Intermediate report

Nordic Energy Perspectives

Insights from NEP policy scenario simulations

November, 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:

- Reference and policy scenarios *(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)*

Our intention in NEP is to present all reports in English. Due to lack of time, some of the texts in some of the reports are at this stage still in Scandinavian languages. We apologize for this. These texts will as soon as possible be translated into English. The translated texts/reports will be available on the project’s web site, *www.nordicenergyperspectives.org*, soon after the Oslo conference.

Oslo, August 2009

The NEP Research Group

Content

Introduction

Background

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 no exceptions; the transition of the energy system constitutes a demanding and interesting challenge for the Nordic markets as well.

Scenario overview

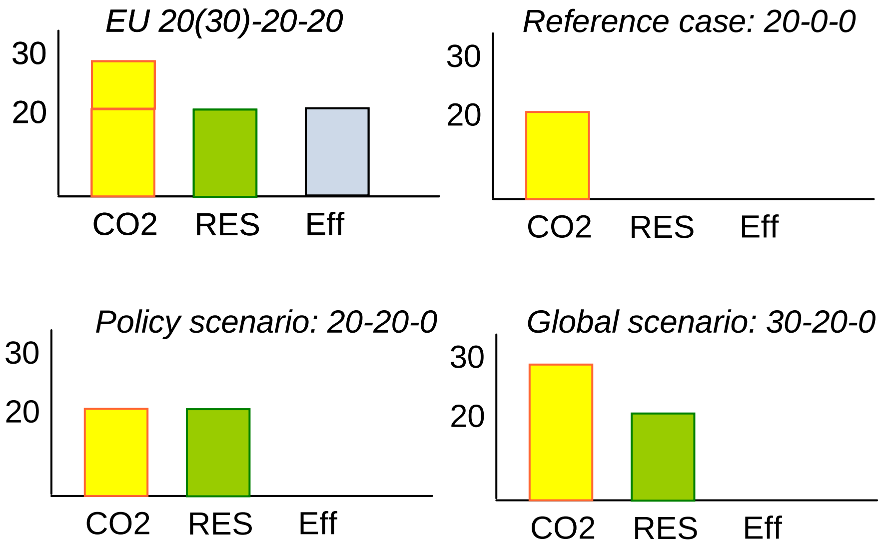
We have used the NEP energy market models to analyze the impacts of the “EU 20-20-20 to 2020” policy package on the Nordic energy system. We have studied three scenarios:

1. *Reference scenario*, where the EU ETS is carried forward according to an overall CO_2 emission reduction target of 20 %, and renewables and energy efficiency policies follow current national policies and targets. This means that the EU renewables and energy efficiency targets are generally not met.
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.

The energy efficiency target is not explicitly modeled in any of the scenarios. This is mainly due to the fact that our models do not cover all energy end-use sectors, and since the energy efficiency policies are not yet developed to the same extent as the emission reduction and renewable energy policies, it is difficult to assess how electricity and heat consumption will be affected by energy efficiency measures.

The policy assumptions for the scenarios are illustrated in the figure below. The EU targets are shown in the upper left side of the figure. The 20(30)-20-20 heading respectively indicates the 20 % emission reduction target which may be increased to 30 %, hence 20(30), the 2 0% renewables target, and the 20 % energy efficiency target. This is for comparison only. The other three panels show the assumption in the scenarios: In the Reference case we assume that only the 20% emission reduction target is met, hence zero on the renewables target and the energy efficiency target. The zeros do not imply that nothing happens, but rather that renewables and efficiency developments are not primarily EU policy driven. The Policy scenario assumes 20 % emission reductions and an increase in the share of renewables to 20 %, but does not take account of any specific energy efficiency measures, hence the zero on this measure. Finally, in the Global scenario emissions are reduced 30 %, and the share of renewables increased to 20%, but the 20 % efficiency target is not applied.

Figure 1 **Overview of Policy scenarios, and comparison with EU 20-20-20 package. EU targets in percentage.**



For all scenarios, we have run the models for 2020 and 2030. In this Intermediate report we present the main conclusions of the policy scenario analysis. For more detail on the specific inputs and results, we refer to the Intermediate report "*NEP policy scenarios*".

Modeling tools

The scenarios have been analyzed using a number of different modeling 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 CO_2 emissions.

Results from the following models are presented:

- EMM
- PoMo
- Econ Classic
- Markal
- Balmorel

In addition, results from the Nordic electricity demand model DoS have been used by some of the models.

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 CO_2 emissions in the Nordic area vary widely.

A large number of assumptions have to be made before model simulations are carried out. Important input assumptions include demand development – including assessments of economic growth and electricity intensity development e.g. for the power intensive industry and space heating – decommissioning of old power generation capacity, subsidy-based investments in renewable energy production, fuel prices, investment behavior, 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.[1] 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 as well. Some models only cover the electricity market whereas others cover the heat market and the interaction between electricity and heat endogenously. Three of the models simulate electricity trade with surrounding areas, although in simplified ways. 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.

It should be noted that none of the models capture all functionalities: all models are simplifications.

Important results are similar in different models

The Nordic market develops an energy surplus in the time period analyzed. In the Reference scenario demand levels increase moderately, renewable energy production increases substantially and net exports from the Nordic area increases (with the exception of the two models 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.

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[1] The input used in Balmorel have been specified differently on a number of variables, including exchange in/out of the Nordic countries, nuclear efficiencies, what technologies to apply for endogenous investments, and possibly others. We should therefore expect Balmorel results to be less in line with results from the other models.

When it comes to CO_2 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 CO_2 emissions remain at the same level as in 2020, or increase 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. On the one hand, demand is not assumed to be very price elastic, and exogenous demand assessments may implicitly take price sensitivities into account. Typically, however, demand will vary between scenarios where price sensitivities are included endogenously, and this effect is not captured by models applying the same exogenous demand level across scenarios.

Despite quite comprehensive harmonization of generation input data, the generation levels vary significantly. The main reason for this is the difference in trade relations. We have assumed a quite substantial expansion of the electricity exchange capacity between the Nordic area and the Continent. This implies that the models with endogenous trade yield dramatic increases in exports from the Nordics.

Given the assumed expansion of renewable capacity, none of the models deem investments in new gas or coal condensing 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 model configurations and coverage yields different results, but also increase the understanding of the crucial drivers for developments in power market balances, wholesale prices and CO_2 emissions from the Nordic power market.

The main modeling features making a difference are:

- *Demand representation*
  Demand is modelled differently in the NEP models. In EMM no long run price sensitivity has been assumed and total consumption is a fixed input parameter. In PoMo and Balmorel the price sensitivity from the DoS model has been used.[2] In Econ Classic, demand in industry is taken from DoS'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, a certain energy carrier may be replaced by another with lower costs. Investments in energy efficiency measures may also be carried out, but to a rather limited extent. Direct saving by e.g. reducing the indoor

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[2] The DoS model is a power demand projection model. It applies a top down approach to demand for electricity specific services in all sectors except the power intensive industry, and a bottom up approach to electricity demand for heating and demand in the power intensive industry.

temperature is, however, not included. Markal hence employs more of a bottom-up approach than Econ Classic. Markal and Balmorel also include 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 behavioral 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 based on market prices and support levels. In PoMo and EMM all investments are exogenously determined. Balmorel and Econ Classic employ a mix of exogenous and endogenous investments. Results show that most investments are based on a mix of policy and market considerations, including support schemes which are not technology neutral. 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, modeling 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 must be 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. In Econ Classic, Markal and Balmorel, trade with Russia and Estonia is fixed, whereas PoMo and EMM employ price driven trade with Estonia, and EMM even with 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 CO_2 emissions.

- *Price structures and time resolution*

Power prices vary from hour to hour in response to variations in demand, price insensitive generation (e.g. wind), and generation opportunities (CHP). These variations affect load factors in flexible generation and trade patterns, and in turn marginal costs, i.e. wholesale prices, CO_2 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 impact on Nordic power prices and CO_2 emissions.

- *Representation of policy instruments*

Even though all models used here have implemented the EU ETS and specified targets for renewable energy, the capture of other existing policy instruments, such as energy and carbon taxes and subsidies, differ and, thus, may influence model results. Especially in the heat market of the Nordic countries, carbon and energy taxation is important.

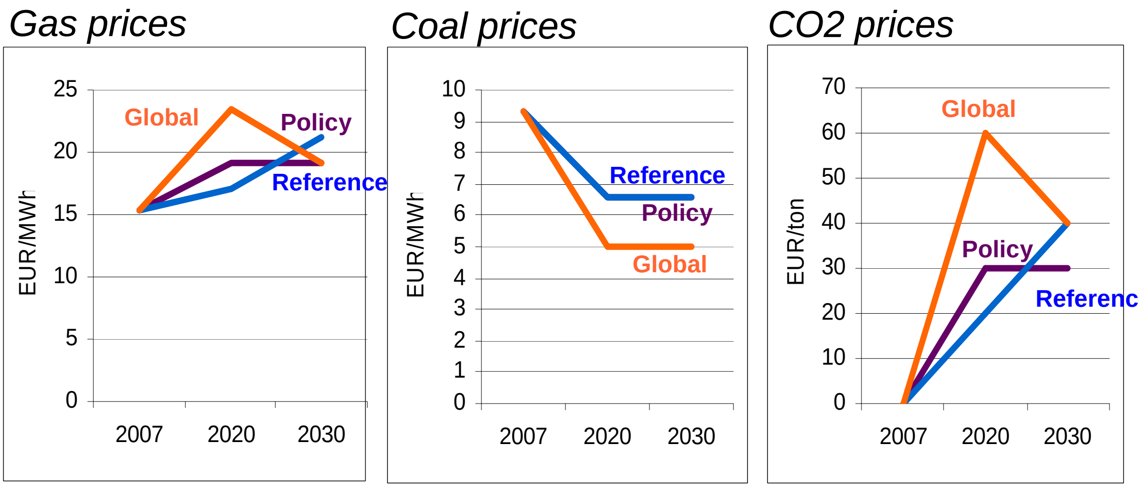
Table 1 Summary of important model features

Model	**Geography**	**Market**	**Investments**	**Annual load representation**
Balmorel	Baltic Sea area	Electricity and district heating	Endogenous and exogenous	Flexible. (Here 52 weeks times 5 segments = 260 time steps.)
PoMo	Nordic countries	Electricity	Exogenous	52 weeks
ECON-Classic	Europe	Electricity	Endogenous and exogenous	Flexible. (Here 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.)

Important input assumptions

When quantifying the scenarios, we have made a large number of common assumptions. These assumptions are described in detail in the report *“NEP Policy Scenarios”*. For example, the same fuel price and CO_2 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 CO_2 prices in the three scenarios:

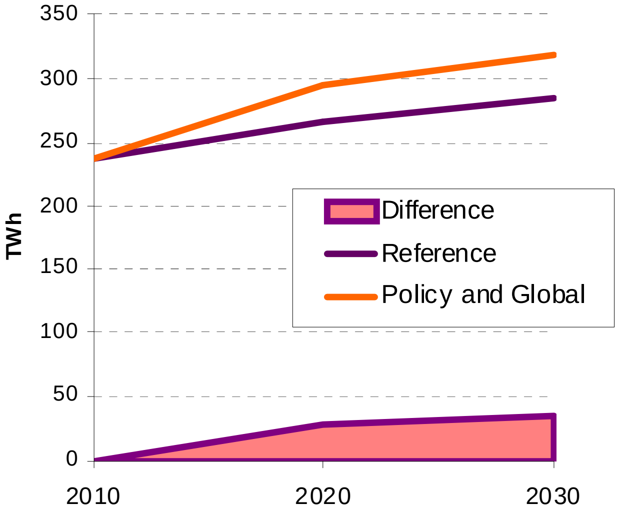
Figure 2 Common gas, coal and CO_2 price assumptions



The CO_2 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, which take the cap into account, the EU renewable policy, and the relative fuel prices. In 2020 the CO_2 price is lower in the Policy scenario than in the Reference scenario because the deployment of renewables is higher, and thus, baseline emissions from the power sector (in Europe) lower. The ETS emission cap is the same in Reference and Policy, but lower in Global. In addition, all developed countries employ ambitious emission reduction policies in Global, hence implying a higher global CO_2 price. In 2030 the global price is set by the cost of CCS.

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).

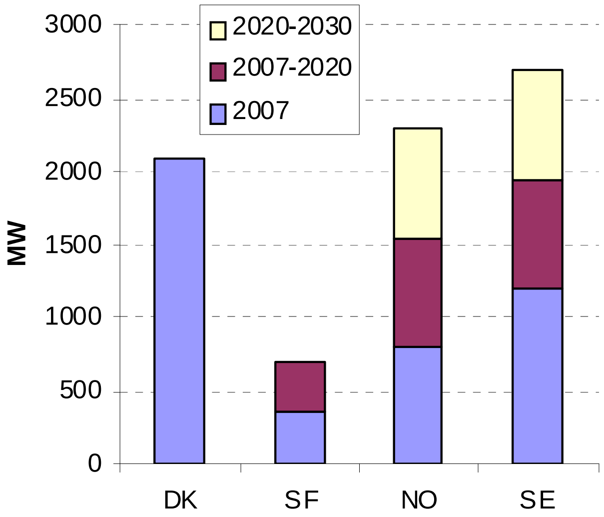
Figure 3 Development in renewable electricity generation per scenario



In the electricity market models these assumptions are used directly as exogenous input. The Markal model, however, includes the whole stationary energy system, 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 therefore differ from the exogenous assumptions made in other models.

In all scenarios we assume that interconnection capacity between the Nordic area and other markets increase quite substantially. The assumed increase in transmission capacities per country is illustrated in the figure below. In addition, the export capacity from Finland to Russia is expected to be increased.[3]

Figure 4 Electricity transmission capacity to the Continent and the Baltic states, per Nordic country, all scenarios.



The increase in exchange capacities and the assumed trading arrangements are crucial assumptions which, as we shall see, have a substantial impact on the general results, and also explain the differences in model results to a large extent.

Markal and Balmorel have exogenous trade between the Nordic area and other markets, and have substantial imports to the Nordic area – ca. 10 TWh and 30 TWh, respectively.

Results from the Reference scenario

Electricity market balances and trade

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

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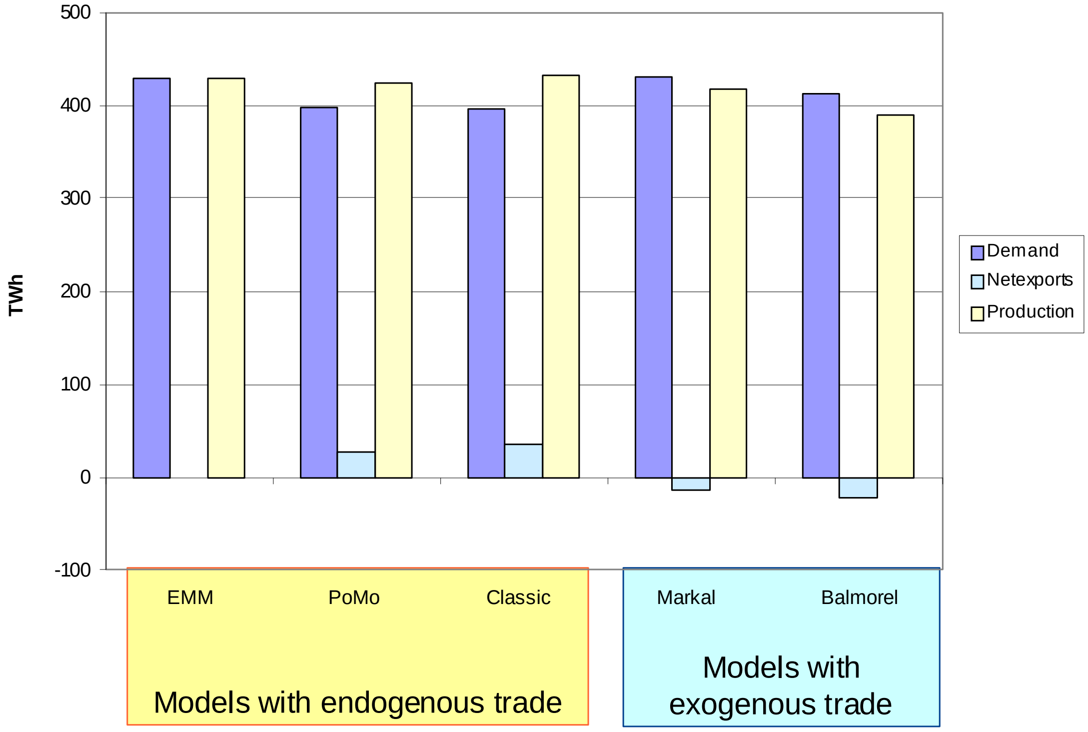
[3] This means that the transmission capacity between Finland and Russia is largely assumed to be a two-way street in the future. None of the models simulate Russian prices. Hence, all models except Markal assume net imports of 5 TWh from Russia in all scenarios.

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 modeling 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. In the models with endogenous trade, electricity generation varies less than electricity consumption, 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)**

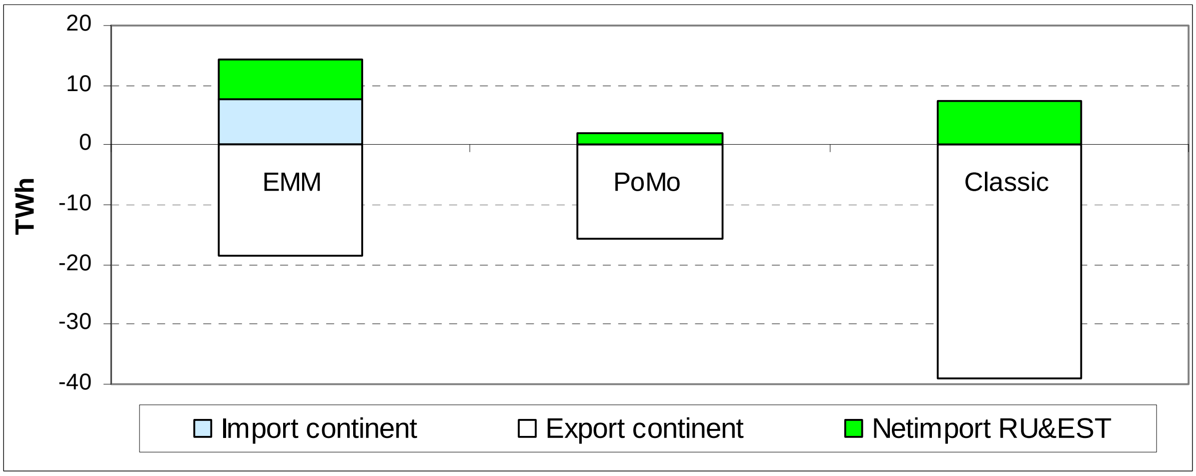
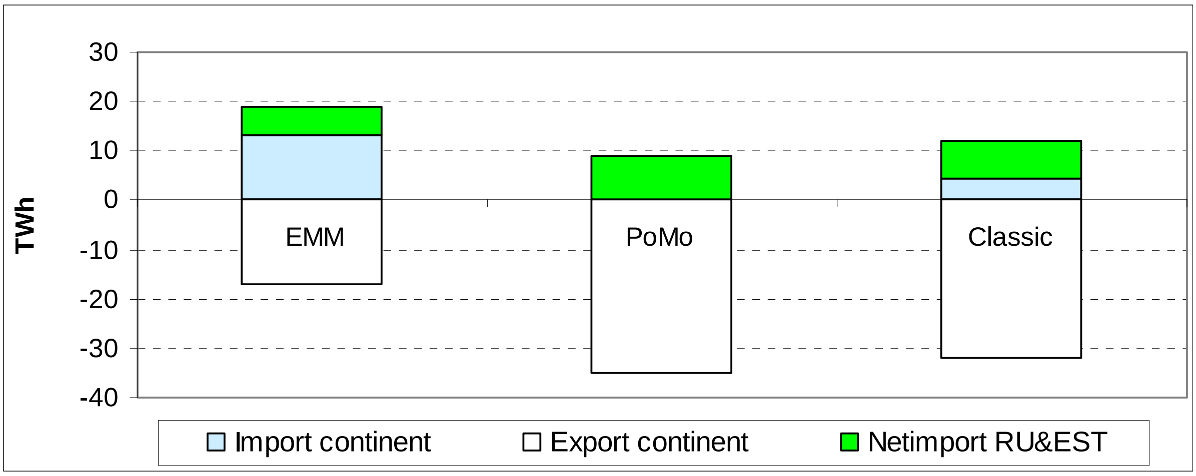


Figure 7 **Nordic electricity imports and exports in the Reference scenario per model (2030)**



Generally, all the models show imports from Russia and Estonia and net exports to the Continent. In EMM, the downward adjustment of Continental prices to match short run costs 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 in Classic, thereby taking some account of price variations during the week (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.

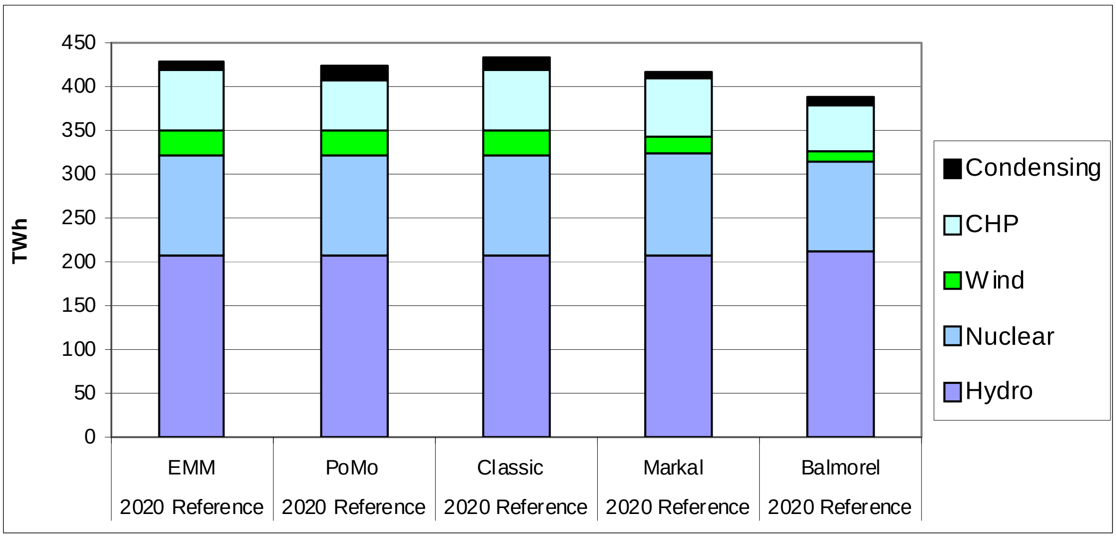
Taken together however, the models are not conclusive when it comes to the net balance of the Nordics, and the differences in volumes are substantial. None of the models show net imports from the Continent, however. All models take market dynamics into account, but none of them does it fully. The conclusion is that it is likely that the Nordic countries 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 due to net import instead of net export, see Figure 8. Markal also has lower wind power generation. Investments in wind power and renewable heat and electricity is endogenous in Markal, and the model results show a lower amount of wind power 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)**

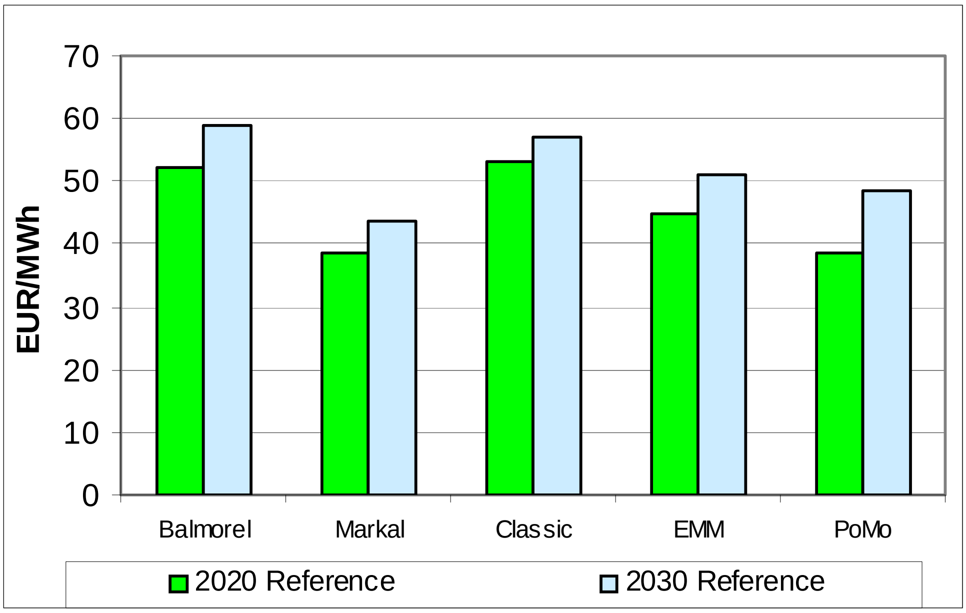


A general conclusion is that the condensing fossil fuel generation (coal and gas) constitutes a small share of generation in 2020, but is important in the sense that it is the marginal generation capacity in many situations. Most models find that fossil fuel generation increases from 2020 to 2030 as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

Wholesale prices

Despite 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)**



Prices in 2020 vary from less than 40 Euro/MWh (in Markal and PoMo) to more than 50 Euro/MWh (in Balmorel 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. EMM and PoMo do not have endogenous investments, and as such, prices are a result of short run marginal costs (srmc) based on the given capacity. Econ Classic allows for endogenous investments if average annual prices (weighted across load blocks) are sufficient to cover investment costs for new market based generation. If market prices exceed long run marginal costs (lrmc), i.e. annualized full costs for conventional plant (coal or gas, depending on fuel and CO_2 prices), the model yields investments and report average price levels equal to lrmc. Prices in the different load blocks are still based on srmc. In cases where the average annual price based on the exogenous capacity development does not reach lrmc, investments in conventional power plant are not profitable. Hence the price level reported by the model will also be lower than lrmc.[4] In the NEP scenarios, endogenous investments are only found in the 2030 simulations. Balmorel and Markal model the long run marginal cost.

The differences are to some extent associated with differences in the model configurations. The time resolution of the models, the modeling of demand (fixed or flexible) and the modeling of trade explain much of the differences. The wholesale prices shown in the figure represent the average annual system price, but are derived somewhat differently in the different models. Classic models all Nordic price areas separately, and report the weighted average of prices across all Nordic market area prices.[5] PoMo has only East-Denmark and West-Denmark as separate price areas, and report the common price for Norway/Sweden/Finland as the Nordic average. EMM has no intra-Nordic separation at all and as such reports the Nordic "system price"; this also holds for Balmorel in the presented simulations.

Comparing wholesale prices and 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; Markal has no net exports and also invests in additional new nuclear capacity in Finland.

The projections for future power prices vary substantially, and the variations can to a large extent be contributed to differences in input assumptions, the composition of exogenous and endogenous parameters and differences in model features, even though all results are based on the same assumptions about short and long run marginal costs. The main conclusion is that the long-term wholesale price projections are very sensitive to the model features. The results (and the market) are particularly sensitive to small changes in demand and trade in situations

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[4] Even in the case where new investments are profitable, the price structure in Classic (diurnal and seasonal) is based on short run marginal costs for the different load blocks. It is however, the annual average price that determines investments.

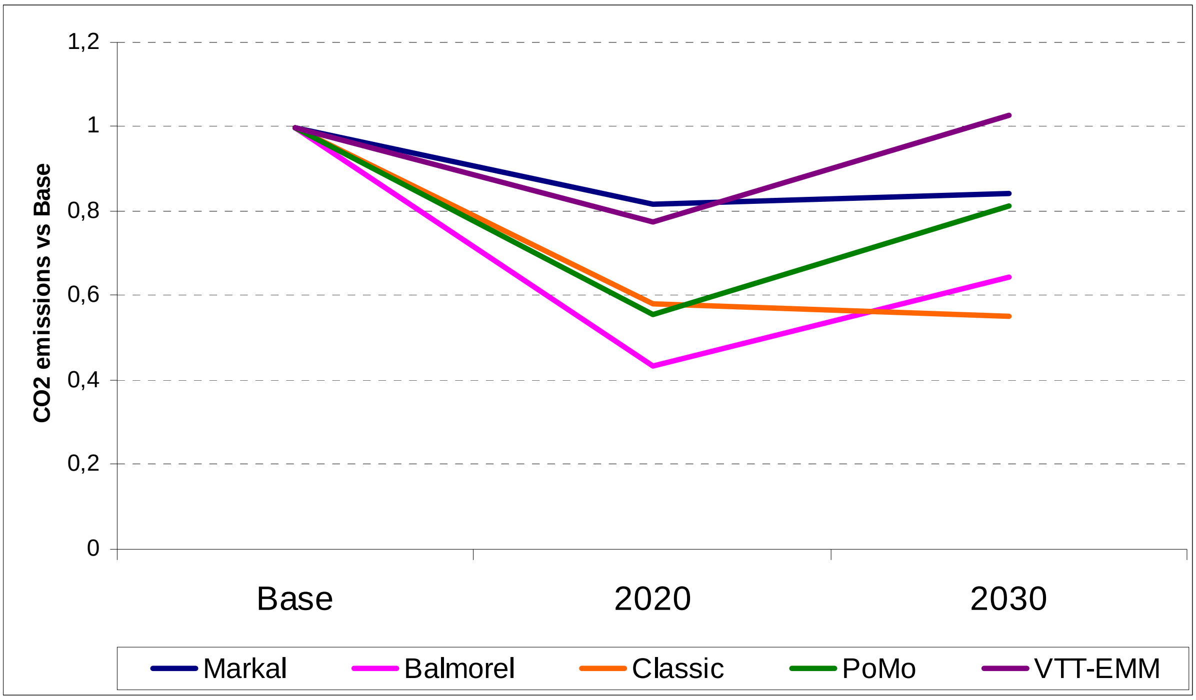
[5] Average prices reported from Econ Classic are weighted by demand in the different areas. Prices for the Danish market areas are generally found to be higher than prices for Norway, Sweden and Finland, which are usually closer to the system price. Since Danish demand is relatively small, less than 10% of Nordic electricity demand, the difference should be only minor.

where markets are not in long-term equilibrium, i.e. in surplus situations. Models with endogenous investments should show more robust predictions for price levels in the long run, i.e. when markets are in equilibrium. Models reporting prices based on short run marginal costs may of course also take long run marginal costs into account in the exogenously assumed investment behavior of the market (check consistency of price level against full cost of market investments).

CO_2 emissions

Since the models cover different parts of the market, total CO_2 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 CO_2 emissions in the Reference scenario per model



CO_2 emissions drop by 20-60 % to 2020, and are stable or increase somewhat from 2020 to 2030 in the Reference scenario. Markal shows the lowest reduction in emissions to 2020, which may due to the fact that the model covers more than the electricity sector. However, Balmorel, which also covers heat sector, has the largest reduction in emissions to 2020. A major explanation must be that Balmorel has assumed electricity imports to the Nordic area, effectively replacing fossil fuel based generation (cf. generation figures in Figure 8). Among the electricity market models, VTT shows the lowest reductions in emissions to 2020, and an increase to 2030. This is mainly due to a strong increase in price insensitive demand which results in a rise in condensing power production from 2020 to 2030.

Again, when it comes to the variation between models, the result is somewhat disheartening 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 and the price sensitivity of demand, trade modeling, and investments, plus the inclusion of trade-offs with the heat sector, drive results. It is not surprising that emission results are sensitive to changes in these parameters as marginal generation capacity is largely coal based, and at the same time a small share of total generation. Hence, even smaller changes in trade, renewables capacities and demand will have substantial impacts on CO_2 emissions both in relative and absolute terms.

The basis for the emission calculations also vary between the models according to coverage – electricity only, electricity and combined heat and power, or electricity plus heat – one should expect results to vary as well. (There is no reason to expect that emission reductions will be 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 spill-over effects, i.e. that savings in one sector may imply increases in other sectors.

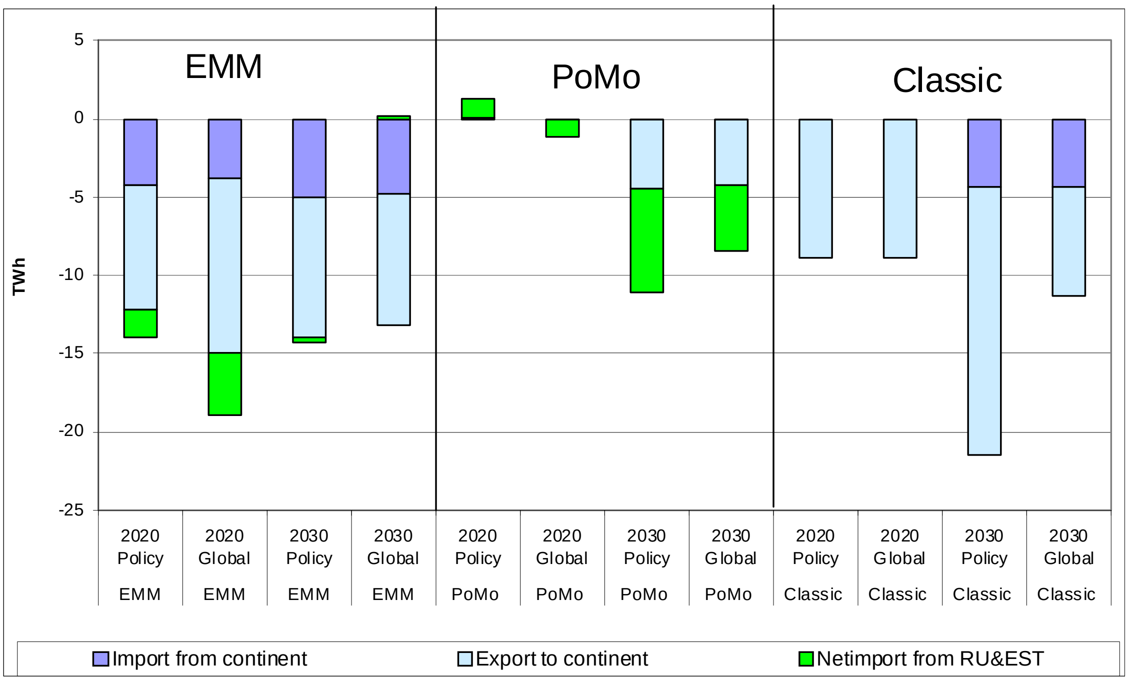
Results from the policy scenarios

In the section above we have presented the results from the different models for the Reference scenario. In this section we will present the main results from the policy scenario analyzes. In the presentation we 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 and Global scenarios compared to the Reference scenario, different electricity market models (2020 and 2030)



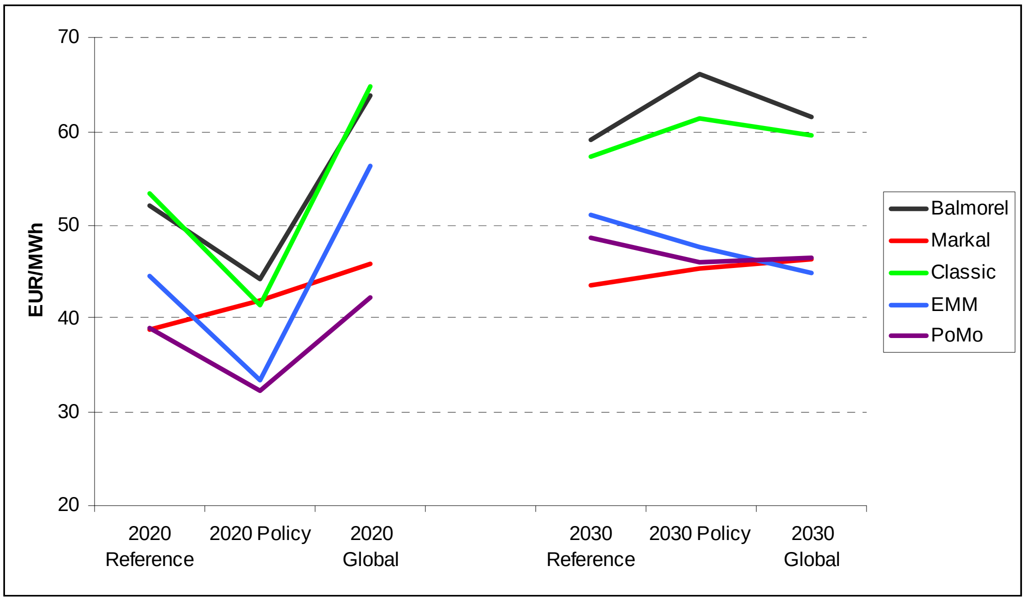
The power surplus in the Nordic market area generally increases in the policy scenarios. This can mainly be attributed to increased investments in renewable generation capacity compared to the Reference scenario. The increase in net exports is made up by reductions in imports from the Continent, increased exports to the Continent, and reduced imports from Russia (EMM) and Estonia (EMM and PoMo). Except for the results from PoMo in 2020 net exports from the Nordic area increases by 8-22 TWh compared to the Reference scenario. Recalling that the increase in renewables in the Policy and Global 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 electricity consumption increases only slightly compared to the reference cases, the excess increase in renewables generation that is not exported mainly replaces generation in existing conventional condensing power plants.

The export surplus in 2020 seems to increase as we go from Policy to Global. This is explained by the higher CO_2 price in Global, which affects Continental price levels more than the Nordic. In 2030, the opposite happens; Exports from the Nordic countries increase more in Policy than in Global. In 2030 the CO_2 price level is the same in Policy and Global, but the fossil fuel prices are slightly lower in the Global scenario.

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 seem to yield consistently higher prices than the other models. In the case of Econ Classic, the higher prices are also to a large extent explained by higher net exports from the Nordic countries. 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 models but Markal yield lower prices in Policy and higher prices in Global than the Reference scenario.[6] Obviously the significant differences in CO_2 prices are a strong

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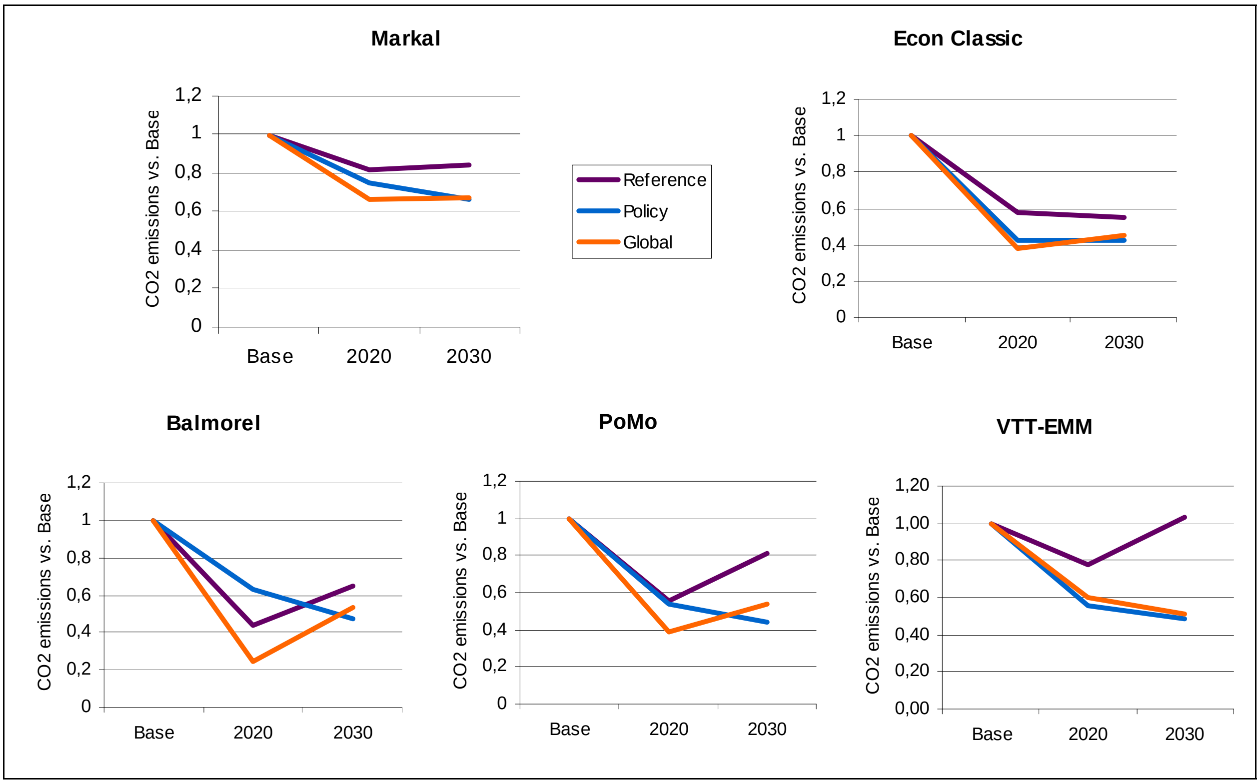
[6] The explanation for this is rather technical and associated with the formulation of the renewables target in Markal. See the ”*NEP Policy Scenarios*” report for details.

driver here. In 2030, the pattern is less clear-cut, but then again, the CO_2 price differs much less between the scenarios and is the same in Policy and Global. Fuel prices, notably coal, are lower in Global than in Policy, which can be seen in all except PoMo and Markal results. Prices are also consistently higher in 2030 than in 2020, except for the Global scenario. Again this is a sign of the strength of the CO_2 price as a driver for prices, even in the Nordic market.

CO_2 emissions

Figure 13 below shows the development in CO_2 emissions for each of the models.

Figure 13 Indexed CO_2 emissions per model and scenario (base, 2020 and 2030)



The patterns are quite clear: Generally, CO_2 emissions are lower in the policy scenarios than in the Reference case. In the Policy 2020 scenario, CO_2 emissions are lower than or largely the same as in Global, attributed to a higher CO_2 price (cf. Figure 2). The Policy scenario generally yields lower emissions than the Reference scenario. However, in Balmorel, the emissions are higher in the Policy scenario than in the Reference scenario, and in PoMo only slightly lower than in the Reference scenario. In EMM emissions are very similar in both policy scenarios, because larger net exports in the Global scenario “compensate” for the increase in renewable production.

From 2020 to 2030 CO_2 emissions in the Reference and the Global scenario increase in all models except EMM. In Global the CO_2 price is lower in 2030 than in 2020, and Nordic emissions thus increase compared to 2020 and are as high as or higher than in the Policy scenario in 2030. In Policy, the CO_2 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 both policy scenarios than in the Reference scenario. Hence, some of the results are robust across models, but it is clear that the modeling of trade and demand affects results.

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 in the policy scenarios. The emission reductions in Markal are somewhat smaller, in the magnitude of 25-30%, as Markal includes broader energy use than electricity. As trade is also modeled differently in Markal, it is however, difficult to say whether the higher emissions (or lower emission reductions) are attributed to fuel switching between heat and electricity.