Ea Energy Analyses

Energy Policy Strategies of the Baltic Sea Region for the Post-Kyoto Period

– focusing on electricity and district heating generation

Prepared for BASREC by Ea Energy Analyses

03-05-2012

Foreword

The recent challenges in reaching a common global climate agreement have increased the importance of regional energy and climate policy initiatives and the demand to develop complementary strategies also at this level.

The Baltic Sea Region has a unique opportunity to become a frontrunner in developing energy strategies for 2020 and beyond. Studies have indicated that the Baltic Sea Region has a strong potential to develop a low carbon energy economy. The region is endowed with vast natural resources in terms of biomass, wind and hydro power potential, and through its industrial and administrative capacities it holds the technology and knowledge base needed for a low carbon transformation.

Against this background the *Baltic Sea Region Energy Co-operation* has commissioned this study on “Energy policy strategies of the Baltic Sea Region for the post-Kyoto period”.

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This study has been prepared for the Baltic Sea Region Energy Co-operation (BASREC) by Ea Energy Analyses. In a hearing process during 2011 and 2012 the members of BASREC have provided input and comments to the study.

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Summary for policy makers

This study presents a comprehensive analysis of energy policy strategies for the Baltic Sea Region for the post-Kyoto period. To this aim, the study provides scenarios for the region in order to develop a both secure and climate-compatible energy system for the year 2020 and beyond. The long-term development of the energy systems in the Baltic Sea Region is analysed, i.e. in Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, Sweden, and the north western part of Russia[1]. The study focuses on the electricity and district heating sectors.

The Baltic Sea Region by this definition has a total population of more than 160 million people with an aggregated gross electricity consumption of approximately 1,300 TWh. In comparison, this corresponds to close to 40 per cent of the total electricity demand in the EU.

Figure 1: The Baltic Sea Region. The study comprises Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, Sweden and the north western part of Russia. The bold black lines represent the borders of the electricity regions considered in the study. Belarus is only considered as a transit country in the study.

A region rich in resources

The Baltic Sea Region is comprised of countries with very different economies and characteristics. Hydropower is an important source of electricity generation in Norway, Sweden, Finland and Latvia. Biomass resources are significant throughout the

[1] The Baltic Sea Region comprises the five Nordic and three Baltic countries - Germany, Poland and Russia. Iceland has not been subject to analysis in this study. Also study only analyses the North West part of the Russian electricity and district heating system.

region, deriving from both agricultural residues and large forested areas. Wind power already contributes considerably to electricity generation in countries such as Denmark and Germany, and is likely to play a much greater role in the region in the years to come, both onshore and offshore.

In the longer term (2030 and beyond), solar power and geothermal energy could also provide notable contributions to the overall energy supply.

Scenario overview

In carrying out the study, a reference scenario and two low carbon scenarios towards 2050 were developed. The scenarios focus on the energy sector and show the economic consequences of different policy options and their implications for the energy systems, the environment, security of supply and the economy.

The scenarios are not made with a view to *predicting* how the future of the energy systems in the region is going to look like. Rather they are used to show how to reach a desirable low carbon future at the lowest cost given different development in the framework conditions.

The target in the low carbon developments is for the power and district heating sectors to become CO_2 neutral by 2050 in the countries that are currently encompassed by the EU Emissions Trading Scheme (EU countries and Norway). Towards 2050 the low carbon development is separated into two scenarios, which differ regarding the role of CCS. The *low carbon renewables scenario* explores a future where fossil fuels are phased out altogether, whereas in the *low carbon scenario* carbon capture and storage technologies become an important part of the solution to reduce CO_2-emissions in the longer term.

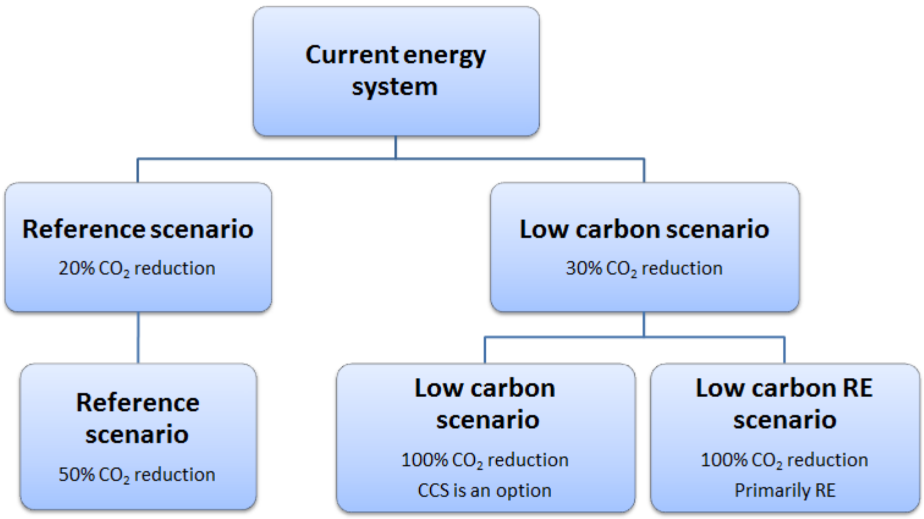

Figure 2: Overview of the scenarios analysed in the study. The reduction figures showed in the diagram are relative to 2005 and concern the EU countries and Norway (ETS[2] countries).[3]

[2] EU Emissions Trading System for trading of greenhouse gas emission allowances.

Balmorel model

To explore how the targets can be complied with at the least possible cost the electricity market model Balmorel[4] was used to simulate optimal dispatch and investments given the provision of framework conditions and technology cost. Data for the technologies, the model can choose between are drawn from a comprehensive technology catalogue.

Key assumptions

Key assumptions include: fossil fuel prices based on the EU Commission's Energy Roadmap 2050, implementation of strong energy efficiency measures, electricity playing a greater role (both in transport and heating, but also in industrial processes), district heating continuing its prominent role, and RE development through to 2020 along the lines outlined in the respective countries National Renewable Energy Action Plans. Gross electricity demand grows by approx. 0.3 % per annum between 2010 and 2050. A more comprehensive list and description of the key assumptions underlying the analyses is provided in the text box on page 12.

Reference scenario

The reference scenario points to a development where the overall composition of electricity supply does not change radically compared to today (see Figure 3). The most notable difference is an increase from wind power, biogas, biomass power plants and waste treatment facilities whereas generation from coal power decreases slightly over time. The share of renewable energy increases from 32 % in 2010 to 53 % in 2050.

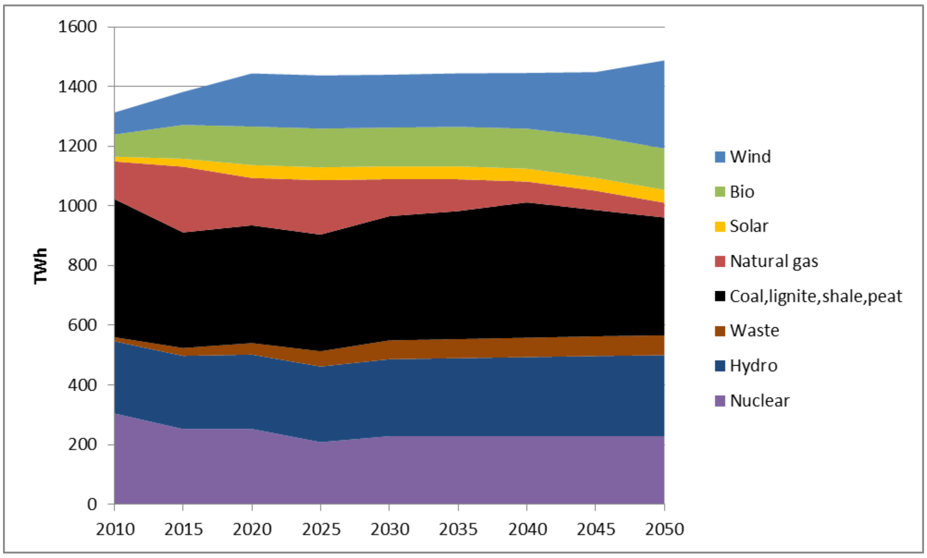

Figure 3: Total electricity generation (TWh) by fuel for Reference scenario.

The gradual replacement of old power plants with new highly efficient state of the art technologies is part of the explanation as to how CO_2 emissions can be reduced by

[3] In North West Russia, which constitutes approx. 7 % of electricity demand in the region, the reference assumes stable CO_2-emissions in 2020 and 25 % reduction in 2050 compared to 2010 emissions. The low carbon scenarios assume 15 % reduction in 2020 in Russia and 50 % reduction in 2050 compared to 2010 emissions. The specified reduction targets concern CO_2-emissions from power and district heating generation. Emissions from municipal solid waste are not subject to the cap.
[4] See www.balmorel.com

close to 50% in the reference scenario in spite of a very significant contribution from coal power in 2050. The marginal price of reducing CO_2 emissions to this level increases from a level of €11/ton in 2020 to €51/ton in 2050.

Low carbon scenario

In the **low carbon scenario** the electricity supply undergoes dramatic changes in order to cope with the target of reducing CO_2 emissions by 100% in the BASREC ETS countries. Most notable is a massive expansion of wind power generation and a significant reduction in coal power which is almost entirely phased out already by 2040. In 2050 wind power constitutes 27% of the total electricity supply in the region. Almost half of the turbines (more than 40 % of total wind generation) are located off-shore, in the North Sea and in the Baltic Sea.

The cost of reducing CO_2 emissions (the carbon price) increases from around €25/ton CO_2 in 2020 to €135/ton in 2050. In 2035 when the CO_2-price reaches €50/ton, and onwards CCS becomes a key carbon reduction measure. CCS can be applied on coal, gas and biomass power plants. Coal CCS benefits from using a cheap fuel whereas gas CCS is less capital intensive making it an attractive option to provide back-up to intermittent renewable energy sources such as wind power. Applying biomass CCS leads to a net reduction of CO_2, which may allow for continued use of gas power at conventional power plants used for balancing wind power and providing peak power. The analyses show that the different CCS technologies are more or less equally competitive and that all three technologies can play an important role in the energy supply in the longer term.

Generation from conventional biomass and biogas generation also increases throughout the period, while conventional gas power plays a very important role as a bridging CO_2 reduction measure between 2020 and 2040. The share of RE in the electricity supply increases from 32 % in 2010 to 67 % in 2050.

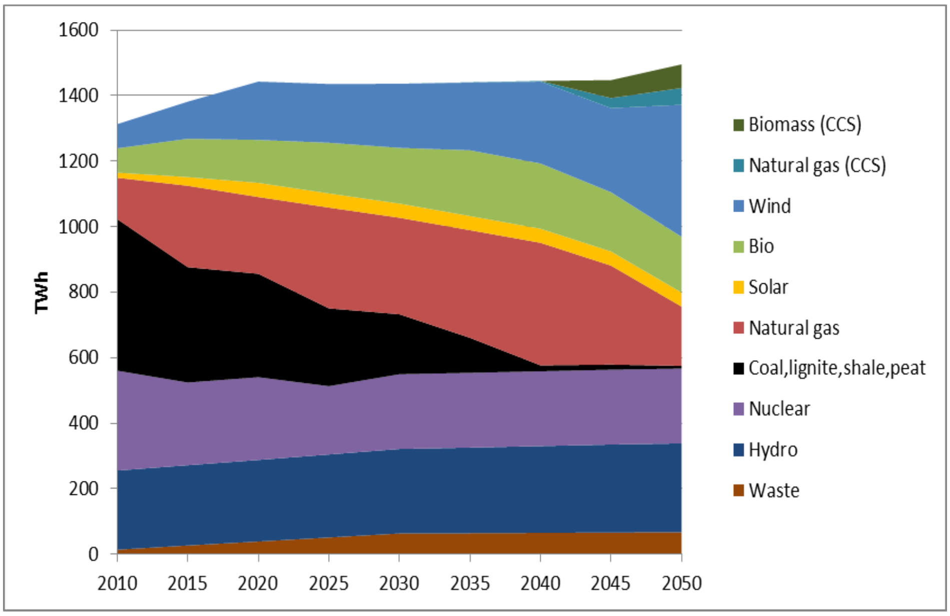

Figure 4: Total electricity generation (TWh) by fuel for the Low carbon scenario.

Low carbon RE scenario

Until 2035 electricity generation in the **low carbon renewables scenario** (see Figure 5) is very similar to the Low carbon scenario. After 2035 generation from biomass power plants and particularly wind power increases significantly to compensate for the generation from CCS power plants, which are not an option in the low carbon RE scenario. In 2050 wind power provides more than one third of all electricity generation in the Baltic Sea Region. The share of renewables increases from 32 % in 2010 to 78 % in 2050, which is 10 % higher than in the Low carbon scenario. The marginal price of reducing CO_2 becomes significantly higher in this scenario reaching a level of around 380 €/ton in 2050 because peak loads options and balancing power become more expensive.

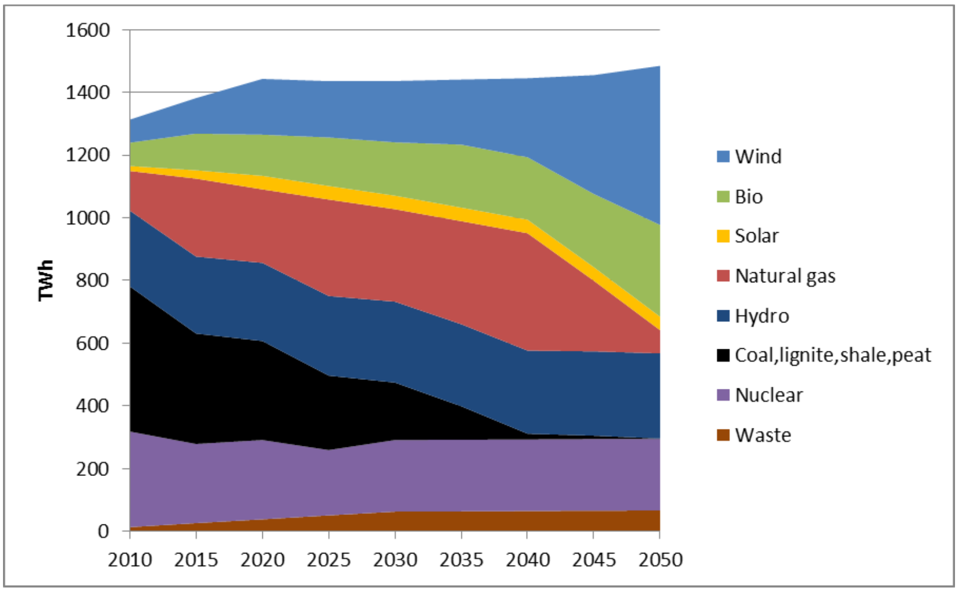

Figure 5: Total electricity generation (TWh) by fuel for Low carbon RE scenario.

Costs

In accordance with the EU energy road map different sets of fuel prices is used for the reference projection and the low carbon scenarios. The low carbon scenarios assume that global action is taken to significantly bringing down greenhouse gas emissions. This again reduces fossil fuel demand worldwide providing a downward effect on fossil fuel prices. Oil, gas and coal prices are therefore lower in the low carbon scenario than in the reference scenario whereas biomass prices are higher. The economic results should be interpreted with this difference in mind.

The total costs[5] of maintaining electricity and district heating supply in 2020 will be approx. 0.5% higher with an EU target of reducing CO_2 emissions by 30% compared to a 20% target[6]. The marginal cost of reducing CO_2 increases from €10 to €25 per tonne in 2020. Supplementary simulations show that the difference in total costs in 2020 would be around 1.5% if fuel prices where the same in all scenarios.

The additional costs of achieving a carbon neutral electricity and district heating system in 2050 via the low carbon scenario is approximately 12% higher than in the reference scenario where CO_2-emissions are reduced by 50 %. In the low carbon renewable scenario where CCS does not play a role, the additional costs are about 19 % higher relative to the reference scenario. Supplementary simulations show that the difference in total costs between the reference and the low carbon scenarios would be around 20-25 % if fuel prices were the same in all scenarios in 2050.

[5] Costs include capital costs of power plants, transmission connections etc. as well as fixed and variable operation and maintenance costs and fuel costs. No price is attached to the emission of CO_2, but the cost of reducing CO_2-emissions can be estimated by comparing the different scenarios.
[6] In North West Russia the assumed target is increased from 0% to 15% reduction.

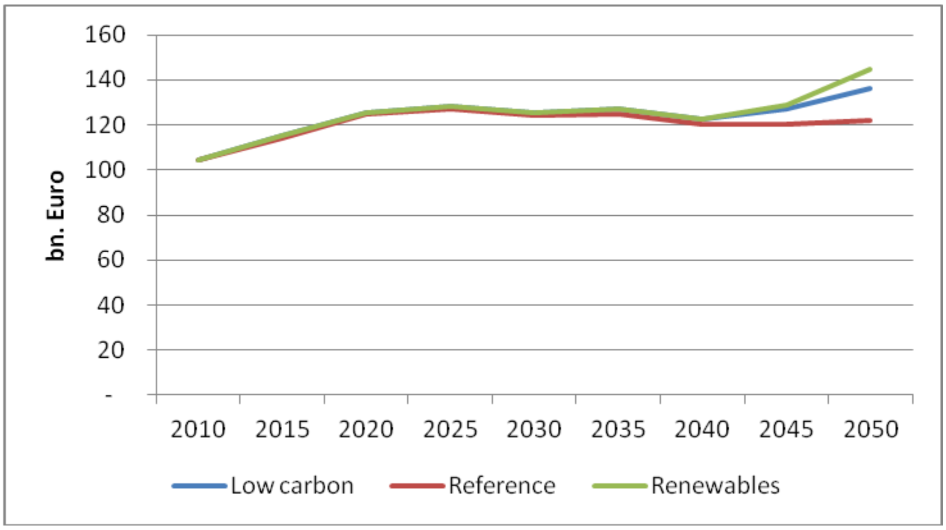

Figure 6: Total capital, fixed, variable and fuel costs in the scenarios (Billion euro/year)

Investments in transmission capacity

The study indicates that especially in the medium and long term, there is a need for large expansions of the transmission grid in the Baltic Sea Region (Figure 7). Current transmission capacities amount to approximately 45 GW[7], which is envisioned to increase to 60 GW in 2020 considering projects that are likely to be implemented.

In both of the low carbon scenarios the expansion of transmission capacity is crucial for the achievements of the emission reduction objective and in particular allows wind power to be utilised cost-efficiently in the region. In total the demand for transmission capacity increases to approximately 110 GW in 2050 in the Low carbon scenario and even higher in the low carbon RE scenario, 144 GW.

[7] This figure represents the capacities on the bottlenecks represented in the Balmorel model.

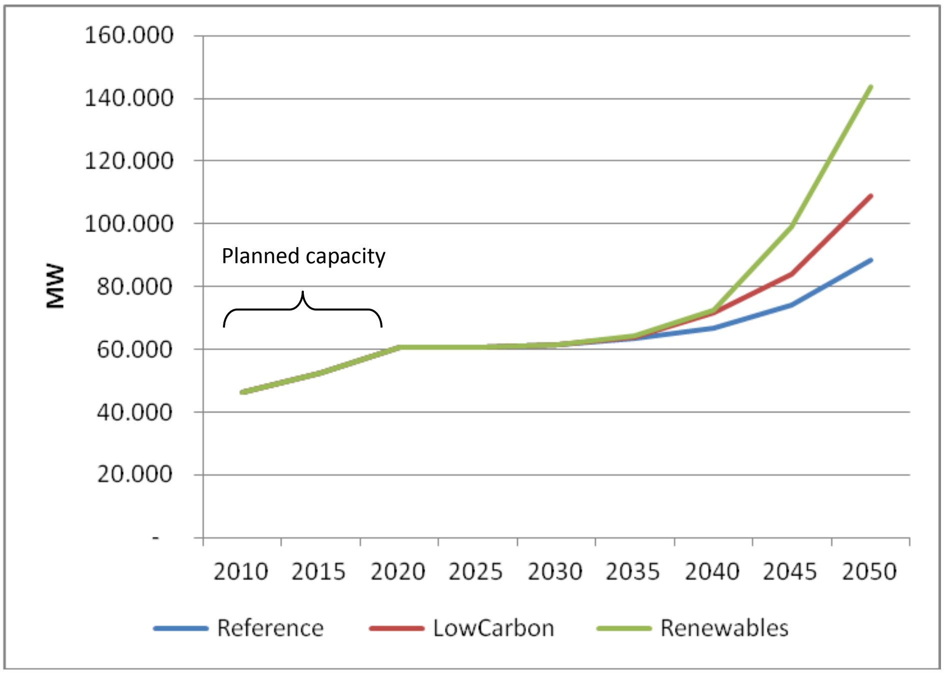

Figure 7: Total cumulated transmission capacity in the scenarios (MW/year). 'Planned capacity' concern transmission lines that are likely to be commissioned between 2011 and 2020, some connections have already been decided upon whereas others are being planned for.

Benefits of cooperation

The simulations show that

- regional cooperation on complying with the National Renewable Energy Action Plans of the BASREC EU member states could reduce the total costs of the Low carbon scenario by roughly 0.5% in 2020.
- linking the EU Emission Trading System with potential Russian CO_2-regulation would reduce total costs of the Low carbon scenario by 0.2% in 2020.
- when the countries in the Baltic Sea Region cooperate on expanding the transmission grid this reduces the total costs by roughly 0.5% in 2050 in the Low carbon scenario.

Key findings

Regional cooperation is the key

The study shows that it is technically possible to reduce greenhouse gas emissions in the electricity and district heating sectors of the Baltic Sea Region by close to 100% using mainly renewable energy sources. The results indicate that this is a challenging, but manageable task. The associated costs are moderate and can be further decreased through regional cooperation. Once the various production technologies have the possibility to interact with district heating and flexible electricity consumption, and transmission connections are optimally utilised, it becomes realistic to integrate e.g. large volumes of wind power into the energy system as a whole.

Furthermore, the hydro power reservoirs, particularly in Norway, play a key role in balancing the generation from wind power.

Ideas for further cooperation in the Baltic Sea Region

The results of this study lead to a number of ideas for strategies to further cooperation in the Baltic Sea Region in order to achieve the long-term target of a sustainable low carbon energy sector at lowest possible cost:

To develop ***a common Baltic Sea Region energy strategy and policy to reduce CO_2 emissions*** in the Baltic Sea Region. The strategy could rely on the following elements:

1. Developing ***a regional long-term strategy for new grid interconnectors*** building on the existing work of ENTSO-E[8] and the BEMIP[9] plan. As investments in the transmission grid have relatively long lead times, a regional strategy combined with a credible timetable for the swift expansion of the necessary transmission connections will have to be an integral part of energy policies for the reduction of CO_2 emissions in the Baltic Sea Region.
2. ***Further regional aligning of support schemes*** for renewable energy and other low carbon technologies, e.g. by developing cross-country tender procedures for off-shore wind farms or CCS power plants to ensure optimal locations of new generation facilities or by regional cooperation in the fulfilment of national renewable energy targets.
3. Making strong efforts to ***improve energy efficiency*** in the region, e.g. through sharing and identifying of best national practices. In particular, develop a regional ***action plan for efficient and sustainable heating*** involving the large cities in the Baltic Sea Region.
4. Testing ***common carbon emission trading schemes*** between ETS countries in the region (EU + Norway) and selected regions in the Russian Federation.
5. Develop a Baltic Sea Region demonstration project that could serve *as* ***showcase for sustainable energy systems*** for specific technologies including regional R&D funding.
6. Develop a regional program for ***training and education of energy planners*** in the Baltic Sea region building on an existing program such as the Baltic Rotating Energy Planning Academy (BALREPA).

[8] European Network of Transmission System Operators for Electricity and
[9] Baltic Energy Market Interconnection Plan

Key underlying assumptions

Fuel prices

In accordance with the EU energy roadmap 2050 different sets of fuel prices is used for the reference projection and the low carbon scenarios. The low carbon scenarios assume that global action is taken to significantly bring down greenhouse gas emissions; in other words reducing greenhouse gas emissions is not an isolated task of the Baltic Sea Region, but part of a global effort to combat climate change. This again reduces fossil fuel demand worldwide providing a downward effect on fossil fuel prices. Coal, oil and natural gas prices are therefore expected to be relatively low in the low carbon scenarios: oil price of 70 USD/boe in 2050 (127 USD/boe in the reference), a European gas price of 70 USD/boe in 2050 (98 USD/boe in the reference) and a coal price of 21 USD/boe in 2050 (34 USD/boe in the reference).

Energy efficiency

It is also an underlying assumption of the study that strong energy efficiency measures are put in place in all countries in the region to curb the demand for energy.

Meanwhile, electricity is expected to increase its role in a number of end-uses; a shift towards electrification of the transport sector; increasing utilisation of electricity for heating through the utilisation of efficient heat pumps (heat pumps can produce 2-4 units of heat while using only one unit of electricity to do so) and for process energy in industry. All things considered, the consumption of electricity in the region is assumed to increase only slightly through to 2050. The growth in electricity demand is highest in the countries where we expect the highest economic growth rates, for example the three Baltic Countries and Poland, whereas the demand is foreseen to decrease in other countries, for example in Germany (in accordance with national projections), as well as in Norway.

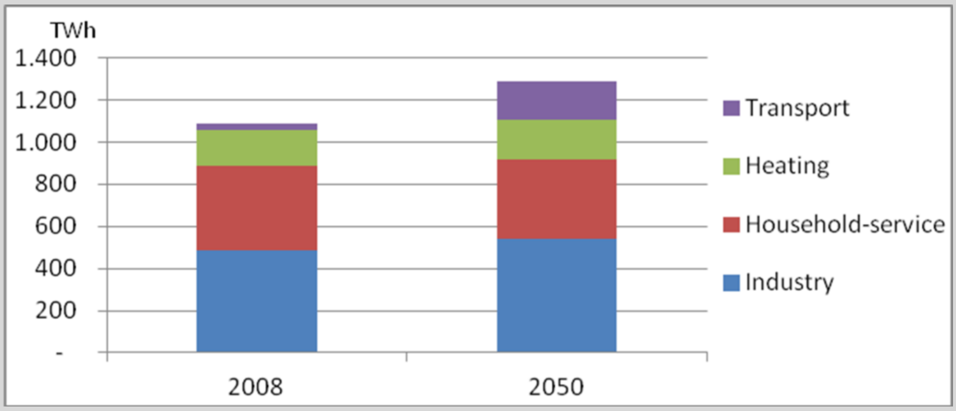

Figure 8: Electricity consumption (final energy demand excluding grid-losses) in the Baltic Sea Region in 2008 and the projection for 2050. Energy sector electricity consumption, for example electricity demand for district heating, is not included.

District heating

District heating is assumed to continue playing a prominent role in the heating sector as it enables the use of combined heat and power generation, which is one of the key measures to obtain a high level of energy efficiency.

Security of supply

The ensure security of supply it is assumed that 2/3 of the countries yearly electricity generation should be produced in the individual countries.

Key underlying assumptions

National Renewable Energy Action Plans

From now to 2020 the development in renewable energy in the EU countries are based on the national renewable energy action plans. This development is also kept as a minimum level of renewable energy generation for each country in all scenarios after 2020. The low carbon scenarios also take into account the German target to increase renewable energy in the electricity sector to 80 %. Norway has not published a NREAP but have agreed with the EU that the share of RE in their energy system should be 67.5 % in 2020. Statnett, the Norwegian TSO, expects 13.2 TWh of new RE generation in the electricity system by 2020 facilitated by their RE certificate scheme. It is therefore assumed that approx. 10 TWh of new wind power generation to come into operation by 2020, with half of it being commissioned by 2015.

CO_2 targets

The CO_2 reduction targets applied in scenarios are specified relative to emissions in 2005 for EU countries as well as Norway and relative to 2010 for Russia. We assume that the reduction of CO_2 emissions will be achieved in the geographical area and within the sectors included in the model, i.e. electricity generation and district heating generation. National CO_2 reduction targets are not considered. CO_2-emissions from waste are excluded from the targets.

CO_2-prices

CO_2-prices are an output of the simulations.

Biomass

Compared to the rest of the EU, and to the rest of the world, the Baltic Sea Region is endowed with relatively large amounts of bioenergy resources. Therefore, in the study the amount of biomass available for energy purposes in the Baltic Sea Region has been confined to the domestic resources, i.e. no import of biomass is assumed from outside the region.

Long-term bioenergy resource	Baltic Sea Region	EU25	World
PJ	6,800	12,400	200,000
Inhabitants in 2050 (mill.)	160	460	9,000
GJ/capita	42	27	22

Table 1: The bioenergy resources of the Baltic Sea Region, the EU25 and globally. The populations of the Baltic Sea Region and the EU are assumed to remain constant between today and 2050 whereas the global population is assumed to increase to 9 billion in 2050.

Nuclear power

It is chosen to specify a fixed development of nuclear power in the future electricity supply as opposed to letting the model make "optimal investments". This approach is chosen because the environmental externalities of nuclear power, such as the risks of nuclear accidents and the issues of long-term storage of radioactive waste, are difficult to monetize. For that reason, assumptions on nuclear power are based as much on political assessments and risk assessments as on financial calculations.

1 Background and scope

The Baltic Sea Region Energy Co-operation (BASREC) has decided to initiate a study on “Energy Policy Strategies of the Baltic Sea Region for the post-Kyoto Period”.

The background for the study is the recent development in international low carbon and energy issues. The challenges of achieving a long-term international low carbon agreement have significantly strengthened the relevance of local and regional energy and low carbon policy initiatives and the demand to develop complementary strategies at this level.

At the same time, previous analyses, such as the report “Sustainable energy scenarios – Energy perspectives for the Baltic Sea region” (Ea Energy Analyses, 2009), have indicated that the Baltic Sea Region has a strong potential to develop a low carbon and green energy economy. The region is endowed with vast natural resources in terms of biomass, wind and hydro power potential, and through its industrial and administrative competences it holds the technology and knowledge base, which is needed for a green transformation.

In this study, a number of policy scenarios are developed showing the economic consequences of different policy options and their implications for the energy systems, the environment, the security of supply and the economy. The policy scenarios are measured against a reference scenario.

The study focuses on the electricity and district heating sectors.

Research questions

The scenario analyses aim to address the following research questions

- *Can the Baltic Sea region become CO_2-neutral by 2050?*
- *What is the additional cost of achieving 30-40% CO_2-reduction in 2020?*
- *What are the benefits of harmonizing renewable energy support schemes?*
- *What are the benefits of a coordinated planning and expansion of the electricity transmission grid in the region?*
- *What are the benefits of linking the EU Emission Trading System with potential Russian CO_2-regulation?*

The table below describes how the different questions are approached analytically.

Can the Baltic Sea region become CO_2-neutral by 2050[10]?	Simulation of power and heating systems till 2050 using an economic optimisation model to find least cost investments given the provision of framework conditions and technology cost. By comparing the CO_2-neutral scenario with a reference development the additional costs is computed.
What is the additional cost of achieving 30% CO_2-reduction of the Baltic Sea Region in 2020[10]?	In the reference development a 20 % CO_2-reduction is achieved in the region by 2020[10]. Alternative simulations are made for 2020 with 30 % CO_2-reduction targets to illustrate what the additional costs will be of achieving these targets.
What are the benefits of harmonizing renewable energy support schemes?	In the reference the development of renewable energy generation is based on the projections in the national renewable energy action plans. In 2020 an analysis is made, which includes the same total RE deployment in the region but excluding any constraints on geographic location of the new capacities.
What are the benefits of a coordinated planning and expansion of the electricity transmission grid in the region?	Provided the investments costs of expanding interconnectors in the region the model is able to compute an optimal grid development. To estimate the benefits of a coordinated grid expansion, the optimal grid development is compared to a situation where the possibilities for establishing cross-border interconnectors are removed.
What are the benefits of linking the EU Emission Trading System with potential Russian CO_2-regulation?	All countries in the region except Russia are encompassed by the EU's emissions trading scheme. In the reference scenario Russia is subject to a national CO_2-target. The benefits of linking the EU scheme and the Russian target are examined by imposing a common cap on CO_2 for the whole region, which gives the same absolute CO_2-reduction as the reference. The hypothesis is that cheaper CO_2-abatements measures are available in Russia leading to lower overall compliance cost for the region if the schemes are linked.

Table 2: Research questions and how they are addressed in the study.

The project has been carried out in close cooperation with BASREC. However the content of this report, calculations and recommendations are the sole responsibility of Ea Energy Analyses.

The report is structured around four main chapters:

[10] These target refer to all BASREC countries except Russia for which less ambitious targets have been assumed, see section 2.2

Chapter 2 provides an introduction to the region and describes the scenario setup and the most important assumptions for the study.

Chapter 3 describes the results of the scenario analyses. It looks at the development of the energy systems towards 2020 - a reference development with 20% requirement to CO_2-reductions is compared to projection with a stronger target of 30 % CO_2-reduction. The chapter also explores how the regions electricity and district heating systems could become CO_2-neutral by 2050.

Chapter 4 presents the results of a number of policy measure analyses. It investigates the benefits of strengthening the electricity grid in the region. It shows where expansions in the transmission grid will be needed and assesses the benefits of a coordinated grid expansion in the region compared to a situation where the possibilities for establishing cross-border interconnectors are limited. This chapter also assesses possible benefits of a harmonised renewable energy support scheme in the region as well as the benefits of linking potential Russian CO2 regulation with the EU ETS.

2 Starting point and key assumptions

The geographical scope of this study is the Baltic Sea Region comprising the countries of Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland and Sweden as well as the north western part of Russia.

The Baltic Sea Region by this definition holds a total population of around 165 million people with an aggregated gross electricity consumption of approx. 1300 TWh. This corresponds to close to 40 per cent of the total electricity demand in the EU.

The largest electricity load centres are located in the south of the region in Germany and Poland – the two countries with the highest population (as the study only considers North West Russia) – but Norway, Sweden and Finland also has relatively high electricity demand due to high consumption of electricity for heating purposes and the presence of energy intensive industries.

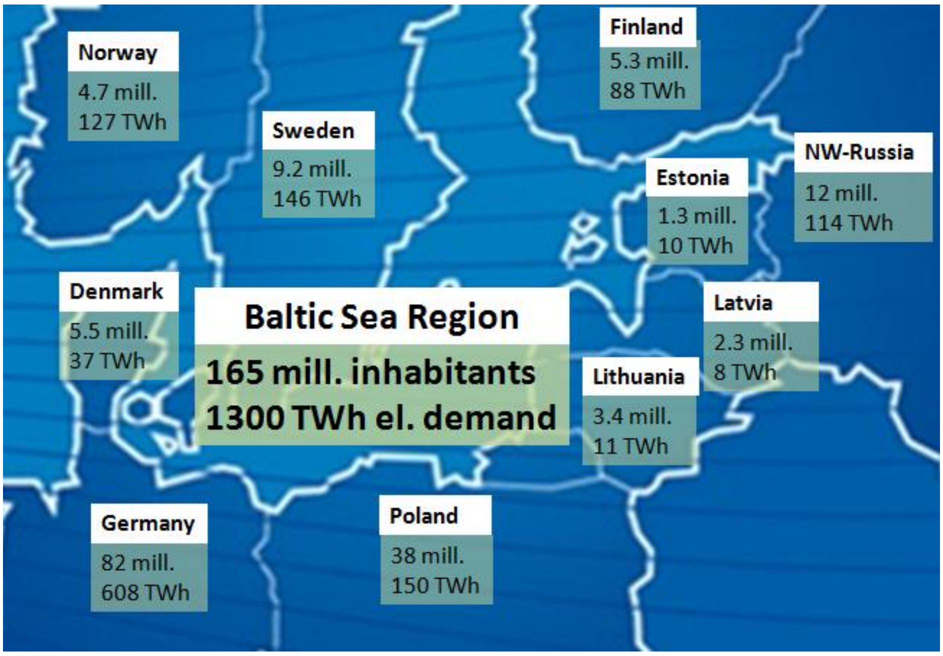

Figure 9: Inhabitants and gross electricity demand (2008) in the Baltic Sea Region

A region which is rich in resources

The countries surrounding the Baltic Sea are rich in resources for energy production – both fossil fuels and renewables. Significant gas reserves are available in Norway and Russia; Germany and particularly Poland have substantial coal resources and Norway has large oil reserves.

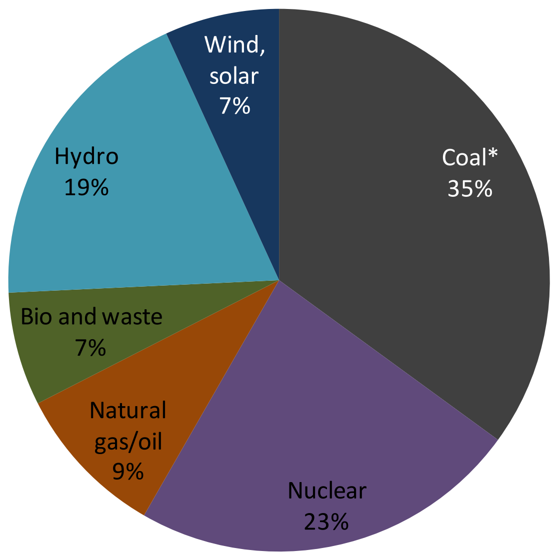

*Figure 10: Energy sources for electricity generation in the Baltic Sea Region in 2010. Simulation with the Balmorel model. *The fuel category "coal" includes lignite, oil shale and peat.*

Hydropower is an important source of electricity generation in Norway, Sweden, Finland and Latvia. Biomass resources are significant as well, deriving from both agricultural residues and from the large areas covered by forests. Wind power already contributes considerably to electricity generation, particularly in Denmark and Germany, and is likely to play a much greater role in the region in the years to come, both onshore and offshore.

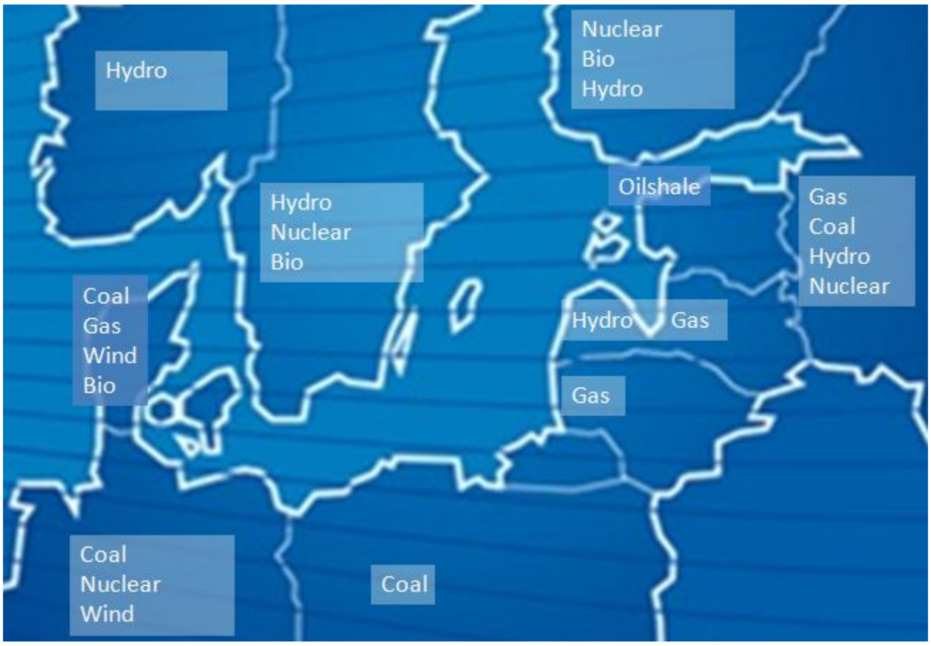

Figure 11: The most important sources of electricity generation in the region today.

In the longer term, solar power and heating and geothermal energy may also provide notable contributions to the overall energy supply.

District heating

The majority of the countries in the Baltic Sea Region have well developed district heating systems. The gross demand for district heating in region is 2050 PJ (570 TWh) corresponding to some 43% of the demand for electricity.

Still there is a potential to further expand district heating grids in parts of the region, particularly in Germany and to a lesser degree in Poland[11]. From an energy resource point of view, this offers huge benefits as combined heat and power generation increases the fuel efficiency of power plants from around 40 per cent (electricity only) to approx. 90 per cent (electricity and heat). District heating also offers consumers a high level of security of supply as multiple fuels may be used for its generation.

In the future, district heating systems can provide a valuable storage medium for wind power by using surplus electricity generation for heating in electric boilers and heat pumps. On the other hand decreasing heat loads as a result of energy savings may challenge the competitiveness of district heating because of the relatively high capital costs of the technology[12].

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[11] The possibilities for expanding district heating supply has been examined on an EU-wide scale in the project ECOHEATCOO (Euroheat & Power, 2005-6) , see work package 4, "Possibilities with more heating in Europe" http://www.euroheat.org/files/filer/ecoheatcool/documents/Ecoheatcool_WP4_Web.pdf

[12] "Long-term Views of District Heating and CHP in the Nordic and Baltic Countries", Energy-AN Consulting (2011) http://www.epha.ee/File/BASREC_AGEE_Future_of_Nordic_DH_Report_Final_3_30.8.2011.pdf

The electricity systems are interconnected

All countries surrounding the Baltic Sea are electrically connected directly or indirectly. Still, power is to a large extent traded on a country level or within smaller regions, though this may change in the future.

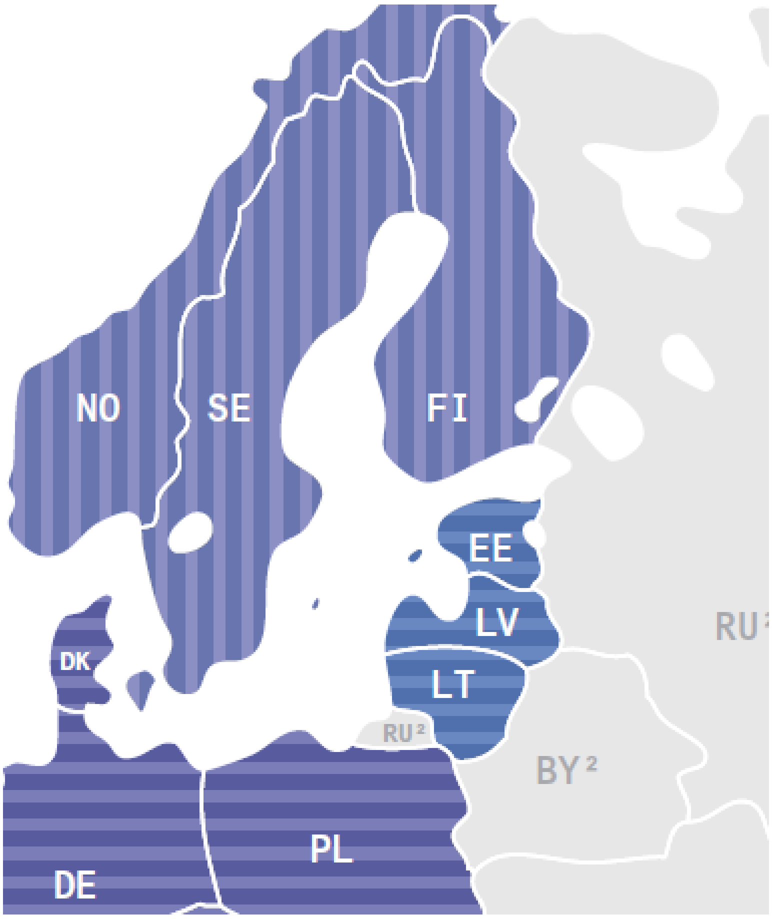

Figure 12: Power systems of the Baltic Region, synchronous areas. Source: ENTSO-E (Factsheet 2011)

Despite a common frequency of 50 Hz the region comprise three different synchronous areas: the Nordic area (Norway, Sweden, Finland and Eastern Denmark), the continental European area (Germany, Poland and Western Denmark and more than 20 other European countries) and the Baltic synchronous area which covers the three Baltic countries and is synchronous with the Russian power system UPS. Between the synchronous areas power exchange can only take place through HVDC links.

The transmission system operators in the EU countries in the region and Norway are organised within ENTSO-E.

Whilst the Nordic countries and central Europe are presently well interconnected, the three Baltic countries are currently only able to exchange energy with Nordic countries through a single interconnector between Estonia and Finland (EstLink). However, new interconnectors are scheduled, which will connect Lithuania with Sweden, Poland with Lithuania and reinforce the connection between Estonia and Finland.

On the way to a common regional electricity market

The Nordic countries – and from 2010 Estonia – form a common power exchange (Nord Pool) jointly owned by the transmission system operators. In Germany power is exchanged through the European Energy Exchange and in Poland through the Polish Power Exchange.

Nord Pool and the European Power Exchange are linked through so-called market coupling to ensure efficient use of existing cross-border interconnections. In the future, as the electricity grids around the region are further integrated, it is likely that we will see a fully integrated electricity market covering the Baltic Sea Region.

The EU has been pushing for a long time to improve market cooperation and an initiative has been launched between power exchanges and the transmission system operators (TSOs) to form a common market in Northwest Europe by 2013. This market will encompass not only the countries in the Baltic Sea Region (Russia excepted) but also France, the Benelux and Austria[13].

Reform of the Russian electricity sector

In Russia the reformation and liberalisation of the electricity sector was completed in 2010. This included an unbundling by separation of generation capacity from transit and distribution, with transit being controlled by the state and the other two being open for competition.

The Russian market now consists of eight wholesale generating companies of which six are based on thermal generation and two state-owned companies: a company consisting of only hydro power plants (RusHydro) and a company consisting of all nuclear power plants (Rosenergoatom). In addition, there are 14 so-called territorial generating companies consisting of the smaller power plants and combined heat and power plants[14].

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[13] News from Statnett (15-09-2011) http://www.statnett.no/en/News/News-archive-Temp/News-archive-2011/Statnett-leads-the-work-of-establishing-the-worlds-largest-multinational-power-market/

[14] Roadmap of the EU-Russia Energy Cooperation until 2050 Progress report July 2011, http://ec.europa.eu/energy/international/russia/press_en.htm

A road-map for EU-Russia cooperation

In the longer-term perspective it is likely that the markets of the EU and Russia may be closer linked via market coupling of day-ahead markets. According to the "Roadmap of the EU-Russia Energy Cooperation until 2050" the *"objective should be a continent wide interconnected electricity market by 2050"*. The road-map mentions increasing reliability and accountability of electricity supplies in a future with significantly higher share of intermittent renewable energy sources as one of the desired outcomes of increased market cooperation.

2.1 Policy targets in the region

In March 2007, EU leaders agreed on three key targets for 2020: improving the energy efficiency by 20 %, reducing greenhouse gases by at least 20 % and increasing the share of renewable energies in the energy consumption by 20 %. Since then the targets have been transformed into concrete policies and regulation committing the EU countries to act.

Energy efficiency target

The energy efficiency target is formulated as a 20 % saving of primary energy consumption compared to projections/baseline in 2020. The target covers the EU as a whole and is not nationally binding. In most recent projections, which take into account measures implemented at national and European level up to the end of December 2009, consumption in 2020 is expected to be at a level equivalent to a saving of only 9%.

In June 2011 the European Commission followed up on the Energy Efficiency Plan with its proposal for an Energy Efficiency Directive. The Directive establishes a common framework for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's target of 20% primary energy savings by 2020 and to pave the way for further energy efficiency improvements beyond that date. The measures in the proposed directive include among other things mandatory yearly savings of 1.5 %, through energy efficiency schemes in all Member States, 10-year national heating and cooling plans and waste heat recovery obligation for new and existing power and industrial plants.

Reduction of greenhouse gases

In connection with COP 15 the EU made a conditional offer to the Copenhagen Accord to increase the reduction target for 2020 to 30 % depending on the international negotiations.

In October 2009 the European Council agreed to set out a long-term objective to reduce the emissions of GHG by 80-95 % in 2050 compared to 1990 levels. In March 2011, this decision was followed by "A Roadmap for moving to a competitive low carbon economy in 2050", showing possible actions up to 2050 which could enable the EU to reduce greenhouse gas reductions in line with the 80 to 95 % target. The road-map shows that electricity is likely to play a central role in the low carbon economy. By 2050 CO_2-emissions can be almost totally eliminated offering the prospect of only partially replacing fossil fuels in other sectors, such as the transport sector where the alternatives are less obvious.

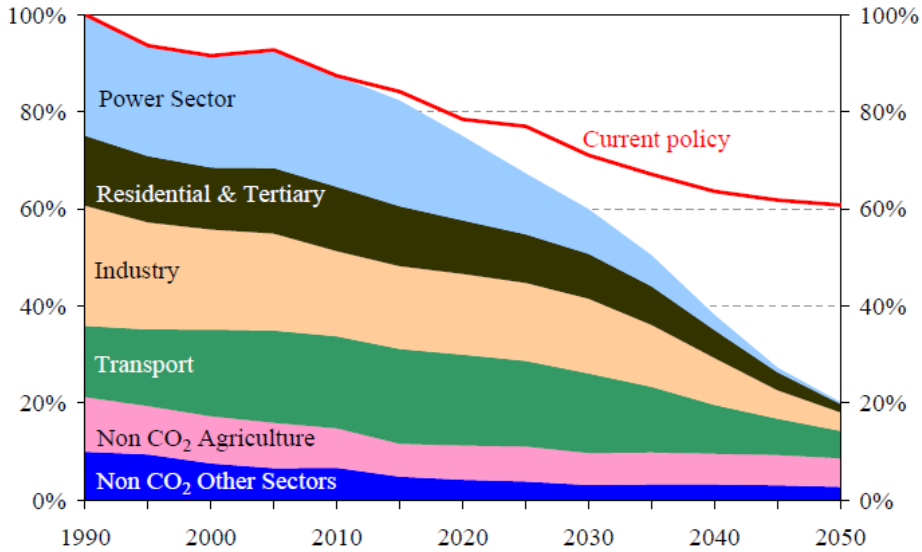


Figure 13: A pathway for reducing greenhouse gas emissions in the EU ("A Roadmap for moving to a competitive low carbon economy in 2050", COM(2011) 112 final)

In December 2011 the Climate Road Map was followed by the Energy Roadmap 2050. By combining in different ways four main decarbonisation routes (energy efficiency, renewables, nuclear and CCS) the energy road-map explores how Europe's energy production could become almost carbon neutral.

The Energy Strategy of Russia till 2030 includes a target reduce greenhouse gas emissions by 2030 to below the level of 1990. Russia has also submitted a conditional target of 15-25 % reduction in 2020 compared to 1990, which is subject to allowance for carbon sinks from the Russian forests.

In addition, Russia has a target to increase the share of electricity produced from renewable energy sources to 4.5 % by 2020 and to significantly improve the energy efficiency.

The EU ETS

The EU ETS covers the majority of fossil fuel power plants in the EU as well as the energy intensive industry. The emission trading scheme is one of the most important tools of the EU to comply with the target of reducing CO_2-emissions by 20 % compared to 1990. By 2020 all companies encompassed by the EU ETS should on average reduce their emissions by 21 % compared to 2005.

Because of the significant biomass and wind power potentials in the Baltic Sea Region it is expected that on average the CO_2 abatement cost in the electricity sector in the region is lower than for companies encompassed by the EU ETS. This would give incentives to reduce CO_2-emissions in the region beyond the targets. On the other hand, the EU ETS allows companies to import carbon credits from CDM projects as a means to comply with the targets. Thereby lowering the requirement to reduce CO_2-emissions domestically within in the EU ETS countries.

All things considered, it was chosen to apply 20 % reduction compared to 2005 as a realistic reduction target for 2020 for the electricity and district heating sector in the reference scenario for the BASREC EU ETS countries. A 30 % target for 2020 will be applied for the Low carbon scenarios.

2.2 Scenario setup

Focus on electricity and district heating

The analyses in the present study focus on the possibilities of transforming the electricity and heating systems in the region. Scenario analyses are used to explore how the power markets may evolve in the future to comply with strategic targets to reduce CO_2-emissions in the region. The intention is to show a least cost strategy – however keeping in mind, that developing a least cost strategy is dependent on a number of uncertain factors such as the future fuel prices and the technological development of key technologies.

The analyses are made for five year intervals for the period 2010 – 2050, but with a particular focus on the ways to achieve the targets set-out for 2020 and 2050. The scenarios are specified to show alternative ways to comply with the objectives to reduce CO_2-emission in the region.

One reference scenario and a so-called low carbon scenario with more ambitious CO_2-targets are developed for 2020. Towards 2050 the low carbon scenario is separated into two low carbon scenarios, which differ regarding the role of CCS. The *low carbon renewables scenario* explores a future where fossil fuels are phased out altogether, whereas in the *low carbon scenario* carbon capture and storage technologies become an important part of the solution to reducing CO_2-emissions in the longer term.

In addition a number of policy scenarios and sensitivity analyses are made.

Reference scenario

The reference scenario differs from a traditional passive business as usual projection by showing a way forward to actually achieving the EU targets of reducing CO_2-emissions by 20 % in 2020 and increasing the share of renewable energy to 20 %. Beyond 2050 the EU CO_2-legislation is not yet in place. In the reference development an arbitrary target of 50 % CO_2-reduction is stipulated by 2050[15].

With respect to Russia the reference assumes stable CO_2-emissions in 2020 and a 25 % reduction in 2050.

It is important to stress, that the targets, which are implemented in the model do only concern power and district heating.

Low carbon scenarios

The low carbon scenarios assume 30 % reduction of CO_2-emissions in the EU by 2020. By 2050 the low carbon scenarios assumes that the region commits to the long-term EU target to reduce greenhouse gas emissions by 80-95 % by 2050. As specified in the EU's climate and energy road maps this would require close to a 100 % reduction of CO_2-emissions by 2050 in the power and heating sector to allow for a certain level of greenhouse gas emissions from the transport sector and the agricultural sector (where abatement costs are generally viewed to be higher).

With respect to Russia the reference scenario assumes stable CO_2-emissions in 2020 and a 25 % reduction in 2050 compared to 2010. The low carbon scenarios assume 15 % reduction in 2020 and 50 % reduction in 2050.

[15] The reference projection in the EU Climate Road Map foresees that CO_2-emissions from the EU power sector are reduced from approx. 1400 Mt in 2005 to approx. 500 Mt in 2050. This corresponds to a reduction of around 65%.

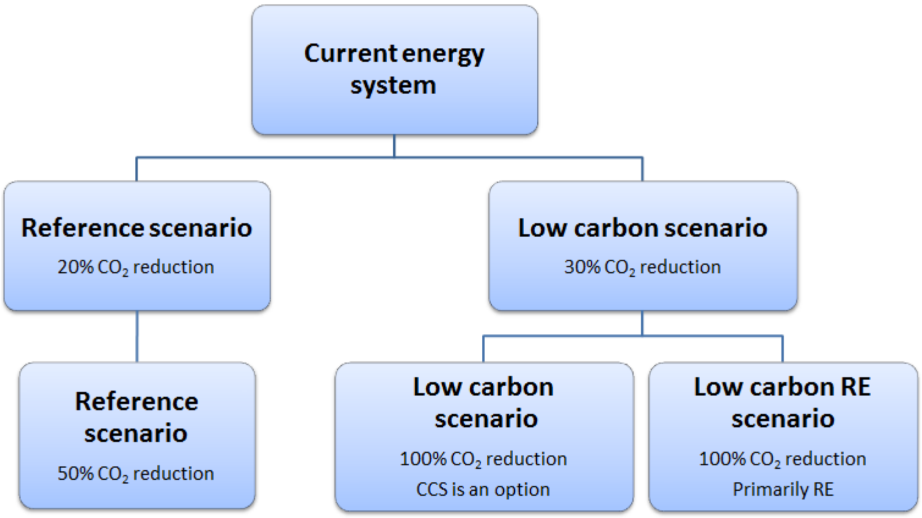


Figure 14: Overview of the scenarios analysed in the study. The reduction figures showed in the diagram are relative to 2005 and concern the EU countries and Norway (ETS[16] countries). In North West Russia, which constitutes approx. 7 % of electricity demand in the region, the reference assumes stable CO_2-emissions in 2020 and 25 % reduction in 2050 compared to 2010 emissions. The low carbon scenarios assume 15 % reduction in 2020 in Russia and 50 % reduction in 2050 compared to 2010 emissions. The specified reduction targets concern CO_2-emissions from power and district heating generation. Emissions from municipal solid waste are not subject to the cap.

Theory on scenarios

Often you distinguish between three types of scenarios: Predictive scenarios, explorative scenarios and anticipative scenarios. Predictive scenarios show the predicted future, and aim at illustrating what future seems most likely given the continuation of current trends. Explorative scenarios show several plausible futures and can be used to discuss, which futures are possible and how to prepare for sets of equally plausible futures. Anticipative scenarios are used to show the desirable future and how to get there

The present scenarios intend to be both anticipative and explore perspectives of the future energy systems in the Baltic Sea Region. The scenarios are anticipative in the sense that they examine how a concrete target of net carbon neutrality can be achieved by 2050. At the same time they are explorative because they examine different routes to achieving the same target.

Tools to reduce CO_2-emissions

The two most notable “tools” to reduce future CO_2-emissions in power and heating sectors in the Baltic Sea Region are probably to use energy more efficiently and to increase the share of renewable energy. In addition to that nuclear power, depending on the political and public support in the different countries in the region, and CCS may also play a key role.

[16] EU Emissions Trading System for trading of greenhouse gas emission allowances.

CCS differs from the other key technologies because it is not fully developed today. As the IEA states in the report Energy Technology Perspectives 2010 (IEA, 2010) "Carbon capture and storage from power generation has only been demonstrated with sub-commercial volumes of flue gas, from small pilot plant or from flue-gas slip-streams from larger plant. Challenges associated with scaling up and integrating these technologies at scale need to be overcome. [...]. The demonstration of CO_2 capture from power generation in the next ten years will be critical to accelerating wider deployment between 2020 and 2050"

Another question relates to the risk of leakage from deposits of stored CO_2. According to the IEA "Monitoring data from projects involving injection into depleted oil and gas fields and saline formations have shown that the CO_2 performs as anticipated after injection, with no observable leakage."[17]. Liability issues related to potential leaks may however impede the development of large-scale CCS.

2.3 Modelling tool

The quantitative analyses are made with Balmorel[18], which is a least cost dispatch power system model. The model is based on a detailed technical representation of the existing power system; power and heat generation facilities as well as the most important bottlenecks in the overall transmission grid. The main result in this case is a least cost optimisation of the production pattern of all power units. The model, which was originally developed with a focus on the countries in the Baltic region, is particularly strong in modelling combined heat and power production.

In addition to simulating the dispatch of generation units, the model allows investments to be made in different new generation units (coal, gas, wind, biomass, CCS etc.) as well as in new interconnectors. A separate analysis on the cost of establishing new interconnectors in the region has been prepared for the project (Ea Energy Analyses 2012, Costs of transmission capacity in the Baltic Sea Region), which estimates the cost of the individual potential new transmission line of the region.

A limit is imposed on the potential to expand grid connections for each 5 year period. This limit is 1000 MW on sea cables and 3000 MW for grid reinforcement on land - except in Germany where the limit is 6000 MW.

[17] IEA, 2010: Energy Technology Perspectives 2010
[18] The Balmorel model and dataset is further described in appendix 1.

These limitations are included to ensure a gradual development of the grid in the region.

Economic analysis

Balmorel is also capable of reflecting political framework conditions such as taxes and quotas and to assess the economic consequences for different stakeholder groups such consumers, producers, grid owners, countries or the region as a whole.

2.4 Key assumptions

Fuel price projection
The fuel price assumptions of the project are based on the EU Commission's Energy Roadmap 2050.

In the energy roadmap the EU Commission uses different sets of prices for its reference projection and decarbonisation scenarios: "The decarbonisation scenarios are based on "global climate action" price trajectories for oil, gas and coal reflecting that global action on decarbonisation will reduce fossil fuel demand worldwide and will therefore have a downward effect on fossil fuel prices. Oil, gas and coal prices are therefore lower than in the Reference scenario and Current Policy Initiative scenario".

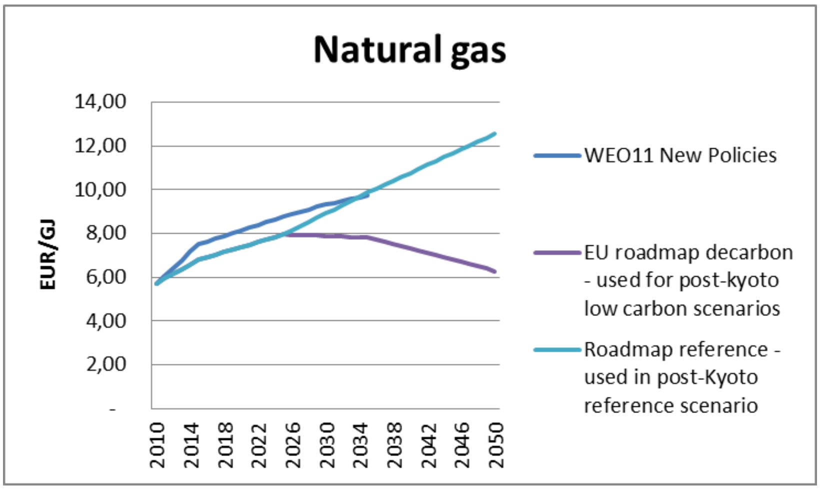
In the present project we used a similar approach with one set of fuel prices for the reference scenario – using the EU reference fuel prices – and another in the low carbon scenario – using the prices in the EU decarbonisation scenarios.

Since the demand for energy in the Baltic Sea Region is likely to have a relatively moderate impact on fossil fuel prices in the region (these are rather shaped by global supply-demand relations) the set of fuel price assumptions implicitly presumes that the climate policies in the Baltic Sea Region reflect similar global policies; i.e. the effort to reduce GHG emissions in the Baltic Sea Region is dependent on a proportionate global effort.

There is a markedly difference in oil prices between the reference and the decarbonisation scenario. In the reference scenario the oil prices reaches 106 USD per barrel in 2030 increasing to 127 USD per barrel in 2050, whereas in the decarbonisation scenarios it drops to 79 USD per barrel in 2030 and further to 70 USD per barrel in 2050. Prices are in constant USD of 2008.

In the power and district heating sector in the Baltic Sea Region, where oil demand is rather limited, particularly the relationship and evolution of the ratio of gas and coal prices influence the investment choices taken by investors. The two graphs below show fuel price assumptions for natural gas and coal in the EU energy road. For comparison the latest fuel price projection from the IEA's World Energy Outlook is also included.

Particularly, it is important to notice the difference in gas prices beyond 2020. In 2050 the gas price in the EU road-map decarbonisation scenarios is close to 50 % lower in 2050 than in the reference.



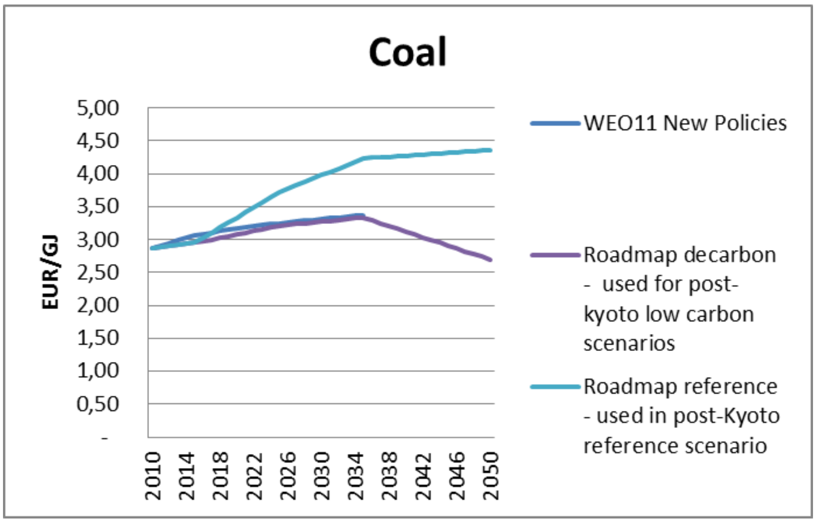


Table 3: Fossil-fuel import price assumptions.

The development in gas prices is associated with a fairly high level of uncertainty, particularly related to the availability of unconventional gas resources. Unconventional gas supplies include resources like shale gas, tight gas and coal-bed methane. Poland has already granted a large number of concessions for exploration of unconventional gas, and activities are also underway in Germany.

Figure 15 shows how gas prices have developed since 2008. Historically the price of gas has been linked to the oil price, but during recent years a decoupling has been observed in certain markets – most profoundly in the United States where gas prices are now considerably lower than oil prices.

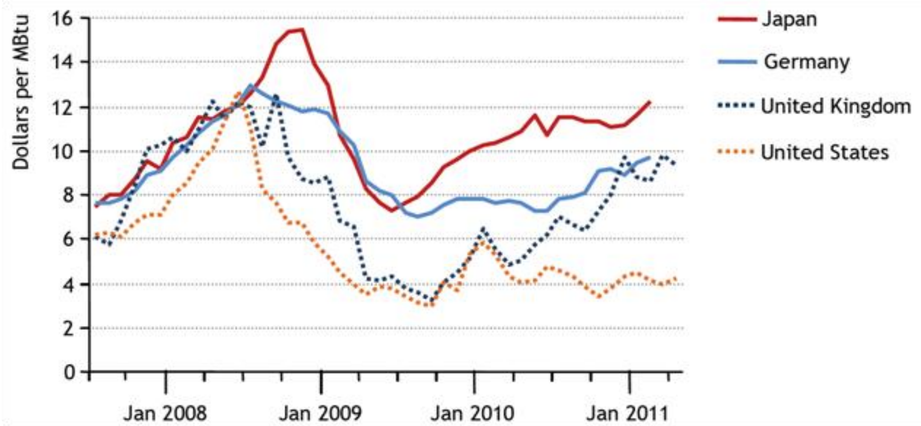


Figure 15: The development of gas prices between in 2008 and 2011 in Japan, Germany, the United Kingdom and the United

Moderately increasing fuel prices

Since Norway, the Baltic countries and Russia are located closer to large gas reserves than any of the other countries in the region, it is assumed that gas can be bought at a lower price in these countries (10 % discount in Norway and 20 % discount in Russia, Finland and the three Baltic countries[19]).

It should be stressed, that a breakthrough in CCS technology may result in increased demand for fossil fuels (especially coal) at the global level, which in turn, may cause fossil fuel prices to increase radically in relation to the prices assumed in the analysis.

Four fractions of biomass are considered in the project: straw, wood chips, wood waste and wood pellets. Assumptions on biomass prices are based on an analysis prepared for the Danish Energy Agency[20] since biomass prices have not been available from the Energy Roadmap 2050. In the low carbon scenarios the biomass prices have been adjusted upwards to take into account that ambitious global climate policies will increase the demand – and thereby the price – biomass. The price of wood pellets – which is an

[19] It should be noticed that gas is currently sold at relatively high prices in the Baltic Countries; however this price level is more likely a results of having only a single supplier rather than costs of transporting the gas.
[20] The report "Opdatering af samfundsøkonomiske brændselspriser BIOMASSE" (Ea Energianalyse & Wazee, 2011) is only available in Danish.

international commodity – is assumed to be 25 % higher in 2050, whereas straw, wood chips, wood waste are projected to be 10 % higher in 2050.

Implementation of renewable energy targets

The EU renewable energy directive requires all member states to increase their share of renewable energy towards 2020. The directive provides a legally binding target for the share of renewable energy of final energy in each member state, but not a separate target for the electricity sector.

To ensure progress and compliance with the directive each member state has to provide a detailed roadmap – a National Renewable Energy Action Plan (NREAP) – showing how it expects to reach its 2020 target for the share of renewable energy, which includes a detailed plan for the development of RE in the electricity system. In this study the information from the NREAPs are used to specify how the expansion of renewable energy in the electricity will take place in each country towards 2020. The concrete assumption about, which technologies will be promoted and timing of the implementation are stipulated in the data report.

Country	2010	2015	2020
Denmark	34.3%	45.7%	51.9%
Sweden	54.9%	58.9%	62.9%
Finland	26.0%	27.0%	33.0%
Germany	17.4%	26.8%	38.6%
Poland	7.5%	13.0%	19.1%
Lithuania	8.0%	17.0%	21.0%
Latvia	44.7%	51.4%	59.8%
Estonia	1.7%	3.5%	4.8%

Table 4: Projected % share of gross final electricity consumption as reported in the National Renewable Energy Action Plans, 2010.

In the study we assume that the above shares of renewables in electricity generation as a minimum are maintained between 2020 and 2050. In the model the above targets are implemented on a technology specific level, which e.g. means that the German plans for development of solar PV will take place. Therefore, towards 2050 the target to reduce CO_2-emissions – reflected in a price of emitting CO_2 – takes over as the main driver for increasing renewable energy generation.

From 1 January 2012, Norway and Sweden form a common market for renewable energy certificates. Up to 2020, Norway and Sweden intend to expand their electricity production based on renewable energy sources by 26.4 TWh. This target is used to estimate renewable energy development in Norway to 2020, as Norway has not developed a National Renewable Energy Action Plan. The Norwegian system operator, Stattnett is preparing the grid to accommodate for at least 13.2 TWh of new renewable energy generation[21]. Norway has not published a NREAP but have agreed with the EU that the share of RE in their energy system should be 67.5 % in 2020. Statnett, the Norwegian TSO, expects 13.2 TWh of new RE generation in the electricity system by 2020 facilitated by their RE certificate scheme. It is therefore assumed that approx. 10 TWh of new wind power generation to come into operation by 2020, with half of it being commissioned by 2015.

In Denmark the study takes into account the recent decision to increase wind power generation to match 50 % of electricity demand in 2020. This means that Denmark will exceed the projected share of renewable energy in the electricity supply which is stated in the NREAP.

Existing subsidies and energy taxes

Many countries in the region are already supporting renewable energy technologies through feed-in tariffs, premiums to the electricity market price, certificate systems, favourable taxation etc. These policy measures are not directly considered in the study, but their impact is simulated via the above-mentioned targets for renewable energy.

Technical opportunities

The model has a technology catalogue with a set of new power generation technologies that it can invest in according to the input data. The investment module allows the model to invest in a range of different technologies including (among others) coal power, gas power (combined cycle plants and gas engines), straw and wood based power plants, power plants with CCS and wind power (on and off-shore). Thermal power plants can be condensing unit – producing only electricity, or combined heat and power plants. The model is also able to rebuild existing thermal power plants from the existing fuel to another. The model can, at a lower cost than building a new power station, rebuild a coal fired plant to a wood pellets or wood chips and natural gas fired plant to biogas. Wave power and solar power technologies are also included in the technology catalogue.

Basic technical and economic data for the power generation technologies that the model may invest in can be viewed in Table 5 on page 36. The technology assumptions develop from now to 2050, which means costs and efficiencies

[21] "Nettutviklingsplan 2011" Statnett, 2011, p. 4.

are assumed to develop depending on the learning curve of the specific technology. This development can be seen from the intervals presented in the table below. Generally the technologies develop to have higher efficiencies and lower investments costs.

Figure 16 shows the levelised cost of generating electricity from a number of key technologies in 2050 with fuel prices of the low carbon scenarios and a CO_2 price of 136 €/ton (corresponding to the price in the Low carbon scenario in 2050). With these fuel and CO_2 prices wind power is the most competitive source of electricity measured on an energy basis, but its level of utilisation is constrained by its intermittency and relatively low capacity factor.

Assuming 8000 full load hours for thermal power plants, as is the case in Figure 16, coal CCS, gas CCS, biomass CCS and gas power have more or less the same generation costs.

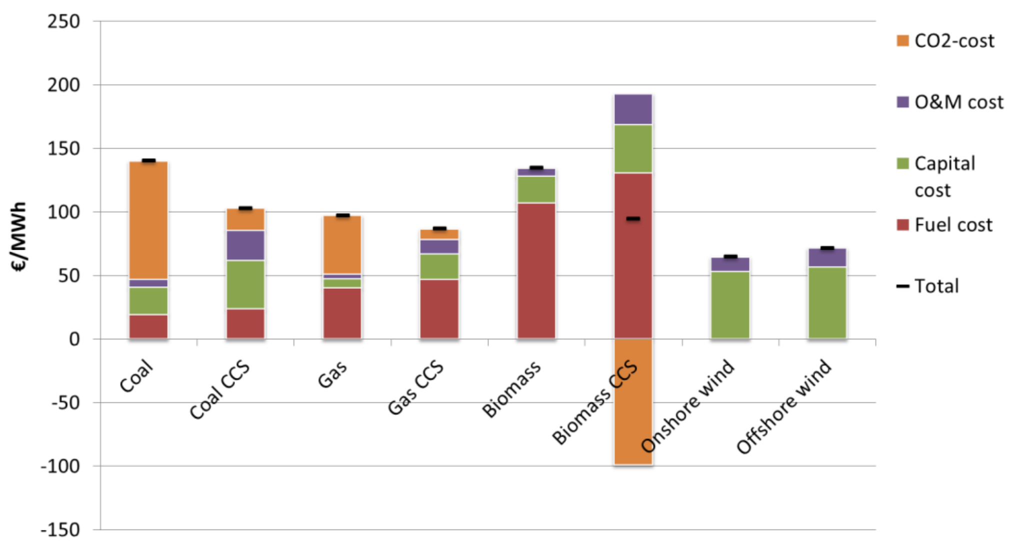


Figure 16: Levelised electricity generation costs in 2050. Fuel price assumption: Coal: 2.7 €/GJ, Natural gas: 6.7 €/GJ, Wood-pellets: 15 €/GJ. The calculations 20 year depreciation time, 10 % IRR (Internal Rate of Return), a carbon price 135 €/ton CO_2 and 8000 full load hours for thermal power plants.

With increasing penetration of wind power and other types of intermittent electricity generation the operation time of thermal power plants will decrease. In Figure 17 the number of full load hours is decreased to 4000 for thermal power plants. In this case gas power and gas CCS becomes relatively more competitive than coal CCS and biomass CCC as the latter power generation technologies have higher investment costs.

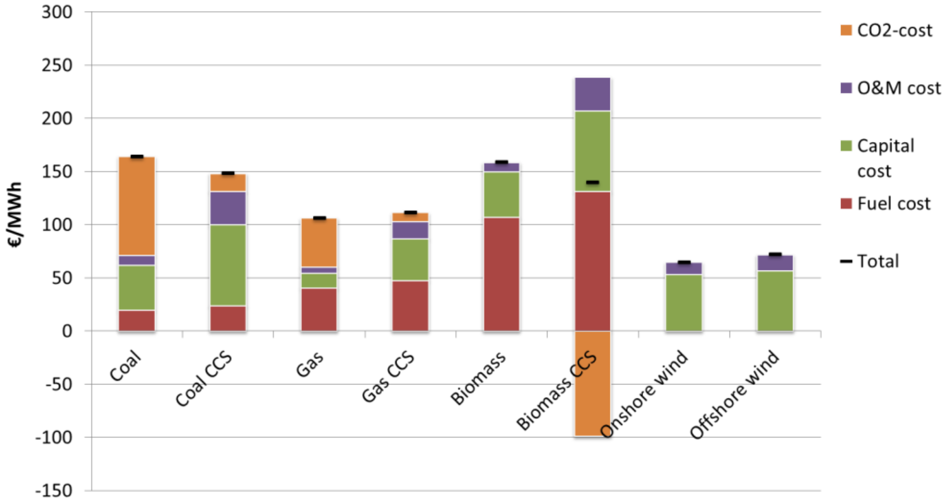


Figure 17: Levelised electricity generation costs in 2050. Fuel price assumption: Coal: 3.7 €/GJ, Natural gas: 12 €/GJ, Wood-pellets: 12 €/GJ. The calculations 20 year depreciation time, 10 % IRR (Internal Rate of Return), a carbon price 135 €/ton CO_2 and <u>4000 full load hours</u> for thermal power plants.

Technology type	Fuel type	Investment cost (mil. €/MW_{el})	Fixed O&M (€1000/MW_{el})	Variable O&M (€/MWh_{el})	Electric efficiency *Condensing mode*	Electric efficiency *CHP mode*	Total efficiency *(Elec. + heat)*
Condensing	Coal	1.5	22	3.6	44-50%	-	44-50%
Condensing	Wood pellets	1.5	22	3.6	43-49%	-	43-49%
Condensing	Natural gas	1.0	37	0.8	46%	-	46%
Condensing with CCS	Coal	2.6	59	16.7	41%	-	41%
Condensing with CCS	Wood pellets	2.6	59	16.7	40%	-	40%
Extraction CHP	Coal	1.5	22	3.6	44-50%	36-44%	87-90%
Extraction CHP	Wood pellets	1.5	22	3.6	43-49%	35-42%	87-90%
Extraction CHP	Natural gas	1.0	37	0.8	46%	37%	90%
Extraction CHP	Wood	1.7	24	3.3	46.5-48.5%	36-39%	103-107%
Extraction CHP with CCS	Coal	2.6	59	16.7	41%	33%	84%
Extraction CHP with CCS	Wood pellets	2.6	59	16.7	40%	32%	84%
Condensing CC	Natural gas/biogas*	0.5-0.6	15	1.9	56.5-60%	-	56.5-60%
Condensing CC with CCS	Natural gas	1.4	39	6.4	51%	-	51%
Extraction CC	Natural gas/biogas*	0.5-0.6	15	1.9	56.5-60%	52-56%	88-90%
Extraction CC with CCS	Natural gas	1.4	39	6.4	51%	46%	80%
Backpressure	Natural gas/biogas*	1.1	7	8.4	-	43-47%	92%
Backpressure	Straw	4.0-5.0	8-10	1.4-1.7	-	30%	90%
Backpressure	Municipal waste	5.7	160	22.8	-	24-26%	97-99%
Backpressure	Biogas	3.2-3.5	93	15.5	-	42-47%	92-93.5%
Onshore wind	Wind	1.4-1.6	28-29	2.9-3.1	-	-	100%
Onshore wind LCI	Wind	1.8-2.0	31-32	2.9-3.2	-	-	100%
Offshore wind (low**)	Wind	1.6-2.0	49-52	3.6-4.1	-	-	100%
Offshore wind (mid**)	Wind	1.9-2.3	49-52	3.6-4.1	-	-	100%
Offshore wind (deep**)	Wind	2.3-2.8	49-52	3.6-4.1	-	-	100%
Solar PV	Solar	1.0-2.0	12-33	-	-	-	100%
Wave power	Wave	2.7-8.9	58-116	3.6-7.2	-	-	100%

*Table 5: Selected generation technologies, which the model can invest in. The intervals indicate the development in technology and costs from 2010 to 2050. * The biogas on this plant is upgraded biogas, meaning it has the same quality as natural gas but with higher fuel costs. ** Offshore wind power is categorised in three groups with different investment costs, i.e. low, mid and deep water depth. The technology catalogue is mainly based on Energinet.dks and the Danish Energy Agencies "Technology Data for Energy Plants", April 2010 and own assumptions. CCS costs are based on the aforementioned catalogue, JRC "The Cost of Carbon Capture and Storage Demonstration Projects in Europe", 2009 and "Energieszenarien für ein Energiekonzeptder Bundesregierung", 2010.*

The model may also invest in heat generation capacity such as coal, biomass and gas boilers, as well as large-scale electric heat pumps, electric boilers, solar heating, electric storages and heat storage.

The opportunities to invest in the different technologies are not uniform across the region, for example because there are differences in the availability of resources in the different countries.

Similar political opinions about certain technologies like nuclear power and coal power influence their future role in some countries.

Investment approach

The Balmorel model is myopic in its investment approach, in the sense that it does not explicitly consider revenues beyond the year of installation. This means that investments are undertaken in a given year if the annual revenue requirement (ARR) in that year is satisfied by the market.

A balanced risk and reward characteristic of the market are assumed, which means that the same ARR is applied to all technologies, specifically 0.12, which is equivalent to 10% internal rate for 20 years. This rate should reflect an investor's perspective.

In practice, this rate is contingent on the risks and rewards of the market, which may be different from technology to technology. For instance, unless there is a possibility to hedge the risk without too high risk premium, capital intensive investments such as wind or nuclear power investments may be more risk prone. This hedging could be achieved via, feed-in tariffs, power purchase agreements or a competitive market for forwards/futures on electricity, etc.

It should be stressed that the recommended socio-economic discount rate in many countries is significantly lower than the 10 % rate applied in the present study (Germany: 2.2%, Sweden and Norway: 4%, Denmark and Finland: 5%, UK: 1.0-3.5%, EU: 3.5-5.5%[22]). Applying a lower discount rate would favour capital intensive technologies like wind power, nuclear power, solar power and CCS as opposed to for example gas power plants.

Nuclear power

Nuclear power accounted for about 23 per cent of electricity generation in 2010 in the Baltic Sea Region. We have chosen to specify a fixed development of nuclear power in the future electricity supply as opposed to letting the model make the "optimal investments".

[22] European Commission (2008): Guide to Cost-Benefit Analysis of investment Projects; Concito (2011): Den samfundsøkonomiske kalkulationsrente – fakta og etik

The reason for this approach is twofold. First of all the investment costs – and the cost of eventually decommissioning the plants – are associated with a high degree of uncertainty. Secondly, a number of environmental externalities are related to nuclear power including the risk of nuclear accidents, radio-active emissions from mine-tailings, long-term storage of radioactive waste and the decommissioning of the power plants. These externalities are extremely difficult to monetize and therefore, in reality, decisions on nuclear power are based as much on political assessments and risk assessments as on financial calculations.

The nuclear development in Lithuania, Poland and Sweden is based on the assumptions made in the EU report "EU energy trends to 2030" (EU Commission, 2010). This means that new units are expected to come online in Lithuania (Visaginas), and in Poland, whereas a stable development is assumed for Sweden. Finland has informed that they expect three new nuclear units to come online before 2030 (including Olkiluoto3, which is currently being constructed). Moreover, one new unit is included in Kaliningrad. In other parts of North West Russia nuclear power capacity is assumed to remain constant. In Germany the planned nuclear phase-out is expected to take place by 2022 in accordance with their phase-out plan.

[MW]	FINLAND	GERMANY	LITHUANIA	POLAND	RUSSIA	SWEDEN
2010	2,691	20,339			5,760	9,372
2015	4,291	12,003			5,760	9,782
2020	4,291	8,052	758	1,515	6,842	9,782
2025	5,691		1,515	2,776	6,842	9,782
2035	7,191		1,515	3,699	6,842	9,782
2050	7,191		1,515	3,699	6,842	9,782

Table 6: Development of nuclear capacity (MW) in the region.

New coal fired power plants

New coal fired power plants without CCS are not considered to be accepted politically in Sweden, Denmark or Lithuania. In Norway gas fired capacity is only to be accepted if CCS is applied, this condition is applied in all scenarios[23].

[23] Norway has no expressed policy on coal power, but we assume that a new coal power plant would only be accepted if equipped with CCS.

Projections of the demand for electricity district and heating

Short term projection

The projections of the demand for electricity and district heating until 2020 are based on the national prognoses included in the countries National Renewable Energy Action Plans[24] (electricity) and the EU Commissions scenario report "EU energy Trends 2030" (district heating). In most countries, both the demand for electricity and the demand for district heating are projected to increase towards 2020.

Long-term projection

Forecasting how the demand for energy will develop in the long-term towards 2050 is associated with great uncertainties related among others to the economic development of the region and the individual countries, the level of energy saving and energy efficiency measures and the transition to new end-use conversion technologies (electric vehicles, heat pumps).

The long-term projection is made with a view to complying with the long-term target of the EU to reduce GHG emissions by 80-95 %. Hence, CO_2-emissions, from final energy consumption (industry, transport, households) are reduced by close to 70 %. For comparison the EU Commission states that CO_2-reductions of 83-87 % are required in industry by 2050 and reductions of 54-67 % are needed in the transport sector[25].

For the purpose of the study a simple spread-sheet model is used to forecast how final energy demand may develop in the long-term. This model is structured around the three steps:

Projection of GDP for each country in the region.
The forecast assumes that the countries in the region with the lowest GDP per capita today will come closer to catching up with the richest economies in the region. This means that the economies with the lowest GDP per capita today are assumed to grow faster (approx. 2.7 % p.a.) than the more developed economies (0.8-1.5% p.a.). The GDP growth projections are based on the previously mentioned EU Commissions scenario report "EU energy Trends 2030"[26], however in the case of Germany we have used the assumption from the German Energy Concept.

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[24] The projection for NW Russia is based on a projection provided by InterRAO UEA and for Norway on the ENTSO-E (cooperation of system operators) report "Scenario Outlook and System Adequacy Forecast 2011-2025"

[25] EU Commission (2011): Roadmap for moving to a competitive low carbon economy in 2050.

[26] For the wealthiest economies the GDP projection from the EU is used between 2010 and 2030, whereas between 2030 and 2050 we assume that the annual GDP growth is only half of that. For example in the case of Denmark GDP is estimated to grow 1.6 % p.a. between 2010 and 2030 and 0.8% between 2030 and 2050.

Level of energy saving and energy efficiency measures
The development in energy intensity (energy per GDP) is assessed within different categories of energy end-uses, considering long-term technical potentials to utilize energy in a more efficient way. By multiplying the projected energy intensity factor with projected GDP an estimate of projected energy consumption is achieved using existing end-use conversion technologies. It should be stressed that both the projections of GDP and the potentials to improve the energy efficiency are associated with a high level of uncertainty. As with regard to GDP it is assumed that the countries with lowest GDP per capita will come closer to the level of energy efficiency which is observed in the richest countries.

When forecasting the demand for heat a different methodology has been used assuming that the richest countries are able to reduce their absolute demand for heating per capita by around 35-40 % through renovation of existing buildings and tough standards for new buildings. The resulting heat demand per capita is afterwards transferred to the countries with lowest GDP assuming that their heat demand per capita will in the long-term equivalent the richest countries. The calculations take into consideration that the need for heat differs between the countries due to different climate conditions[27].

Changes in end-use conversion technologies
Finally an assessment of changes in end-use conversion technologies is made for heating, process energy and in the transport sector. This leads to additional improvements in total energy efficiency.

Increasing electricity demand for heating and transport

Table 7 summarizes the assumptions made for different types of end uses in the projections. The shifts towards electrification of the transport sector as well as the increasing use of electricity for heating – using heat pumps – causes the demand for electricity to increase in all countries except Norway and Germany.

The growth in demand are highest in the countries, which today have the lowest relative GDP per capita, i.e. Estonia, Latvia, Lithuania, Poland and North West Russia. Norway today has a very high electricity consumption per capita compared to any of the other countries in the region due to a high

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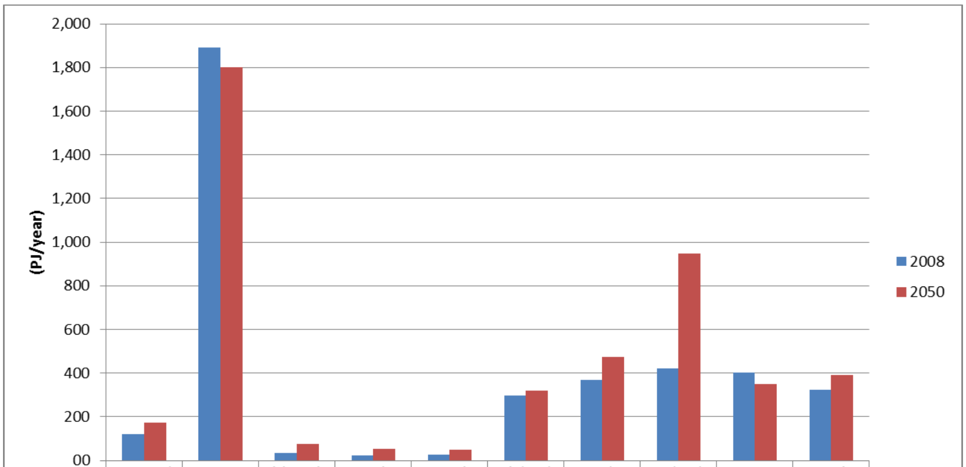
Hence, average GDP growth is 1.2 % p.a. between 2010 and 2050. For the countries with lowest GDP (Lithuania, Latvia, Estonia and Poland) we prolong the projected growth rates between 2010 and 2030 to the period 2030 to 2050.

[27] The heat demand is adjusted to account for the number of heating degree days per annum in the different countries

share of heating supplied by electricity as well as the presence of energy intensive industry. By 2050 the relative Norwegian electricity consumption comes closer to the average in the region, explaining the decreasing consumption in Norway. The decrease in German electricity consumption is explained by an expectation of a relatively low GDP growth compared to the rest of the region. Moreover, a lower electrification of the heating and transport sector is assumed in accordance with the policies specified in the German Energy Concept.

End use	Assumptions
Electricity households/service (excl. electricity for heating)	GDP growth causes increasing demand for electricity for appliances, lighting etc. In the most developed countries this development is off-set by energy saving measures of the approx. similar size. In the least developed countries electricity demand increases considerably.
Heating	Considerable heat savings. Same relative level (i.e. per capita) of energy consumption for heating in all countries in the region. Increasing share of heat supplied from district heating and individual electric heat pumps.
Industry	GDP growth causes increasing demand for energy in industries, but this development is largely counterbalanced by increasing energy efficiency. Regional differences in location of energy intensive industries are assumed to prevail. Shift from fuels to district heating and electricity.
Transport	By 2050 more than 50 % of transport demand is covered by electric vehicles, though lower in Germany according to their national projection. At the same time the demand for transport services will increase significantly. Conventional cars are assumed to have their specific energy consumptions reduced by approx. 50 %.

Table 7: Assumptions about the development in electricity demand within different end-use categories.



	Denmark	Germany	Lithuania	Latvia	Estonia	Finland	Sweden	Poland	Norway	Russia
2008	120	1,892	32	24	25	297	370	423	401	324
2050	172	1,802	75	52	50	319	473	947	350	392

Figure 18: Final electricity demand in 2008 and the projected demand for 2050.

The demand for district heating increases in all countries in the region except Denmark (which already has a very high share) and Germany where the Energy Concept does not envision a stronger role for district heating.

The generally increasing district heating demand is due to two circumstances: 1) An assumption about expanding district heating network particularly in the countries, which have low district heating shares today, 2) increasing use of CHP for producing process heat for industries to replace fossil fuels and improve energy efficiency.

More details in the data report

The data report accounts in more detail for the assumptions used in the study. The data report also contains a more thorough description of the applied modelling tool.

3 Long-term energy scenarios

This chapter presents the results of the reference scenario and the two low carbon scenarios. In 2020 the target in the reference development is to reduce CO_2-emissions from power and district heating generation in the EU ETS by 20 % compared to 2005. Towards 2050 this target is increased to 50 %.

The two low carbon scenarios have a target of 30 % CO_2-reduction in EU ETS in 2020 going to carbon neutrality (100 % reduction) in 2050. The two low carbon scenarios differ by the role of CCS. In the Low carbon scenario – as in the reference scenario – carbon capture and storage becomes an option in 2025. In the low carbon RE scenario CCS is not an option, either because the technology is not commercialised or because of local opposition.

Separate CO_2-targets have been stipulated for North West Russia.

It should be stressed that all 2010 figures are model simulations and can divert from the statistics. This is due to the model operating with normalised hydro generation, wind profiles, etc., and perfect market conditions as well as an aggregated time resolution.

3.1 Reference scenario

As mentioned the reference scenario is developed to comply with the national renewable energy targets for 2020 as well as 20 % reduction of CO_2-emissions in 2020 compared to 2005.

Going towards 2050 the national renewable energy targets are kept constant whereas the CO_2-reduction target is gradually increased to 50 % in 2050.

In North West Russia the CO_2-emissions are kept constant at 2010 levels until 2020 and thereafter they are assumed to decrease to 25 % below the 2010 level.

Investments in new generation capacity

Figure 19 shows the investments in new electricity generation technologies for all countries until 2020. It appears, that given the framework conditions and reviewed data on the cost of the different possible technologies the model mainly chooses to invest in wind power plants and gas fired power plants. Also a significant expansion with solar power takes place in Germany in accordance with the projections in the NREAP.

Power plants under construction and exogenously specified investments such as the development of nuclear power capacity are not depicted in the figure (see data report).

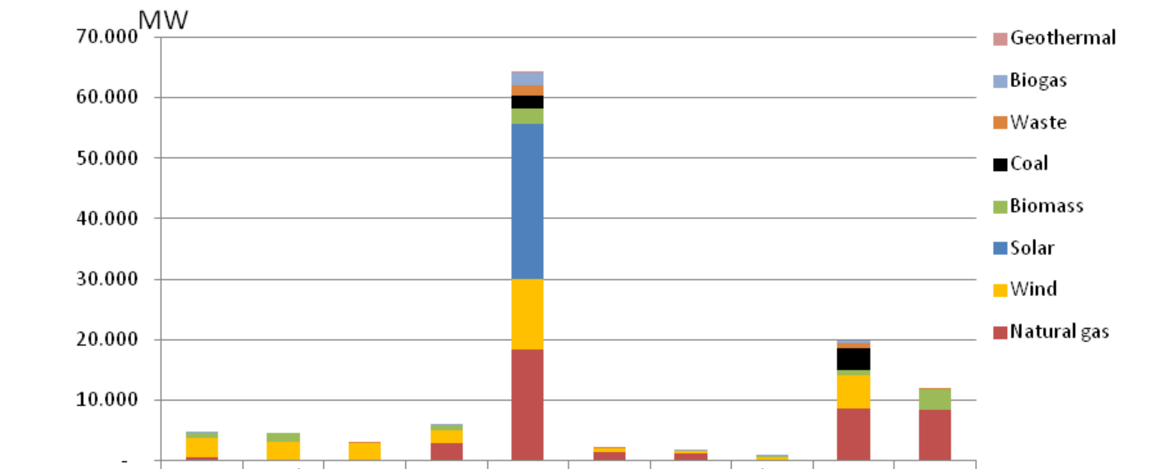
Sensitivity analyses show the choice of gas vs. coal fired technologies is very sensitivity to both the required rate of return of investors (10 % in the study) and the gas price level. A lower discount rate or a somewhat higher gas price (+20 %) could tip the balance towards coal power.

The massive investments in natural gas capacity in Germany are made not only to compensate for the nuclear generation capacity, which is decommissioned, but also to replace existing old fossil fuel plants, which are decommissioned during the same period.

The coal power plants that the model commissions in Germany, Poland and Russia are a new very efficient technology with electric efficiencies of 48 % when running in condensing mode.

Wind power capacity increases significantly in all countries except in Russia. The most notable expansion takes place in Germany, where total installed wind power capacity is increased to almost 40,000 MW, of which 11,700 MW is commissioned in the period 2010-2020. Around two-thirds of this investment, 7,000 MW, is in off-shore capacity.

Significant investments are also made in biomass and biogas capacity in all parts of the region. In the case of biogas the model takes into account the additional reduction of greenhouse gases (CO_2-equivalents) in the agricultural sector due to the abatement of methane and nitrous oxide emissions.



	Denmark	Sweden	Norway	Finland	Germany	Estonia	Latvia	Lithuania	Poland	Russia
Geothermal					198					
Biogas	129			40	2.022		66	45	456	
Waste			94		1.761	21	55	42	983	169
Coal					2.077	23	21		3.411	20
Biomass	850	1.561	1	796	2.522		54	234	842	3.287
Solar	2	3			25.691		4	16	2	
Wind	3.235	2.910	2.969	1.984	11.704	580	307	488	5.563	
Natural gas	625	234		3.001	18.317	1.469	1.312		8.678	8.497

Figure 19: Investments in new generation capacity (MW) in the period 2011-2020 as decided by the model. Power plants under construction are not depicted in the table, e.g. the off-shore wind farm at Anholt in Denmark and the new nuclear generation power plant in Finland.

CO_2 and RE prices

The investment in new renewable energy capacity until 2020 are only partly made to comply with the targets set out in the renewable energy actions plans.

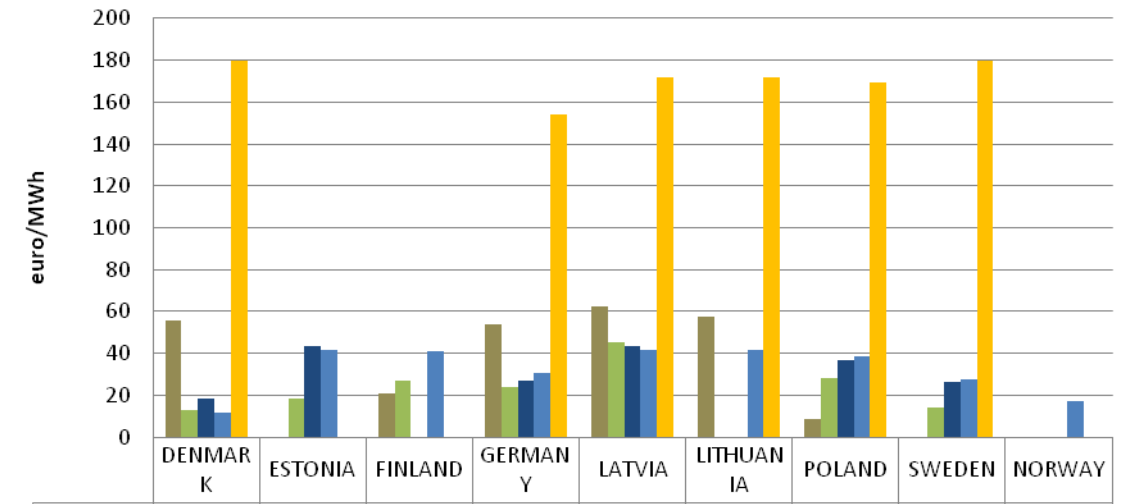
The model is able to compute the cost of tightening the CO_2-target by one additional ton of CO_2 as well as the cost of additionally increasing RE generation for different technologies by one MWh. Respectively, these values can be interpreted as estimates of the CO_2-price in the emissions trading scheme, and the marginal level of support need for renewable energy.

Figure 20 shows the required renewable energy support level for the eight EU member states in the region. Solar PV requires the greatest support level – approx. 150-180 €/MWh. The needed support level is much lower for the other technologies, up to approx. 60 €/MWh for biogas, in some countries.

The differences reflect the costs of new renewable energy generation in each of the countries compared to the value of new renewable energy electricity in the electricity markets.

In some cases the cost of CO_2 and the prices in the market are sufficient to drive the investments in the generation capacity. In that situation the renewable energy shadow prices become zero; this is for example the case for biomass generation in Lithuania.

It should be stressed in this connection that the simulations assume a 10 % requirement on return of investments and 20 year depreciation time. A lower requirement on return of investors would decrease the need for support and vice versa if the requirement on return is increased. The choice of support scheme, specifically the level of uncertainty that the investor is exposed to, will affect the risk premium that he/she will require and thereby also the need for support.



	DENMARK	ESTONIA	FINLAND	GERMANY	LATVIA	LITHUANIA	POLAND	SWEDEN	NORWAY
Biogas	56		21	54	62	58	9	0	
Biomass	13	18	27	24	45	0	28	14	
Offshore	18	43		27	43		37	26	
Onshore	12	42	41	31	42	42	39	28	17
Solar	180			154	172	172	169	180	

Figure 20: Renewable energy shadow prices (€/MWh) in 2020. The shadow prices can be interpreted as the support level required to stimulate investments in the given technologies. A blank cell indicates that the country has not specified a target for that technology.

It is assumed that CO_2 can be traded across all EU countries including Norway; consequently there is one common price of CO_2 for these countries. North West Russia has its own CO_2 target and therefore its own CO_2 price. Renewables, on the other hand, are taken care of by national policies and therefore the prices are different for each country in the region as illustrated above.

The calculated price of CO_2 is approx. 25 € per ton in 2015 dropping to 10-15 € per ton in 2020-2030. Towards 2050 the price of CO_2 increases to about 50 € per ton. The impact of investors banking quotas over the period to profit from fluctuations, as well as trading outside the region or with other sectors is not considered in the modelling. Therefore, the CO_2 shadow prices cannot be directly viewed as an estimate of the future CO_2-price in the EU ETS, which is currently much lower, approx. 7 €/ton.

In North West Russia, the CO_2 shadow price is zero until 2040 indicating that the cap set for Russia does not bind. After 2040 the price climbs steeply and comes close to the price of the EU ETS. A reason for the relative high CO_2-price in Russia by the end of the period – in spite of a less strict target - is that the onshore wind resources in Russia are assumed to be not as good as in others parts of the Baltic Sea Region. Moreover, Russia has a limited access to off-shore wind power and a lower price on gas, which makes renewables relatively more expensive.

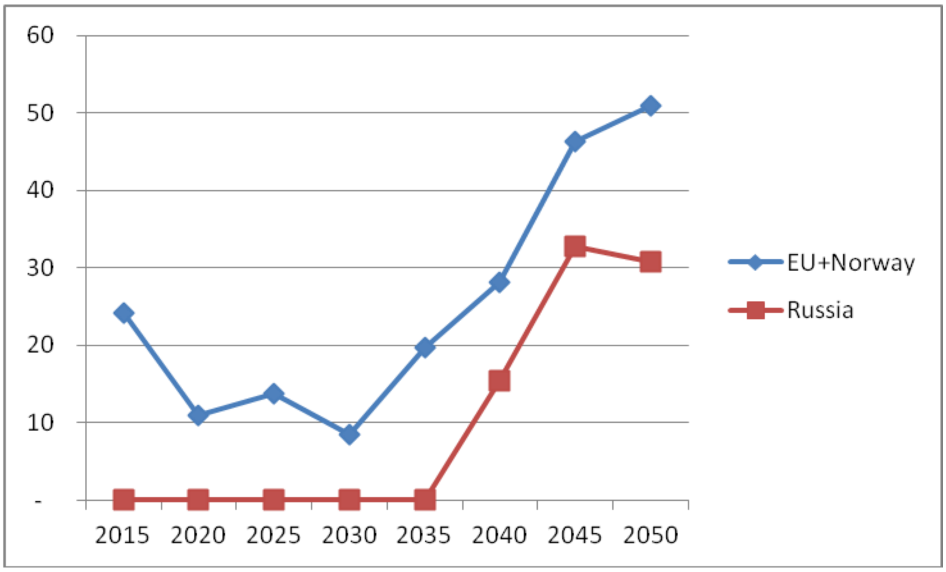


Figure 21: Calculated CO_2-shadow prices (€/ton) in EU+Norway and in Russia.

Electricity market prices

Figure 22 shows the average annual electricity market prices in each country in the region in 2010 and every ten year forward. Electricity market prices increase from a level around 5 to approx. 7 €C/kWh in 2050. In the beginning of the period the differences in electricity prices between the countries are limited, but they increase somewhat during the period. Norway and Sweden have the lowest electricity prices by 2050, which can be explained by the two countries' good access to hydro, wind and biomass resources.

It should be stressed that the costs of supporting renewable energy electricity is not included in the electricity market prices. The costs to the consumers of supporting renewables will depend on the design of the support schemes in the individual countries.

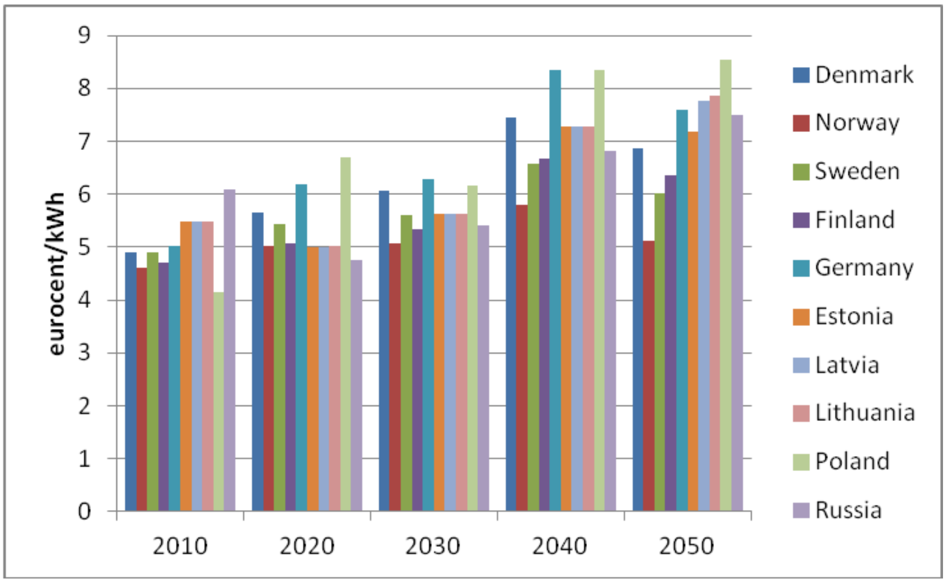


Figure 22: Average yearly electricity market price (Euro cent/kWh) by country in the Reference scenario.

Electricity generation by fuel

The development in electricity generation by fuel for the whole region is shown in Figure 23. Towards 2020 the most notable development is the increase in particularly wind power, biomass, biogas and municipal waste. By the end of the period the role of wind power increases further and by 2050 wind power contributes with close to one fifth of total electricity generation in the region.

In spite of new nuclear units coming online in Poland, Finland and Lithuania total nuclear power generation decreases between 2010 and 2030 due to the phase out in Germany. From 2030 nuclear power generation is assumed to remain constant.

The share of production from natural gas increases markedly between 2010 and 2015 and maintains an important role until around 2030. After that point its role decreases. It should also be mentioned, that the investments in gas power generation are quite sensitive to both the price of gas and the choice of discount rate.

The role of coal power decreases from supplying 35 % of electricity generation in 2010 to 26 % in 2050. The new coal power plants that are established throughout the period are much more efficient (close to 50 % electric efficiency) than the existing plants. This explains why coal power is able to continue playing an important role by 2050 while CO_2-emissions are reduced by 50 %.

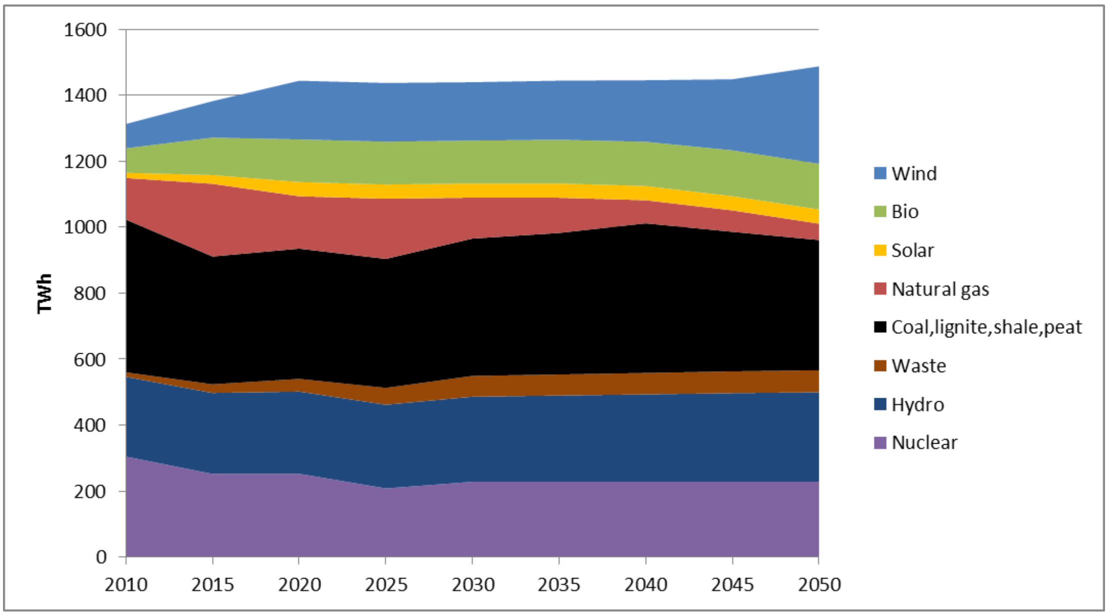
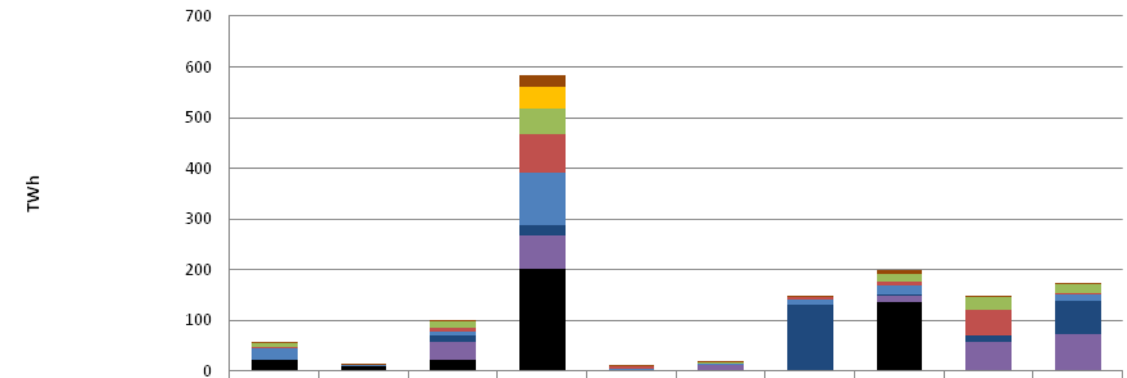


Figure 23: Total electricity generation (TWh) by fuel for Reference scenario.

Electricity generation by country

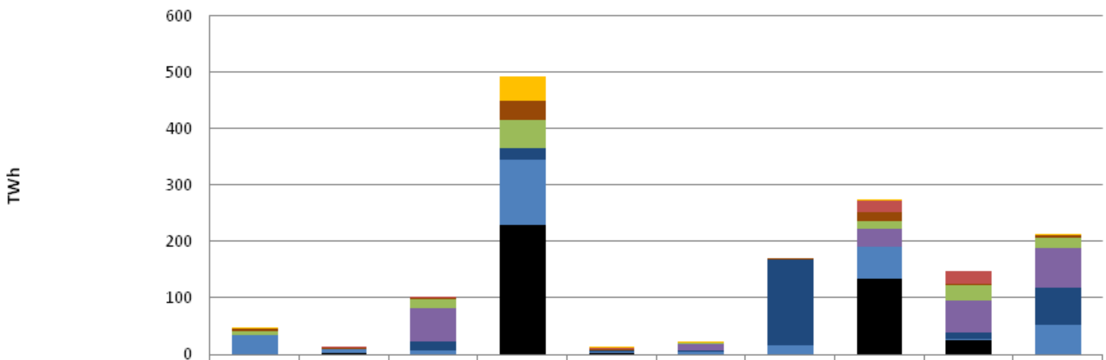
Electricity generation divided by country in 2020 and 2050 can be seen in Figure 24 and Figure 25 respectively. In 2020 the new generation enforced by the National Renewable Energy Action Plans (NREAPs) is in operation as well as the 20% CO_2 reduction target, which e.g. can be seen from the increased generation from solar power in Germany. Towards 2020 these plans and the decommissioning of power plants facilitate the main change in the system on a country level.



	DENMARK	ESTONIA	FINLAND	GERMANY	LATVIA	LITHUANIA	NORWAY	POLAND	RUSSIA	SWEDEN
Waste	2	0	2	23	1	0	1	8	1	1
Solar	0			43	0	0		0		0
Bio	9	0	13	49	1	2	0	14	24	17
Natural gas	1	1	8	75	5	2	4	8	51	3
Wind	22	2	6	104	1	2	11	17	0	13
Hydro			14	20	3	0	130	2	12	67
Nuclear			35	66		12		12	56	71
Coal,lignite,shale,peat	23	9	22	201	0			137	2	1

Figure 24: Electricity generation (TWh) by country in 2020 for the Reference scenario

The electricity generation in 2050 can be seen in the figure below. A high share of wind power generation is deployed in Denmark, Germany, Poland and Sweden. Bioenergy is utilised in the entire region, and primarily in the large load centres of Poland, NW Russia and Germany.



	DENMARK	ESTONIA	FINLAND	GERMANY	LATVIA	LITHUANIA	NORWAY	POLAND	RUSSIA	SWEDEN
Solar	0			43	0	0		0		0
Natural gas	0	2	2		2			20	23	
Waste	3	1	2	35	1	1	2	16	3	4
Bio	9	0	16	49	1	3		15	27	18
Nuclear			59			12		30	56	71
Hydro			16	20	3	0	151	2	12	67
Wind	33	6	6	117	1	5	17	57	1	52
Coal,lignite,shale,peat		3	1	229	2			133	26	

Figure 25: Electricity generation (TWh) by country in 2050 for the Reference scenario

Heat generation

District heating demand is also expected to grow towards 2050 in spite of measures taken to improve the energy efficiency of buildings significantly. The demand includes heat delivered for process industries, a portion which is expected to increase over time as a mean to improve the overall energy efficiency.

Heat generation from municipal solid waste plants increase significantly already in the short term as EU regulation, banning the deposition of combustible waste, is assumed to lead to an increase in the number of incineration facilities or alternative treatment methods (such as biogas or gasification) that enable the utilisation of waste for energy purposes. Electricity is increasingly used for heat generation using electric boilers as well as heat pumps. Using electricity for heat generation enables the integration of wind power by utilizing power in situations where there would otherwise be a surplus of generation.

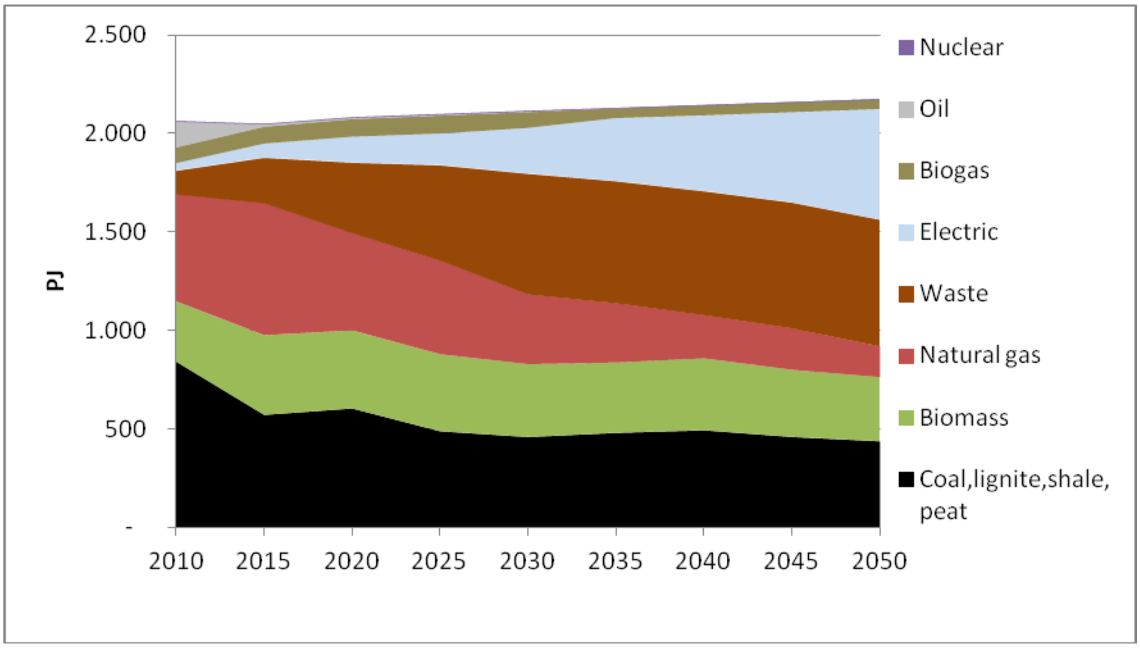


Figure 26: Total heat generation (PJ) by fuel for Reference scenario.

CO_2-emissions

Figure 27 shows the total CO_2 emissions from electricity and district heating generation in each country between 2010 and 2050. The CO_2 emissions in the region are mainly emitted in Germany and Poland.

In 2050 CO_2-emissions are almost eliminated in Sweden, Estonia and Finland. In Germany emission are reduced by very close to 50 % whereas the reduction in Poland is only 30 % compared to 2005.

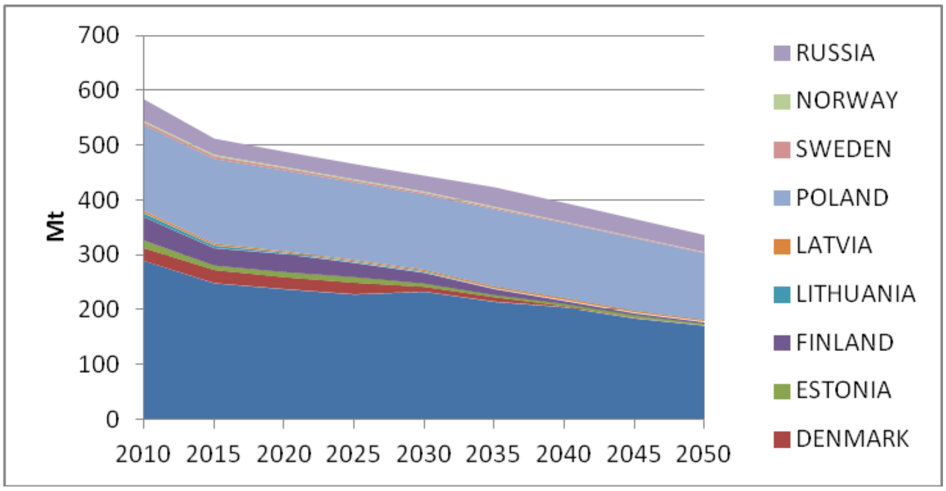


Figure 27: Total CO_2-emission (megatons) by country from 2010 to 2050 in the reference scenario.

The figure below shows actual emissions in each of the countries in the region in 2020 compared to a 20 % reduction of actual 2005 emissions ("target").

It appears that Germany reduces emissions more than the regional average of 20 % whereas Denmark, Finland and Poland have higher emissions.

NW Russia over-complies with the target of stabilising emissions in 2020 at 2010 levels. This was also reflected in the cost of CO_2 in NW Russia, which as previously mentioned, was 0 €/ton between 2010 and 2035.

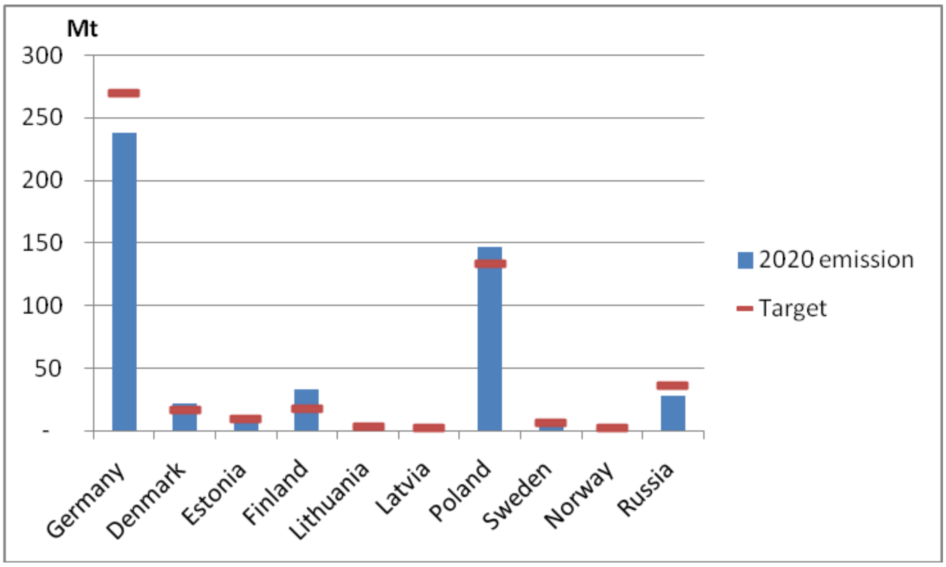


Figure 28: CO_2 emissions in all countries in 2020 compared to a 20 % CO_2 targets distributed evenly on all countries.

Figure 29 shows the total CO_2 emissions for all countries grouped by fuel. Coal is by far the greatest source of emissions throughout the period. The contribution from gas power is much less significant.

The emissions from biogas are negative due to the abated methane and nitrous oxide emissions in the agricultural sector.

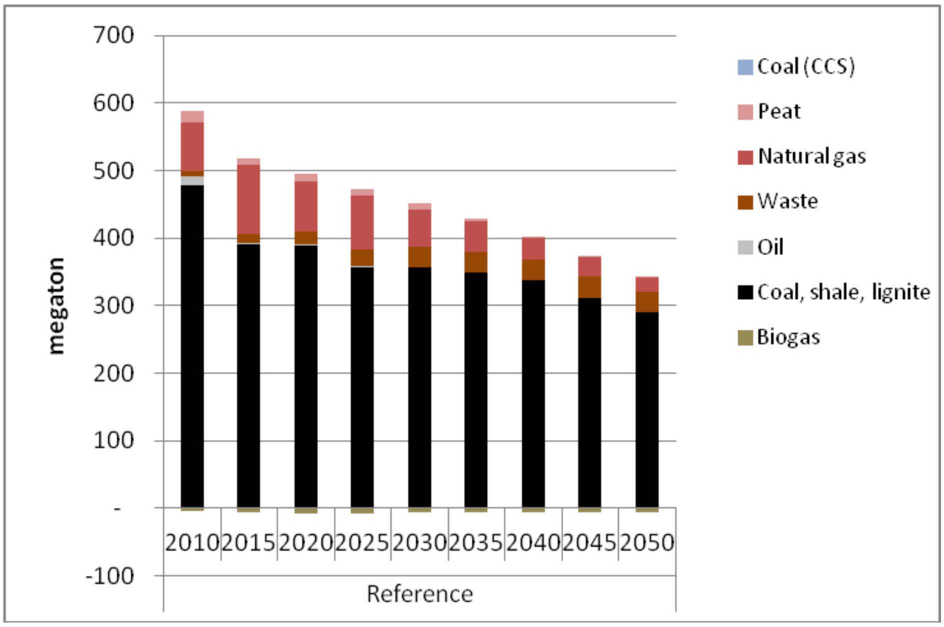


Figure 29: Total CO_2-emission (megatons) from 2010 to 2050 grouped by fuel for reference scenario.

Utilisation of biomass resources

The utilisation of biomass resources and waste increases in the reference scenario but it does at no point exceed the domestic resources of the region, which amounts to approx. 3800 PJ including municipal solid waste.

Wood pellets, which are the most expensive of the solid biomass fractions considered in the study, only find a limited application. The utilisation of biogas grid increase throughout the period, particularly upgraded biogas (termed “biogas grid”) which is fed into the natural gas grid. Still the total potential for biogas is not utilised at any point.

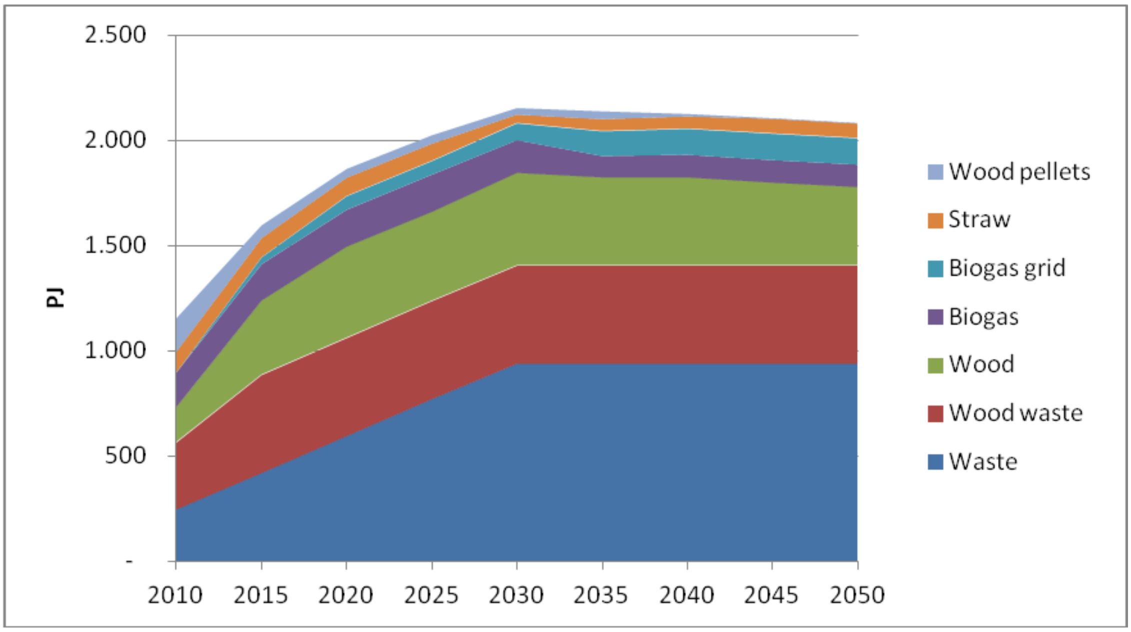


Figure 30: Utilisation of biomass resources in the reference scenario.

Exchange of electricity

The exchange of electricity between the countries in the region increases throughout the period. The table below shows net export of electricity from each country in the region. Most noticeable is that Germany and particularly Poland end up as significant importers of electricity whereas Norway and Sweden export large amounts of power by the end of the period. The Norwegian export is explained by the fact that Norway as the only of two countries in the region see a reduction in the demand for electricity. In combination with the large potential for hydro power generation this causes Norway to become a net exporter of electricity.

The continued use of nuclear power and hydro power and large potentials for renewables energy resources – including wind power – explains why Sweden becomes a major export country by the end of the period.

(TWh/year)	2010	2015	2020	2025	2030	2035	2040	2045	2050
Denmark	5.5	11.1	14.3	13.1	-4.2	-1.1	-4.8	-6.5	-9.3
Sweden	-6.2	-3.3	-6.2	-1.0	2.3	6.1	10.9	17.2	27.1
Norway	2.6	5.4	8.5	17.9	26.1	34.1	38.8	53.0	61.4
Finland	-5.5	-1.7	-4.0	1.9	6.4	-3.2	-9.3	-7.5	-5.1
Germany	-7.6	-28.2	-31.2	-49.7	-40.8	-46.2	-28.1	-31.6	-27.7
Estonia	3.0	0.2	1.1	1.3	-3.7	-4.5	-4.8	-5.1	-5.4
Lithuania	-3.5	-4.1	0.1	-1.0	-3.0	-6.1	-6.6	-7.1	0.2
Latvia	1.3	3.0	0.5	-0.6	-1.4	-2.0	-2.3	-3.7	-5.4
Poland	9.5	1.5	-5.0	-3.4	-0.6	-0.2	-11.0	-25.0	-40.7
Russia	1.0	16.0	22.0	21.6	18.8	23.0	17.3	16.3	4.9

Table 8: Import (-) and export (+) in all countries in the reference scenario in 2010-2050 in TWh.

The following table shows investments in transmission capacity. Between 2025 and 2035 the demand for reinforcements of the grid is limited, but from 2040 and onwards substantial amounts of investments are economic, including both reinforcements of internal grids, e.g. within Germany from North to South and in new sea cables. A 10 % discount rate (real) is applied for investments in grid, as it is the case for investments in new generation capacity.

MW/Year	2025	2030	2035	2040	2045	2050
DE_NW						
DE_CS					956	2.959
FI_R						
EE_R					50	882
LV_R						
EE_R						280
NO_S						
DK_W				1.000	1.000	1.000
NO_M	15	255	169	144		
PL_Central						
LT_R						795
PL_NW						
DE_CS	225	521	1.439	1.188	2.021	393
PL_W						
DE_CS					48	1.901
RU_KAL						
PL_Central						738
SE_M						
DK_W				32	719	924
LT_R						1.000
SE_N						
NO_M						57
NO_N			337	665	1.095	1.320
SE_S						
DE_NE				37	402	1.000
DK_E						74
PL_NW				156	1.000	1.000

Table 9: Investments in new transmission capacity between regions (MW/year)

3.2 Low carbon scenario

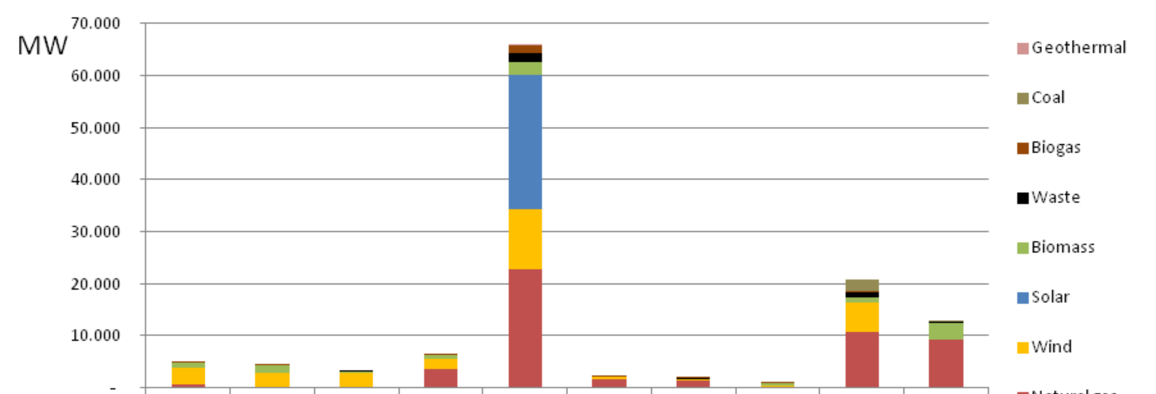
The low carbon scenario is developed to comply with the national renewable energy target for 2020 as well as 30 % reduction of CO_2-emissions in 2020 compared to 2005. Between 2020 and 2050 the CO_2-reduction target is gradually increased to 100 %.

Going towards 2050 the national renewable energy targets are kept constant, except for Germany where the national target to increase renewable energy in the electricity sector to 80 % is taken into account.

From 2025 CCS is expected to become commercially available.

Investments in new generation capacity

The overall investment pattern in the low carbon scenario towards 2020 is not very different from the reference, but stills differs from having significantly fewer investment in coal power capacity and more investments in gas power and wind power - whereas there are not significant changes in the investments in biogas and biomass capacity. In Germany, there are not made any investments in new coal fired capacity. This change of pattern is caused by the stricter CO_2-reduction target of 30 % in 2020.



	Denmark	Sweden	Norway	Finland	Germany	Estonia	Latvia	Lithuania	Poland	Russia
Geothermal					198					
Coal									2.196	28
Biogas	129	97		40	1.388	16	61	45	472	
Waste			93		1.763	21	54	42	986	169
Biomass	821	1.472	46	644	2.488	0	52	278	838	3.288
Solar	2	3			25.691		4	16	2	
Wind	3.235	2.910	2.969	1.984	11.704	580	307	488	5.563	
Natural gas	730			3.599	22.740	1.526	1.391		10.851	9.251

Figure 31: Investments in new generation capacity (MW) in the period 2011-2020.

CO_2 and RE prices

The cost of reducing CO_2 emissions (carbon price) increases from just around €25-30/ton in 2020 to about €135/ton in 2050. From around 2035, when the CO_2-prices reach €50/ton and onwards CCS becomes a competitive carbon reduction measure.

CO_2-prices in 2015-2020 are about 5-10 €/ton higher than in the reference.

The CO_2-price in NW Russia is 0 €/ton between 2015 and 2025 and thereafter climbs to almost the same level as the EU ETS price from around 2030 and onwards.

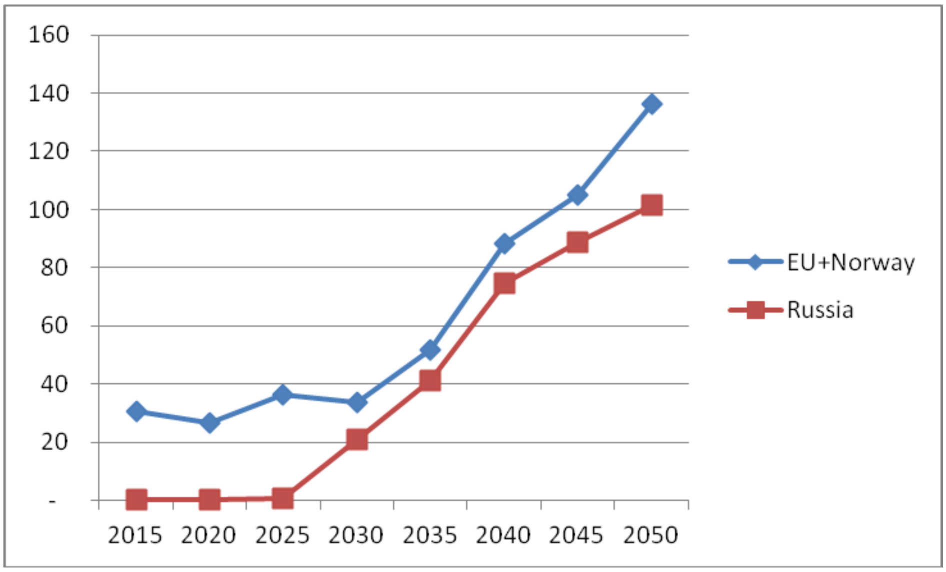
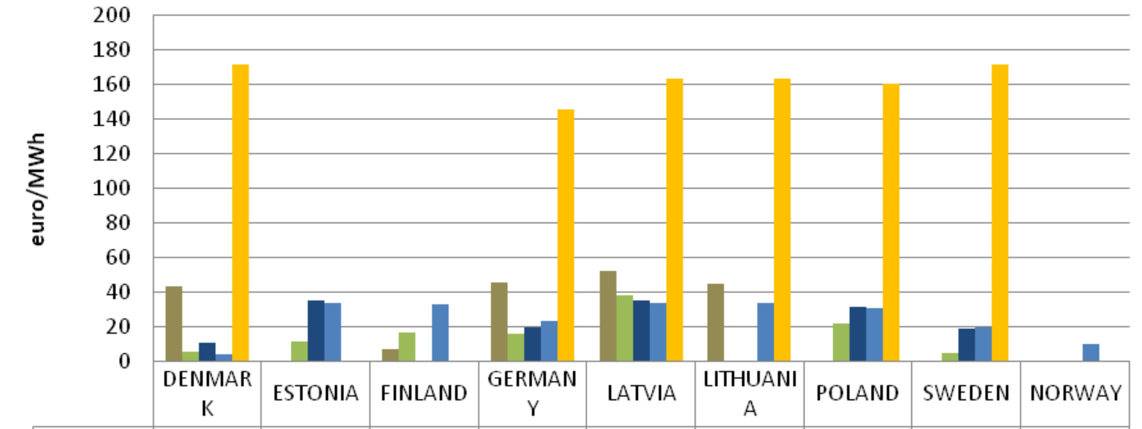


Figure 32: Calculated CO_2-shadow prices (€/ton) in EU+Norway and in Russia in the Low carbon scenario.

The RE shadow prices are generally around €5/MWh lower than in the reference. This is a result of higher electricity market prices – due to the higher CO_2-prices – which reduces the demand for dedicated support to renewables.

A number of technologies do not require additional RE subsidies, including for example biogas generation in Poland and Sweden and biomass generation plants in Lithuania.



	DENMARK	ESTONIA	FINLAND	GERMANY	LATVIA	LITHUANIA	POLAND	SWEDEN	NORWAY
Biogas	43		7	46	52	44	0	0	
Biomass	5	11	17	15	38	0	22	5	
Offshore	11	35		19	35		31	18	
Onshore	4	34	33	23	34	34	30	19	10
Solar	171			146	164	164	160	172	

Figure 33: Renewable energy shadow prices (€/MWh) in 2020. The shadow prices can be interpreted as the support level required to stimulate investments in the given technologies. A blank cell indicates that the country has not specified a target for that technology.

Electricity market prices

Electricity market prices increase from a level around 5 €C/kWh in 2010 to 5.5 €C/kWh in 2020 and 7 €C/kWh. As it was the case in the reference scenario the price diversity also increases with Poland and Germany experiencing the highest prices by the end of the period.

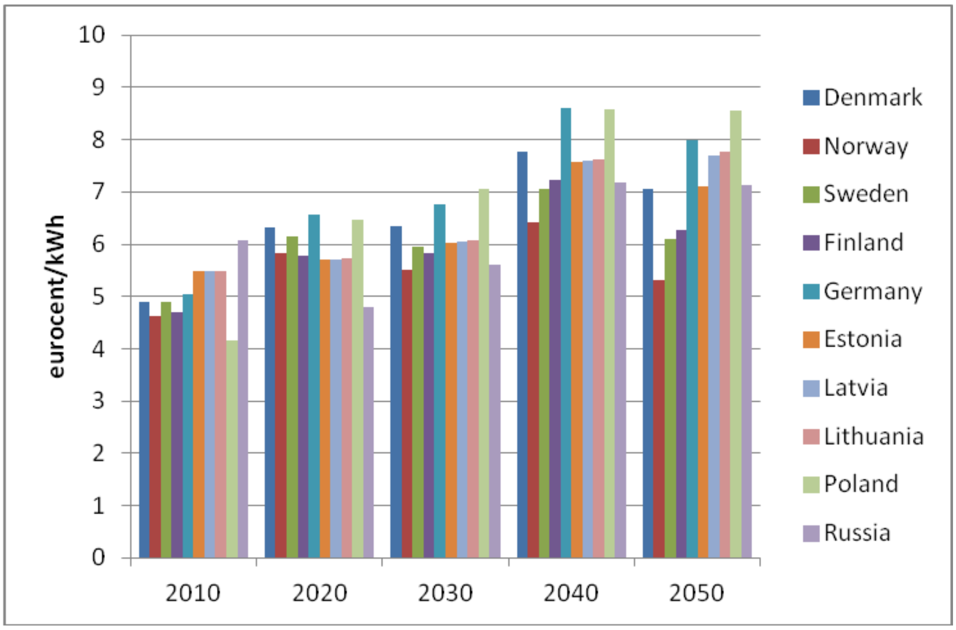


Figure 34: Average yearly electricity price (€C/kWh) by country in the Low carbon scenario.

Electricity generation by fuel

In the low carbon scenario the electricity supply undergoes dramatic changes in order to cope with the target of reducing CO_2 emissions by 100% in the BASREC ETS countries. Most notable is a massive expansion of wind power generation and a significant reduction in coal power, which by 2040 is almost completely phased out. In 2050 wind power constitutes some 27% of the total electricity supply in the region. A large portion of the wind turbines, supplying more than 40 % of total wind generation, are located off-shore in the North Sea as well as in the Baltic Sea.

CCS is primarily applied on gas fired combined cycle power plants as well as on large biomass power plants using wood pellets as fuel. Using CCS technologies on biomass fired power plants leads to a net reduction of CO_2 allowing for continued use of conventional gas power, which is an attractive technology for balancing wind power and providing peak power. Coal CCS is close to being competitive with gas and biomass CCS and could play a greater role than the simulations indicate depending on the development of fuel prices etc.

Generation from conventional biomass and biogas generation also increases throughout the period, while conventional gas power plays the role of bridging CO_2 reduction measure between 2020 and 2040 and as peak load option in the CO_2 neutral energy system in 2050.

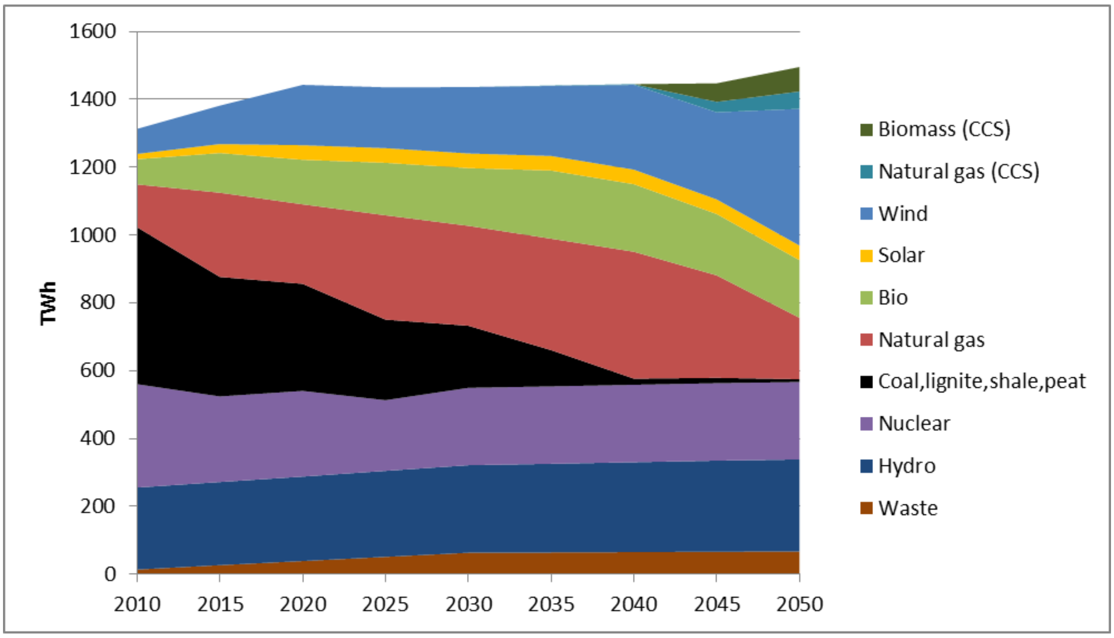
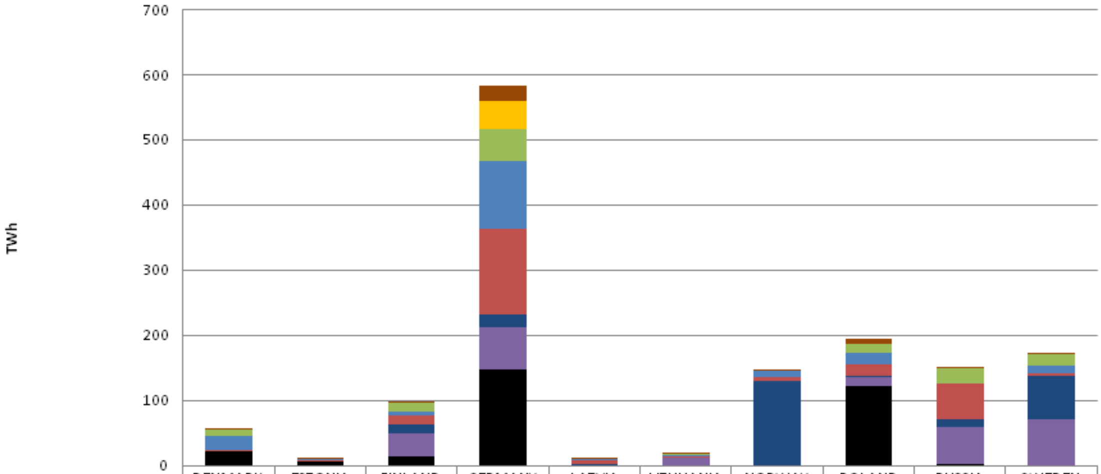


Figure 35: Total electricity generation (TWh) by fuel for the Low carbon scenario.

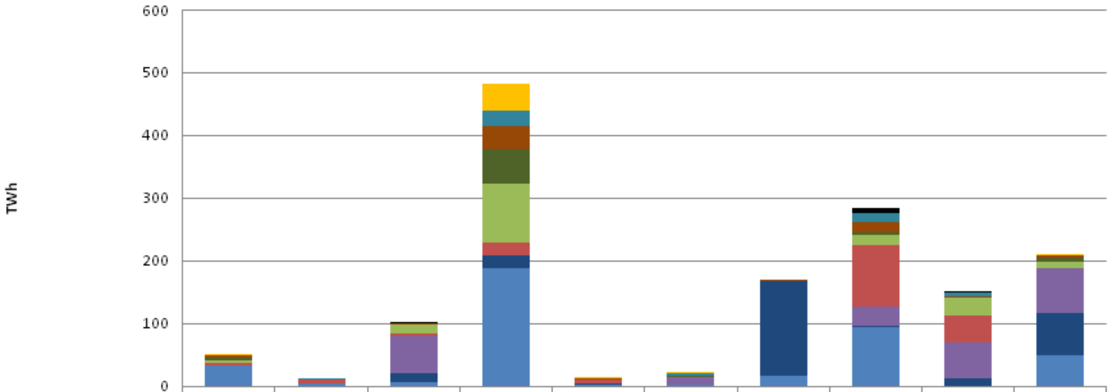
Electricity generation by country

Electricity generation divided by country in 2020 and 2050 is depicted in Figure 24 and Figure 25 respectively.



	DENMARK	ESTONIA	FINLAND	GERMANY	LATVIA	LITHUANIA	NORWAY	POLAND	RUSSIA	SWEDEN
Waste	2	0	2	23	1	0	1	8	1	1
Solar	0			43	0	0		0		0
Bio	9	0	13	49	1	2	0	14	24	17
Wind	22	2	6	104	1	2	11	17	0	13
Natural gas	2	2	13	130	6	2	5	18	54	3
Hydro			14	20	3	0	130	2	12	67
Nuclear			35	66		12		12	56	71
Coal,lignite,shale,peat	22	6	15	147				123	3	1

Figure 36: Electricity generation (TWh) by country in 2020 for the Low carbon scenario



	DENMARK	ESTONIA	FINLAND	GERMANY	LATVIA	LITHUANIA	NORWAY	POLAND	RUSSIA	SWEDEN
Coal,lignite,shale,peat			0					7	1	
Solar	0			43	0	0		0		0
Natural gas (CCS)		1		25		4		15	6	
Waste	3	1	2	35	1	1	2	16	3	4
Biomass (CCS)	4	0		56		0		5		6
Bio	5	0	15	93	1	2		15	28	11
Natural gas	4	5	4	21	5			98	44	
Nuclear			59			12		30	56	71
Hydro			16	20	3	0	151	2	12	67
Wind	33	5	6	190	3	2	17	95	1	51

Figure 37: Electricity generation (TWh) by country in 2050 for the Low carbon scenario

Heat generation

District heating generation is increasingly supplied from waste treatment facilities and from electric boilers and heat pumps. Using electricity for heating becomes more and more attractive throughout the period as the production from wind power increases. The close to total phase-out of coal power plants is also reflected in heat generation and a greater share of generation comes from CCS power plants and power plants using biomass.

Only in Germany electricity is not used for heating purposes because the amount of surplus heat from waste incineration facilities and CHP plants are plentiful to supply the relatively moderate demand for district heating.

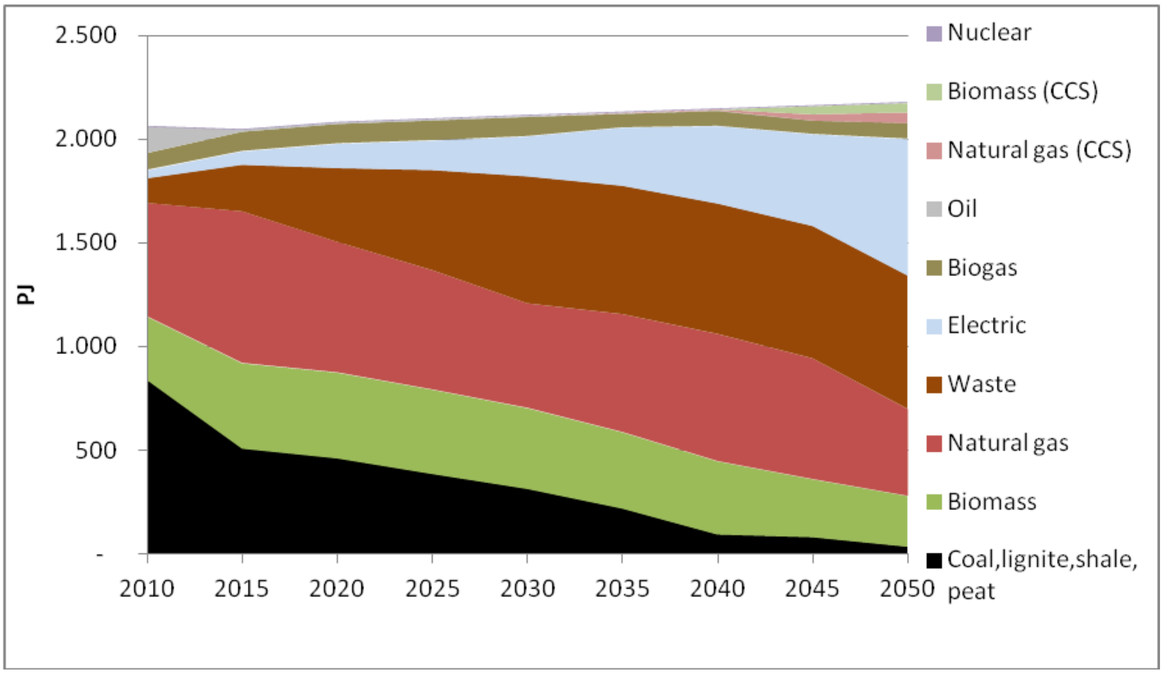


Figure 38: Total heat generation (PJ) by fuel for Low carbon scenario.

CO_2-emissions

CO_2-emissions follow a "close to linear" reduction pattern from 2010-2050. The relative reductions in Poland and Russia are lower than in the other countries in the region, i.e. reductions are made in the other ETS countries to compensate for emissions in Poland.

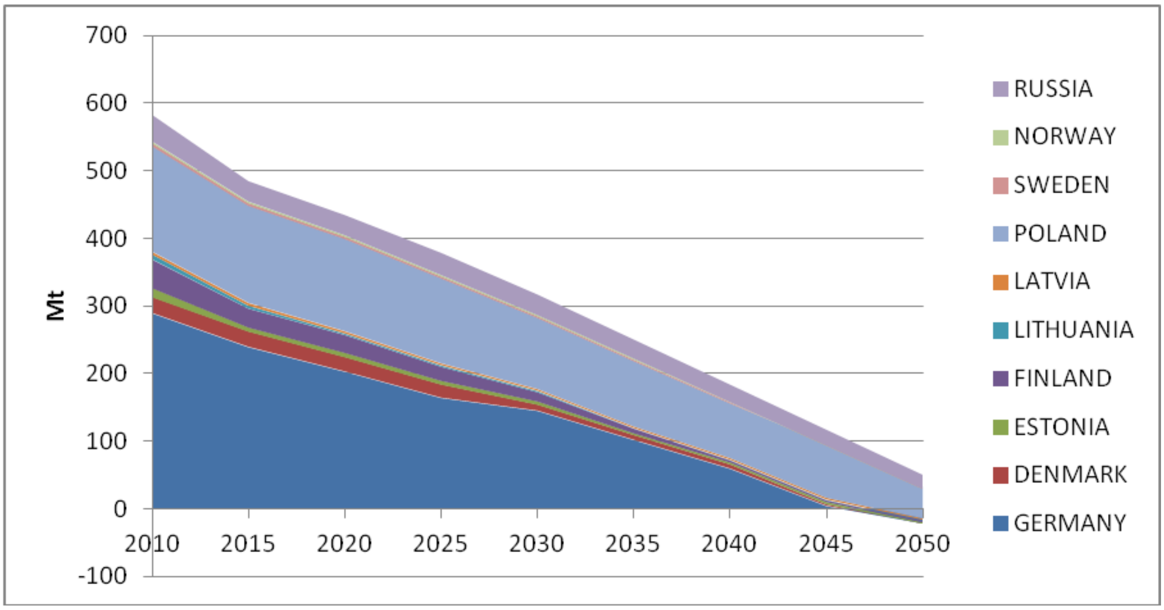


Figure 39: Total CO_2-emission (megatons) by country from 2010 to 2050 for the Low carbon scenario.

The vast majority of CO_2-emissions also derive from coal power in the beginning of the period in this scenario. Only from 2035 this pattern changes as emissions from coal power have been reduced to a level where natural gas becomes an equally important CO_2-source. The introduction of biomass CCS plants with negative net emissions by the end of the period makes allowance for continued use of gas power.

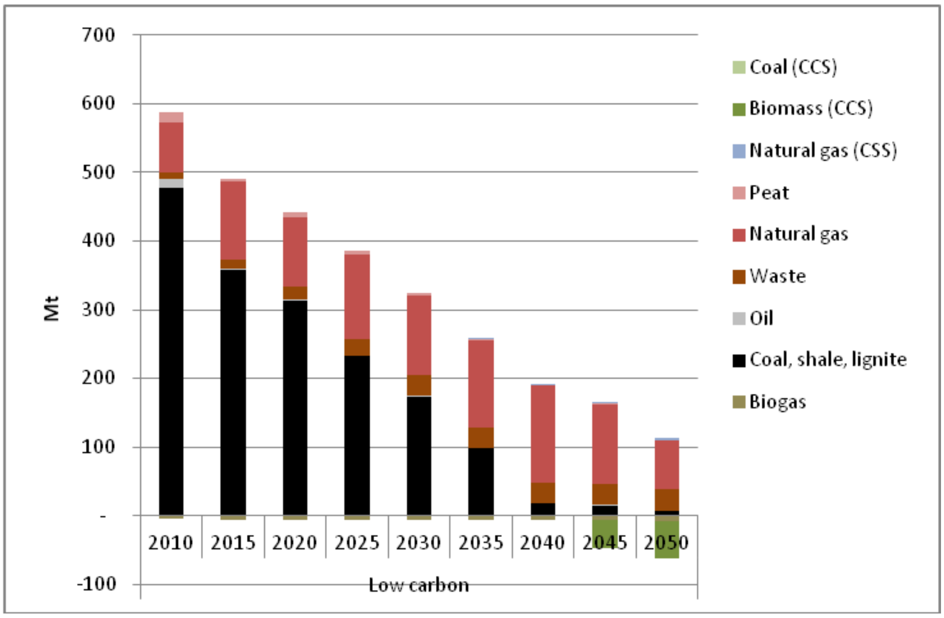


Figure 40: Total CO_2-emission (megatons) from 2010 to 2050 grouped by fuel for the Low carbon scenario.

The reduction pattern in 2020 is similar to the reference. Germany over-complies with the 30 % reduction target whereas emissions are higher in Denmark, Finland and Poland.

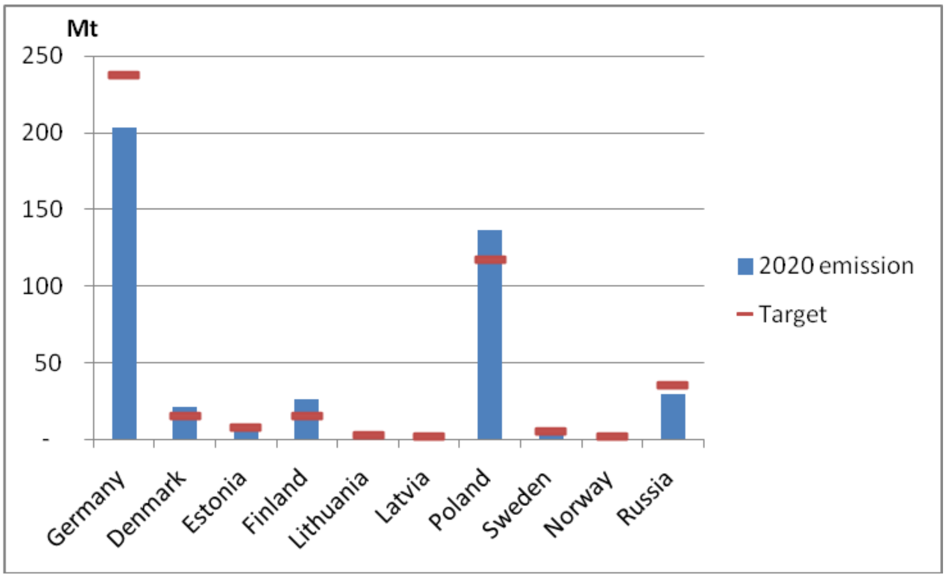


Figure 41: CO_2 emissions in all countries in 2020 compared to CO_2 targets in the Low carbon scenario.

Exchange of electricity

As was the case in the reference Germany and Poland become netimporters of electricity, whereas Norway and Sweden are important export countries.

(TWh/year)	2010	2015	2020	2025	2030	2035	2040	2045	2050
Denmark	5.5	11.9	14.1	13.0	1.2	1.0	8.6	4.8	-4.6
Sweden	-6.2	-2.1	-5.5	-0.4	2.7	6.3	10.3	12.7	28.1
Norway	2.6	5.7	9.6	18.5	26.3	34.8	45.0	52.8	61.2
Finland	-5.5	-2.0	-6.3	2.5	5.9	-3.7	-9.7	-8.2	-5.8
Germany	-7.6	-28.1	-30.8	-47.5	-35.3	-33.7	-42.7	-39.9	-39.4
Estonia	3.0	-1.4	-1.4	-2.7	-4.3	-4.5	-4.8	-5.1	-5.4
Lithuania	-3.5	-4.1	1.0	-0.1	-2.4	-6.1	-6.6	-7.1	0.5
Latvia	1.3	4.0	1.7	-0.1	-1.8	-3.0	-3.3	-3.8	-3.9
Poland	9.5	-1.9	-8.2	-9.4	-10.4	-9.8	-15.5	-22.9	-38.6
Russia	1.0	18.1	25.9	26.2	17.9	18.6	18.9	16.8	7.7

Table 10: Import (-) and export (+) in all countries in Low carbon scenario in 2010-2050 in TWh.

In the low carbon scenario more investments are made in transmission capacity than in the reference. Also, the investments are made earlier than in the reference indicating that the bottlenecks appear sooner – among others because of the greater expansion with wind power between 2020 and 2040.

MW/year	2025	2030	2035	2040	2045	2050
DE_NE						
DE_CS			1.407	128	1.168	6.000
DE_NW						
DE_CS			25	4.069	4.408	6.000
FI_R						
EE_R						683
NO_S						
DE_NW						271
DK_W				442	1.000	1.000
NO_M	31	262				
PL_Central						
LT_R						758
PL_NW						
DE_CS				461	1.216	90
PL_W						
DE_CS					538	2.757
RU_KAL						
PL_Central		659	315	71		715
SE_M						
DK_W				575	875	1.000
LT_R						1.000
SE_N						
NO_M						70
NO_N			512	817	1.108	1.329
SE_S						
DE_NE			56	341	958	1.000
DE_NW						597
DK_E						344
PL_NW			84	1.000	1.000	1.000

Table 11: Investments in new transmission capacity between regions (MW/year)

Utilisation of biomass resources

The utilisation of biomass grows gradually from the current level around 1000 PJ to reach approx. 3000 PJ in 2050. For comparison the total amount of bioenergy, which is available for power and district heating generation, in the model is approx. 3900 PJ. As mentioned in chapter 2 the biomass resource is confined to the domestic resources of the region.

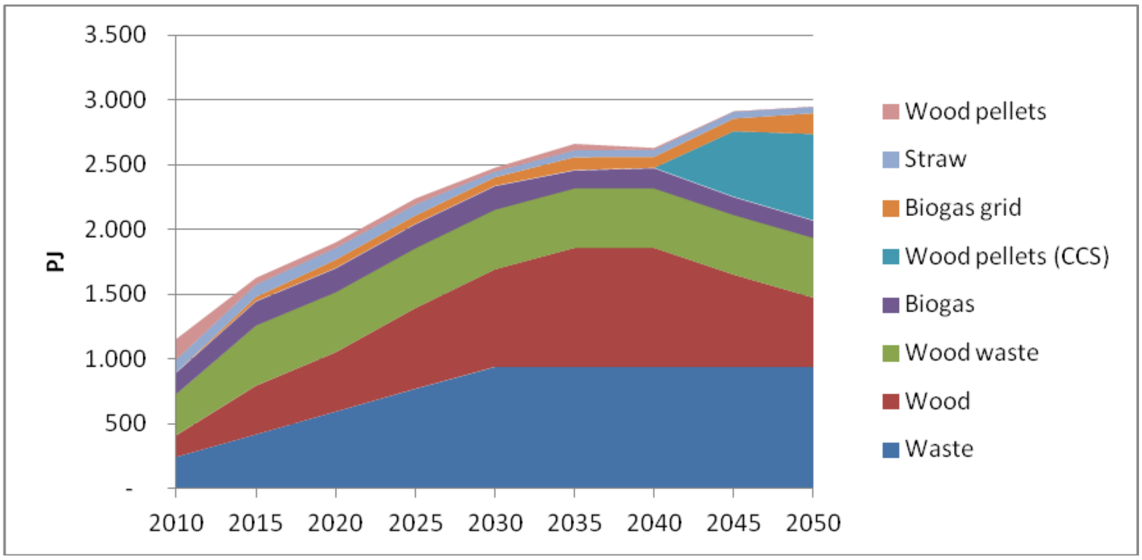


Figure 42: Utilisation of biomass resources in the Low carbon scenario.

3.3 Low carbon renewable scenario

The low carbon renewable scenario to a higher degree focuses on renewable energy as the long-term means to reduce CO_2-emissions. CCS is not an option in the low carbon renewable scenarios, whereas the development of nuclear power is the same as in the low carbon scenario and the reference. The Low carbon renewable scenario also complies with the same targets as the Low carbon scenario, i.e. the national renewable energy target for 2020 as well as 30 % reduction of CO_2-emissions in 2020 compared to 2005. Between 2020 and 2050 the CO_2-reduction target is gradually increased to 100 %.

Going towards 2050 the national renewable energy targets are kept constant, except for Germany where the national target to increase renewable energy in the electricity sector to 80 % is taken into account.

Therefore, until 2035 when CCS is introduced in the Low carbon scenario, the two scenarios are identical. This presentation of the Low carbon renewable scenario focuses on the period beyond 2020.

Electricity generation by fuel

In the Low carbon renewable scenario the utilization of CCS technologies is compensated for by higher generation from wind power, biomass and biogas. Wind increases its share in electricity generation in 2050 from 27 % to 34 % and biomass/biogas from 16 % to 20 %. Coal-fired power plants are completely phased out as biomass CCS plants are not available in this scenario to compensate for their emissions and the share of natural gas based electricity generation (incl.) drops from 15 % to 5 %.

In total the share of electricity from renewable energy plants increases by more than 10 % from 67 % in the Low carbon scenario to 78 % in the Low carbon renewable scenario.

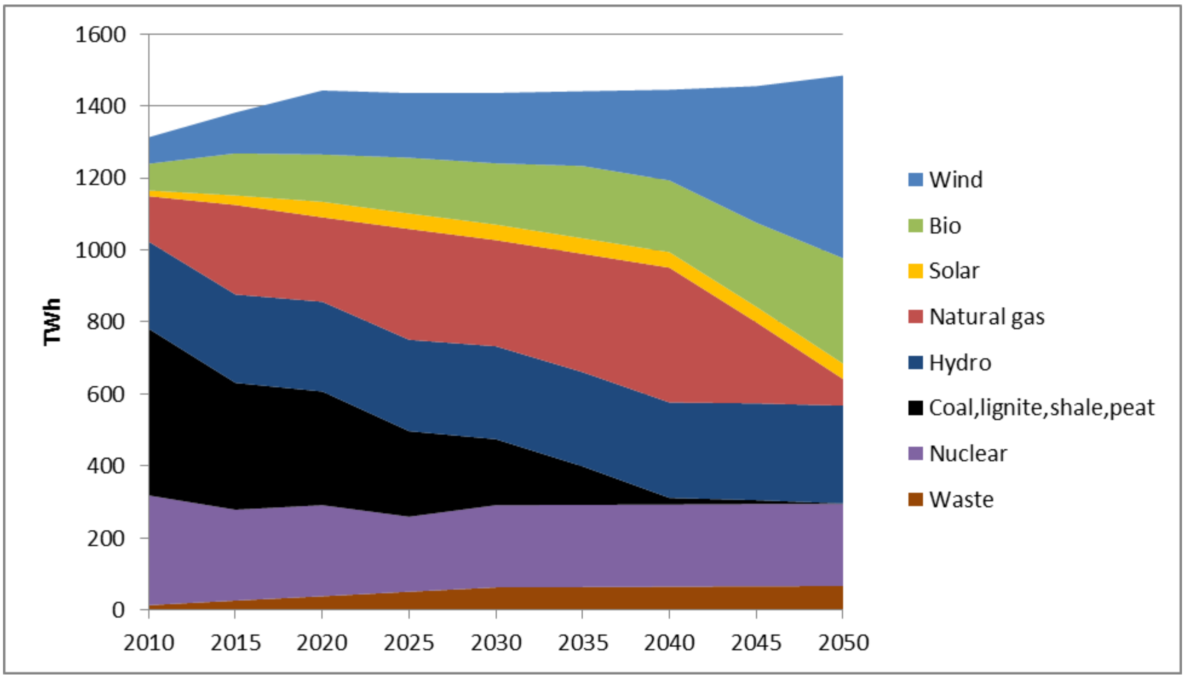
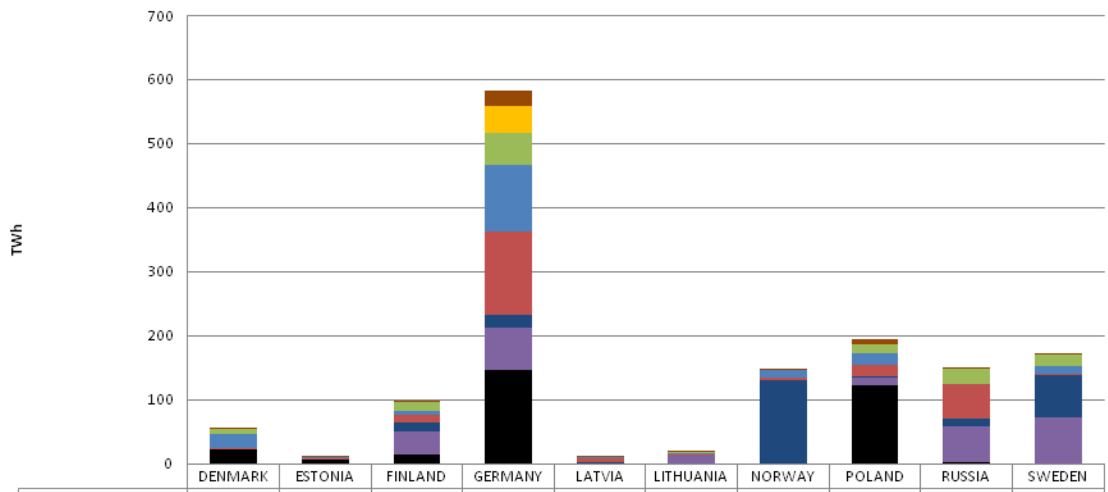


Figure 43: Total electricity generation (TWh) by fuel for Low carbon RE scenario.

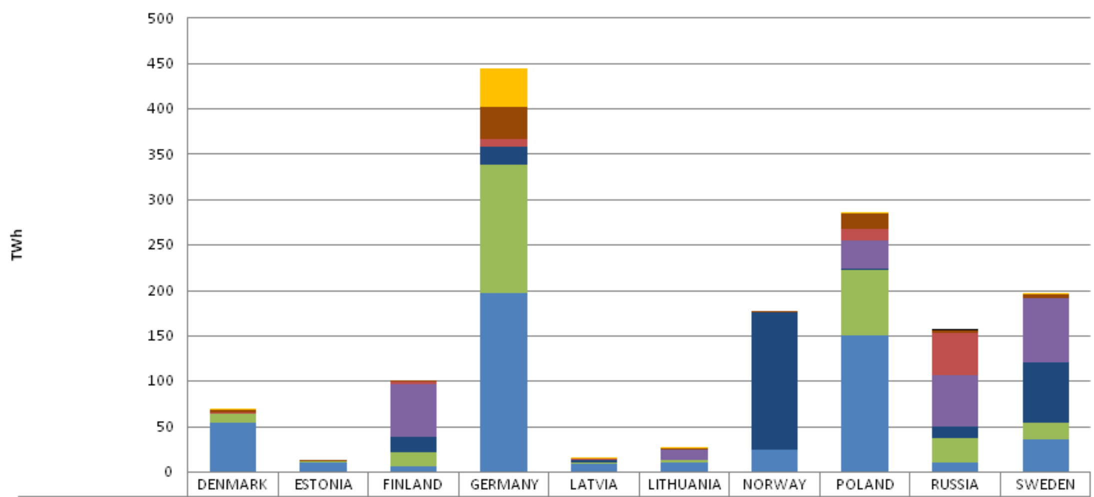
Electricity generation by country

Electricity generation divided by country in 2020 and 2050 can be seen in Figure 24 and Figure 25 respectively.



	DENMARK	ESTONIA	FINLAND	GERMANY	LATVIA	LITHUANIA	NORWAY	POLAND	RUSSIA	SWEDEN
Waste	2	0	2	23	1	0	1	8	1	1
Solar	0			43	0	0		0		0
Bio	9	0	13	49	1	2	0	14	24	17
Wind	22	2	6	104	1	2	11	17	0	13
Natural gas	2	2	13	130	6	2	5	18	54	3
Hydro			14	20	3	0	130	2	12	67
Nuclear			35	66		12		12	56	71
Coal,lignite,shale,peat	22	6	15	147				123	3	1

Figure 44: Electricity generation (TWh) by country in 2020 for the Low carbon RE scenario



	DENMARK	ESTONIA	FINLAND	GERMANY	LATVIA	LITHUANIA	NORWAY	POLAND	RUSSIA	SWEDEN
Coal,lignite,shale,peat									1	
Solar	0			43	0	0		0		0
Waste	3	1	2	35	1	1	2	16	3	4
Natural gas	1	1	2	8	1			14	47	
Nuclear			59			12		30	56	71
Hydro			16	20	3	0	151	2	12	67
Bio	11	1	16	142	1	3		73	27	19
Wind	54	11	6	197	9	10	24	150	10	36

Figure 45: Electricity generation (TWh) by country in 2050 for the Low carbon RE scenario

Heat generation

The sources of fuel for district heating generation are not very different between the low carbon scenario and the low carbon renewable scenario. By the end of the period generation from biomass, biogas and electricity generation plays a greater role in the renewable scenario whereas there is a marked decrease in the generation of heat from gas-fired power plants.

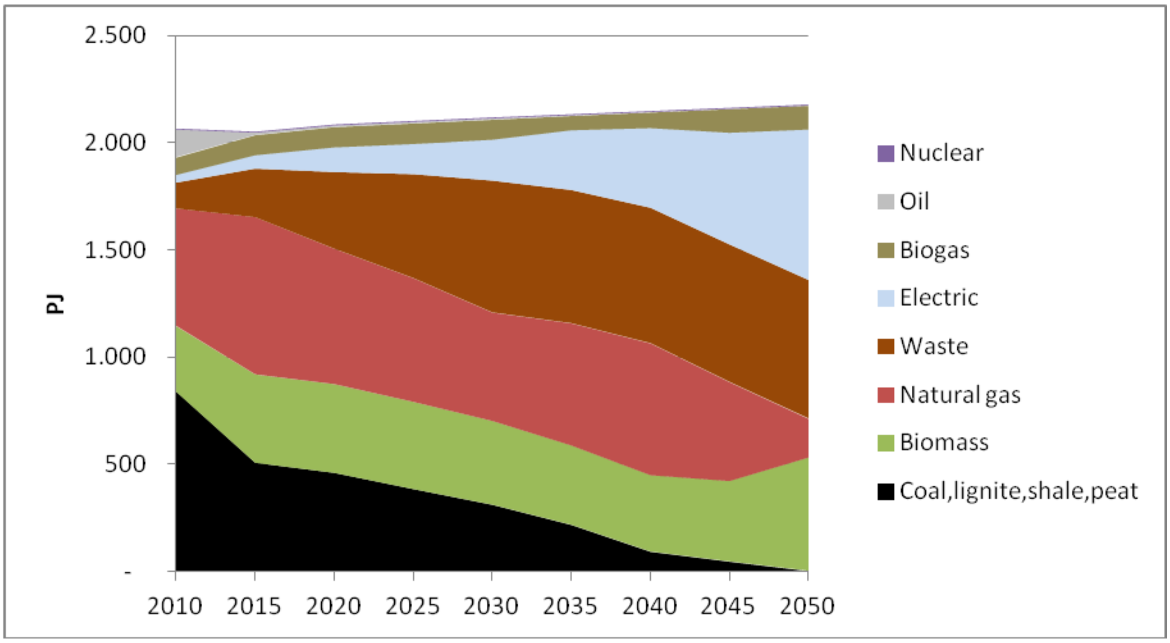


Figure 46: Total heat generation (PJ) by fuel for Low carbon RE scenario.

CO_2-prices

Figure 47 compares CO_2-prices of the Low carbon scenario with the Low carbon renewable scenario. In the long-term the CO_2-prices in the Low carbon renewable scenario increase to a much higher level than in the Low carbon scenario, in 2050 the price is app. 384 €/ton in the EU ETS compared to about 135 €/ton in the Low carbon scenario. The reason for this is that among other things peak loads options and balancing power for wind becomes more expensive in the renewable scenario where the role of conventional gas power is marginal.

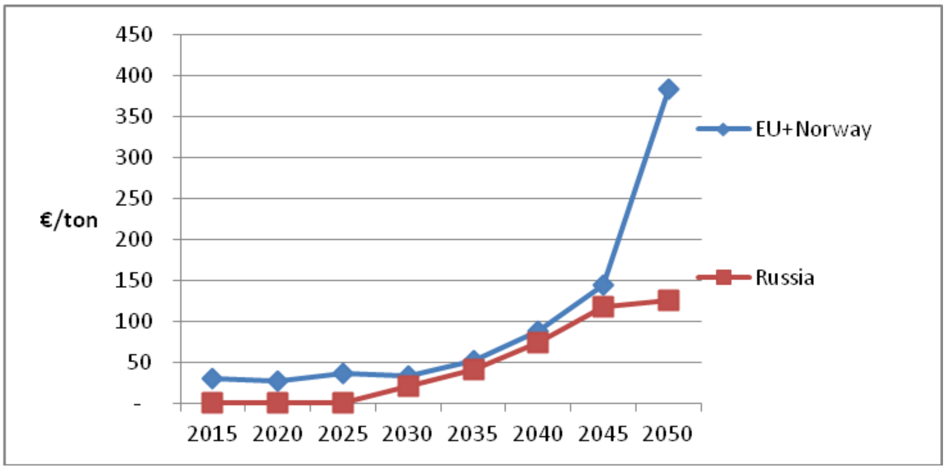


Figure 47: Calculated CO_2-prices (€/ton) in EU ETS (EU+Norway) and in Russia in the Low carbon RE scenario.

Electricity market prices

In general an increasing level of electricity market prices is observed in Low carbon renewable scenario compared to the Low carbon scenario.

Electricity prices in Norway, Sweden and Finland remain at a relative stable and low level whereas prices in Germany and Poland reach around 11 €C/kWh. The price diversity between countries increases compared to the Low carbon scenario.

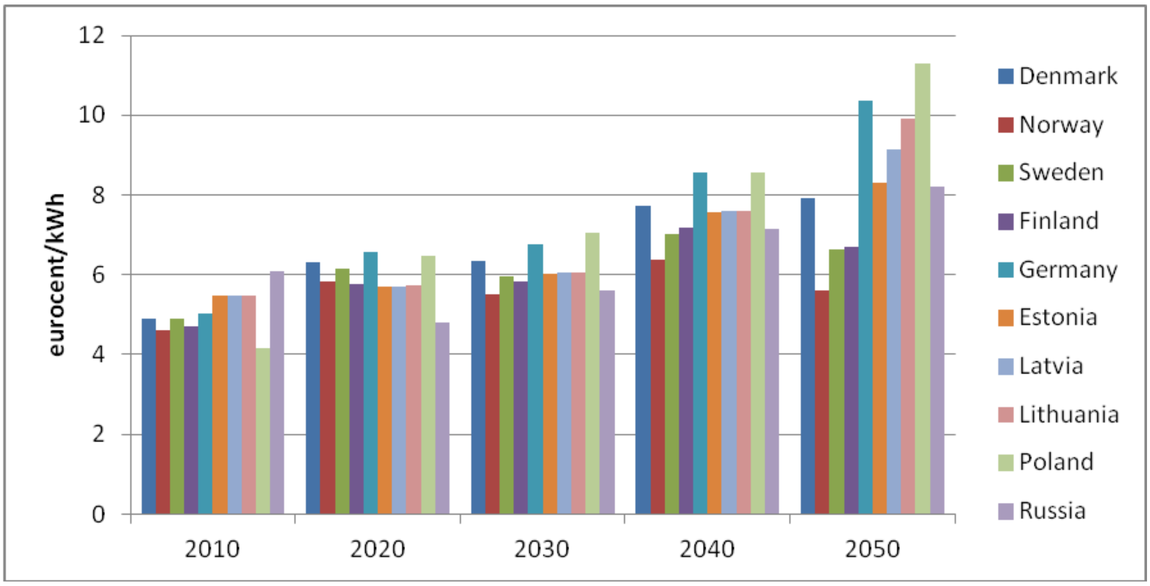


Figure 48: Average yearly electricity market prices (€C/kWh) by country in the Low carbon RE scenario.

CO_2-emissions

Contrary to the development in the Low carbon scenario – where CO_2-emissions in Poland were relatively constant for a long-period – the reduction of CO_2 emissions beyond 2040 in this scenario takes place more uniformly across all countries.

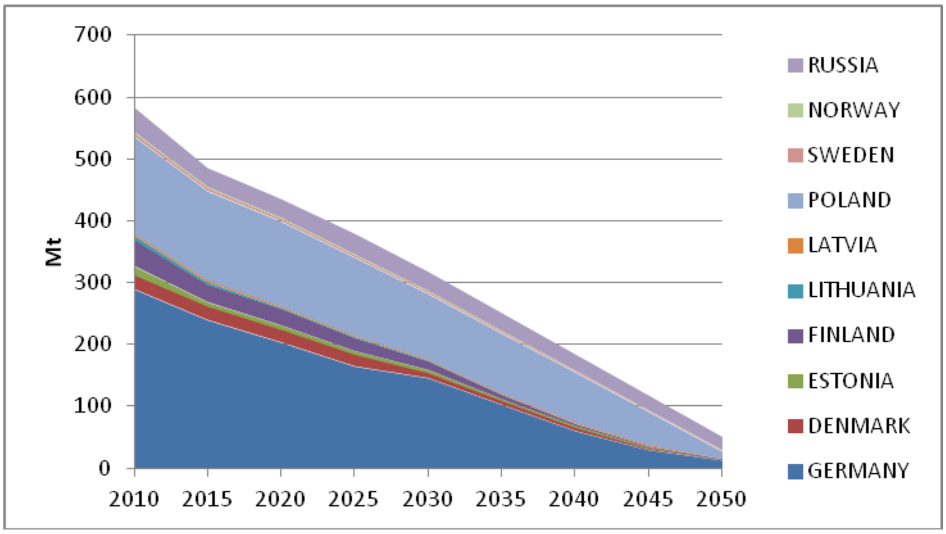


Figure 49: Total CO_2-emission (megatons) by country from 2010 to 2050 for Low carbon RE scenario.

As coal power generation is phased out almost completely by 2040 gas power is the greatest source of CO_2-emissions.

The negative emissions from biogas allows for a small fraction of natural gas to be used for electricity and heat generation within the EU ETS in spite of the target to be carbon neutral by 2050.

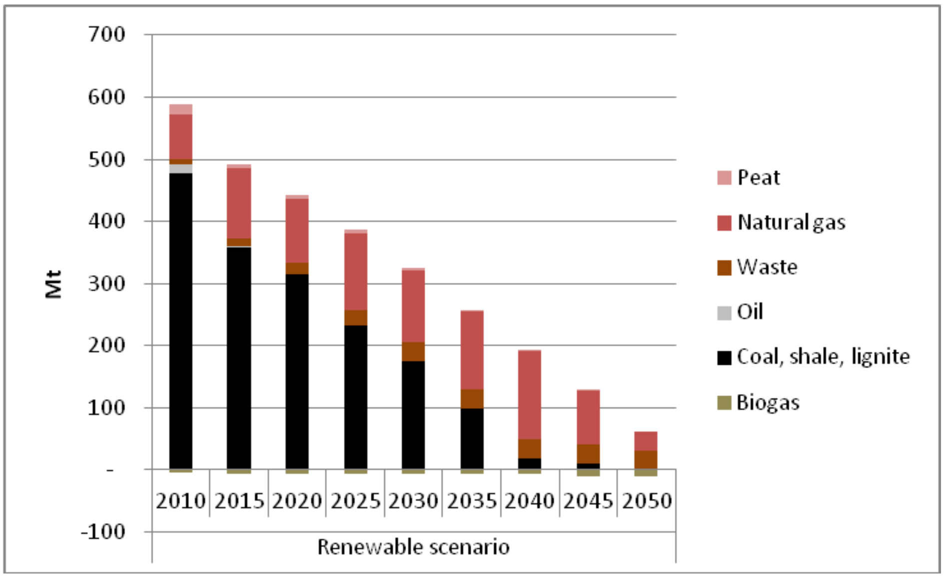


Figure 50: Total CO_2-emission (megatons) from 2010 to 2050 grouped by fuel for Low carbon RE scenario.

Utilisation of biomass resources

The use of bioenergy resources increases gradually over the period and by 2050 approximately 3300 PJ is utilised, including municipal solid waste.

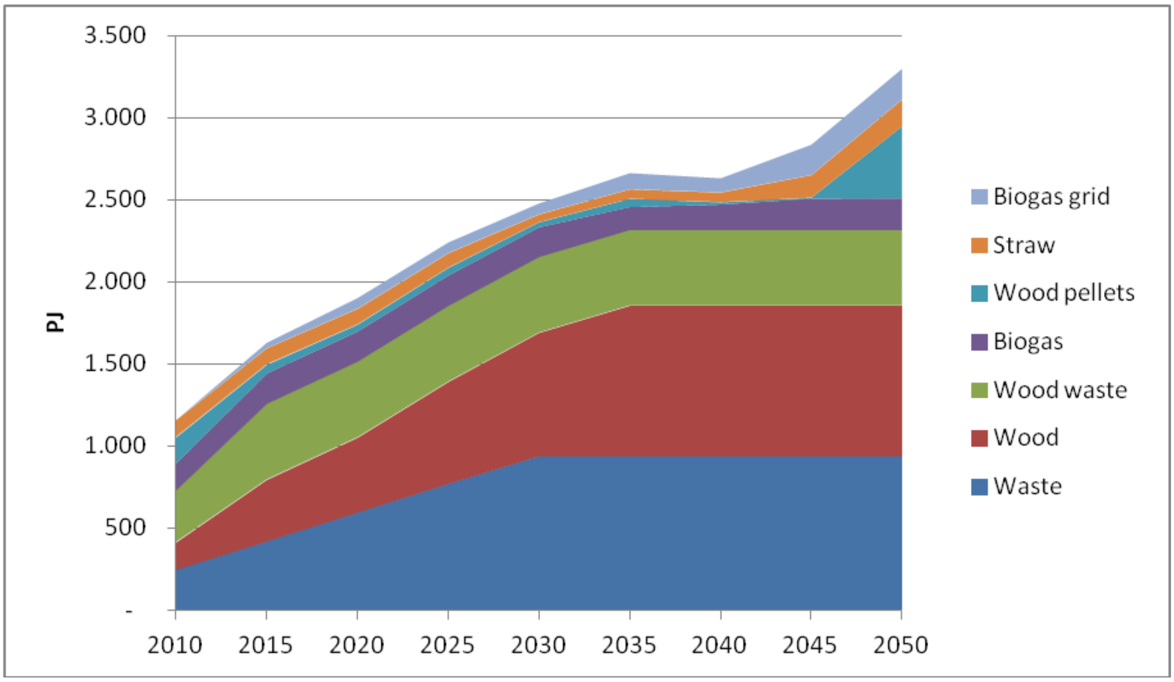


Figure 51: Utilisation of biomass resources in the Low carbon RE scenario.

The import/export figures confirm the trend from the low carbon scenario that Germany and Poland become import countries whereas particularly Norway, Sweden and Denmark and Russia are exporters. The German import of electricity is considerably higher than in the Low carbon scenario because there is no option of investing in generation with CCS.

(TWh/year)	2010	2015	2020	2025	2030	2035	2040	2045	2050
Denmark	5.5	11.9	14.1	13.0	1.2	1.0	8.5	22.5	18.9
Sweden	-6.2	-2.1	-5.5	-0.4	2.7	6.1	10.0	8.5	15.1
Norway	2.6	5.7	9.6	18.5	26.3	34.8	45.0	60.5	64.9
Finland	-5.5	-2.0	-6.3	2.5	5.9	-3.7	-9.7	-8.1	-5.6
Germany	-7.6	-28.1	-30.8	-47.5	-35.3	-33.6	-42.7	-70.9	-81.2
Estonia	3.0	-1.4	-1.4	-2.7	-4.3	-4.5	-4.8	-5.1	-0.3
Lithuania	-3.5	-4.1	1.0	-0.1	-2.4	-6.1	-6.6	0.4	1.8
Latvia	1.3	4.0	1.7	-0.1	-1.8	-2.9	-3.3	-3.5	-1.8
Poland	9.5	-1.9	-8.2	-9.4	-10.4	-9.6	-15.1	-16.6	-14.3
Russia	1.0	18.1	25.9	26.2	17.9	18.6	18.9	12.3	2.5

Table 12: Import (-) and export (+) in all countries in Low carbon scenario RE scenario in 2010-2050 in TWh.

The level of investments in transmission capacity in this scenario is noticeably higher than in the Low carbon scenario. This is result of the greater expansion with wind power, which is located further away from the load-centres than the CCS power plants that are established in the Low carbon scenario. Moreover, wind power to high degree benefits from a strong transmission grid because of the smoothing of wind output through the spatial distribution of generation.

MW/year	2025	2030	2035	2040	2045	2050
DE_NE						
DE_CS			1.497	223	3.306	6.000
DK_E					530	1.000
DE_NW						
DE_CS			24	4.069	3.788	4.986
DE_NE						373
DK_W					374	422
FI_R						
EE_R					122	855
LT_R						
LV_R						557
LV_R						
EE_R						503
NO_N						
FI_R						656
NO_O						
DK_E						1.000
NO_S						808
NO_S						
DE_NW					587	636
DK_W				671	1.000	1.000
NO_M	26	260	169	144	366	
PL_Central						
LT_R					724	1.517
PL_NW						
DE_CS	225	521	1.439	680	2.079	1.161
PL_W						
DE_CS					757	2.553
RU_KAL						
PL_Central		659	320	65	470	1.485
SE_S						1.000
SE_M						
DK_W				409	865	975
EE_R						1.000
LT_R					1.000	1.000
SE_N						

NO_M				50
NO_N	454	767	1.298	1.439
SE_S				
DE_NE	89	258	787	1.000
DE_NW			654	798
DK_E				170
LT_R				1.000
PL_NW	75	695	1.000	1.000
SE_M				2.463

Table 13: Investments in new transmission capacity between regions (MW/year)

3.4 Cross-cutting comparison

Figure 47 compares the CO_2-prices in the three scenarios. CO_2-prices are markedly higher in the Low carbon scenario and again markedly higher in the Low carbon renewable scenario.

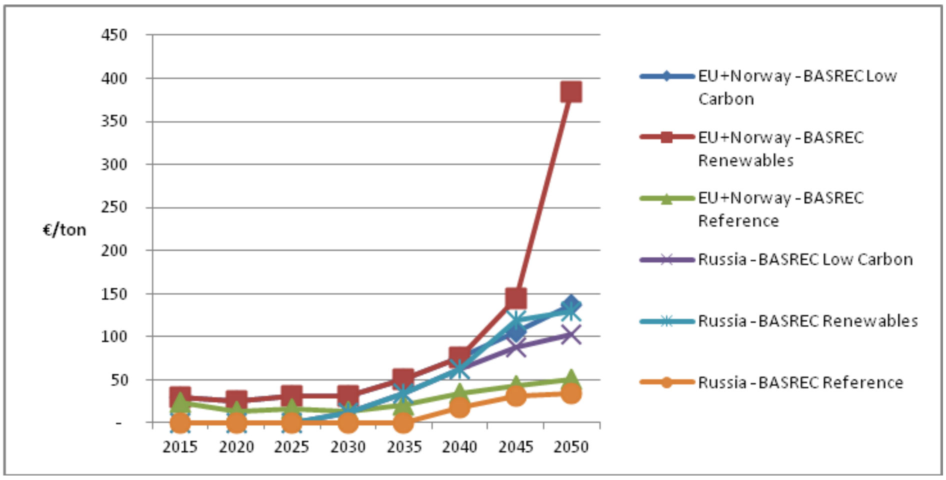


Figure 52: Calculated CO_2-prices (€/ton) in EU ETS (EU+Norway) and in Russia in the three scenarios

Looking at the total energy cost (capital, fuel and operation and maintenance cost) the difference between the scenarios is much smaller.

The total costs[28] of maintaining electricity and district heating supply in 2020 will be approx. 0.5% higher with an EU target of reducing CO_2 emissions by 30% compared to a 20% target[29]. As previously mentioned, in accordance with the EU energy road map different sets of fuel prices is used for the reference projection and the low carbon scenarios. The low carbon scenarios assume that global action is taken to significantly bringing down greenhouse gas emissions. This again reduces fossil fuel demand

[28] Costs include capital costs of power plants, transmission connections etc. as well as fixed and variable operation and maintenance costs and fuel costs. No price is attached to the emission of CO_2, but the cost of reducing CO_2-emissions can be estimated by comparing the different scenarios.
[29] In North West Russia the assumed target is increased from 0% to 15% reduction.

worldwide providing a downward effect on fossil fuel prices. Oil, gas and coal prices are therefore lower in the low carbon scenario than in the reference scenario whereas biomass prices are higher. The economic results should be interpreted with this difference in mind.

Supplementary simulations indicate that the difference in total costs in 2020 would be around 1.4% if fuel prices where the same in all scenarios[30].

The additional costs of achieving a carbon neutral electricity and district heating system in 2050 via the low carbon scenario is approximately 12% higher than in the reference scenario where CO_2-emissions are reduced by 50 %. Meanwhile, in the low carbon renewable scenario where CCS does not play a role, the additional costs are about 19% higher relative to the reference scenario. Supplementary simulations show that the difference in total costs between the reference and the low carbon scenarios would be around 20-25 % if fuel prices were the same in all scenarios in 2050[31]. Capital costs are highest in the Low carbon renewable scenario, but this scenario has the lowest fuel costs.

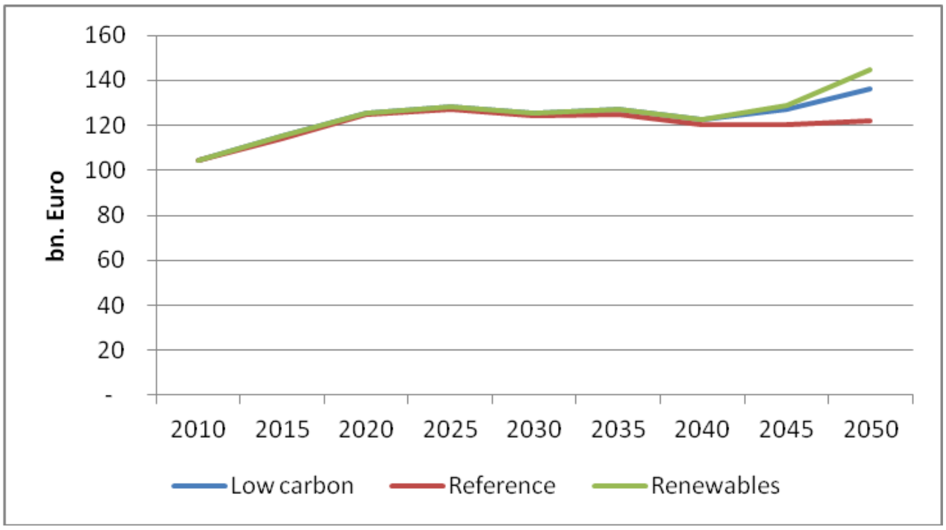


Figure 53: Total capital, fixed, variable and fuel costs in the scenarios (Billion euro/year)

Investments in transmission capacity

The study indicates that especially in the medium and long term, there is a need for large expansions of the transmission grid in the Baltic Sea Region (Figure 7). Current transmission capacities amount to approximately 45 GW[32], which is envisioned to increase to 59 GW in 2020 considering projects that are likely to be implemented.

In both of the low carbon developments the expansion of transmission capacity is crucial for the achievements of the emission reduction objective and in particular allows wind power to be utilised cost-efficiently in the region. In total the demand for

[30] Based on the IEA WEO 2011 fuel price forecast prolonged from 2035 to 2050.
[31] Based on the IEA WEO 2011 fuel price forecast prolonged from 2035 to 2050.
[32] This figure represents the capacities on the bottlenecks represented in the Balmorel model.

transmission capacity increases to approx. 110 GW in 2050 in the Low carbon scenario and even higher in the low carbon RE scenario, 145 GW.

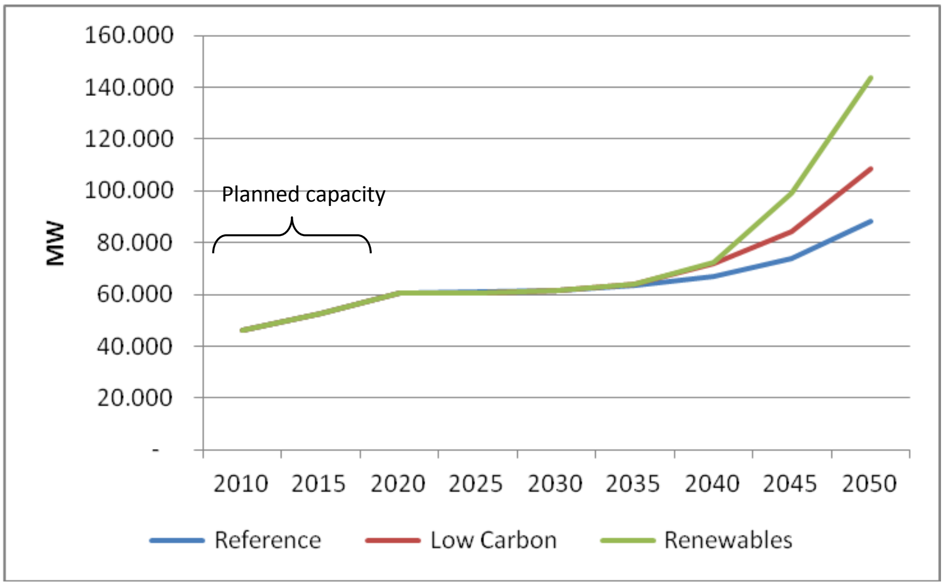


Figure 54: Total cumulated transmission capacity in the scenarios (MW/year). 'Planned capacity' concern transmission lines that are likely to be commissioned between 2011 and 2020, some connections have already been decided upon whereas others are being planned for.

4 Analyses of selected policy measures

This chapter presents the results of a selected number of policy measures addressing a number of the research questions raised in chapter 2:

1. *What are the benefits of harmonizing renewable energy support schemes?*
2. *What are the benefits of a coordinated planning and expansion of the electricity transmission grid in the region?*
3. *What are the benefits of linking the EU Emission Trading System with potential Russian CO_2-regulation?*

The measures were analysed on the Low Carbon scenario.

4.1 Analyses of selected policy measures

1. Renewable energy support scheme cooperation.

The National Renewable Energy Action Plans (NREAP) of the EU member states specifies the national plans for deployment of renewable energy towards 2020. In this scenario these national targets are set as a regional target that should be fulfilled within the BASREC EU member states. In the reference the development of renewable energy generation is based on the projections in the national renewable energy action plans. In 2020 an analysis is made, which includes the same total RE deployment in the region but excluding any constraints on geographic location of the new capacities.

An economic evaluation of the cooperation on complying with the NREAPs shows that total costs could be reduced by roughly 0.5% in 2020, which corresponds to a benefit of approximately €500 million.

In Figure 55 biomass generation in the case with and without the common energy support scheme cooperation is shown on the individual BASREC EU countries. It can be seen that the model chooses to increase the utilisation of the bio resource in Sweden, where there is a higher potential for biomass with low costs.

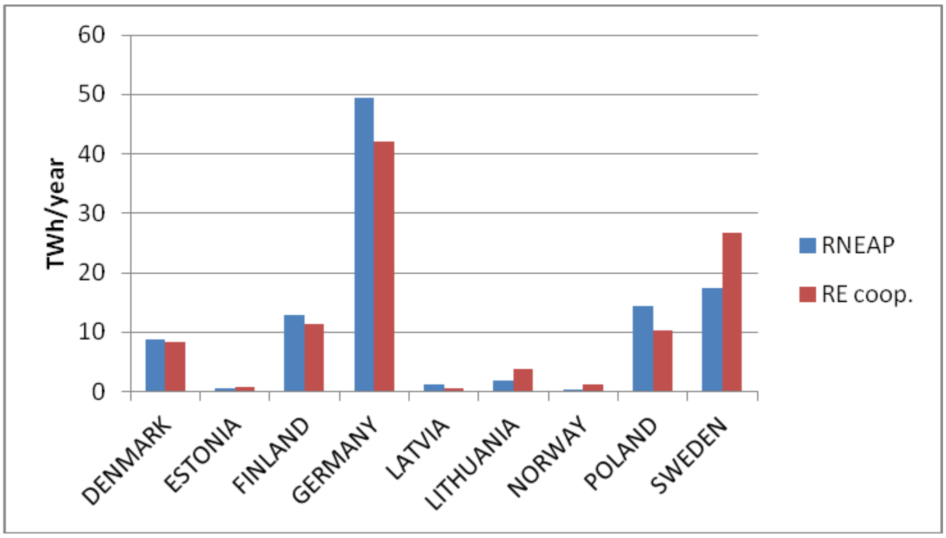


Figure 55: Biomass generation in 2020 in the Low carbon scenario with the specific RNEAP development in the individual countries and the cooperation scenario with a common target for biomass generation.

Figure 56 shows the distribution of wind generation in the scenario with and without RE support scheme cooperation. The figure illustrates how the model chooses to deploy the wind power generation in the countries with the best available onshore wind resource to reduce the costs, i.e. in Sweden, Norway and Denmark.

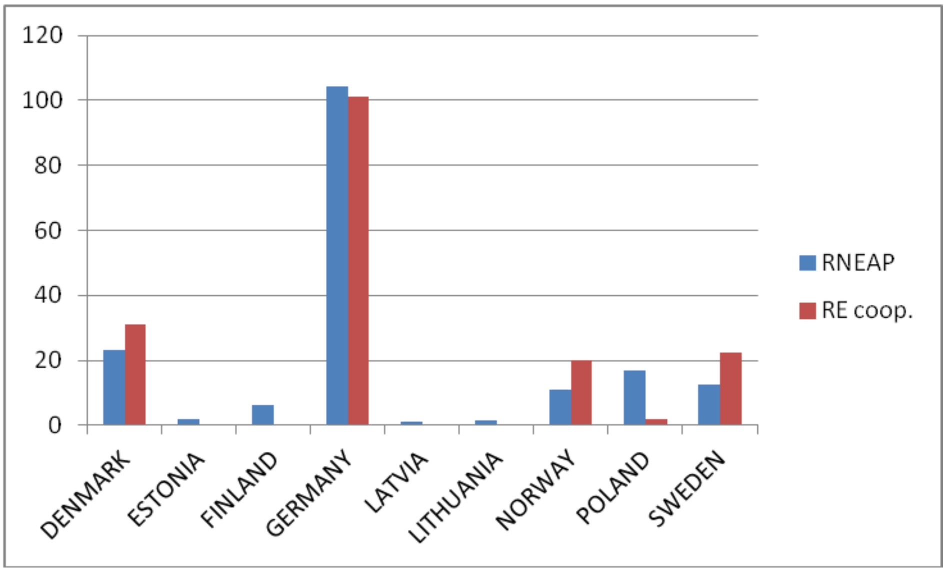


Figure 56: Wind generation in 2020 in the Low carbon scenario with the specific RNEAP development in the individual countries and the cooperation scenario with a common target for wind generation.

2. Linking the EU Emission Trading System with potential Russian CO_2-regulation.

The base assumption is that one CO_2 cap is set for countries within the EU Emission Trading System (EU ETS) and another cap for Russia. In this scenario the cap on CO2 emissions is set as one cap for the entire region. All countries in the region except Russia are encompassed by the EU's emissions trading scheme. In the reference scenario Russia is subject to a national CO2-target. The benefits of linking the EU scheme and the Russian target are examined by imposing a common cap on CO2 for the whole region, which gives the same absolute CO2-reduction as the reference. The hypothesis is that cheaper CO2-abatements measures are available in Russia leading to lower overall compliance cost for the region if the schemes are linked.

An economic comparison shows that linking the EU Emission Trading System with potential Russian CO2-regulation will reduce total costs of the Low carbon scenario by 0.2% in 2020, which corresponds to a reduction in costs of around €225 million.

The figure below illustrates the CO_2 prices in the situation with and without linking of the CO_2 markets. The EU+Norway price drops by €2 in 2020 when linking the EU and Russia and less than €1 in 2050 within the EU ETS. This means that there is a potential for cost reductions when linking the schemes.

The reason why the impact on the EU price is relatively small is that NW Russia only makes up approx. 7 % of the total market for electricity in the region. If the EU ETS was connected with a similar system covering the whole of Russia, the benefits could potentially be significantly greater.

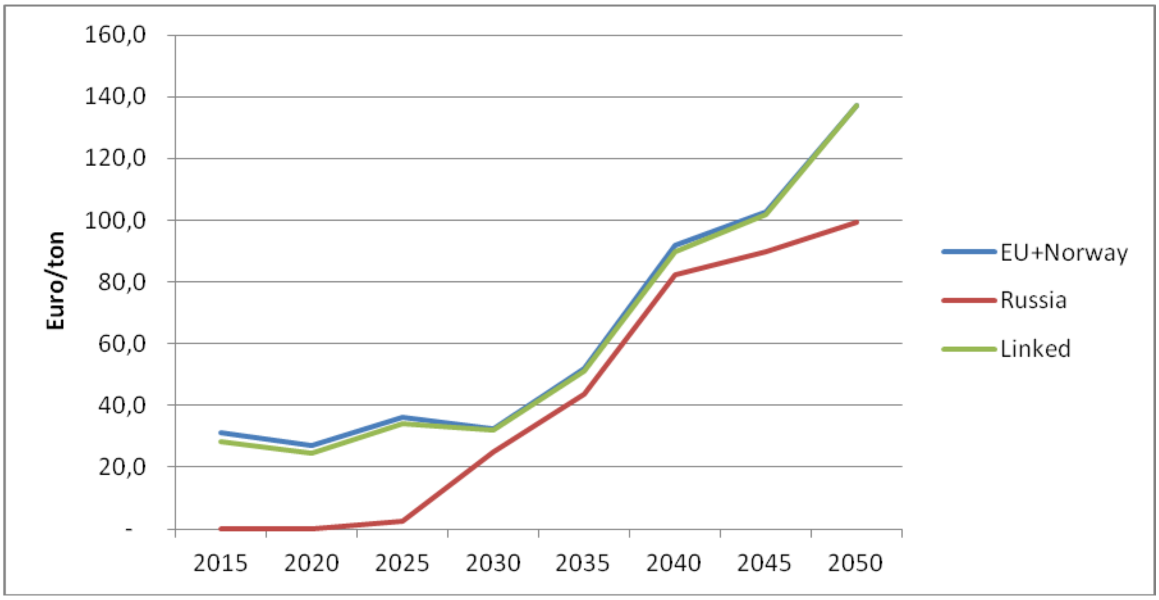


Figure 57: Calculated CO_2-prices (€/ton) in EU ETS (EU+Norway) and in Russia in the Low carbon RE scenario compared to a price when the schemes are linked.

3. Coordinated planning and expansion of the electricity transmission grid in the region.

In this policy scenario the expansion of the transmission grid is not allowed across the countries of the Baltic Sea Region other than what is already planned for to date for the period towards 2020. Development of the internal grid in each country is still an option. Comparing this scenario with the case of unrestricted cross-border expansion of the transmission grid shows the benefits of regional cooperation on transmission development. Provided the investments costs of expanding interconnectors in the region the model is able to compute an optimal grid development. To estimate the benefits of a coordinated grid expansion, the optimal grid development is compared to a situation where the possibilities for establishing cross-border interconnectors are removed.

The simulations show that when the countries in the Baltic Sea Region cooperate on expanding the transmission grid the total costs are reduced by roughly 0.5 % in 2050. This saving corresponds to roughly €600 million.

In the table below the investments in transmission capacity in the scenario is illustrated. There is no option for investing in cross-border transmission is this scenario. Compared to the Low carbon scenario without this restriction, it can be seen that the total investments in transmission capacity made towards 2050 is more than halved from 48 GW to 22 GW. The model also chooses to invest in more internal transmission capacity in some countries. In e.g. Norway more than 1000 MW extra capacity is build compared to the low carbon scenario.

MW/year	2025	2030	2035	2040	2045	2050
DE_NE						
DE_CS			689	23	407	3756
DE_NW						
DE_CS				3347	3945	6000
NO_M						
NO_N				110	267	86
NO_S						
NO_M	28	261	511	814	1111	1064
Total	**28**	**261**	**1200**	**4294**	**5730**	**10906**

Table 14: Investments in new transmission capacity between regions (MW/year)

4.2 Higher electricity demand growth[33]

Forecasting how electricity demand will develop in a 40 year time perspective is associated with a high level of uncertainty relating to among others the degree of electrification of other sectors (transport, heating, industry), the demand for new types of energy services – that we may not be able to imagine today – and the effect of energy efficiency policies.

Against this background a variation of the Low carbon scenario has been analysed where electricity demand in the region grows at a higher pace of 1.0 % per annum corresponding to a 50 % increase between today and 2050.

In this case, the share of CCS in total electricity supply increases from 5 % to 14 %. Moreover, it becomes attractive to utilize both gas CCS, coal CCS and biomass CCS.

Generation from conventional gas power also increases significantly, reaching a higher level of production in 2050 than in 2010, whereas wind power maintains a share of 30 % in overall electricity supply. The marginal cost of reducing CO_2 reaches €150/ton in 2050 compared to €95/ton in the Low carbon scenario.

[33] This policy scenario has been simulated using assumptions that are slightly different from the core scenarios. Most importantly, the IEA WEO 2011 fuel price forecast is used, prolonged from 2035 to 2050.

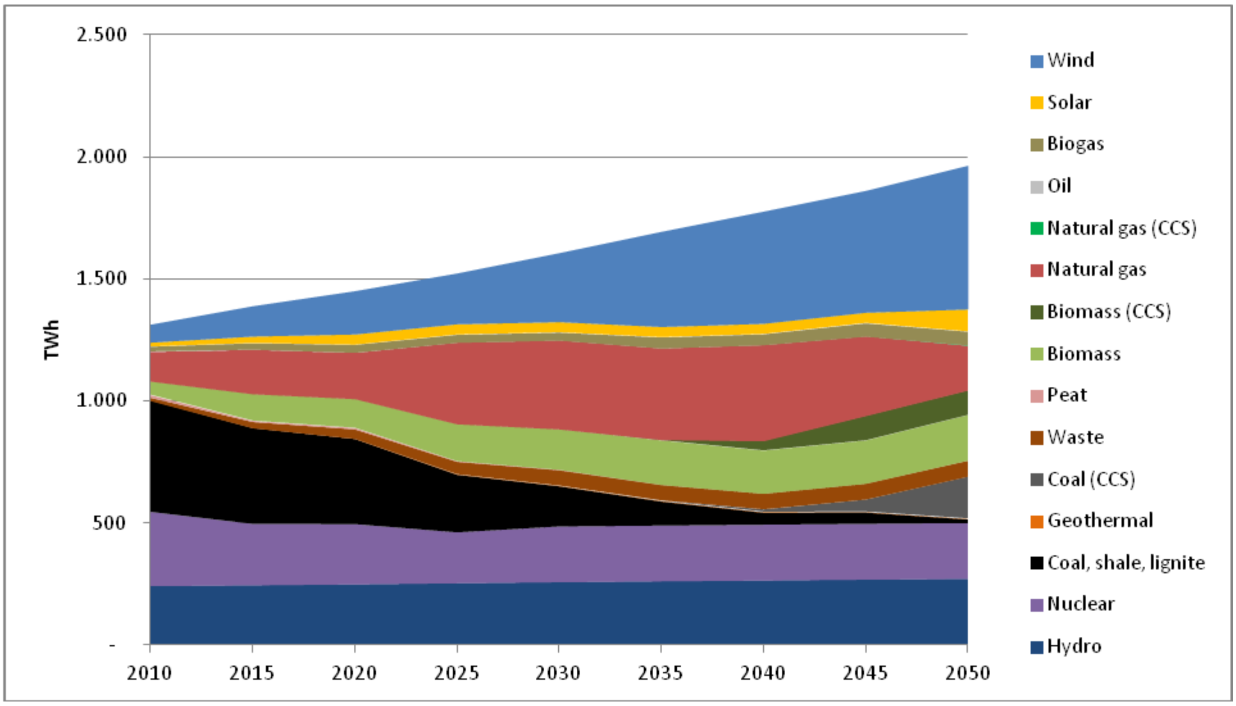


Figure 58: Electricity generation in the case Low carbon scenario with high electricity demand.

CCS plays a key role in the scenario because it becomes an economically attractive when the cheapest renewable energy options are exhausted. The power plants equipped with CCS are mainly located in southern/central Germany and in Poland. The reason for this is probably the less favourable access to competitive wind and hydro power resources here than in the other parts of the region. By 2050 some 210 Mt of CO_2 is stored annually.

For comparison a survey of the storage capacities in the EU indicate that the total potential for storage is around 3.000 Mt in Poland and 17.000 Mt in Germany. Continuing depositing CO_2 at an annual rate of 210 Mt would then be possible for around 95 years.

In addition, there are large storage capacities in Norway, approx. 29000 Mt, which could be utilised if the infrastructure is established.

Country	Annual total CO_2 emissions (Mt)	Annual CO_2 emissions from large point sources (Mt)	CO_2 storage capacity in deep saline aquifers (Mt)	CO_2 storage capacity in hydrocarbon fields (Mt)	CO_2 storage capacity in coal fields (Mt)
Slovakia	46	23	1716	-	-
Estonia	21	12	-	-	-
Latvia	4	2	404	-	-
Lithuania	18	6	30	7	-
Poland	325	188	1761	764	415
Czech Republic	128	78	766	33	54
Hungary	79	23	140	389	87
Romania	74	67	7500	1500	-
Bulgaria	52	42	2100	3	17
Albania	0	0	20	111	-
FYROM	6	4	390	-	-
Croatia	23	5	2710	189	-
Spain	423	158	14000	34	145
Italy	212	140	4669	1810	71
Slovenia	20	7	92	2	-
Bosnia-Herzegovina	-	9	197	-	-
Germany	864	465	14900	2180	-
Luxemburg	-	-	-	-	-
The Netherlands	180	92	340	1700	300
France	-	131	7922	770	-
Greece	110	69	184	70	-
United Kingdom	555	258	7100	7300	-
Denmark	52	28	2553	203	-
Norway	-	28	26031	3157	-
Belgium	-	58	199	-	-
Total	-	**1893**	**95724**	**20222**	**1089**

Table 15: Summary of CO_2-emissions (today) and storage capacity estimates (EU GeoCapacity, Assessing geological capacity for geological storage of carbon dioxide, Geological Survey of Greenland and Denmark, 2006-9[34])

[34] http://www.geology.cz/geocapacity/publications/D16%20WP2%20Report%20storage%20capacity-red.pdf

A cleaning efficiency of 85 % is assumed for coal CCS plants. By the end of the period the emissions released from coal CCS plants also provide a visible contribution to overall emissions.

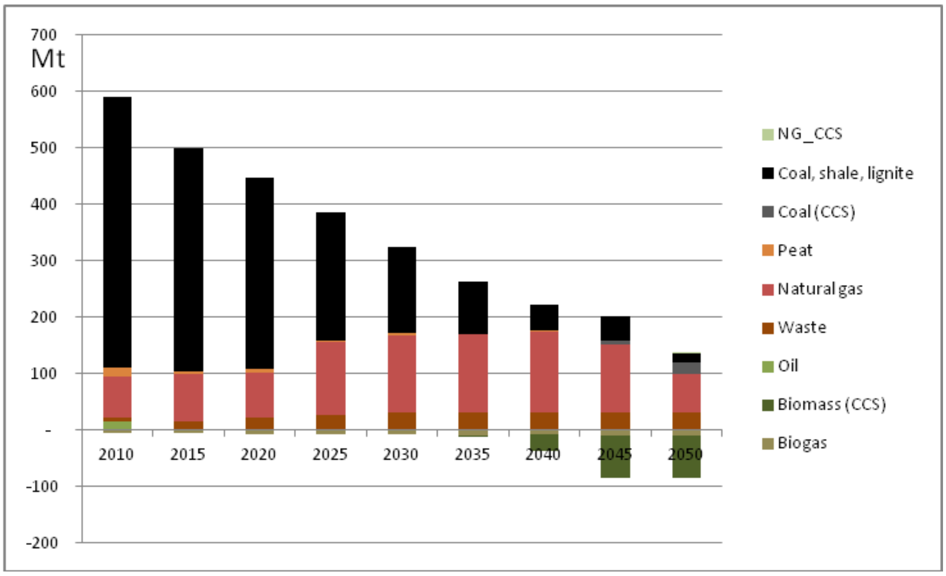


Figure 59: CO_2-emissions by fuel

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