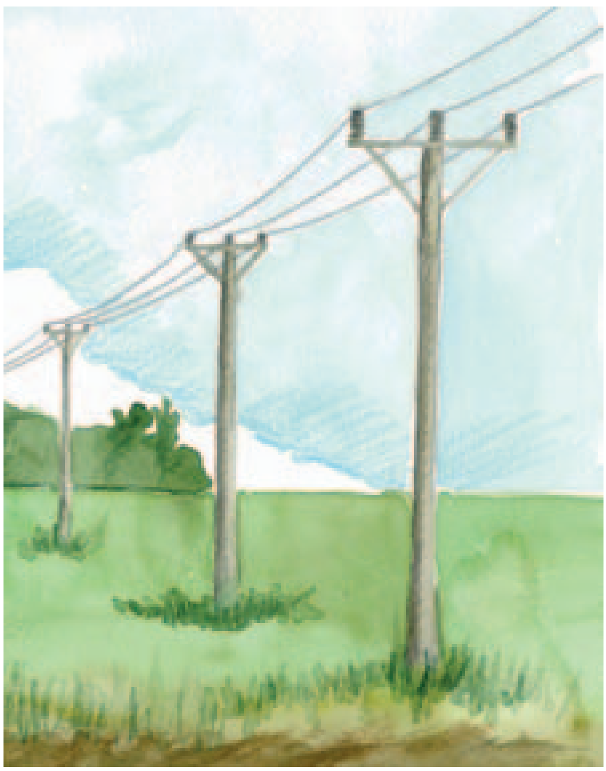
Electricity-price volatility is likely to rise as the share of intermittent production is increased. However, a geographical widening of the electricity market may reduce the significance of such volatility.

Increasing electricity trade and creating an integrated North European market for renewable support, through e.g. green certificate trading, is likely to change the electricity balances significantly in some of the countries participating in such a market. Thus, depending on the country consumers and producers may face higher or lower electricity prices. Therefore, producers of the Nordic countries may increase their profits while consumers of the Nordic countries may face increased costs. Increasing interconnector capacities is likely to imply increasing wholesale electricity prices for the Nordic countries while a common European market for renewable electricity support is likely to imply also higher support costs, paid e.g. by the consumers, for the Nordic countries.

The role of non-renewable electricity generation

The significant electricity-export opportunities of the Nordic countries pointed out by the NEP project is not only enabled through an expansion in renewable electricity generation, but is also largely dependent on maintaining the existing non-renewable thermal electricity generation. In the case of nuclear power, the capacity is likely to increase during the coming decade due to the fifth nuclear power station in Finland and due to repowering of several nuclear power stations in Sweden. A more rapid phasing out of any of the non-renewable electricity capacity due to economic or political reasons will, of course, reduce the electricity-export potentials of the Nordic countries that have been identified by the NEP project.

Above it is argued that increased interconnector capacity may imply somewhat higher CO_2 emission from Nordic electricity production than otherwise. This is due to the fact that fossil-based thermal electricity generation in the Nordic countries generally have higher efficiencies than their counterparts in Continental Europe. Thus, increasing the export capabilities of the Nordic countries may imply crowding-out of fossil-based electricity generation in Continental Europe rather than in the Nordic countries. In a European perspective this is, due to the EU ETS, equivalent in terms of reducing CO_2 emissions. But will this be in accordance with political ambitions in the Nordic countries?



VII. The district heating challenge

– how to remain competitive and contribute to a sustainable development if/when energy demand starts to decline

District heating is an energy carrier that has been growing steadily for decades in the Nordic countries. The use of district heating is still increasing, but there are signs that this is happening at a slower pace. Eventually this could lead to the stagnation or even the reduction of district heating use.

A number of factors will influence the use of district heating in the future, including:

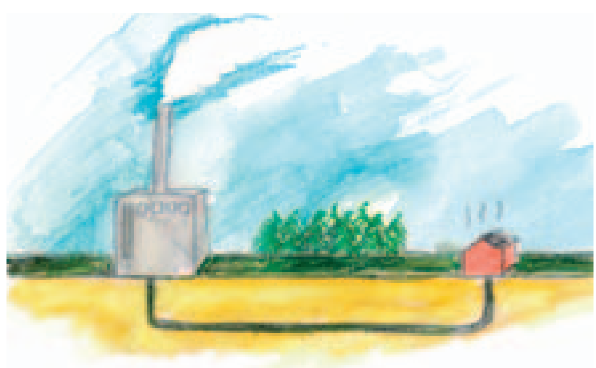
- Increased energy efficiency in buildings (decreases demand)
- Conversion to other heating alternatives (decreases demand)
- Warmer climate due to increased greenhouse effect (decreases demand)
- District heating to new customers, both through conversion of existing buildings and for new buildings (increases demand)
- Heating demand due to more efficient household appliances (increases demand)
- New markets for district heating (increases demand)

Increased efforts towards a more efficient use of energy in buildings tends to reduce heating demand

The situation for district heating imposes a number of challenges. We touch upon some of these in this text. Some analyses indicate that the heating demand in the Swedish housing and service sectors may decrease considerably as a consequence of increased energy efficiency efforts by existing district heating customers. Energy savings is not a new phenomenon. While heating demand has gradually decreased, new customers have enabled the district heating sector to continue growing. From the figure VII.1 it is clear that district heating deliveries to new customers moderate the decline of district heating, which would be even more drastic without this effect.

However, other analyses are less pessimistic and foresee continued growth. It may be wise though to be prepared for a situation with declining demand. Norway may be an exception in this respect due to a large growth potential.

At present, more ambitious energy policies are being implemented, like the EU target for 20% reduction in primary energy use compared with projected levels, to be achieved by 2020 by improving energy efficiency. Together with national policies in the Nordic countries this is expected to intensify energy savings efforts.



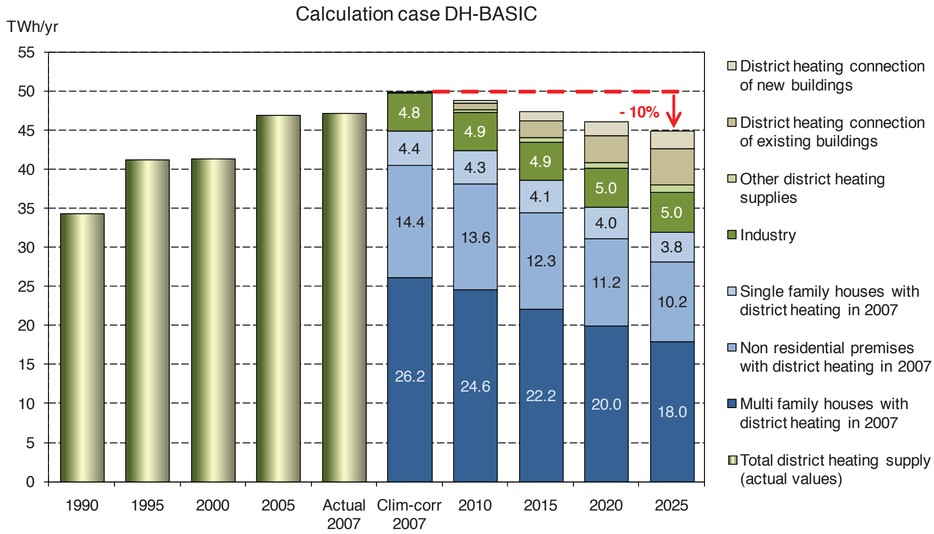


Figure VII.1: Calculated development of Swedish district heating use

Competition from efficient heat pumps may decrease district heating demand

It is very unusual for existing district heating customers to convert from district heating to other heating alternatives. This is partly due to regulation issues, but it may also indicate that customers are either satisfied with district heating or that there is a lack of competitive alternatives. However, competition from ever more efficient heat pumps has become more and more intense. For example, there is a growing trend for Swedish customers to switch part of their heating consumption from district heating to heat pumps. There are also examples of this in Finland. These customers often remain as district heating customers, but consume considerably less. At present this happens on a very limited scale, but the underlying economic incentives are obvious. Based on data from the Swedish Energy Markets Inspectorate we have calculated that a new heat pump is economically favourable compared to existing district heating in almost half of the Swedish municipalities where district heating is available. Competition is obviously most critical in municipalities in which the price of district heating is the highest. It is reasonable to expect that competition from heat pumps will reduce demand for district heating in the Nordic countries.

District heating can grow through expansion to new customers, but the potential is limited

District heating can be seen as a mature business in three of the Nordic countries - Denmark, Finland and Sweden. This means that its growth potential is limited. Most buildings in energy dense areas are already connected to district heating. Conversion of existing buildings to district heating provides only limited potential for expansion. In Norway, market penetration of district heating is much lower as Norway has traditionally relied on electrical heating. This means that the potential for conversion to district heating is large. Nevertheless, there are obstacles to overcome, like the fact that many buildings lack the internal heat distribution system necessary to make district heating feasible.

District heating is also a competitive alternative for new buildings. However, volumes are limited in the short term, both due to the rate of construction of new buildings and to the often very small specific heating demand in new buildings. Passive houses, energy neutral buildings and low energy buildings are concepts that are often discussed, and increasingly put into practice.

New markets provide opportunities but expectations are limited

As the growth of district heating in its traditional markets starts slowing down it is natural to intensify the efforts to identify and exploit new markets. Some examples are:

- Heating of ground (e.g. streets and sidewalks)
- Absorption cooling
- Appliances in households (e.g. washing machine and dish washer)
- Laundries in multi family houses (e.g. washing machine and drying)
- Greenhouse heating
- Refining of fuels (e.g. drying)
- Combined processes (e.g. transportation fuel, electricity and industrial waste heat)

Discussions with Swedish district heating representatives indicate that although these new markets are viewed as interesting and it is important to try to develop them, expectations for future district heating demand from these markets are low. It is reasonable to assume that the situation is similar in the other Nordic countries.

Climate and energy policies influence district heating demand and production, positive and negative

The EU 20/20/20 goals will have a profound impact on the development of Nordic district heating business. This has been analysed within the NEP project through model calculations for each of the four countries.

A scenario assuming current policy instruments in use in the Nordic countries, including an EU-ETS price of €25/t CO_2, leads to a marginal increase in the total use of district heating in the coming years. The use of coal decreases, while waste incineration and the use of natural gas increases. Bio fuels maintain a dominant role in district heating production for another 25 years. The use of peat increases in Finland.

The addition of the increased use of renewable energy target leads to a marginally larger district heating production than in the previous case. This indicates that district heating is an effective way to utilize renewable energy. The most obvious difference regarding the production mix is a large increase in the use of biofuels at the expense of coal and peat, see Figure VII.2.

When we on top of current policy instruments and the EU 20 % target for increased use of renewable energy also add the EU's energy efficiency target (-20 % energy use), the use of district heating remains almost constant, i.e. clearly lower than in the two previous scenarios. Biofuels retain their dominant role, but at a smaller volume. The use of natural gas grows less than in the other two scenarios.

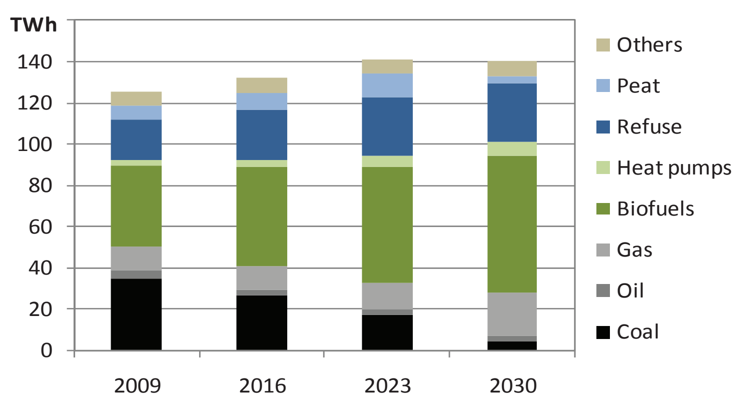


Figure VII.2: Nordic district heating production with EU renewable energy goal applied

How to utilize five strategic heat source advantages

In order to be competitive in the heating market, district heating must rely on inexpensive energy sources. This is important since district heating includes a heat distribution system whose costs must be justified by the low cost of heat production. Fortunately the district heating concept provides opportunities for such low cost energy production. Five strategic advantages can be identified from an energy production point of view:

1. Combined heat and power (CHP) production is a powerful measure for improving energy efficiency in energy conversion. By not using separate plants for electricity and heat production, considerable efficiency improvements can be achieved. Economies of scale are an important issue for CHP and district heating is in line with this.
2. Waste incineration is a competitive measure from a waste management perspective if efforts are made to minimize landfill. Energy recovery is, in addition to volume reduction, an important part of waste incineration. Electricity production efficiency is limited due to boiler material restriction related to the nature of the fuel. This means that heat production, and the necessary heat demand, is a prerequisite for effective energy recovery.
3. Industrial waste heat is often available as a by-product in connection with energy intensive industry. Industrial waste heat is typically low temperature and therefore lacks useful applications. District heating however, makes it possible to utilize this otherwise wasted heat for heating purposes.
4. Geothermal energy is a very large energy source in a global perspective. It is often available at relatively low temperatures, which means that district heating is often a prerequisite for the utilization of this heat source.
5. ”Difficult fuels” could be seen as a label for fuels that require large efforts for handling, combustion, flue gas cleaning, etc. Examples could be wood residues, peat, coal and heavy fuel oil. The advantage of such fuels is, of course, the low cost. However, given the high fixed costs associated with combustion, the energy conversion plant must have a certain scale, which district heating can facilitate.

Combining two or more strategic advantages is obviously better. For example, a combined plant that uses what could be labelled as difficult fuels in a process for production of transportation biofuels, and where waste process heat is recovered and electricity is produced through CHP, combines three of the strategic advantages mentioned above.

Strategies for environmental sustainability of municipal companies

- Pathways of sustainable development in the stationary energy system

There is a need for companies in the stationary energy system to take a strategic approach to sustainable development and intensify their efforts to integrate sustainable practices into their business. The NEP project has studied how municipal energy companies mitigate their impact on the environment by working systematically with the sustainability challenge in several dimensions. Companies with a proactive strategy for environmental sustainability follow a sustainable vision for their business that includes reducing their carbon emissions, improving the environmental qualities of their products and investing in clean technologies. Besides mapping what such proactive strategies for environmental sustainability involve by conducting case studies of municipal energy companies with a strong environmental focus, key mechanism facilitating such strategies have been investigated to show pathways for sustainable development for companies in the stationary energy system. The study illustrates that, by applying a strategic perspective to the environment, municipal energy companies can develop new business opportunities and contribute greatly to sustainable development within their sphere of activitiess.

A production mix in which these strategic advantages are utilized as much as possible creates a strong foundation for a competitive district heating concept.

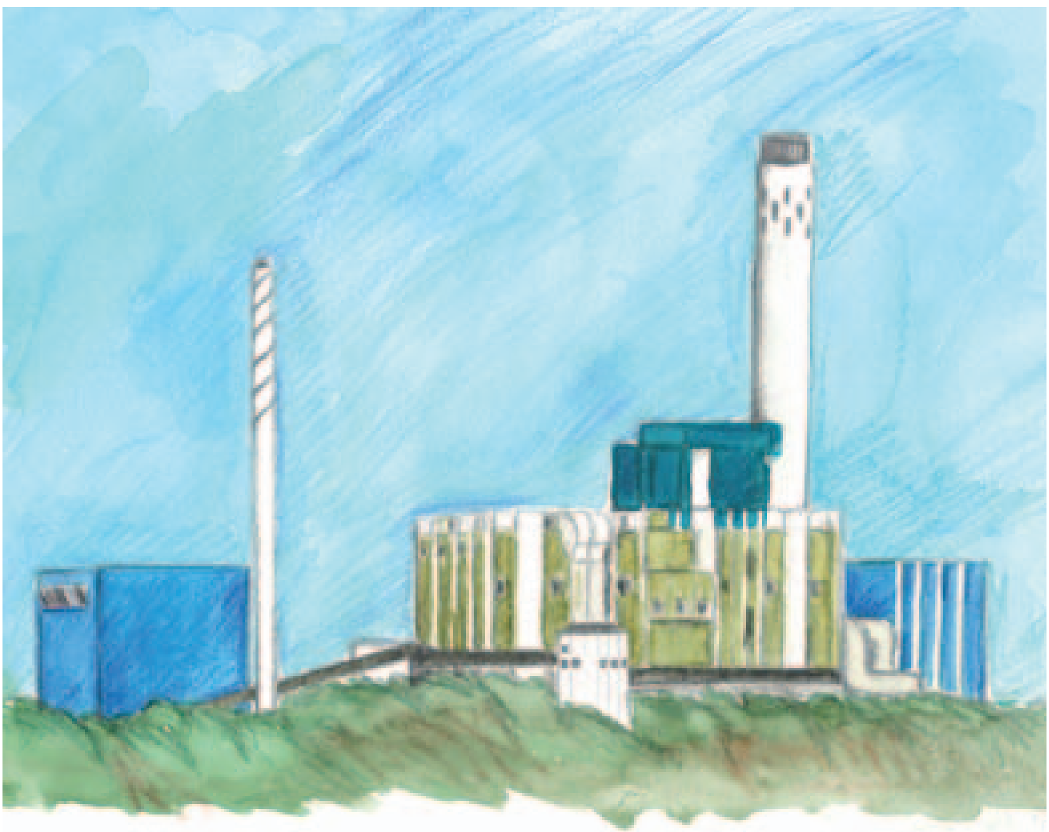
District heating provides additional value for the customers

The competitiveness of district heating is not only determined by the comparison between the price of district heating and the price of alternative heating options. District heating can present other advantages, such as:

- Often favourable from an environmental and climate change perspective
- Inherent flexibility regarding production mix
- Carefree for the user
- Creates additional space

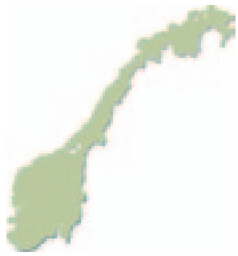
These aspects are of course important to take into consideration when district heating is compared with its alternatives. A recurring argument against district heating is that customers are locked to one company and that it is more or less impossible to switch to other forms of heating. This is often used as an argument for the regulation of district heating.

However, it can be argued that real alternatives are in fact available. Conversion from district heating to heat pumps is one such alternative. Furthermore, the customer-company relationship can be viewed as being a mutual dependence. It is not only the customer that is dependent on one supplier; the district heating company is also dependent on its customers. Since the district heating system is fundamentally coupled to one location the district heating company must present a competitive offer in order not to lose its customers.



District heating in Norway facing other challenges

The district heating sector in Norway is booming, and thus distincts itself from the other Nordic countries. This is mainly due to public policy, as funding from Enova has been made available for both green-field plants and development of existing plants.

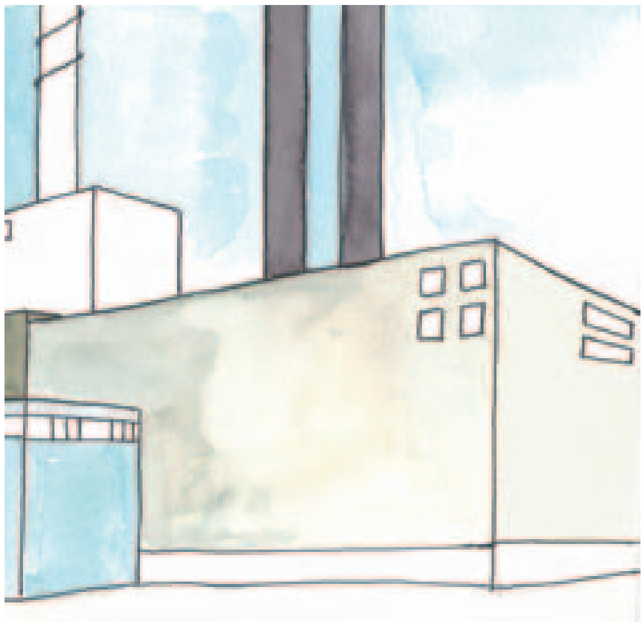


During the last 1-2 years, companies have competed to get hold of the most valuable concessions. NVE (the Norwegian Energy and Water Directorate) has granted a lot of new concessions in areas not yet supplied with district heating. A concession is a necessity to get the financial support from Enova, and also for the municipality to make connection to district heating mandatory for new buildings.

However booming, even in Norway two important challenges have arisen for the district heating companies. First, heat pumps represent a commercially highly attractive alternative to district heating, especially if the customer also has a cooling demand. Second, the export boom of municipal and industrial waste to Sweden imposes a demand surplus for low value energy sources.

As the Norwegian district heating systems are still under extensive development, they may apply investment strategies to design plants more adaptable to future challenges than the case is for the fully developed district heating systems in the other Nordic countries.

VIII. Industrial development and future export for Nordic industry
– opportunities and challenges



International interest for Nordic environmental technology has been growing immensely over the past few years. Sub-segments such as water treatment, waste management, renewable energy and energy efficiency are on top of the international agenda. The demand for e.g. bio-energy solutions for the production of heat, electricity and transport fuels is growing all over the world. Driving forces are environmental concerns, climate focus and urbanization.

In the NEP project we have investigated the possibilities for the Nordic countries to meet these global challenges. There is a chance that Nordic industry could get a boost from climate and energy policies. The picture is, however, mixed and there will be both winner and losers. Global climate policies would be considerably more favourable for Nordic industry than regional EU policies.

Macro economic changes

The growth in world population and economy drives the demand of scarce commodities that are difficult to substitute, such as primary energy, as well as generally all primary production factors. This growth drives international energy prices and shift traditional industries to regions with lower price for labour and resources. In the Western world in general, and in the Nordic countries in particular, the share of manufacturing industries decreases in favour of services and industries with high degree of processing. Attempts to limit the green house gas emissions with climate policy regimes can be compromised by carbon leakage if the participation in the regime is not global. Further, the cost of the reductions can be decreased if more countries are included in emissions trading.

World economies grow, emissions grow and leak

The NEP simulations show evidence on *carbon leakage*. In the developing countries, fast economic growth is accompanied with increased emissions, as discussed above. In a reference scenario, in which only Western Europe have adopted CO_2 reduction targets, developing countries account for 77% of total world CO_2 emissions growth in the period 2004-2020. However, emissions are growing fast, not only in the developing countries but also in those Annex I countries not committed to international climate policy. The figure below shows regional and world emissions in "Reference" and "Global policy" scenarios (a scenario where all developing countries limit their emissions) compared to a hypothetical scenario with no climate policies at all. In the "Reference" scenario, 70% of the reductions in the EU are offset by emissions growth in other regions. One fourth of this leakage is attributable to other rich countries, about 60% to the developing countries and the rest to former Soviet Union countries. In the "Global policy" scenario (with a commitment for all developed countries), EU emissions actually increase, as permits are bought from other countries, especially USA, where reduction costs are considerably lower. At the same time, the leakage to developing countries grows in absolute terms, but relatively speaking the total leakage is only half of the reduction in the developed countries.

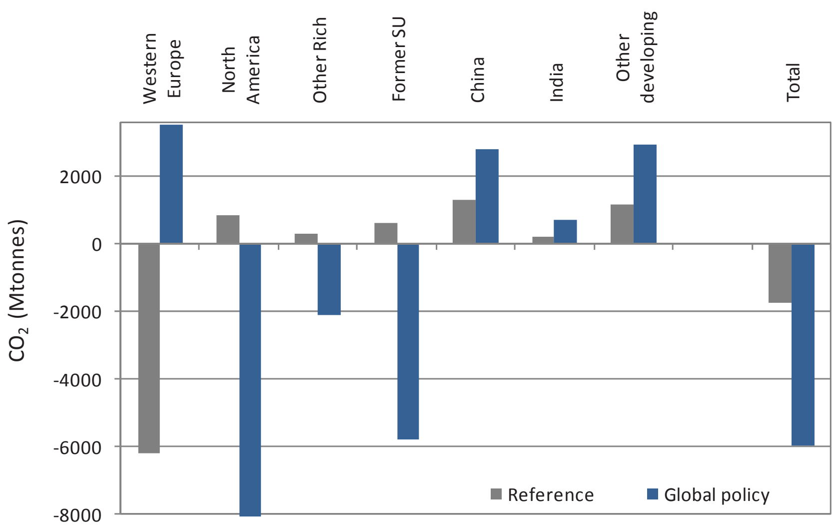


Figure VIII.1: Carbon leakage. World emissions in 2020, difference to no climate policies in Megatons of CO_2

Can energy also in the future support the global competitiveness of Nordic industry?

Industries in the Nordic Countries are among the most energy-intensive in the world due to the large shares of paper, metal and chemical industries in the total production. In Finland and Sweden, paper and pulp industries are clearly the largest energy users, whereas in Norway, metal and mineral industries consume half of the total electricity used in manufacturing sectors.

The loss of comparative advantage of energy-intensive industries in Nordic countries is a long-term trend. Though the economic recession has undoubtedly accelerated the decline, there are more fundamental, long-term changes in the global competitive environment and local Nordic primary factor markets affecting energy-intensive industries.

Structural threats for the Nordic forest industry observed long before the financial crisis ...

The Nordic forest industry has historically profited from a relative closeness to both customers and raw materials. Other advantages include relatively low electricity prices and a high proportion of raw materials based on long wood fibres.

However, a number of negative factors are now affecting the Nordic forest industry.

- Demand for paper products in developing countries has been growing at a high rate of about 10 % per year. Nevertheless, this increase in demand has been met by an even larger growth in the production capacity of pulp from fast growing eucalyptus and rainforest wood. China imports fibre, but its paper production has increased significantly and China is now a net exporter of paper.
- Demand for newsprint has already fallen in the United States, and is now falling in Europe as well.
- A continuing modification of eucalyptus trees towards longer wood fibres will result in a larger supply of newspaper quality fibre and therefore increased competitive pressures on the Nordic forestry industry. Even Russia is expected to increase production of newsprint-quality pulp.

... but a sustainable development also provides opportunities

On the other hand, facing the tightening regimes for green house gas emissions reduction, the Nordic countries have an advantage in clean energy production, which may imply lower energy price increases due to climate policies than in the rest of the world. The geographic and natural conditions in the Nordic countries give opportunities for energy production using land, coasts, forests and hydro power, and there is also unused potential for further wind and solar power. Another example is the forest industry. Climate policies stimulate the forest industry to develop new high-value products such as new biomaterials, liquid bio-fuels, and electricity from renewables. This could balance reduced competitiveness for pulp and paper.

Case study:

Time consuming physical presence in local markets is often necessary

Given the right conditions, the biomass combustion sector is an example of a branch that can become a booming market for the coming 20 years. The biomass combustion sector is one of the sectors in the Swedish Clean Tech industry that has been identified as especially promising by Swedish authorities and is also receiving international recognition.

The results have so far not lived up to expectations something that support the belief that existing Clean Tech facilitation schemes do not trigger a satisfactory increase in growth and export volumes in companies with a long operating history. This is a business context that stands apart from the typical Clean Tech companies commonly referred to in media reporting; very small, innovation-driven start-up companies with difficulties finding venture capital.

The results from our work indicate that in order to increase low to moderate growth and export volumes in small Clean Tech companies characterized by an extensive operating history. Facilitation schemes must be able to foster the following three core capabilities:

- creating competetive advantage based on customer value,
- developing foreign sales capabilities and
- increasing value from stakeholder collaboration.

The relatively complex product demands high standards regarding abilities to manage intricate procurement processes, capabilities for onsite construction management and subsequent operating training. In markets where the concept of biomass combustion is new or unknown there is also a great demand for educating the customers and offering help to establish a business model for the customers regarding necessary supply chains. The difficulties involved establishing these international sales organizations are prominent in these companies.

The need to get involved in these markets through stakeholder collaboration is framed by prior experiences. In many instances these experiences have been negative from the company's point of view. Small organizations have limited capacity to engage in these long ranging and time consuming activities with rather uncertain and sometimes also vague value to the company.

IX. Security of supply challenges in the Nordic countries

Security of supply (SoS) is one of three cornerstones of European energy policy. The EU Council of Ministers expediently approved the EU Renewables Directive after a proposal by the EU Commission. The reason for this quick acceptance of the Directive was a concern for energy SoS in the EU, possibly aggravated by SoS problems resulting from Russia shutting off all gas supplies to Europe through the Ukraine a few months earlier. In spite of all this, we have found that it is very difficult to discuss these issues in a Nordic context.

Mixed views on what the SoS issues are for the Nordic region

To get a feeling for what energy experts feel about SoS we constructed a questionnaire where respondents provided information on their opinions about various aspects of SoS in the energy sector in their own country and in the Nordic region as a whole. We asked energy experts, including participants in the research group and financiers of this project to participate.

The results indicate mixed views on which areas that are problematic - there is not one sinlge category that is regarded as especially problematic.

SoS is a geopolitical issue, not a technical or economical issue

Coal resources are spread relatively evenly over the world. This is not the case with oil. Approximately 70 % of global oil production takes place in only seven countries. Natural gas is even more concentrated - approximately 50 % of currently known global natural gas reserves are located in only three countries.

Throughout history, many different strategies have been implemented to secure the delivery of energy resources. Many European countries had colonies until the middle of the 20th century. There were many reasons for the establish

ment of colonies, but one reason was the desire to secure the delivery of critical goods. US foreign policy has consistently sought to secure deliveries of oil and other key fuels, as well as to obtain low prices for imported goods. China, with an expanding industry in need of raw materials and other inputs, has recently tried to secure deliveries of energy and other goods by signing treaties with other countries, or by buying access to various resources in other countries.

A common feature of these attempts to secure key supplies is a political game where buyers, or "takers", play a very tough game – sometimes even resorting to war – to secure delivery of critical goods at low prices. Conversely, oil and natural gas exporting countries try to counteract the influence of importing nations in the West and Far East. The OPEC oil cartel that tries to maximize the price of oil is an example. Another example is Russia, which tries to use its natural resources in a geopolitical perspective.

Economics cannot be used to study these issues. The NEP project is strong on economics, but in-depth knowledge of international politics would probably be more valuable when studying SoS issues. Therefore NEP has concentrated on other aspects of security of supply.

From a Nordic perspective, the region's strong and increasing dependency on nuclear power and biofuels should be high on the agenda, next to traditional SoS issues such as the dependence of modern societies on firm deliveries of electricity and heat. Historically, we have seen severe disturbances to nuclear power production. Due to common constructions features in many reactors, even minor safety issues can cause long production stops in a large share of the installed capacity. Our analysis indicates that the Nordic power system is rather robust in terms of energy, and that even major nuclear power disturbances could be handled reasonably well. The problem will mainly be a capacity problem, securing the system during peak load periods. Potential problems will increase with more wind power in the system.

The strong focus on renewable energy in the Nordic region and in the EU has lead to a rapid shift from fossil fuels to biofuels in district heating and in combined heat and power (CHP) generation. Most often these plants cannot use any other fuel. Sudden delivery disturbances or price shocks can be problematic especially for district heating. This development can be explained by strong support systems for renewable energy and high CO_2 taxes/prices, which make investors reluctant to invest in plants that can burn other types of fuel in addition to bioenergy.

The situation in the Nordic region differs from that in the rest of Europe

In continental Europe, security of supply issues tend to focus on the strong and increasing dependency on imported natural gas from Russia. Even though the use of natural gas in the Nordic region is limited, a severe delivery disturbance or a rapid price increase in continental Europe will also influence the Nordic region through interlinked electricity markets and other mutual economic dependencies.

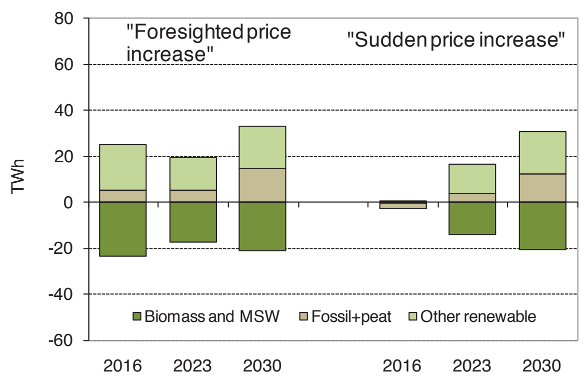


Figure IV.1: Difference in fuel use if biomass-prices increase significantly from 2016 and onwards. Including the renewable Directive!

X. The challenge to use energy systems modelling in a “wise and appropriate” manner in large multidisciplinary research projects

Lessons learned during the course of the NEP project

The insights that are presented here summarize the lessons that have been learned from using energy systems modelling during the course of the NEP project. This project is characterized by a number of distinguished features: a comprehensive multidisciplinary research project involving a multitude of complex research questions and using, and coordinating, a wide variety of different models from different countries and different scientific disciplines. The many research questions have defined and governed the modelling process of the project, which is essential. Model-related limitations may not affect, or govern, the choice of research questions. Furthermore, model analyses have frequently during the NEP project been complemented and scrutinized by other scientific disciplines from e.g. social and management sciences using methods such as deep interviews, questionnaires and statistical analyses. Thus, the findings presented here are based on this specific project context.

Every model is biased by traditions and preconceived opinions stemming from the model developer, the model user that constantly updates and develops the model and, finally, the model client for whom the model results are intended and who delivers feed back to model input as well as output. This fact also became very apparent during the course of the modelling process of the NEP project. However, a huge effort was done in order to liberate the models and model results from such influence. This does not necessarily mean re-coding or reorganizing the models or by changing a lot of input, but rather an awareness of the fact that model results differ and to expose the different fundamentals and assumptions of the models. Thereby, model results may be explained on a higher level than otherwise. The often quite interval in results may be used as an indicator of the relevant and actual uncertainties that are present in certain important assumptions. Thus, the end result of such a modelling analysis is significantly more balanced, and thus more representative, than if only a single model approach would have been used. On the other hand, there are also differences in model assumptions based on traditions and opinions that in fact should be possible to harmonize once they have been identified and exposed. In some cases, there actually may exist “a single truth” or at least, agreed compromise. It is indeed an important, and cumbersome, challenge to balance assumptions which may be synchronized between different model approaches with assumptions that are better left in an unchanged state.

1. Use models to increase understanding of causes and effects!

Using energy- and climate-policy modelling is an efficient and feasible way of dealing, in a consistent way, with complex systems. The use of models provides new insights. Furthermore, gathering around a model or several models is a process that works as an objective platform, a “clearing house”, where issues can be analyzed and discussed among participants with different interests on equal grounds.

2. Involve stakeholders and clients at an early stage

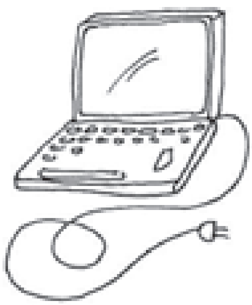
Model inputs and results should be validated and verified by other project participants and by external expertise during the entire project. This ensures a high degree of credibility to the modelling work.

3. Consider an interdisciplinary approach, and...

Many issues related to energy and climate policy analysis are truly interdisciplinary in their nature. Therefore, research within the field should reflect that fact and should, if possible, use more than one scientific discipline or method. Thus, model results and insights become supported by not just one but several scientific disciplines.

...organize model users with complementary model approaches

The NEP project has used an approach which has proven both efficient and successful, namely to involve several model approaches developed independently of each other. Using several models means that the issues in focus may be tackled from different angles, different scientific approaches and disciplines can be used simultaneously, and the risk of bias due to a "common background" is reduced.



However, working closely with several models representing different methodologies rarely is a walk in the park. The models must be coordinated and one of the main challenges involves input data.

4. It is not possible to harmonize all input assumptions

A large number of assumptions have to be made before model simulations are carried out. Even though the input assumptions have been harmonized to an extensive degree in all NEP models, it has not been possible to reach full harmonization. The reason is that the models are designed differently. Some of these differences make it impractical to fully harmonize model input without compromising the functionality of the models, and some of these differences turn out to significantly affect important model results.

5. Important results are similar in different models

The extensive model analyses of the NEP project have shown that several and important results are similar when comparing model outputs. This indicates robustness of the results.

6. Some results may vary substantially between the models…

For other model results, variations between the models have been rather significant.

… but we can explain why …

Differences in model configurations and coverage yield different results, but also increase the understanding of the crucial drivers for developments in e.g. power market balances, wholesale prices and CO_2 emissions from the Nordic power market.

Model output should actually, to a certain extent, differ between different models since they are designed differently and for different purposes, they rely on different philosophies, and they cover different systems (both in terms of geography, time horizon and part of the energy system/macro economy). Furthermore, some of the output is simply not fully comparable.

…and the differences in model output give an added value to the analysis!

It is the differences in model output that actually give an added value to the analysis since the differences reflect the uncertainties in the system in focus. If the output is relatively similar among all models, this is, on the other hand, a strong indication that such specific results are robust.

7. Use each model where it is best suited

The models can be used to address the same (or similar) issues. Thereby, results that are robust (many models show very similar results) may be separated from model results that are significantly more uncertain (model results vary largely among the models). Such model comparisons are also very efficient for increasing the understanding and for validating the models. However, it must also be recognized that certain models simply are not properly designed for analyzing all the issues that are dealt with.

8. Linking the models: Use output from model A as input to model B

The intention of the NEP project has not been to develop nor use a super model which includes as much of the issues to be analyzed as possible. Instead, the NEP project has used several separate models. However, these have to be coordinated in terms of input (refer to the discussion above) and in terms of benefit from each other, i.e. linking input and output between models. While performing the linking, let there be a "human touch" in between models.

9a. Recognize the "cultural" differences of the models and the modellers

The modeller makes his or her own considerations. Therefore, each model is in a sense biased. Furthermore, there exist "cultural" differences in the view on how to use models and apply different methods. Some of these cultural differences stem from the fact that modellers may have different educational background. During the NEP project also "cultural" differences with respect to e.g. the principals and practices of energy markets, policy measures etc. were identified. One such example is the view on the relation between the two commodities, electricity and district heating, from combined heat and power schemes which differs somewhat between the Nordic countries.

9b. Recognize the "national" differences of the models and the modellers

As for "cultural" differences, "national" differences may involve e.g. how to consider and describe e.g. energy markets, policy instruments and taxation. "National" differences also relate to the view on e.g. future available options for the development of the energy system. This is strongly influenced by the "energy history" of a certain country. Models originating from countries where a certain fuel or technology to the existing date has played an important role tend to look generously on the prospects for that

fuel or technology also in the future. And not only in the country of origin but also in other countries also described by the model.

10. Recognize human errors

There is always a risk of errors or bugs within a model, especially if it is a complex and comprehensive model. Such errors may be minimized by performing a vast amount of model runs and carefully analyzing results and let them be scrutinized by other experts. Furthermore, as in the case of the NEP project, working with several models, harmonizing input data and compare outputs also reduces the risk of using a model with a non-discovered error.

Success factors recognized and identified by the NEP project

Based on the experiences of the modelling work during the NEP project, we here summarize the findings that we encourage others to consider when using several energy-systems models in multi-disciplinary analyses. The list on next page, is based on the "success factors" that we have identified during the course of the NEP project. Even though we do not claim to have identified all the success factors associated with working with several energy systems models at the same time, we firmly believe that the following items may come in very handy for those considering to work with energy systems modelling in an interdisciplinary way. This may involve projects where modellers as well as clients are responsible for the modelling process and the model coordination.

Success factors for energy systems modelling in multidisciplinary projects

Modelling process

Define research questions and let them govern the modelling activities. Model limitations shall not decide the contents of the research.

Early involvement of stakeholders (feedback on input and output)

Initiate model runs as early as possible, prior to the finalization of input synchronization. Such early model activities are very important for starting the learning process and for achieving a general acquaintance with the model package available to the project for modellers as well as clients.

Identify an appropriate balance between the number of model runs (e.g. sensitivity analyses) and the effort put into the analysis of the model runs. Not all model runs need to be reported unless they generate additional knowledge.

Establish a well-organized clearing-house where modellers and models are gathered with a shared and agreed view on the research questions and a shared model "language". Keep these gatherings on a frequent basis

Ensure that model input and output becomes scrutinized also by other scientific methods such as deep interviews, questionnaires and statistical analyses.

Model synchronization

Synchronize important input data – within reasonable limits

Use output from model A as input to model B where it is appropriate

Model validation

Models should be well validated (and documented)

Put effort in tracking down human errors (by e.g. comparing model outputs)

Differences in model approaches

Choose models with different methods aiming at a final overall interdisciplinary approach. Models should be complementary (and not too similar)…

..but recognize model overlaps and use it to highlight selected issues with more than one (in this case similar) model approach. This enables quality assurance for the models used and adds value to the analysis.

Identify similarities in model output among the models – Robustness?

Identify differences in model output among the models used. Expose and explain the differences! Highlight differences explained by realistic assumptions rather than differences explained by model imperfections or shortcomings

Identify system-boundary differences between the models

Identify differences in geographical scope – How is the "surrounding world" described

Use each model for what it is aimed for …

…but also identify areas or issues where a specific model is less useful

Identify the "cultural" differences in the models (or in the use of models) when working with different approaches, e.g. differences in the way markets are described

Identify "national" differences between models from more than one country. This may be due to national differences in existing energy systems