Intermediate report

Nordic Energy Perspectives

Draft

Insights from NEP policy scenario simulations

April, 2009

Preface

Nordic Energy Perspectives (NEP) is an interdisciplinary Nordic energy research project with the overall goal of demonstrating means for stronger and sustainable growth and development in the Nordic countries.

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 markets and energy systems and the infrastructures and institutional structures. NEP aims at clarifying to decision-makers the consequences of political and strategic decisions for politicians, energy actors and the public. The project is to promote a constructive dialogue among researchers, politicians, authorities and actors on the energy markets.

For further information about the project, please visit: *www.nordicenergyperspectives.org*.

This series of reports are the second reporting from the second phase of the project. The following intermediate and final reports are now presented:

Synthesis report, March 2009:

- Second NEP2 synthesis report *(Responsible: Peter Fritz, Håkan Sköldberg, Bo Rydén)*

Final reports, March 2009:

- Widened view of energy efficiency and the resource management *(Responsible: Bo Rydén)*
- Technology options for a low CO_2 energy system *(Responsible: Tiina Koljonen)*
- Wood markets and the situation of the forest industry in the Nordic countries *(Responsible: Per Erik Springfeldt)*

Intermediate reports, March 2009:

- Insights from policy scenario simulations *(Responsible: The NEP model group)*
- Global scenarios *(Responsible: Janne Niemi)*
- Biomass market and potentials *(Responsible: Tiina Koljonen)*
- Nordic perspectives on the EU goals relating to CO_2, renewable energy and energy efficiency *(Responsible: Thomas Unger, Bo Rydén)*
- Prominent strategies for environmental sustainability in the stationary energy sector *(Responsible: Anders Sandoff)*
- The future of the Nordic district heating *(Responsible: Monica Havskjold, Håkan Sköldberg)*
- Trade within the RES directive and related power interconnection issues *(Responsible: Berit Tennbakk)*
- Natural gas in the Nordic countries *(Responsible: Peter Fritz)*

Oslo, March 2009

The NEP Research Group

Content

Introduction

The adaptation of the EU energy and climate policy package is moving forward, strengthening the focus on emission reductions and energy conservation. The emission reduction target is extended beyond the Kyoto period and the EU is setting out to reduce emissions in 2020 by 20% compared to 1990 levels. Existing indicative targets for expansion of renewable energy are replaced by a binding target implying that 20% of energy consumption is to be covered by renewable energy in 2020. Finally, energy consumption is to be 20% more efficient by 2020.

At the same time international climate negotiations are going forward towards the United Nations Climate Change Conference of the Parties in Copenhagen in December 2009 (COP 15) with the aim to reach a new international climate policy agreement with targets for emission reductions from 2013 onwards. If such an agreement is reached, and if it implies that other industrialized countries take on ambitious emission reduction targets as well, the EU has said it will increase its emission reduction target to 30% in 2020.

These ambitious policies and targets require a profound reorientation of energy markets, national regulations and policy measures, and require massive investments in the energy sector. The Nordic countries are not exceptions; the transition to a sustainable energy system constitutes a demanding an interesting challenge for the Nordic markets as well.

Scenario analyses

Scenario overview

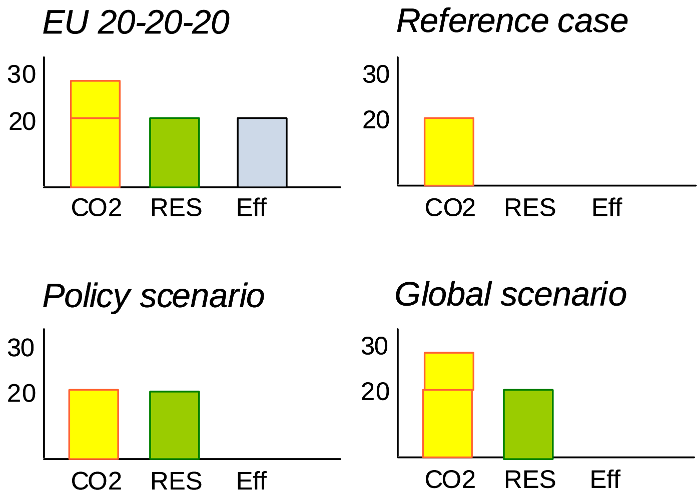
We have used the NEP energy market models to analyze the impacts of the “EU 20-20-20 to 2020” policy package on the Nordic energy system. We have studied three scenarios:

1. *Reference scenario*, where the EU ETS is carried forward with a reduction target of 205, and renewables and energy efficiency policies follow current national policies and targets
2. *Policy scenario*, where the EU 20% target for renewable energy is met and emissions are reduced by 20%
3. *Global scenario*, where a new global climate policy agreement is reached and the EU emission reduction target is increased to 30%, and the 20% renewables target is met.

For all scenarios, we have run the models for 2020 and 2030.

The policy assumptions for the scenarios are illustrated in the figure below.

Figure 1 Overview of Policy scenarios, and comparison with EU 20-20-20 package



Modelling tools

The scenarios have been analyzed using a number of different modelling tools applicable to the Nordic energy markets. The purpose of the analysis has thus been two-fold:

- To investigate in detail the consequences of different policy scenarios on the Nordic energy sector
- To use the differences between the models to deepen our understanding of the crucial policy and market drivers, and the interaction between them

In the presentation of results, we particularly focus on the impacts on Nordic energy balances and prices, and the impacts on Nordic CO2 emissions.

Results from the following models are presented:

- EMM
- PoMo/DoS
- Econ Classic
- Markal
- Balmorel

Lessons learned

It is not possible to harmonize all input assumptions

Using several models to analyze the same scenarios gives us a unique basis to understand how different model configurations and model boundaries affect the results. No model captures the whole picture. Even though this is a well-known feature of models, we have a tendency to downplay and/or underestimate the shortcomings of models generally. The scenario simulations show that although some results are quite similar for different models, the differences are substantial. For example, the results on important parameters like prices and CO2 emissions in the Nordic area are substantial.

A large number of assumptions have to be made before model simulations are carried out. Important input assumptions include demand development and/or economic growth and global market developments for power intensive industry, decommissioning of old power generation capacity, subsidy-based investments in renewable energy production, fuel prices, investment behaviour, etc. Even though the input assumptions have been harmonized to an extensive degree in all models, it has not been possible to reach full harmonization.

The reason is that the models are designed differently: For example, some models have exogenous demand, whereas others model demand as a function of economic growth, price levels or the profitability of energy efficiency efforts. Some models only cover the electricity market whereas others cover the heat market and the interaction between electricity and heat endogenously. In all but one model, electricity trade with surrounding areas is modelled, but in a simplified way. The actual representation of trade in the models varies substantially, and is related to varying time resolutions in the models. 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.

However, none of the models capture all functionalities.

Important results are similar in different models

The Nordic market develops an energy surplus. In the Reference scenario, all models show very moderate increases in demand levels, a substantial increase in renewable energy production and increased net exports from the Nordic area (with the exception of the model that does not take trade into account).

The Nordic price level stays below Continental prices, and all models find that prices increase from 2020 to 2030.

When it comes to CO2 emissions the models show varying levels. The results are not directly comparable however, because the model boundaries are different: Some models capture the electricity and heat markets, some only the electricity market, and some electricity and heat from CHP. The trends are however similar: Compared to the (simulated) levels in the base year (2006-2008), emissions are reduced to between 60 and 80% in 2020. From 2020 to 2030 CO2 emissions remain at the same level as in 2020, or increases somewhat, but do not increase to the same level as in the base year.

The main differences between the models are hence issues of magnitude, not direction or trend. This is reassuring.

Important results vary substantially between the models …

Demand levels vary between the models, mainly due to the extent to which demand is assumed to be price sensitive or not. The variation in demand levels is however not dramatic.

Despite quite comprehensive harmonization of generation input data, the generation levels vary substantially. The main reason for this is the difference in trade relations. We have assumed a quite substantial expansion of the electricity exchange capacity with the Continent. If this capacity is allowed to be used fully by the market – as represented in the models – the result is a dramatic increase in exports.

Given the input assumptions on expansion of renewable capacity, none of the models deem investments in new gas or coal power generation in the Nordics profitable. Thermal generation based on fossil fuels hence constitute a very small share of electricity generation in 2020 and 2030.

… but we can explain why!

Differences in mode configurations and coverage yields different results, but also increase the insight into what the crucial drivers for developments in power market balances, wholesale prices and CO2 emissions from the Nordic power market are.

The main modelling features making a difference are:

- *Demand representation*

Demand is modelled differently in the NEP models. In EMM total consumption is analyzed outside the model and used as a fixed input parameter. In PoMo consumption in some sectors is fixed, while demand in the industry is represented by a price sensitive demand curve, derived from a bottom-up analysis. In Econ Classic, demand in industry is taken from PoMo's demand curve, while demand in other sectors is modelled according to income and price elasticities. In Markal, demand is price sensitive to some extent in the sense that if prices are high, investments in energy efficiency measures are profitable and carried out (direct saving by e.g. reducing the indoor temperature is not included). Markal hence employs more of a bottom-up approach than Econ Classic. Markal and Balmorel also includes trade-offs with the heat market, i.e. the competitiveness of different fuels and technologies for heating purposes. Generally, there is a lot of uncertainty when it comes to projecting demand and assessing how demand is affected by price changes and other behavioural factors.

- *Investments in new capacity*

The degree to which the models generate investments in new capacity endogenously varies. In Markal all investments in electricity, heat and energy efficiency, are endogenous and in PoMo and EMM all investments are exogenous. Econ Classic employs a mix of exogenous and endogenous investments. After taking exogenous investments, e.g. in renewables based on subsidies, the model can choose to invest from a menu of conventional capacities, mainly based on gas and coal, if it is profitable. In Markal, support levels are taken into account, whereas investments in Econ Classic are based on wholesale prices vs. full costs. In the models with exogenous investments only, profitable investments in conventional capacities may be derived by manual iterations. In addition, whereas Markal bases investment decisions on average annual prices over the whole lifetime horizon, investments in Econ Classic are based on annual price levels, taking price variations (and hence, load factors) into account. Even in reality, investments are restricted by support schemes which are not technology neutral, bans on certain technologies and political uncertainties. These features are difficult to model perfectly, but should still be taken into account in the projections.

- *Trade with surrounding market areas*

As is the case for investments and consumption, modelling of trade spans from full fixing to (more or less) full flexibility according to price differences and capacity constraints. As none of the models fully represent hourly price structures on both sides of all interconnectors, simplifications are made even in the models with endogenous trade. Knowing that prices vary significantly diurnally, trade according to average prices would not be realistic. PoMo and EMM solve this by adjusting weekly capacities and by adjusting price levels, respectively. EMM, Classic and PoMo model trade with the Continent according to price differences. In Econ Classic Continental prices are endogenously simulated. Econ Classic and EMM have fixed trade with Russia (and Estonia?), whereas PoMo employs price driven trade even to Russia. Historically, trade has not been perfect across the interconnectors for different reasons; lack of adequate market prices, auctioning of transmission capacities, internal bottlenecks, outages, etc. As markets and technologies develop, the picture may change, but it is not easy to accurately model trade in scenario models like the ones used in NEP. The results of the scenario simulations suggest that trade volumes are important for projections of wholesale prices and CO2 emissions.

- *Price structures and time resolution*

Power prices vary from hour to hour with variations in demand and price insensitive generation (e.g. wind and CHP). These variations affect load factors in flexible generation and trade patterns, and in turn marginal costs, i.e. wholesale prices, CO2 emissions and trade. The models employed in the NEP scenarios apply time resolutions from seasonal to hourly prices. The implied simplifications are likely to explain a substantial share of the differences in model results. The general conclusion is that trade, including increases in exchange capacities and efficiency in trade (e.g. market coupling), could have a significant income on Nordic power prices and CO2 emissions.

Table 1 Summary of important model features

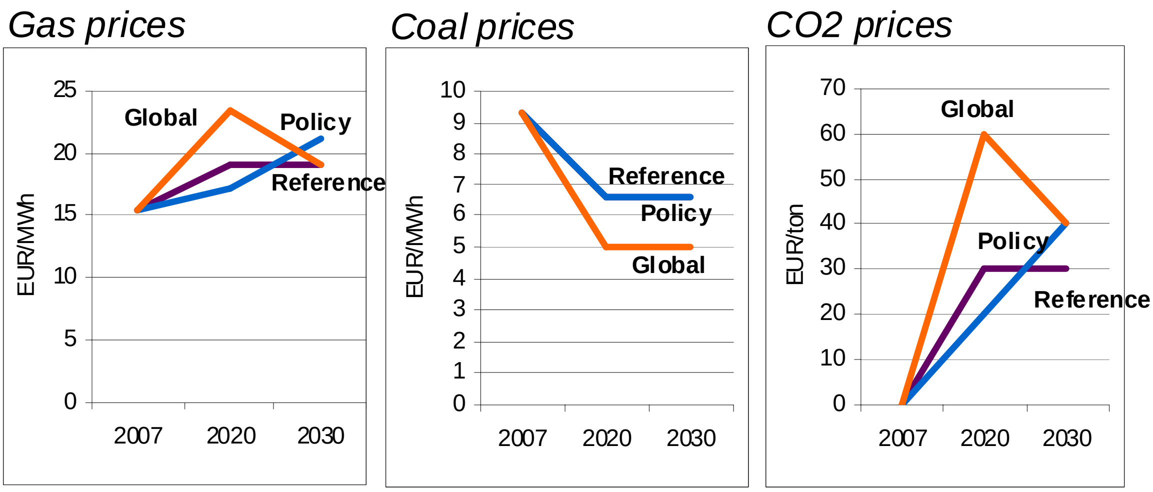
Model	Geography	Market	Investments	Annual load representation.
Balmorel	Baltic Sea area	Electricity and district heating	Choice of endogenous or exogenous	Flexible (*e g* 8760 hrs)
PoMo	Nordic countries	Electricity	Exogenous	52 weeks
ECON-Classic	Europe	Electricity	Endogenous and exogenous	13 “months”*5 load segments= 65 time steps
VTT-EMM	Nordic countries	Electricity	Exogenous	Flexible (*e g* 52 weeks * 3 segments= 156 time steps)
MARKAL-NORDIC	Nordic countries	Stationary energy system	Endogenous	6 (electricity), 3 (district heat) and 0 (other) seasons
DoS	Nordic countries	Electricity (demand)	Endogenous suggestion to the forecaster	4 time periods (winter peak and off-peak, and summer peak and off-peak)

Overview of model assumptions and results

Important common input parameters

When quantifying the scenarios, we have made a large number of common assumptions. These assumptions are described in detail in the report XXX. For example, the same fuel price and CO2 price assumptions (i.e. the price of EUAs in the EU ETS) have been used by all models. The figure below shows gas, coal and CO2 prices in the three scenarios:

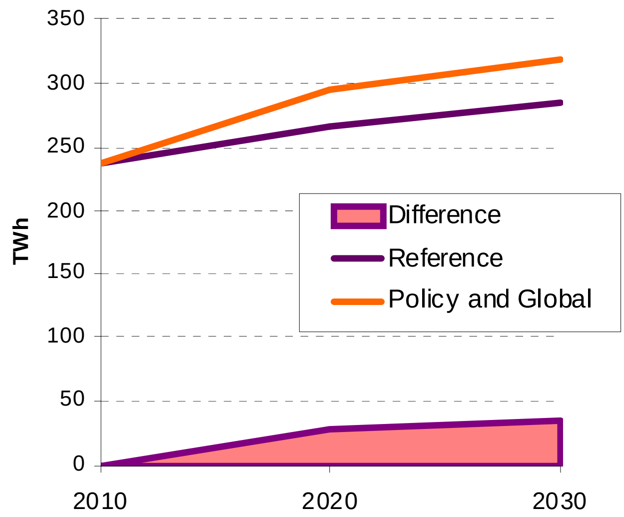
Figure 2 Common gas, coal and CO2 price assumptions



The CO2 price assumptions for 2030 are based on the long-term cost of CCS (Carbon Capture and Storage), whereas the 2020 prices are loosely based on Econ Carbon Model runs taking into account the cap and the relative fuel prices. In 2020 the CO2 price is lower in the Policy scenario than in the Reference scenario because the renewables deployment is higher, and thus, baseline emissions from the power sector (in Europe) lower. The ETS cap is the same in Reference and Policy, but higher in Global.

Other central assumptions include investments in renewable electricity generation and electricity transmission capacity to the Continent. There are substantial investments in renewables in all scenarios, but investments are higher in Policy and Global, 29 TWh and 35 TWh in 2020 and 2030 respectively (see figure below).

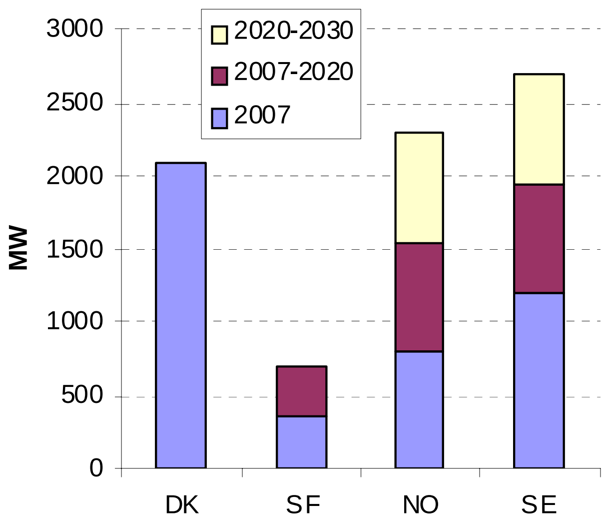
Figure 3 Development in renewable electricity generation per scenario



The electricity market models have used these assumptions directly as exogenous input in the models. The Markal model, however, includes the heat market, and the model optimizes investments in renewable energy between the electricity and heat market based on market developments and the cost of different technologies. The renewable electricity results from the Markal model may hence differ from the exogenous assumptions made in other models.

In all scenarios we assume that interconnection capacity between the Nordics and the non-Nordic neighboring countries increases quite substantially. The increase in transmission capacities per country is illustrated in the figure below.

Figure 4 Electricity transmission capacity with the non-Nordic neighbors, per country, all scenarios



This is a crucial assumption which we shall see, has a substantial impact on the general results, but also explains the differences between the models to a large extent.

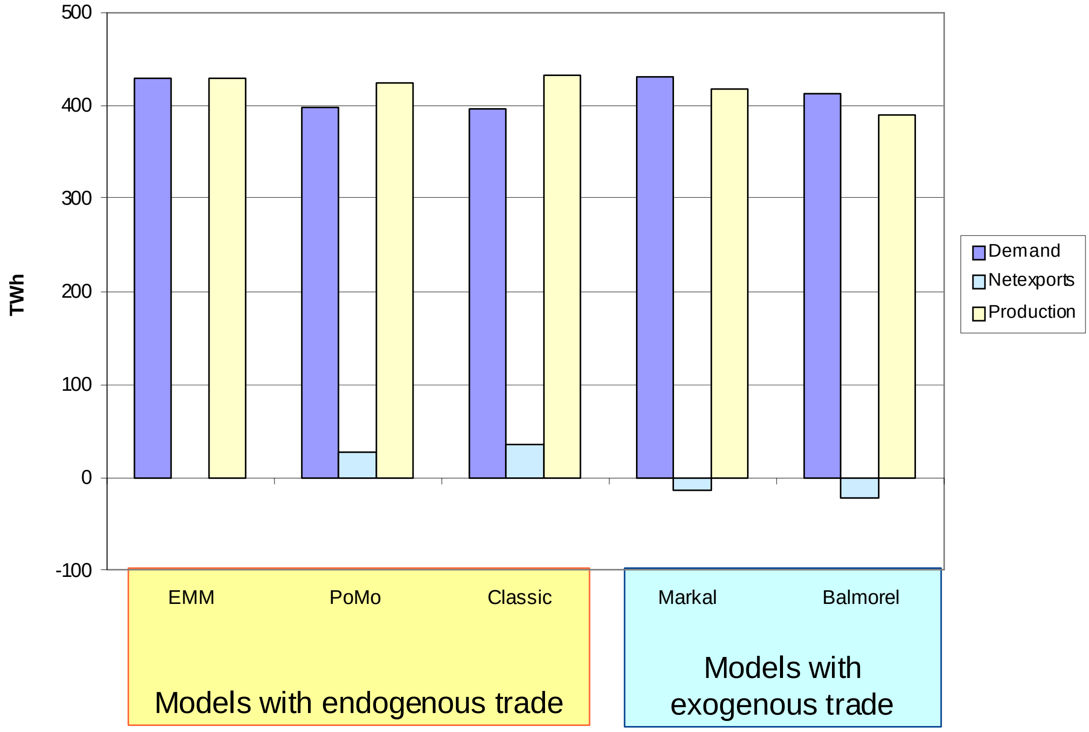
This assumption is also not fully used by all the models, e.g. the Markal model has not modelled electricity trade at all, Balmorel has fully exogenous trade, whereas the PoMo model has applied restrictions on the (weekly) capacity utilization based on historical utilization factors.

Results from the Reference scenario

Electricity market balances and trade

Electricity generation, consumption and net balances for 2020 are shown in the figure below.

Figure 5 Electricity market balances in the Reference scenario per model (2020)



The model results are not in agreement when it comes to the net balance of the Nordic electricity market in 2020. However, the different results may be attributed to the modelling of trade. As we can see, the models with exogenous trade show a trade deficit, whereas the models with endogenous trade show balanced trade or a surplus. Electricity consumption levels vary somewhat between the models, but generation levels vary more, reflecting the flexibility of trade.

The figures below show the net balances for the three models with endogenous trade and for the reference scenarios in 2020 and 2030.

Figure 6 Nordic electricity imports and exports in the Reference scenario per model (2020)

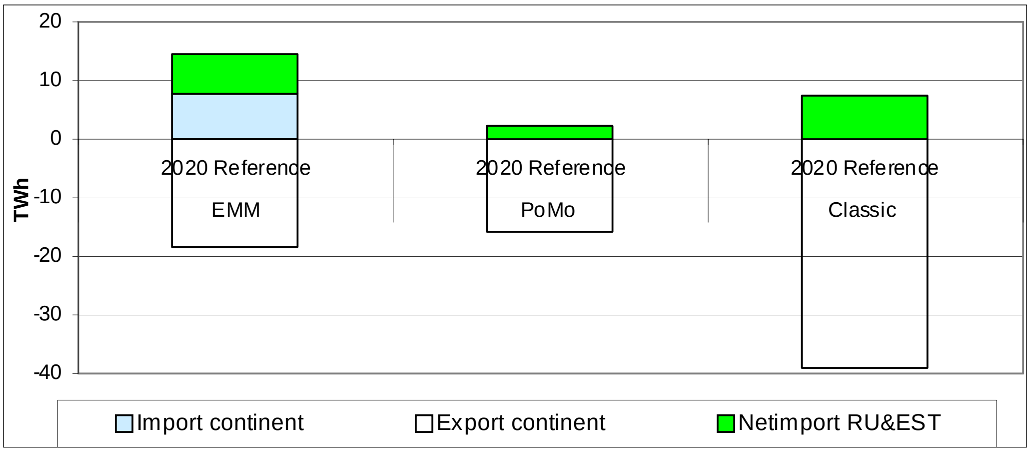
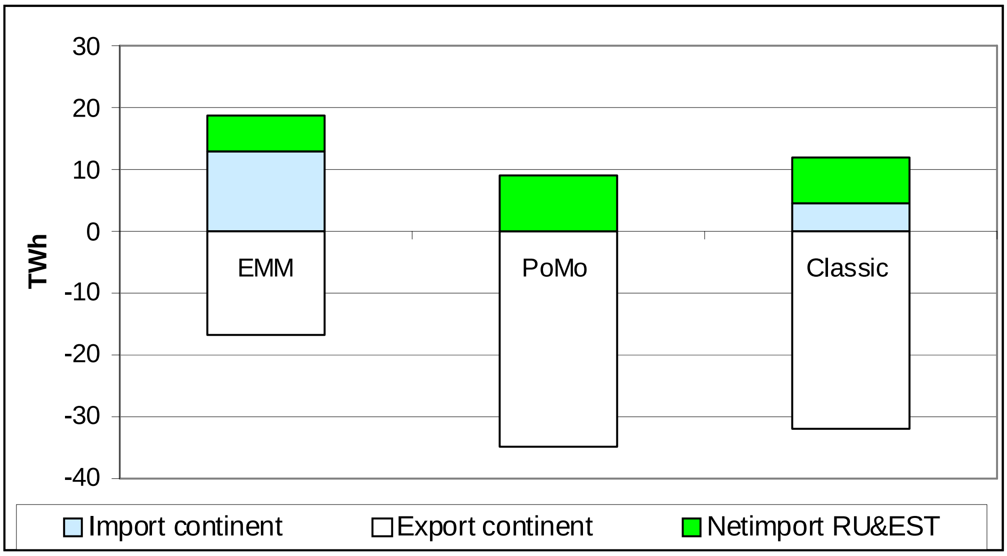


Figure 7 Nordic electricity imports and exports in the Reference scenario per model (2030)



Generally, all the models show imports from Russia and Estonia and net exports to the Continent. In EMM, the downward adjustment of Continental prices yields more *exchange* with the Continent than that found in PoMo and Econ Classic. In Classic, trade is less restricted than in PoMo. This is possible since the time resolution is finer (five load blocks per week). The result is high net exports in both 2020 and 2030 (between 38 and 25 TWh respectively), due to the expansion of both renewables and transmission capacity, and high prices on the Continent. PoMo has lower exports than Classic in 2020 and higher net exports in 2030. This is based on the same price levels as in Econ Classic, but weekly exchange and capacity limitations. It should also be noted that Classic has somewhat lower consumption than PoMo in 2020 (cf. Figure 5) which also ”improves” the market balance.

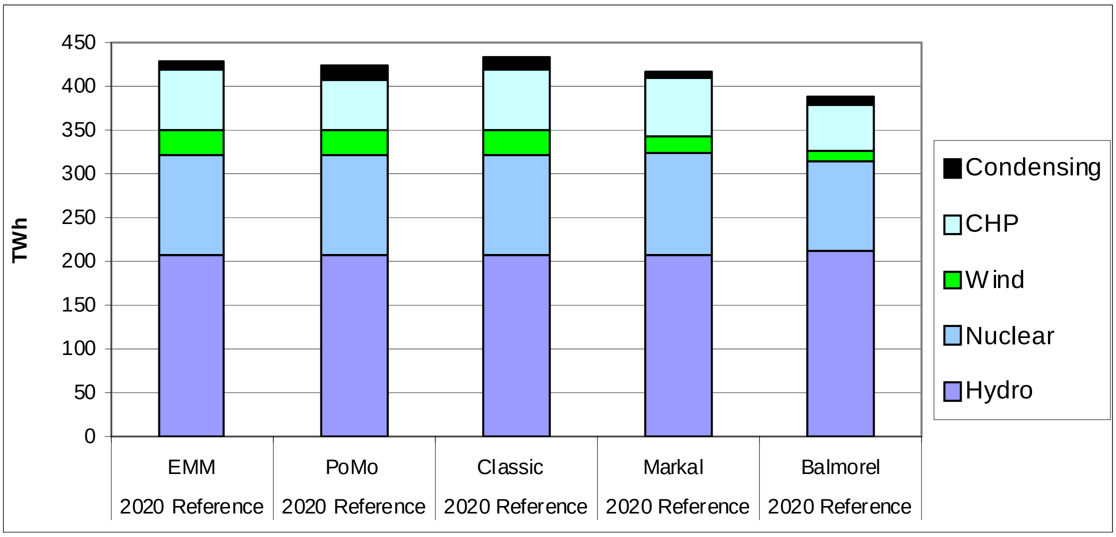
Taken together however, the models are not conclusive when it comes to the net balance of the Nordics, and the differences in volumes are substantial. None of the models show net imports towards the Continent, however. All models take market dynamics into account, but none of them does it fully. The conclusion is that it is likely that the Nordics will develop a net export balance towards the Continent in the Reference scenario, but it is clearly uncertain how large the net exports will be.

Electricity generation

Although generation capacities have been strongly harmonized, there are some differences between the models. Both Markal and Balmorel include optimization and investments in CHP and district heating, and yield lower electricity generation than the electricity market models, see Figure 8. Markal also has lower wind power generation because the model endogenize investments in renewable heat and electricity, and find less wind power profitable than the exogenous input used in the other models.

Figure 8 shows generation in 2020. The pattern in 2030 is very similar, and is therefore not shown here. Total generation levels increase from 2020 to 2030 in all models.

Figure 8 Annual electricity generation in the Reference scenario per model (2020)

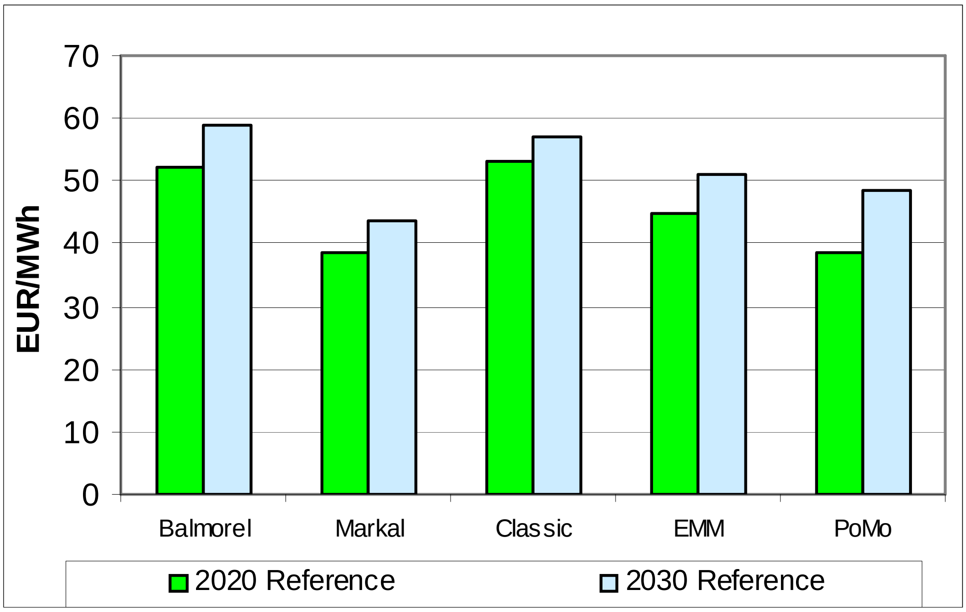


A general conclusion is that the condensing fossil fuel generation (coal and gas) constitutes a small share of generation in 2020, but is important in the sense that it is the marginal generation capacity in many situations. Most models find that fossil fuel generation increases from 2020 to 2030 when we have assumed that the growth in renewable deployment slows down somewhat.

Wholesale prices

Dispite the strong harmonization and the similarities in generation patterns, the resulting wholesale electricity prices vary substantially between the models, cf. Figure 9.

Figure 9 Wholesale electricity prices in the Reference scenario per model (2020 and 2030)



In 2020 prices vary from less than 40 Euro/MWh (in Markal and PoMo) to more than 50 Euro/MWh (in Blamorel and Classic). In 2030 both the variation and the price level is higher than in 2020. Although price levels vary significantly, the pattern is consistent. All models yield higher prices in 2030 than in 2020, and the ranking of price results is more or less the same.

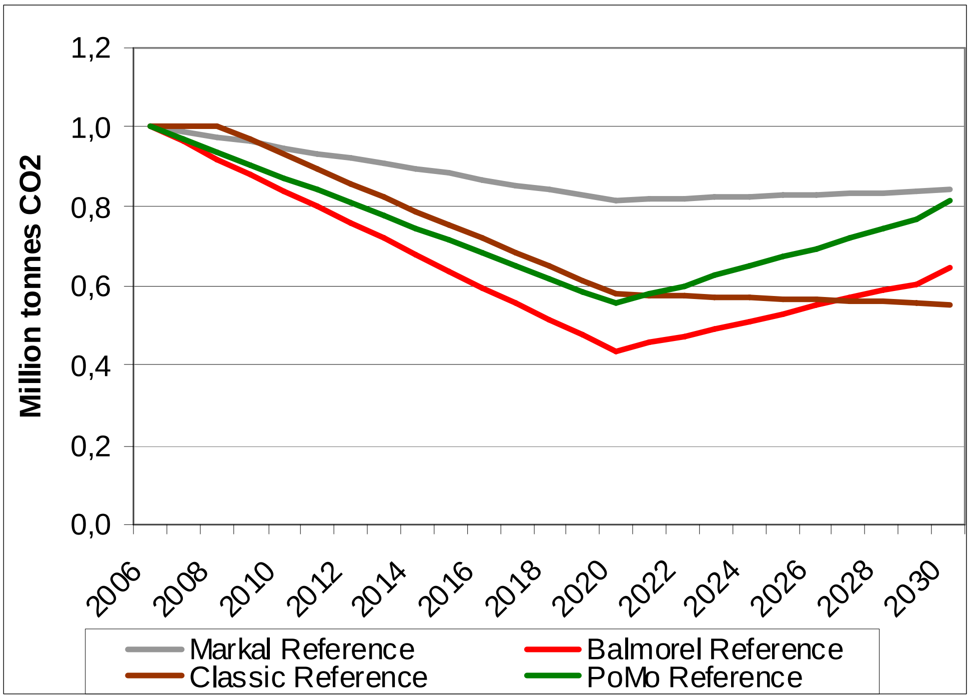
There are several reasons why wholesale price projections vary so much. Some reasons are associated with the model configurations. For example, the modelling of demand and the modelling of trade, which is again linked to the modelling of price structures, explain some of the differences. The wholesale prices shown in the figure are average annual prices. But comparing the wholesale prices with the net export volumes in Figure 6 and 7,we see that models with high net exports do not necessarily yield higher wholesale prices. For example, PoMo does not show higher prices than EMM, which might be expected since PoMo has higher net exports and higher fossil condensing generation. PoMo does however yield a steeper price increase from 2020 to 2030 than the other models. This can be attributed to the large increase in net exports. It is not surprising that Markal yields lower prices than the electricity market models; It has no net exports and also invests in new nuclear capacity in Finland.

The conclusion is to some extent that the models are not particularly accurate in predicting wholesale prices. Or, stated differently, that the wholesale price projections are very sensitive to the model features. It should be noted that the models (and the market) are particularly sensitive to small changes in demand and trade, since markets are not in long-term equilibrium, but in a surplus situation in both model years.

CO2 emissions

Since the models cover different parts of the market, total CO2 emission levels are not comparable. We therefore present resulting emission levels as a share of the emissions from the relevant sectors in a base year (2006 or 2008, depending on the model), cf. Figure 10.

Figure 10 Development in CO2 emissions in the Reference scenario per model



CO2 emissions drop by 20-60 % from 2020, and is stable or increases somewhat from 2020 to 2030 in the Reference scenario. Markal shows the lowest reduction in emissions, due to the fact that the model covers more than the electricity sector.

Again, when it comes to the variation between models, the result is somewhat dishartening even on this crucial parameter. As is the case for wholesale price projections, however, the combination of differences on crucial features play a role in explaining this. Demand levels, trade, and investments, plus the inclusion of trade-offs with the heat sector, drive results. Since the basis for the emission calculations clearly vary between the models (only electricity, electricity and combined heat and power, or electricity plus heat), one should expect varying results. (There is no reason to expect that reductions in emissions are uniform across sectors.) It is thus important that results from one model are not generalized and used to verify effects outside of the sectors that are actually covered. Great care should also be taken when analyzing replacement effects, i.e. that savings in one sector may imply increases in other sectors.

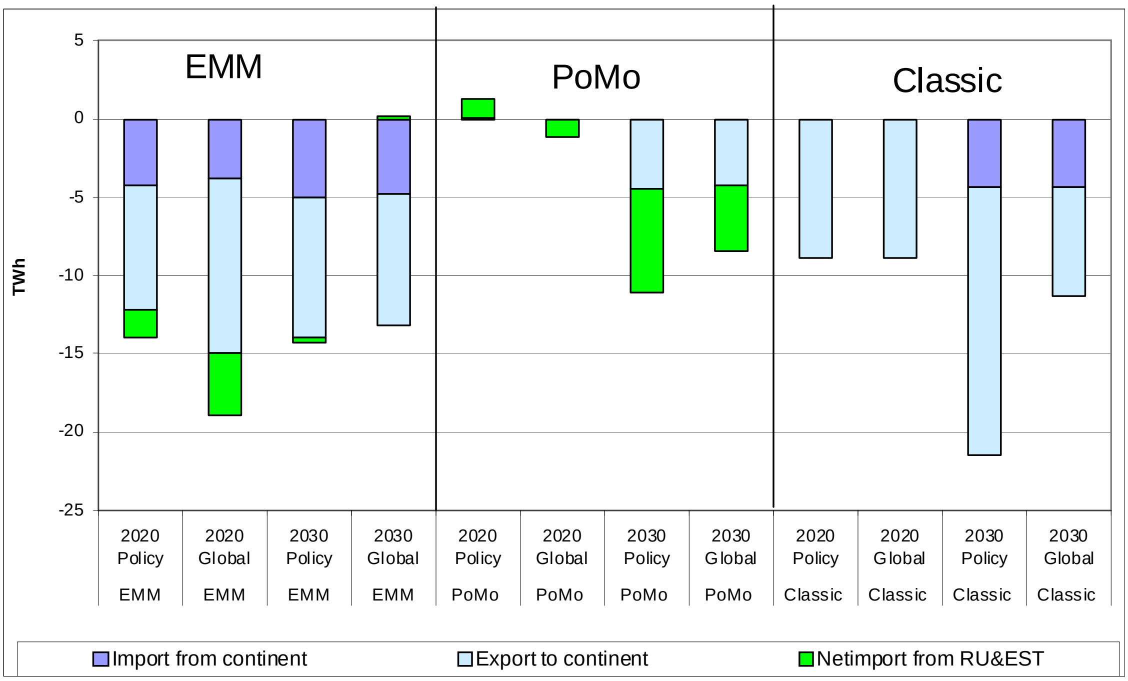
Results from the policy scenarios

Here focus on the changes in results when going from the Reference scenario to the policy scenarios, Policy and Global, respectively.

Power market balance

Figure 11 shows exports to the Continent in EMM, PoMo and Classic. Markal and Balmorel does not model trade with the Continent, hence, there is no change from the Reference scenario.

Figure 11 Trade with neighboring non-Nordic areas in the policy scenarios compared to the Reference scenario, different electricity market models (2020 and 2030)



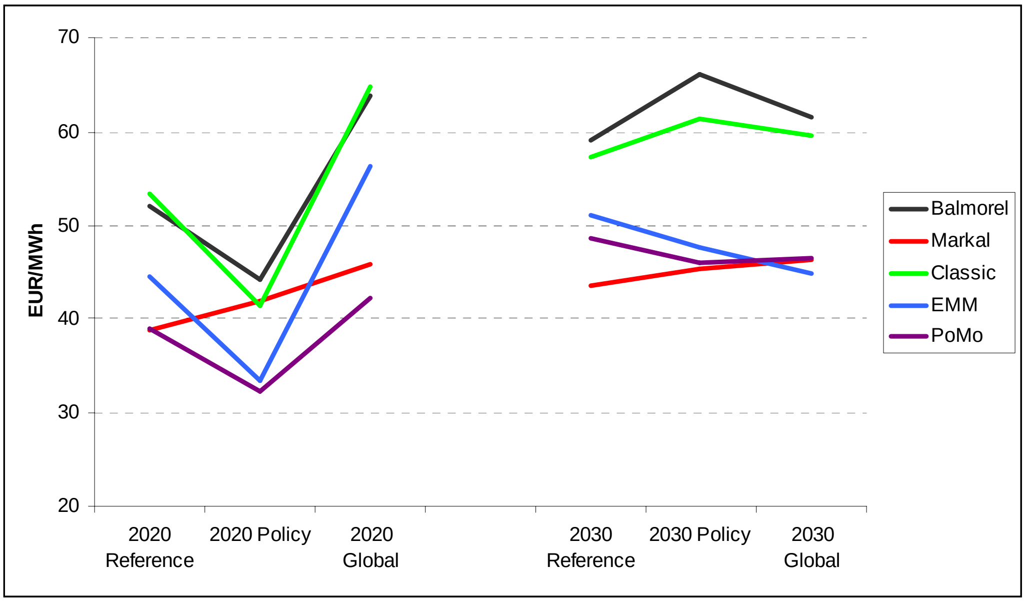
The power surplus in the Nordic market area generally increases in the Policy scenarios. This can mainly be attributed to increased investments in renewable generation capacity compared to the Reference scenario. The increase in net exports is made up by reductions in imports from the Continent, increased exports to the Continent, and in PoMo and EMM, reduced imports from Russia and Estonia. Except for the results from PoMo in 2020, net exports, or the net power surplus in the Nordic area increases by 8-22 TWh in the model runs. Recalling that the increase in renewables in the Policy scenarios compared to the Reference scenario is 29 and 35 TWh, respectively (cf. Figure 3), it is clear that the renewables expansion also impacts on other supply and demand in the Nordic area. As the changes in consumption are however small, the increase in renewables generation that is not exported, mainly replace generation in existing conventional power plants and CHP plants as well.

The export surplus in 2020 seems to increase as we go from Policy to Global. This is probably explained by the higher CO2 price in Global, which affects Continental price levels more than the Nordic. In 2030, the opposite happens; Exports from the Nordics increase more in Policy than in Global. In 2030, however, the CO2 price level is the same in Policy and Global.

Wholesale prices

Price projections differ significantly even in the policy scenarios, and the ranking of the models is not robust, cf. Figure 12.

Figure 12 Wholesale prices per scenario and model (2020 and 2030)



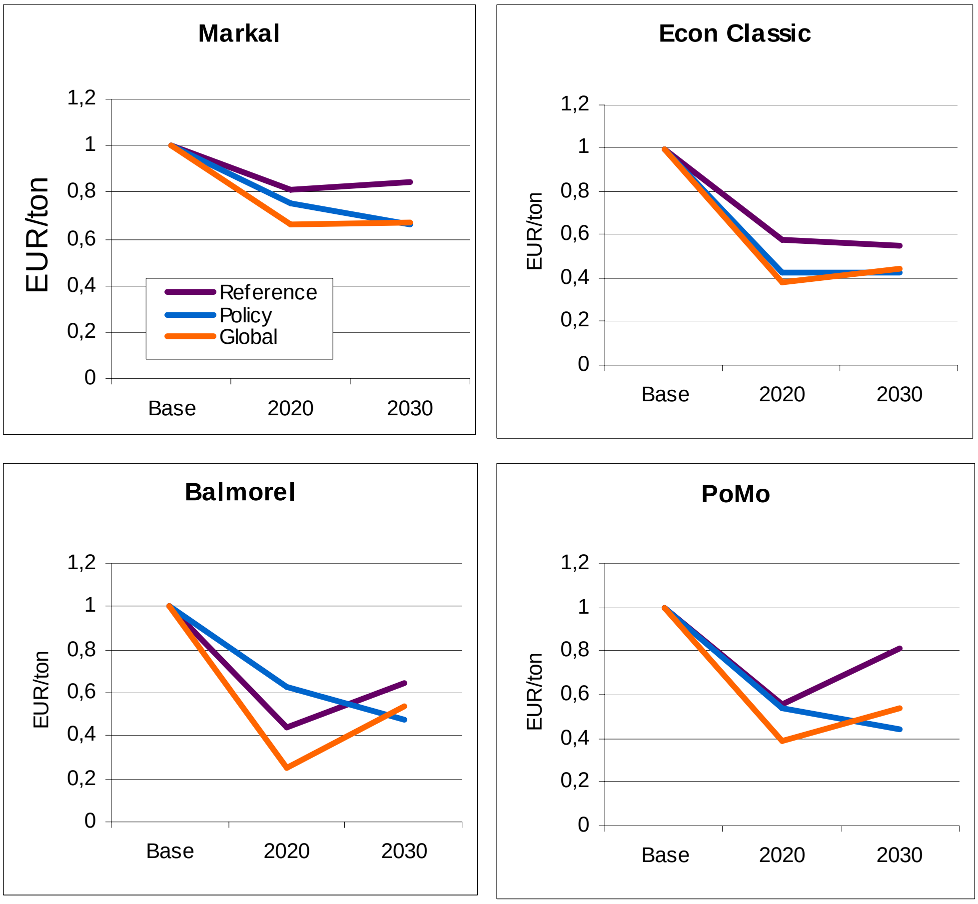
Some patterns emerge, however. Econ Classic and Balmorel seems to yield consistently higher prices than the other models. In the case of Econ Classic, this is to a large extent explained by the rather higher net exports from the Nordics in this model. PoMo also has high exports in 2030 both in the Reference scenario and the Global scenario without getting this price effect, however.

In 2020, all but Markal yield lower prices in Policy and higher prices in Global than the Reference scenario. Obviously the significant differences in CO2 prices is a strong driver here. In 2030, the pattern is less clear-cut, but then again, the CO2 price differs much less between the scenarios and is the same in Policy and Global. Prices are also consistently higher in 2030 than in 2020, except for the Global scenario. Again this is a sign of the strenght of the CO2 price as a driver for prices, even in the Nordic market.

CO2 emissions

Figure 13 below shows the development in CO2 emissions for each of the models for all three scenarios.

Figure 13 CO2 emissions per model and scenario (base, 2020 and 2030)



The patterns are quite clear: In 2020 the CO2 emissions are lower in Global than in Policy, attributed to a stricter European emission policy and a higher CO2 price (cf. Figure 2). The Policy scenario generally yields lower emissions than in the Reference scenario. However, in Balmorel, the emissions are higher, and in PoMo only slightly lower than in the Reference scenario. In the Reference and Global, CO2 emissions increase from 2020 to 2030. In Global we assume that CCS is used large scale at the Continent, and hence, the CO2 price is lower. European emissions are lower, but Nordic emissions are higher in this scenario. In Policy, the CO2 price increases from 2020 to 2030, and all models show a leveling out or reduction in Nordic emissions. Emissions in 2030 are clearly lower in the policy scenarios than in the Reference scenario.

For the power market models, the estimated emission reductions from the Nordic power market are quite consistently between 40 and 60% in 2020 and around 50% in 2030. The emission reductions in Markal are somewhat smaller, in the magnitude of 25-30%, as Markal includes broader energy use than electricity.