# SUSTAINABLE ENERGY SCENARIOS

2009

## Energy Perspectives for the Baltic Sea Region

Setting an agenda for the future

Ea Energianalyse

norden
Nordic Council of Ministers

Baltic Development Forum

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# Foreword and prefaces

## Foreword

Global attention is firmly directed towards the Baltic Sea Region due to UN Climate Summits in Copenhagen in December 2009 and in Poznan in 2008. The UN Summit in Copenhagen takes place in parallel with the Swedish EU Presidency. These high-level events are unique opportunities for the countries in the region to illustrate to a broader audience the political importance of the region by highlighting the Baltic Sea cooperation and regional solutions to global challenges.

Climate change and energy consumption are challenges that influence almost all aspects of our daily life. Global challenges regarding reduction of green house gasses, increase of renewable energies and energy efficiency need to be tackled on all levels – private households, national, European and global levels. Often energy co-operation on *regional* or *sub-regional* levels can indeed provide very positive results that leave each country better off when implementing the EU's or the UN's targets on climate change and energy, as well as in ensuring greater security of energy supply. This has been the basic assumption behind the present report, not least based on the Nordic experience. The Baltic Sea Region's specific character in terms of many different energy sources and the individual countries' energy-mix supports implicitly such an assumption.

The present report discloses some of the advantages of enhanced energy co-operation in the Baltic Sea Region based on facts and data. It illustrates that there is a huge potential for cost-efficient energy savings and energy efficiency measures through a stronger coordination of the energy policies across the region.

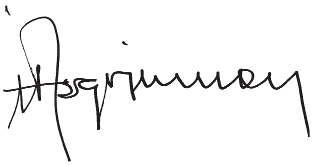
In preparing the report, data on energy generating facilities in all Baltic Sea States have been collected and used in the open and transparent analytical models – Stream and Balmorel. These models were also used in the preparation of national/regional policies in Denmark and in the European Parliament and they similarly proved to be useful and interesting in the Baltic Sea Region when looking at the region as one integrated energy system. With the different energy data collected a unique database has been created. It can now serve as a platform for identifying and implementing very specific energy projects in the Baltic Sea Region.

The analytical and empirical results and findings have been presented for and discussed with different public and private stakeholders in the region in order to anchor the different energy scenarios, results and recommendations. We hope that this final report and its recommendations can continue to serve as a key point of reference in the further discussions on energy planning in the Baltic

Sea Region, not least in the framework of BASREC, the Nordic-Baltic energy cooperation through the Nordic Council of Ministers as well as initiatives under the EU strategy for the Baltic Sea region. First and foremost, the report will form the basis for the regional energy discussions at the Baltic Development Forum Summit, 5-6 October in Stockholm. And it will provide an input to the Nordic Council's 61st session, 27-29 October in Stockholm.

The analysis and conclusions of the report are those of the authors and do not necessarily reflect the views of the Nordic Council of Ministers or Baltic Development Forum. However, we are convinced that the report will be inspiring. We wish you all good reading.

Copenhagen, 15 September 2009



Halldór Ásgrímsson
Secretary General
Nordic Council of Minsters

Hans Brask
Director
Baltic Development Forum

# Preface by Mr Andris Piebalgs, Commissioner for Energy

At the 2007 Baltic Development Forum's Summit in Tallinn, it was concluded in the session on energy and climate change in which I took part– together with Prime Minister Fredrik Reinfeldt, Prime Minister Matti Vanhanen and CEO of Forum Michael Lilius – that there was a need to draw up a paper that could help the governments realize the vision of closer and more efficient energy cooperation in the Baltic Sea Region. The Baltic Sea Region indeed has a huge potential for implementing energy projects that are of wider importance due to their potential and diversified energy-mix.

I am therefore glad to acknowledge the work and effort that has been invested in elaborating this report on Sustainable Energy Scenarios. I have had the chance to observe the process since the preliminary results were presented to me in connection to the BASREC Ministerial conference in February 2009. I was introduced to the two overall scenarios for regional co-operation based on a "small-tech and big-tech" approach. I find the approach useful to present different sc enarios as a means of involving different stakeholders in agreeing on the most pressing energy projects and priorities that can be beneficial for a larger group of countries.

As I mentioned in February at the Ministerial Conference, we indeed need both small-tech and big-tech solutions if we are to successfully implement the EU's 20-20-20 targets. We must not ignore the importance of small-tech solutions.
As it is issued while the discussions on the EU strategy for the Baltic Sea area take place, the report is very timely. The Baltic Sea Region has the potential to show to the rest of the world how many of the energy and climate challenges can be solved intelligently. The region could become home of many lighthouse projects – like the Windmill Park at Krieger's Flak that the Commission has decided to support. In this respect, the present report is an important tool which I hope will be used by all stakeholders in the region, and beyond.

As European Commissioner responsible for Energy, I am very pleased by the initiative taken to draw up this report and by many results in the report.
With every good wish for a successful follow-up,

Andris Piebalgs
EU Commissioner for Energy

# Preface by the Baltic Sea Energy Cooperation (BASREC) Group of Senior Energy Officials (GSEO)

In spite of the current economic downturn the Baltic Sea Region has a great potential for developing into a more coherent and prosperous economic region in the aftermath of the crisis. It depends on the future policy design and the ability of the countries to benefit from closer cooperation on issues that enhance competition, green growth and job creation and cater for the climate.

Energy is crucial when it comes to designing policies that meet the future challenges of developing renewed growth and prosperity in the region, competition and climate friendly new technologies.

Keen political interest is taking in the Baltic Sea region in these years providing great opportunities for the region to shape its energy policies to develop and obtain prosperity.

The ministers of the Baltic Sea Energy Cooperation (BASREC) have recently agreed to continue and strengthen the transnational energy cooperation in order to make contributions to stability, growth and development in the region by promoting market-based, secure, competitive and sustainable energy systems.

The EU has taken initiatives to abolish the energy isolation of the Baltic Sea states from the EU energy markets by the endorsement of the Baltic Energy Market Interconnector Plan (BEMIP) in June 2009. BEMIP is a plan for the future development of the energy markets in the region. The EU has also launched the EU Economic Recovery Plan which gives substantial financial support to some of the essential BEMIP infrastructure projects in the region.

The EU will also launch a Strategy for the Baltic Sea Region in 2009. Energy plays a central role in this strategy and the implementation of BEMIP will be one of the essential actions in this energy strategy for the Baltic Sea Region.

Past experience has shown that political support is crucial to success in developing coherent and common energy policies and strategies for the region.

The present report on Sustainable Energy Scenarios for the Baltic Sea region clarifies the strengths of the region and the opportunities for shaping coordinated regional energy policies and solutions that can meet the triple challenges of renewed growth, energy security of supply and climate change for the region.

The report shows that the region has a sufficient potential of renewables, energy efficiency and new efficient technologies to become a low-emission growth region with secure energy supplies in 2030.

The report underlines that strong and dedicated cooperation on achieving the EU 20-20-20 goals will bring substantial economic benefits to the region as will further integration of the infrastructure in the region.

The present report has been initiated by Baltic Development Forum, prepared by Ea Energy Analyses and financed by Nordic Council of Ministers, Nordic Council, and Fabrikant Mads Clausens Fond, Danfoss. The conclusions are those of Ea Energy Analyses and do not necessarily represent the opinions of the organisations that have initiated the report. The report provides a good and useful background and shows the great opportunities for designing co-ordinated energy strategies and policies to our common urgent challenge for the benefit of the region. In that capacity it will be included in the basis for the future co-operation in BASREC.

Hans Jørgen Koch
Deputy State Secretary
Chairman of the BASREC Group of Senior Energy Officials
1 July-30 June 2008-09

# Preface by the Baltic Sea Parliamentary Conference Working Group on Energy and Climate Change

Life on Earth is impossible without production, conversion and transmission of energy in all its diversity. Those who are able to find energy in the environment and use the resources rationally are better fit to meet the challenges of life and are more likely to survive over long periods of time. Today, energy issues have a higher priority in our daily life than ever before. On one hand, fuels which fed economies and countries throughout the last century are becoming scarce due to intensive and often inefficient use, on the other hand, wasteful use of energy and fuels in just a few human generations have released back to the environment chemical compounds which cause a warming of the Earth's atmosphere, leading to irreversible catastrophic changes in the foreseeable future.

Effects on the climate are global and not restricted by national or political borders, thus in order to mitigate and stop climate change, our efforts must be global, agreements regional and actions - individual. The Baltic Sea Region joins countries with very different economies and energy resources, but for natural or historical reasons there are still gaps and barriers between different areas. This report, using transparent analytical instruments, weighs today's situation and draws scenarios for a common future. The diversity of fuels and energy production is seen as an advantage rather than an obstacle, as it has created a wide range of practices and know-how in the fields of energy production and sustainable use. With dedication and co-operation this unique opportunity can be developed into a world-leading concept of energy efficiency supporting our imminent efforts to stabilize the environment of our overheating planet Earth.

As a marine biologist I have learned how delicate the energetic balance of global environment is, and I have seen the consequences of recent developments in human energy consumption. This report looks several generations ahead, helping us to plan and secure our energetic future.

Mart Jüssi

Mart Jüssi, MP
Chairman of the Estonian Parliament Environment Committee
Chairman of the BSPC WG on Energy and Climate Change

# Preface by the Union of Baltic Cities Energy Commission

Energy will be one of the defining issues of this century. A new global revolution is needed in ways of how energy is used and supplied. We need this energy revolution not only for stopping the green house gas emissions that cause climate change, but also for generating jobs and new economic growth. Energy demand is soaring like never before as populations grow and economies start to take off again. Millions of citizens in the new democracies around the Baltic Sea Region (BSR) are expecting to enjoy a lifestyle that definitely requires more energy. This report outlines how we as municipalities and cities can take concrete action to meet this challenge. The technology and science is there – what is missing is a strategy and decisive measures on a local political level. The policies in the BSR related to energy and associated big tech infrastructure will increasingly be a national and regional concern. This report is visionary in its BSR integrated market approach. But its greatest value is that it defines the importance of the Small Tech measures that can be taken on a local municipal level in order to implement a better energy system and the thereby meet global and regional environmental targets. This report definitely puts us citizens back in the driver's seat and in charge of our own future.

Stefan Windh
UBC Energy commission

# 1 Summary and recommendations

## 1.1 Introduction

Baltic 21 Energy

In 1996-1998 the first comprehensive energy study for the Baltic Sea Region, Baltic 21 Energy, was carried out, investigating a sustainable energy development the Baltic Sea Region. The study, carried out by authorities, non-governmental organisations and consultants, concluded, that a sustainable pathway would include energy savings in all sectors, reduction of losses in energy transformation and increased use of renewable energy and natural gas in the energy system in the region.


Figure 1: The Baltic Sea Region: Denmark, Estonia, Finland, North East Germany, North West Russia, Kaliningrad, Latvia, Lithuania, Poland, Norway and Sweden.

Baltic Ring I and II

In the same period the electricity sector in the region carried out the first Baltic Ring study with the purpose of examining the benefits from stronger electricity interconnectors in the Baltic Sea Region. In 2003, the second Baltic Ring study was concluded, this time with more focus on market integration. Both studies concluded that a stronger cooperation between the stakeholders around the Baltic Sea would benefit the development of the electricity sector.

New energy agenda

In recent years the energy agenda has changed in Europe. The EU countries have placed a strong focus on meeting the challenges from climate change. The energy sector has to comply with tough targets for the reduction of greenhouse gas emissions, targets for deployment of renewable energy sources and targets for energy efficiency improvements. At the same time, security of fuel supply has become an even more urgent topic on the energy agenda.

This agenda calls for a new basis for strategic decisions and an updated overview of the possibilities for developing the energy system in the Baltic Sea Region. It is particularly relevant to explore the potential in the region for developing regional solutions to the energy challenges and to identify projects that could benefit the region as a showcase for sustainable energy development and becoming frontrunners in innovative solutions through regional cooperation.

**BEMIP and the EU Baltic Sea Region strategy**

In June 2009 the eight Baltic EU member states reached agreement on a Baltic Energy Market Interconnection Plan (BEMIP), underlining the urgent need for connecting the Baltic region with the EU. The BEMIP is also identified as a flagship project in the broader context of the EU Strategy for the Baltic Sea Region, presented by the EU Commission on 10 June 2009. The plan and strategy highlight the need for a stronger regional co-operation in the field of energy in order to harvest the potential synergies in the region.

**The present study**

In this context Baltic Development Forum (BDF) has initiated the study 'Enhanced regional energy cooperation in the Baltic Sea Region. The study is a multi-client study, financed by Nordic Council of Ministers, Nordic Council, Baltic Development Forum and Fabrikant Mads Clausens Fond, Danfoss and carried out by the consulting company Ea Energy Analyses.

**Objectives**

The study has two parallel objectives:

1) To promote a common energy agenda for the Baltic Sea Region through the involvement of key stakeholders;
2) To provide a substantial basis for discussion of different energy scenarios for the region based on an analysis of energy data of all the countries in the region.

**Three phases**

The study consists of three phases. The first phase (mid 2008 – ultimo 2008) included an overview of the current energy situation, collection of data for the region and setting up of scenarios for the future regional energy system. Phase II of the project (beginning of 2009 – mid 2009) includes more detailed scenario analyses of the electricity and district heating markets and a prioritized list of regional projects/policies to promote the region as a sustainable region. A vital part of this phase has been to collect data for the whole region, including Northwest Russia. A planned phase III will develop strategies for the deployment of regional projects, identify activities for regional knowledge sharing in the field of sustainable energy, and outline the possibilities for the industry to be front runners in the development of new energy technologies.

**Dialogue with the stakeholders**

Dialogue with the stakeholders on the energy scene in the Baltic Sea Region has been an important part of the study process. Preliminary results from the study have been presented and discussed at a number of occasions. See Annex 1 for more details about the stakeholders' involvement.

**Summary report and background report**

Phase II of the study is documented in two reports. This summary report gives an overview of the approach, the results and recommendations from the analyses. More detailed information is provided in the background report.

## 1.2 Scenarios in phase I and phase II

### Different scenario techniques

In the study, two different scenario techniques have been used.

Phase I scenarios

The scenarios in phase I are inspired by a study for the European Parliament[1], where the future composition of technologies in the energy system are based on best estimates and visions for the development of a sustainable energy system. These estimates are then evaluated and fitted to meet the political targets regarding $CO_2$, shares of renewable energy and non-quantified objectives regarding security of supply and different stakeholder involvements in the decision process. The scenarios comprise the whole energy system including the transport sector.

The scenarios in phase I were developed with STREAM, a bottom-up based spread-sheet modeling tool looking at the energy flows of the region on an annual basis[2].

Phase II scenarios

In phase II, the scenarios focus on detailed analyses of the electricity and district heating system in the Baltic Sea Region. The future composition of technologies in the electricity and district heating system are determined by the energy market model Balmorel[3], developed as a part of the energy cooperation in the Baltic Sea Region in the late 1990-ties. The model decides which technologies should be used, based on input of technical and economical data for the individual technologies and assumptions about the future fuel prices. The model calculates a least cost solution for the whole system taking the given constraints regarding e.g. $CO_2$-targets and shares of renewable energy into account.

Both scenario techniques have their strengths and in a dialogue process, as the present study, the combination of the techniques gives valuable information to the decision making process between the stakeholders in the region.

### Phase I: Big Tech and Small Tech scenarios

Data

Phase I of the study focused on a description of the current situation in the energy sector in the Baltic Sea Region and collecting data for the scenarios, including data for relevant new technologies that could be used in the future energy system in the region.

Targets

In order to shed light on different pathways towards achieving the long-term strategic goals of the region two essentially different developments have been explored through a so-called Small-tech scenario and a Big-tech scenario. Both scenarios aim at achieving two concrete goals for 2030: reducing $CO_2$ emissions by 50 % compared to the 1990 level and reducing oil consumption by 50 % compared to the present level.

1 Future energy systems in Europe, STOA-2009
2 See. www.streammodel.org
3 See www.balmorel.com

**Small-tech scenario**

The Small-tech scenario focuses on distributed energy generation, energy savings and efficient utilisation of energy through combined heat and power generation. This scenario assumes a high level of interconnection of the electricity grids in the Baltic Sea Region to allow for the integration of a high share of wind power. So-called 'smart grid technology' and improved communication between the different parts in the energy system play a key role in providing an optimal dispatch and efficient utilization of the energy infrastructure.

**Big-tech scenario**

The Big-tech scenario explores the opportunities of more centralised solutions. In the Big-tech scenario, almost all new coal and natural gas power plants established from 2020 and onwards will be equipped with carbon capture storage technologies (CCS). In addition, it is assumed that most new large coal power plants commissioned in the period 2010-2020 are prepared for CCS and retrofitted in the subsequent decade. The nuclear power capacity will be increased by 35 % compared to today. New nuclear generation capacity is presumed to be built in Finland, Lithuania and Poland, and existing nuclear power plants in Germany, Sweden and North West Russia will continue generation.

**Transport**

In both scenarios the transport sector undergoes fundamental changes in order to comply with the target of 50 % oil reduction. In both the Small tech and the Big-tech scenarios it is a critical assumption that the technical potentials for improving the fuel economy of conventional vehicles are partly realised. Moreover, in the Small-tech scenario, electric vehicles and plug-in hybrids displace oil consumption, and information and communication technologies are put in place to decrease the demand for "physical" transportation. In the Big-tech scenario, in addition to the electrification of the transport sector 2$^{nd}$ generation biofuels and natural gas are important means for reducing oil dependence.

**Key decision makers in the two scenarios**

In the Big-tech scenario, the existing structure of the energy supply system remains essentially unchanged, and the large suppliers of electricity become the main actors. Hence, the implementation of the Big-tech scenario depends on relatively few decision-makers. Partnerships for the demonstration of the CCS technology provide an obvious opportunity for regional cooperation in the Big-tech scenario.

In the Small-tech scenario, citizens play an important role as active consumers of energy, changing energy behaviour according to price signals and investing in energy-efficient appliances and buildings; grid owners must develop their systems and the suppliers of energy will have to change sources gradually from large power plants to renewables and to distributed units located closer to the consumers. In the Small-tech scenario the integration of fluctuating energy sources calls for a high level of cooperation on energy markets and new infrastructure projects, particularly concerning off-shore wind. Local authorities and cities are crucial for the facilitation of district heating grids and sustainable transport systems – and the need for more efficient supply and demand technologies provides business opportunities in many industry branches.

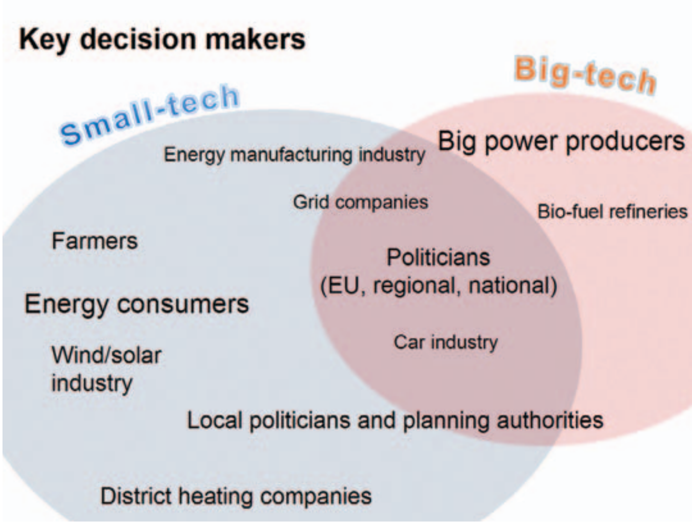



Figure 2: Key decision makers in the Small-tech and Big-tech scenarios

## Results

To illustrate the consequences of the two scenarios, the key indicators – the development in gross energy consumption and the emission of $CO_2$ – are compared with historic data as well as with a reference for 2030 resembling the most recent projection from the European Commission.

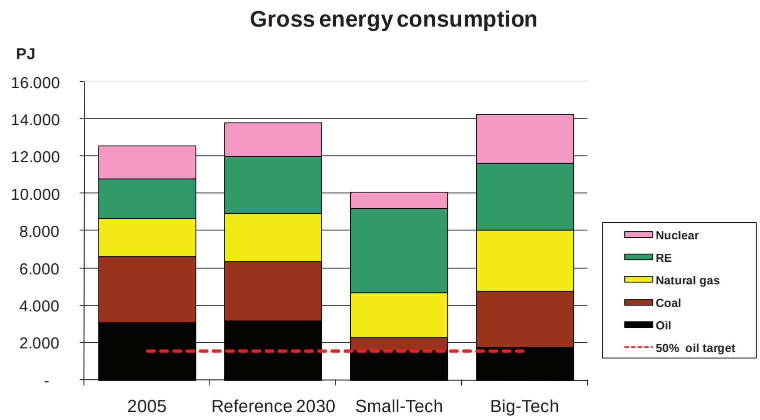



Figure 3: Gross energy consumption in 2005 and projections for 2030 (excluding fuels for non-energy purposes). Data is only included for North East Germany and North West Russia.

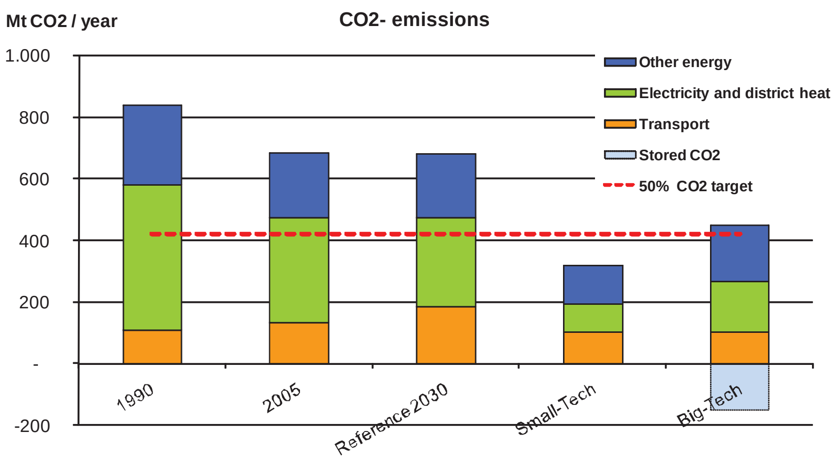



Figure 4: $CO_2$ emissions from the energy and transport sectors in 1990, 2005 and projections for2030. "Other energy" includes oil, gas and coal used in households, industry and the trade/service sector. Data is only included for North East Germany and North West Russia.

The scenarios show that resources and technologies are available to achieve the targets set out. In the Small-tech scenario, it is foreseen that the gross energy consumption is reduced by approx. 20 % in 2030 compared to 2005. In the Big-tech scenario, gross energy consumption increases by 13 % compared to 2005. This increase, which is slightly higher than in the 2030 reference projection, is mainly due to increased utilisation of carbon capture and storage technologies that are expected to require a considerable expenditure of energy, particularly for the capture and transportation of $CO_2$. In the Big-tech scenario, compliance with the $CO_2$-reduction target is secured by yearly storing almost 150 Mt of $CO_2$ underground by 2030.

## Phase II: Detailed scenarios for electricity and district heating

In Phase II of the project detailed scenario analyses have been developed for the power and district heating sectors in the region. Besides showing a pathway towards lower $CO_2$-emissions and an improved security of supply, the scenarios explore the benefits of closer cooperation around the Baltic Sea on energy policies and specific projects, as well as shedding light on the value of establishing new interconnectors in the region.

The scenarios in phase II are analysed using the energy market optimisation model Balmorel. Data used in the scenarios are publicly available data. The model optimises the system as a whole, but the electricity and heating system are modelled for the individual countries, making it possible to examine the differences between regional targets, and targets for the individual countries.

The scope of the analyses in phase II is to:

- examine how the electricity and district heating systems may develop in order to comply with medium and long-term policy objectives given different developments in the framework conditions;
- show the value of establishing new electric interconnectors;
- assess the costs and benefits of a concerted off-shore wind power planning and interconnection at Kriegers Flak.

In Phase II the geographical scope of the analyses has been expanded to comprise the whole f Germany, whereas Phase I only included the North Eastern part of Germany bordering the Baltic Sea.

## 1.3 The Baseline scenario

### The framework

Scenarios toward 2030

A Baseline scenario has been developed to show how the electricity sector in the Baltic Sea region may develop leading up to 2030. The baseline scenario seeks to combine measures from the Small- and Big-tech scenarios elaborated in the project's Phase I. Three alternative scenarios have been developed. These scenarios are described in Chapter 4.

$CO_2$-emission targets

The *Baseline scenario* differs from the 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 %. Moreover, a project target of a 50 % reduction of $CO_2$ compared to 1990 is applied for 2030. Compared to 2005 this corresponds to a reduction of $CO_2$-emissions by 38 %. The means to achieve the policy targets in the Baseline scenario are to a large extent determined by the modelling tool based on a least cost analyses of supply side measures.

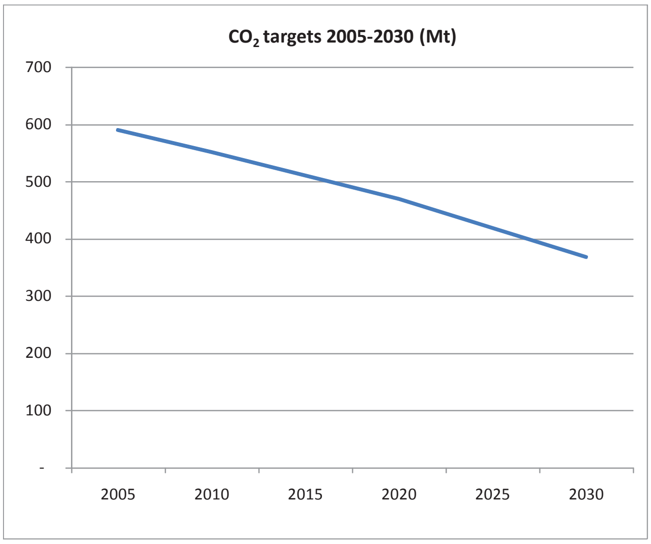



Figure 5: Modelled targets for reducing $CO_2$ emissions from the electricity and district heating sectors in the period 2005-2030 for the Baltic Sea Region. In 2020 $CO_2$ emissions from the electricity generators in the region are to be reduced by 21 % compared to 2005 as this is the general requirement for the companies encompassed by the EU $CO_2$ emissions trading system. In 2030, the target is to comply with a 50 % reduction of $CO_2$ compared to 1990 - compared to 2005 the target corresponds to a reduction by 38 %. A linear development is assumed between 2005 and 2020 and between 2020 and 2030

EU renewable energy targets

The targets for renewable energy are set in accordance with the renewable energy directive endorsed at the EU Council Summit in December 2008. The renewable energy directive provides a target for the share of RE of final energy in each member state, but not a separate target for the electricity sector.

The level of renewable energy that will have to be introduced in the electricity sector will, among other things, depend on the economical and technical opportunities compared to increasing renewables in other sectors such as the transport sector and the industry. In the present analyses it is chosen to operate with a target for the electricity sector corresponding to: RE share of electricity in 2005 + 1.5 * required increase in RE in overall final energy demand in the directive.

As an example, 28 % of electricity consumed in Denmark in 2005 was supplied from renewable energy. The RE directive requires Denmark to increase its share of RE in final energy demand by 13 percentage points from 17 % in 2005 to 30 % in 2020. Hence, the RE target for the Danish electricity sector is set at 48 % in 2020 (i.e. 28 % + 1.5 * 13 %).

For the Baltic Sea Region as a whole renewable energy electricity corresponded to 26 % of total electricity supply in 2005. For 2020 the target for the region is 37 % based on the approach outlined above. The targets are shown in Table 1. Russia has no target for RE.

| **Final energy** | **Germany** | **Denmark** | **Estonia** | **Finland** | **Lithuania** | **Latvia** | **Poland** | **Sweden** | **Norway** | **NW Russia** | **REGION** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 RE share | 6% | 17% | 18% | 29% | 15% | 35% | 7% | 40% | 60% | 3% | 14% |
| 2020 target | 18% | 30% | 25% | 38% | 23% | 42% | 15% | 49% | 60% | 0% | 25% |
| Increase 2005-2020 | 12% | 13% | 7% | 10% | 8% | 7% | 8% | 9% | 0% | 0% | 11% |
| **Electricity** | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2005 RE share | 11% | 28% | 1% | 27% | 4% | 48% | 3% | 54% | 100% | 19% | 26% |
| Expected increase in electricity sector | 18% | 20% | 11% | 14% | 12% | 11% | 12% | 14% | 0% | NA | 15% |
| 2020 target | 29% | 48% | 12% | 41% | 16% | 59% | 15% | 68% | 100% | NA | 37% |

Table 1: Renewable energy targets. No renewable energy target has been included for North West Russia

Fuel prices

The development in prices of fossil fuels is based on the latest forecast from International Energy Agency's (IEA) World Energy Outlook 2008 (WEO-2008). According to this projection the price of crude oil will increase from an expected 100 $/bbl in 2010 to 122 $/bbl in 2030. The price of natural gas is expected to rise from just above 5 €/GJ in 2010 to slightly over 10 €/GJ in 2010.

Existing support-schemes

Phase II of the present study focuses on the least-cost ways of achieving the targets from a socio economic point of view. Hence, the existing country specific policy measures for promoting renewable energy are not considered in the calculations as they would tend to divert investments in renewable energy technologies to the countries with the most favourable support scheme, rather than the countries with the best renewable energy resources.

Technology data

The model has a data catalogue with a set of new power station 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 gas turbines and gas engines), straw and wood based power plant, power plants with CCS and wind power (on and off-shore). Assumptions regarding technology data are presented in the background report.

Nuclear

Regarding nuclear power, it has been chosen to model the development based on best available information about the future role of nuclear in the different countries in the region as opposed to letting the model make the "optimal investments". The nuclear forecast is made with the intention to form a compromise between the strong views (pro and against) towards nuclear power among politicians and other stakeholders in the region. In Sweden for example, the nuclear capacity is assumed to remain at the existing level whereas a delayed phase-out is anticipated in Germany.

| MW | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Denmark | - | - | - | - | - | - |
| Sweden | 9,372 | 9,372 | 9,372 | 9,372 | 9,372 | 9,372 |
| Finland | 2,656 | 2,656 | 4,256 | 4,256 | 4,256 | 4,256 |
| Norway | - | - | - | - | - | - |
| Germany | 20,264 | 20,264 | 20,264 | 20,264 | 17,870 | 9,256 |
| Poland | | - | - | - | 2,089 | 4,385 |
| Lithuania | 1,200 | - | - | 1,500 | 1,500 | 1,500 |
| Estonia | - | - | - | - | - | - |
| Latvia | - | - | - | - | - | - |
| NW Russia | 5,760 | 5,760 | 5,760 | 5,760 | 5,760 | 5,760 |
| **Total** | **39,252** | **38,052** | **39,652** | **41,152** | **40,847** | **34,529** |

Table 2: Assumed development in nuclear capacity in the Baltic Sea Region. This development is applied in all scenarios.

With the exception of nuclear power and hydro power the investments in new power producing units are determined by the model, based on information about the technical and economical data for each technology.

A number of assumptions on the rate of decommissioning of existing plants are assumed. These assumptions are based on, among other things, the expected technical life time of power plants, and in certain cases information about the conditions of specific power plants.

## Results

### *New generation capacity*

Figure 6 shows the development in new generation capacity for the whole region – as determined by the model. Investments in new capacity are only allowed from 2015 due to the lead time of new generation facilities.

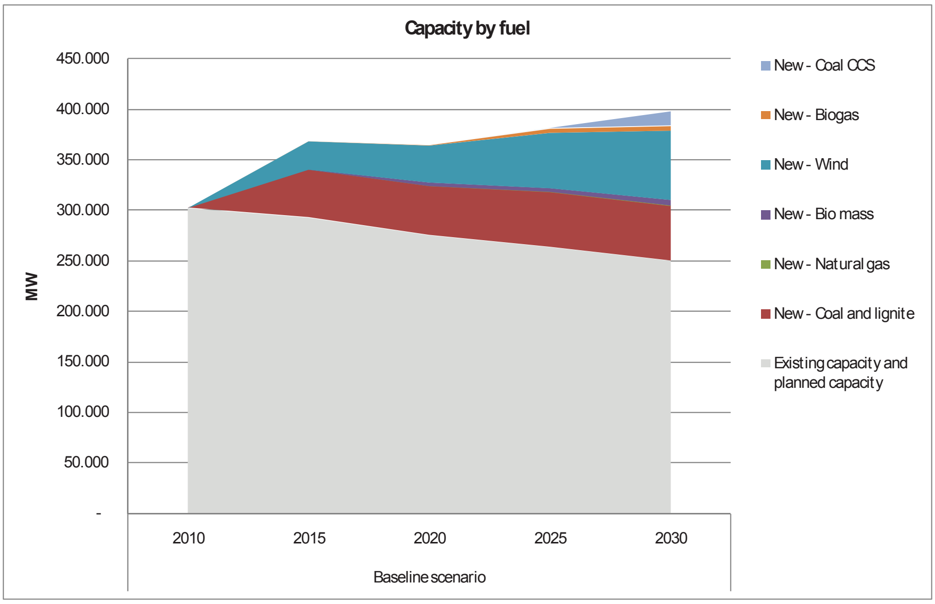



Figure 6: Total electrical capacity (MW) for Baseline scenario distributed on new and existing capacities

Wind and coal

In the Baseline scenario it appears that the economically most attractive technologies are wind power and coal power. The coal fired power plants that the model chooses to invest in use new highly efficient technology with electric efficiencies of 48 % when running in condensing mode. The coal fired power plants are primarily established in the beginning of the period while the wind power plants are established more evenly during the whole period from 2015 to 2030.

Biogas and biomass

The model also invests in new biogas based generation capacity, new biomass fired capacity and coal fired power plants with CCS. The majority of these investments are made in the period 2020-2030. Though the level of investments is fairly small compared to the investments in e.g. wind power, it indicates that these technologies are competitive.

## *Fuels*

Electricity generation by fuel for all countries is shown in Figure 7 .

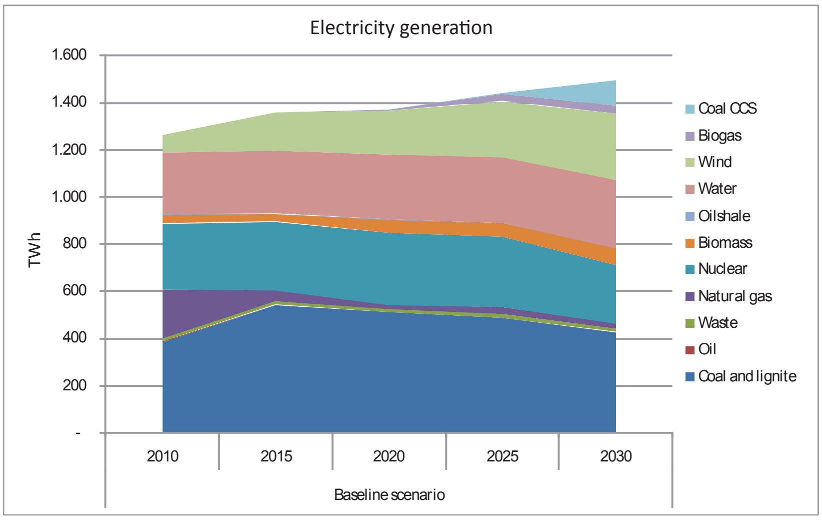


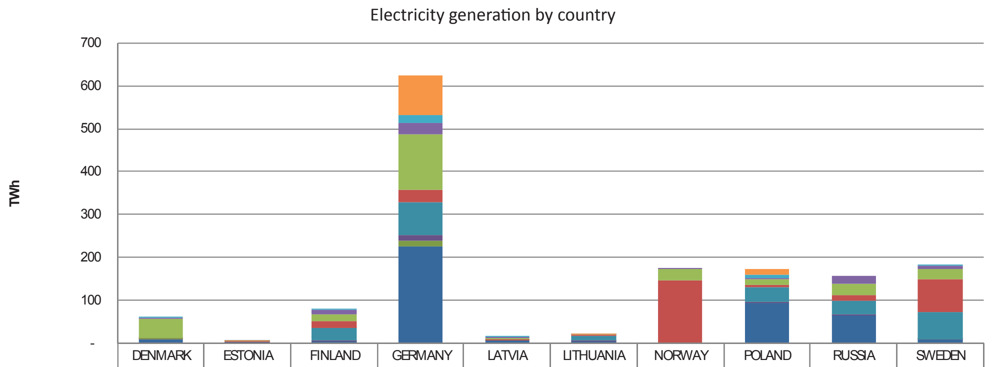

Figure 7: Total electricity generation (TWh) by fuel for Baseline scenario.

Natural gas consumption decreases

The utilisation of natural gas decreases very significantly between 2010 and 2015 as a result of the investments in wind power and new efficient coal power plants. This development is particularly profound in Russia where approximately half of the electricity is produced from natural gas in the 2010 simulation. It should be mentioned that such a significant decrease in the demand for natural gas is likely to result in a drop in the regional natural gas price, which will to some extent moderate the overall impact. This correlation has not been quantified in the model.

The role of wind power is gradually increased over the period and by 2030 wind power is the largest source of electricity next to coal power and hydro. Biomass and biogas only gain some significance by the end of the period.

Figure 8 gives an overview of the electricity generation (TWh) for each country in 2030 grouped byvfuel in the Baseline scenario.




| | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2030 | | | | | | | | | |
| | Baseline scenario | | | | | | | | | |
| Coal CCS | | 2 | | 92 | | 1 | | 14 | | |
| Biogas | 2 | 1 | 2 | 18 | 1 | 1 | | 9 | | 1 |
| Biomass | 2 | 1 | 11 | 26 | 2 | 0 | 0 | 2 | 17 | 9 |
| Wind | 44 | 1 | 16 | 129 | 2 | 0 | 25 | 13 | 28 | 24 |
| Water | | | 16 | 30 | 3 | 1 | 147 | 4 | 12 | 75 |
| Shale | | 0 | | | | | | | | |
| Peat | | 0 | 0 | | 0 | | | | | |
| Nuclear | | | 29 | 76 | | 12 | | 36 | 31 | 63 |
| Natural gas | 1 | 1 | 1 | 13 | 1 | 0 | 1 | 1 | 4 | 0 |
| Waste | 2 | 0 | | 11 | 0 | | 0 | 0 | | 1 |
| Oil | 0 | | 0 | | | 0 | | | 0 | |
| Coal and lignite | 10 | 3 | 5 | 227 | 6 | 5 | | 95 | 65 | 10 |

Figure 8: Electricity generation (TWh) for each country in 2030 grouped by fuel for Baseline scenario.

## $CO_2$-emissions

Figure 9 illustrates the development in $CO_2$-emissions in the Baseline scenario country by country. The emissions are capped by the regional target indicated by the yellow line.

The simulations show that the marginal cost of abating $CO_2$ is approx. 7 € per ton in 2020 and approx. 60 € per ton in 2030 for the electricity and heating sector.

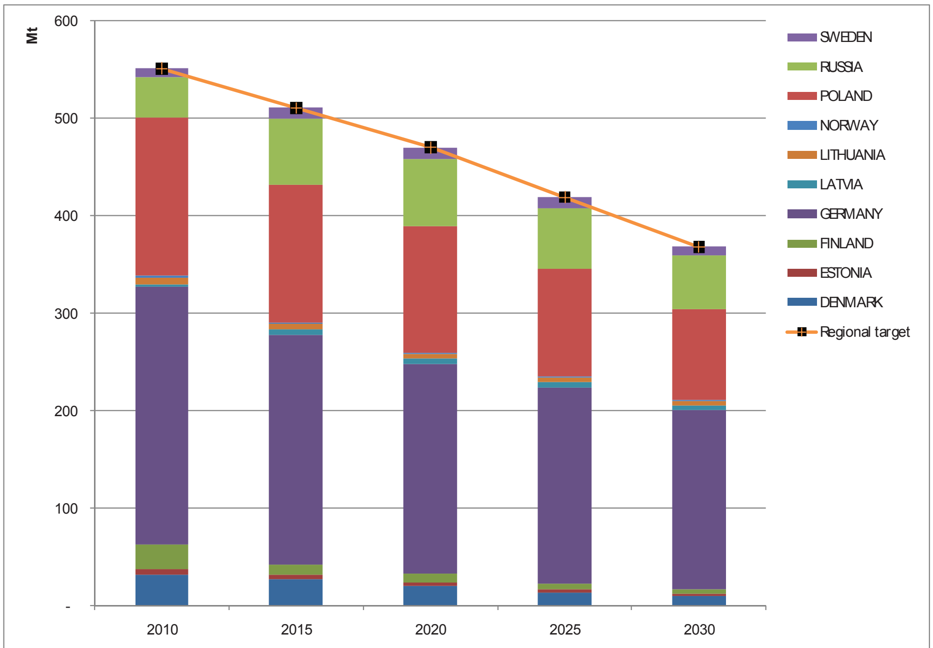



Figure 9: Development in $CO_2$-emissions (Mt) for the electricity and district heating sector by country in the Baseline scenario

## *Renewable targets*

All countries succeed in complying with their national target, but the marginal cost of fulfilling the targets differs between the countries. In Russia there is no price of renewable energy because no national renewable energy target is assumed. In Norway the price of renewable energy is zero, because the expected development of new hydro power leads to compliance with the national renewable energy target. Lithuania, Latvia and Germany have the highest marginal costs of expanding renewable energy electricity generation in 2020, see Table 3.

| Country | Denmark | Estonia | Finland | Germany | Latvia | Lithuania | Norway | Poland | Sweden | NW Russia |
|---|---|---|---|---|---|---|---|---|---|---|
| Baseline scenario | 16 | 16 | 29 | 30 | 31 | 31 | - | 24 | 16 | - |

Table 3: Shadow prices for RE targets in 2020 in the different scenarios (EUR/$MWh_{el}$)

The difference in compliance costs reflects 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.

Bioenergy resources

To determine the potential and costs of expanding renewable energy generation, wind, biomass and hydro power resources have been mapped for each country in the region[4]. Assumptions about potentials are available in the background report. Figure 10 shows the utilisation of biomass resources (columns) in the baseline scenario (2010 to 2030) in the whole region compared to the long term potentials (lines).

By 2030, when $CO_2$ emissions have been reduced by 50 % compared to 1990, a very significant potential remains for further increasing the use biomass and waste for electricity and heat generation.

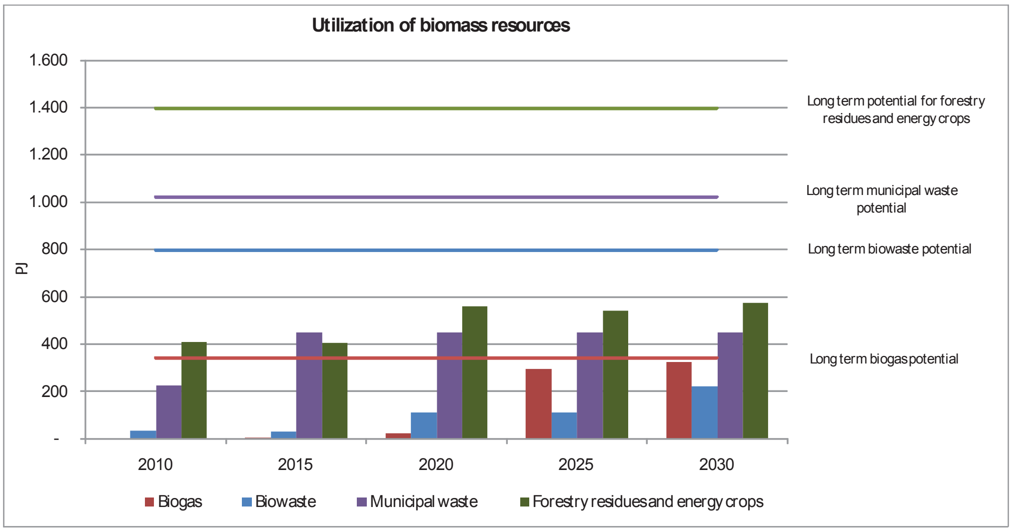



Figure 10: Utilisation of biomass resources (columns) in the baseline scenario compared to the long term bioenergy potentials available for power generation and district heating (lines). It has been assumed that only 60 % of the total bioenergy resource in the region will be available for the power and district heating sector, leaving 40 % to be used in industries, households and the transport sector. The municipal waste resource also includes the non-renewable energy fraction of the waste.

Of the different bioenergy fractions considered, biogas is the most attractive to use with an utilisation factor close to 100 % in 2030. The reason for this is that the utilisation of biogas for energy production leads to supplementary reduction

4 Data on bioenergy potential is lacking for North West Russia.

of fugitive emissions (methane and nitrous-oxide) in the agricultural sector – related to the alternative use of the manure. Hence, a negative $CO_2$ emission factor (-43 kg/GJ) is used for biogas in the model making it a very attractive $CO_2$-reduction measure.

## Conclusions from the Baseline scenario

The Baseline scenario shows the following conclusions:

- The targets for reducing $CO_2$ and increasing the share of renewables can be met given the resources and technologies available. The scenarios do not assume any technological leaps.
- Wind power is an economically viable technology that contributes considerable to reaching the renewable energy targets and to reducing $CO_2$-emissions.
- The region has a number of old power plants with low efficiency. In the short run, the model chooses to replace these old power plants with new coal-fired power plants or combined heat and power plants with very high efficiency. This strategy could be reasonable to meet the $CO_2$-targets in the short run, but it may not be the most viable in the long run with more strict $CO_2$-targets.
- New biomass-fired power plants, biogas plants and coal fired power plants with CCS are close to being competitive with new conventional coal-fired power plants. These technologies could be part of the region's focus on new energy technologies with a strong global potential. Further use of biomass in existing coal-fired power plants should be investigated further.
- Natural gas based power generation generally becomes uncompetitive given the assumed development in fossil fuel price and the policy targets included. This issue deserves further investigation, specifically the connection between regional gas demand and gas prices.
- Even in 2030, when $CO_2$ emissions are reduced by 50 % compared to 1990, there is a significant unexploited bioenergy and wind potential, signifying that further reductions of $CO_2$ emissions are possible.

## 1.4 Three alternative policy scenarios

In addition to the Baseline scenario, three scenario variations have been investigated. These variations differ in the way policy targets are complied with and whether common solutions or national solutions are put in play.

The scenario variations comprise:
- a scenario with *regional targets* for increasing the share of renewable energy instead of national targets
- an *Improved efficiency scenario* where electricity consumption is expected to be reduced considerably compared to the baseline projection
- a *30%@COP15 scenario* showing a situation where $CO_2$-emissions from the power and district heating sectors are reduced by an additional 10 percentage points in 2020

The latter scenario variation reflects a situation where an ambitious international agreement is obtained at the Copenhagen Climate summit in December 2009 committing the EU Member States to cut their overall $CO_2$-emissions by 30 % in 2020.

### Regional renewable energy target scenario

Relocation of wind

In the *Regional RE Target scenario* the model still chooses to invest mainly in wind and coal power, but a large share of the investments in wind power is relocated from Germany, Sweden and Finland to Denmark and particularly Norway, where wind conditions are assumed to be somewhat better. Transferring the national targets to a regional target thus means a better utilisation of the investments in wind power.

The simulations show that the benefit of this relocation of investments is approx. 5 billion € in net present value. However, this figure should be interpreted with caution, because the country specific estimates of renewable energy potentials and costs are associated with a significant degree of uncertainty, particularly in the long-term. Moreover, it should be stressed, that the total generation of renewable energy in the Baltic Sea Region is approx. 8 TWh lower in the regional renewable energy scenario compared to the Baseline scenario. This may appear surprising since the renewable target is the same in the two scenarios. The reason for this is that, due to the expected development of new hydro power plants, Norway over-complies in the Baseline scenario. In the scenario with a regional renewable target Norway's over-compliance contributes to achieve the regional renewable target.
In the situation with a common RE target the cost of increasing renewable energy becomes the same in all countries in the region, 19 € per MWh of renewable energy electricity in 2020.

RE directive opens up for regional cooperation

The EU Directive on renewable energy, endorsed by the European Parliament in December 2008, is built on national targets. However, Member States may agree on the statistical transfer of specified amounts of renewable energy between themselves and they may cooperate on any type of joint project relating to the production of renewable energy. Finally, Member States have the opportunity to join or coordinate their national support schemes in order to help achieve their targets.

Case: Kriegers Flak

In addition to the overall scenarios a case analysis has been made to illustrate the costs and benefits of a concerted planning for wind power plants in the shallow waters of Kriegers Flak in the Baltic Sea. Germany, Sweden and Denmark are all planning to build off-shore wind farms at Kriegers Flak (400, 600 and 600 MW respectively).

The case explores the consequences of a developing a common integrated off-shore grid, which could also serve as link between the Nordic and German electricity markets. The area and a possible common international connection are sketched in Figure 11.

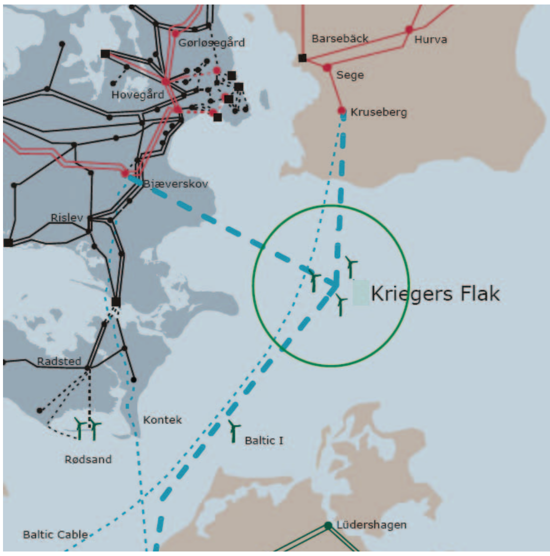



Figure 11: Location and sketched connection of Kriegers Flak. The thinner dashed lines indicate the existing connections between Denmark and Germany (Kontek) and Sweden and Germany (Baltic Cable). Source: Energinet.dk

An integrated off-shore wind grid could serve a twofold purpose by connecting the wind farms to the transmission grid at shore, as well as by linking the electricity markets in the region. Kriegers Flak could serve as a pilot project for an integrated offshore grid.

Transmission of power at Kriegers Flak

Figure 12 shows a duration curve of the transmission between the off-shore wind farms in Kriegers Flak and their respective countries in the Baseline situation without a common international connection (dotted lines) and a situation with common interconnection (full lines). In the first situation the cables are only used to transmit power from the wind farms to land. In the second case, the off-shore grid is also used as a mean to transport electricity to and from the three countries. This leads to a significant higher utilisation of the cables.

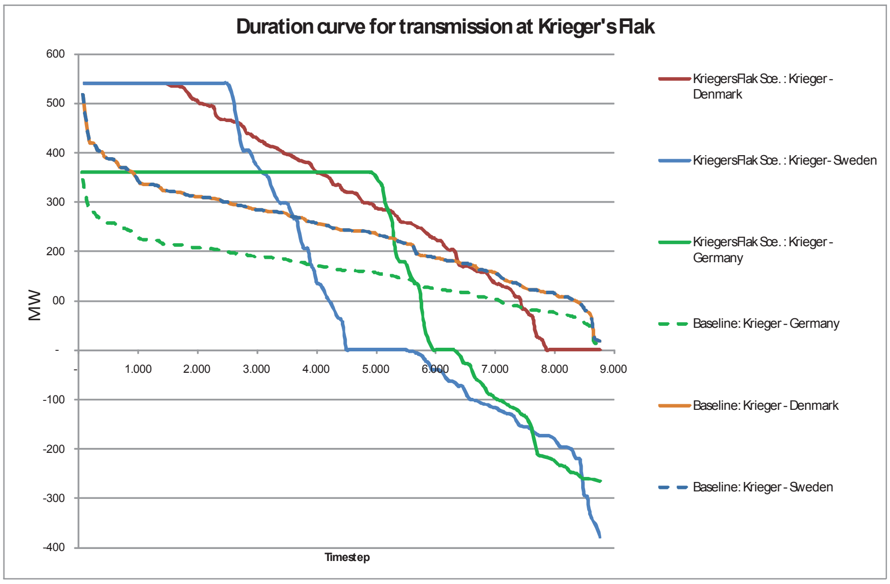



Figure 12: Duration curves showing the utilisation of the connections to Kriegers Flak in the Baseline Scenario with individual on-shore connection and in the situation with a common interconnection at Kriegers Flak.

The common interconnection at Kriegers Flak compared to a situation with no common interconnection shows a benefit a Net Present Value of €17 million. This figure does not include the possible higher capital cost associated with the common solution.

The above calculation assumes only 400 MW of transmission capacity between Germany and Kriegers Flak. This is sufficient to connect the 400 MW of expected wind power capacity at the German part of Kriegers Flak; however in connection with an integrated offshore grid it may appear more economic to establish a stronger connection to Germany, particularly considering that the connections from Kriegers Flak to Denmark and Sweden are 600 MW each.

## Improved efficiency scenario

Electricity savings

In the "Improved efficiency scenario" electricity consumption is expected to be reduced considerably compared to the Baseline projection. This is a result of stringent policies to make consumers use electricity in a more rational manner. In 2030 the general electricity consumption is approximately 20 % below the Baseline level. The same relative level of electricity savings is assumed to take place in all countries across the region.

| **All countries** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** |
|---|---|---|---|---|---|---|
| Savings in general electricity consumption relative to baseline | 0 | 2 % | 7 % | 10 % | 15 % | 20 % |

Reduced electricity demand for heating

In addition to the general effort to reduce electricity consumption, a specific focus is put on reducing electricity demand for conventional electric heating - through improved insulation of buildings and by converting to other forms of heating with lower marginal $CO_2$-emissions, such as electric heat pumps, district heating, solar heating and boilers fuelled by biomass or natural gas.

Particularly in Norway, Sweden and Finland, electricity is a very important source of heating. Today's high consumption of electricity in these countries should be seen in relation to the history of the energy systems, particularly the access to cheap hydro power and base-load nuclear power. However, as the electricity markets have been opened, and considering that the electricity may alternatively be exported to neighbouring countries where the marginal generation comes from thermal power plants, using electricity for direct heating becomes expensive and unsustainable.

| Country | Electricity demand for heating 2005, approx. | Share of total final electricity demand in 2005 |
|---|---|---|
| Finland | 9 TWh | 11% |
| Norway | 30 TWh | 27% |
| Sweden | 21 TWh | 16% |

Table 4: Electricity demand for heating in Finland, Norway and Sweden

In the "Improved efficiency scenario" it is assumed that the demand for electricity for heating in Finland, Norway and Sweden is reduced by 50 % towards 2030. When including the additional effort to reduce electricity demand for direct electric heating, the total electricity savings in 2030, in the improved efficiency scenario are 22 % for the region as a whole compared to the Baseline scenario. In the *Improved Efficiency Scenario* wind power and coal power are still the preferred choices by the model, but the level of investments is significantly lower than in the Baseline scenario.

Electricity generation by fuel

Figure 13 shows the development in total generation in the improved efficiency scenario. It appears that electricity generation (and hence demand) in this case is more or less constant during the course of time.

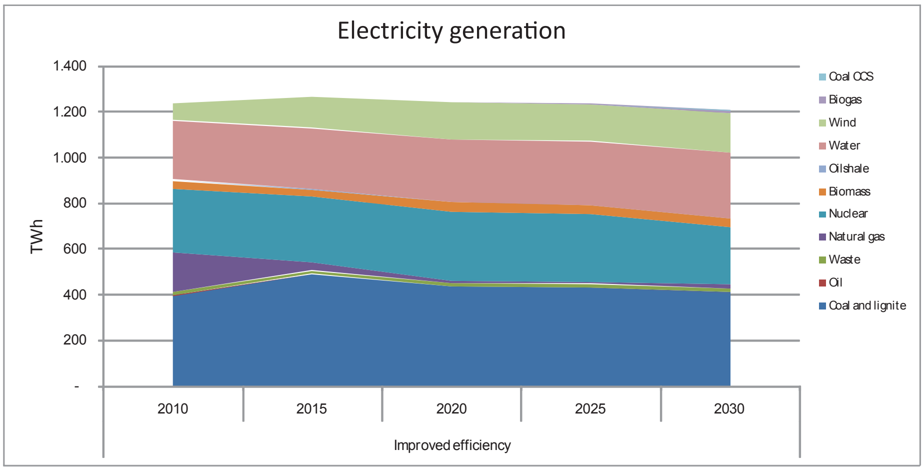



Figure 13: Total electricity generation (TWh) by fuel for Baseline scenario

The lower demand for electricity, in combination with the targets for increasing the share of renewable energy, results in an overachievement of the $CO_2$ targets in the period 2015 - 2025. Only by 2030 the target on $CO_2$ becomes binding. At that time the marginal cost of reducing $CO_2$ emissions is 38 € per ton in the scenario compared to 52 € per ton in the Baseline scenario.

This reflects that cheaper abatement measures are put into play at the supply side in this scenario. By combining demand and supply side measures it will be possible to achieve stronger $CO_2$ targets in the longer term when the most cost-efficient supply side measures will be used up.

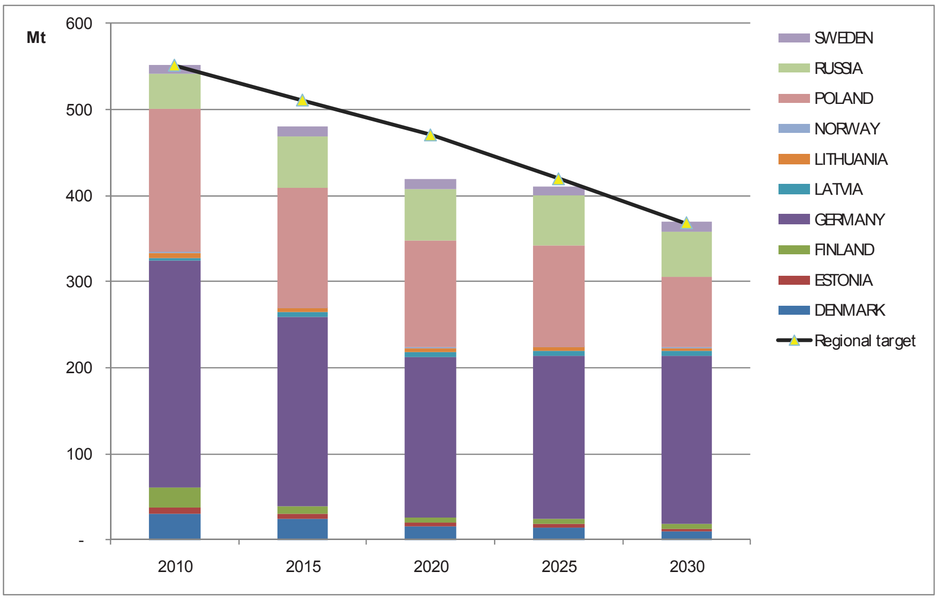



Figure 14: Development in $CO_2$-emissions (Mt) by country in the Improved efficiency scenario

## The scenario 30%@COP15

The scenario explores a situation where $CO_2$-emissions from the power and district heating sectors are reduced by an additional 10 percentage points in 2020. This reflects a situation where an ambitious international agreement is obtained at the Copenhagen Climate Summit in December 2009 committing the EU Member States to cut their overall $CO_2$-emissions by 30 % in 2020. The target for 2030 is still 50 %. The tables below shows accumulated investments in the 30%@COP15 scenario compared to the baseline.

| 30%@ COP15 MW | Coal and lignite | Natural gas | Biomass | Wind | Biogas | Coal CCS |
|---|---|---|---|---|---|---|
| 2020 | 45.992 | 4.058 | 2.780 | 38.102 | 3.258 | 33 |
| 2030 | 51.473 | 4.694 | 6.623 | 68.364 | 4.512 | 11.196 |

Table 5: Accumulated Investments in new electricity generation capacity in 30%@COP15 scenario

| Baseline MW | Coal and lignite | Natural gas | Biomass | Wind | Biogas | Coal CCS |
|---|---|---|---|---|---|---|
| 2020 | 48.260 | 310 | 3.653 | 36.673 | 306 | |
| 2030 | 54.195 | 541 | 5.506 | 68.710 | 4.455 | 13.651 |

Table 6: Accumulated Investments in new electricity generation capacity the Baseline scenario

The stricter $CO_2$ target in 2020 leads to fewer investments in new coal fired power plants in 2020, but more investments in natural gas fired capacity, wind power and biogas based capacity. The investments in biogas capacity are to some extent made at the expense of a smaller amount of investments in biomass fired capacity.

Biogas is more attractive in the 30%@COP15 scenario, because the negative $CO_2$-emissions factor of biogas becomes a greater benefit with the tougher $CO_2$-

target. This should be viewed in the light of the $CO_2$-price, which is 30 €/ton in the 30%@COP15 scenario in 2020 compared to only 7 €/ton in the Baseline scenario.

The cumulated investments by 2030 also differ between the two scenarios even though the 2030-target is the same. The main difference is that higher level of investments in natural gas up to 2020 in the 30%@COP15 scenario leads to fewer investments in new coal power and coal power with CCS in the subsequent decade.

$CO_2$-emissions

As intended, the $CO_2$-emissions in the scenario follow a lower trajectory than in the Baseline. Figure 44 displays $CO_2$-emissions distributed on countries between 2010 and 2030.

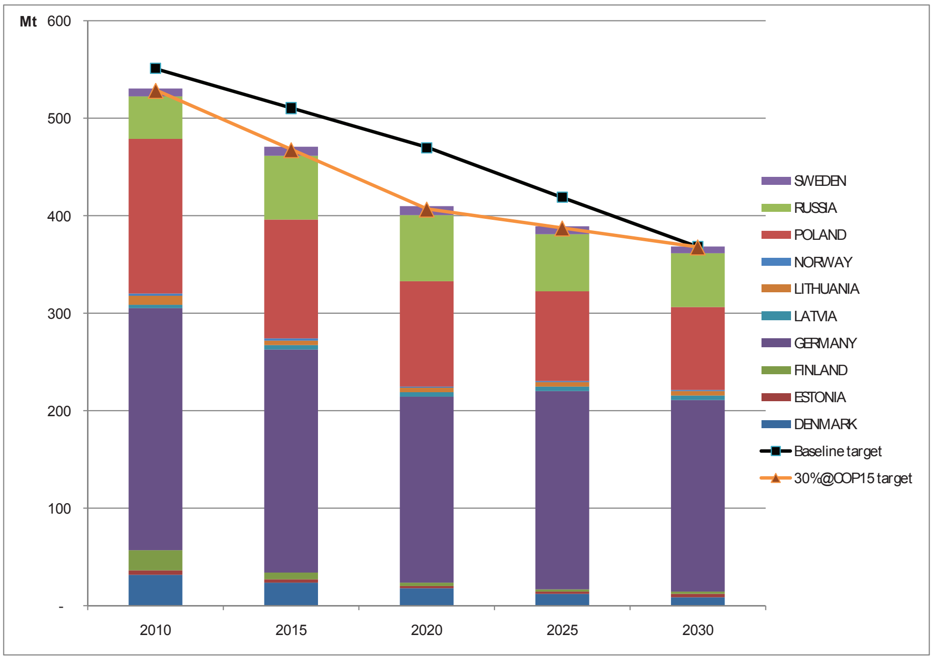



Figure 15: Development in $CO_2$-emissions (Mt) by country in the scenario 30%@COP15. The scenario specific $CO_2$ targets are shown by the orange line and the $CO_2$ target in the baseline by the black line.

Economic consequences

Electricity generators have their profits increased as the higher $CO_2$-prices lead to higher prices in the electricity markets, whereas the energy costs of electricity consumers are increased considerably. The total cost for the region of following the lower $CO_2$-emission path is estimated to be approx. €16 billion, measured as net present value (2009).

## Screening of new interconnectors

The study considers the existing interconnectors in the Baltic Sea Region. In addition, it is assumed that all five prioritized Nordic cross sections have been established by 2015.

The model takes into account the most important bottlenecks in the electricity systems and is able to assess the utility to the electricity market (including the different stakeholders in the market) of expanding transmission capacity between the different electrical areas. As part of the study a screening has been made to identify the most attractive new interconnectors.

The simulations indicate that there will be benefits of strengthening the electricity transmission grid in the region, particularly connections linking the thermal power based systems in Poland and Germany, and the Nordic power system dominated by hydro power. Strengthening connections between the Baltic countries and the Nordic countries may also be attractive.

Selected results from the screening of new interconnectors:

| Baseline scenario | Lithuania to Sweden M | Latvia to Sweden M | Germany NW to Norway S | Germany NW to Denmark W | Poland to Sweden S | Poland to Kaliningrad |
|---|---|---|---|---|---|---|
| In 2020 | 36,000 | 42,000 | 103,000 | 94,000 | 50,000 | 54,000 |
| In 2030 | 118,000 | 105,000 | 223,000 | 168,000 | 271,000 | 153,000 |

Table 7: Screening of new interconnectors. The table shows the total socio-economic benefit of adding 1 MW of transmission capacity between the different transmission areas in the model

These results are based on marginal benefits in the electricity market of increasing the capacity on interconnectors linking the different electric areas in the model in the Baseline scenario in 2020 and 2030. It should be noted, that an expansion of the existing transmission capacities in the region has been included in the Baseline scenario (see the Background Report).

The value of new interconnectors increases significantly between 2020 and 2030.

The benefits indicated in the table above should be compared to the capital costs of the connections. These costs are site specific and have not been quantified as part of the present study. For comparison it could be mentioned that the annual capital cost of Skagerrak IV linking Denmark West and Norway have been estimated to be approx. 35,000 €/MW and for NordBalt linking Lithuania and Sweden costs have been projected to be approx. 70,000 €/MW.

More comprehensive analyses are required to properly assess the value of new interconnectors to the general electricity system.

## Conclusions

The alternative policy scenarios indicate some of the advantages of cooperation between the countries and between the stakeholders in the Baltic Sea Region:

- Regional RE-targets instead of national targets reduce the costs of complying with the EU targets for RE in 2020.
- Regional planning for new interconnectors and regional development of energy markets would ensure the most efficient use of the available energy resources and energy infrastructure in the region.
- Joint planning for wind farms would ensure the best utilisation of the wind farms and the transmission lines connecting the wind farms to the electricity grid.

- Biomass should be treated as a regional resource and a regional market for biomass for energy purposes would be an advantage for the whole region.

Furthermore the analyses illustrate that a long term planning horizon would be needed in order to ensure sustainable investments in relation to the long-term $CO_2$-targets. This includes the right timing in investments in e.g. coal fired power plants.

Finally the scenario analyses show that savings in the electricity consumption would reduce the costs of meeting the $CO_2$ target in the region.

## 1.5 Dialogue with stakeholders

### The dialogue process

The use of scenario technique in strategic policy formulation is very fruitful, particularly if the scenarios are developed via dialogue with the policy makers and the main stakeholders. The scenarios quantify the visions of the politicians and illustrate how the targets could be fulfilled in the most efficient way.

Dialogue with the stakeholders on the energy scene in the Baltic Sea Region has been an important part of the study process. Preliminary results from the study have been presented and discussed at a number of occasions, comprising:

- Energy conference: "Energy and Climate Change: Global Challenges, Regional Solutions", 21 May 2008 in Warsaw;
- Meeting of the Baltic Sea Parliamentary Conference's Working Group on Energy and Climate Change, 22 May 2008 in Tallinn;
- Dinner-debate hosted by the Baltic Sea Parliamentary Conference, 20 October 2008 in Copenhagen;
- Meeting of the Joint Platform on Energy and Climate[5], 22 October 2008 in Copenhagen;
- Baltic Development Forum's Summit, 2 December 2008 in Copenhagen
- Meeting of the Group of Senior Energy Officials of BASREC, 3 December 2008 in Copenhagen;
- Baltic Sea Region Energy Cooperation (BASREC) Energy Ministers conference, 17 – 18 February 2009 in Copenhagen with the participation of the European Commissioner Andris Piebalgs;
- Meeting of the Baltic Sea Parliamentary Conference's Working Group on Energy and Climate Change, 18 May 2009 in Berlin;
- Energy seminar and joint meeting with the Ministers of Foreign Affairs in the Baltic Sea Region, 4 June 2009 in Elsinore;
- Energy workshop, 10 – 11 June 2009 in Kaliningrad.

The dialogue process is described in details in Annex 1.

5 Representing Baltic Development Forum (BDF), Baltic Sea Parliamentary Committee (BSPC), Council of the Baltic Sea States (CBSS), Union of Baltic Cities (UBC), Baltic Sea States Subregional Co-operation (BSSSC), Nordic Council (NC), Nordic Council of Ministers (NCM), CPMR Baltic Sea Commission Energy Workgroup, Baltic Metropoles (BaltMet), Baltic Islands Network B7 and Baltic Assembly (BA).

### Recommendations from stakeholders' discussions

This involvement of various stakeholders on different levels contributes to a better shared understanding of the possibilities and interests in the region.
The discussions have resulted in general recommendations on how to develop the Baltic Sea Region as a frontrunner on energy and climate issues:

- Develop a shared vision 'A Green Valley of Europe' in order to mobilize the strong traditions in the region for public-private co-operation.
- Establish an energy stakeholders' forum that includes different cross-border, cross-sector and cross-level actors. Not least the private sector needs a larger international platform in order to go beyond small markets.
- Develop regional projects that could benefit the region as a showcase for comprehensive and sustainable energy systems including R&D and demonstration activities.
- Develop a common interconnector strategy for the region to allow for a higher level of renewable energy penetration including that from offshore wind power.
- Launch an action plan for efficient and sustainable heating, involving the larger cities in the region and the district heating companies.
- Establish a common regional training program to strengthen the capacities in energy planning. Such a program should aim at developing the exchange of experiences and best practices among officials at local and national levels.

## 1.6 Next steps

As a key outcome of Phase II, the foundation has been laid for more comprehensive analyses and stakeholders' discussions on the future development of the energy systems in the Baltic Sea Region.

Questions to be answered:
The present analyses provide many answers as to how the energy sector in the region may evolve in the future. However, it also raises new questions, including

- How will the energy systems develop if fuel prices or technology costs evolve differently than anticipated? This calls for sensitivity analyses in relation to the existing analyses.
- How ambitious targets can be achieved in the region in the long-term if all measures are put into play? This calls for an analysis where the scope is expanded to 2050 in order to show how the region can comply with long-term objectives of the reduction of $CO_2$ emissions by 80 %.
- How can the Nordic countries assist the other countries in the region in meeting their policy targets? The results indicate that the Nordic countries have a potential in becoming large exporters of green electricity to other countries in the region and potentially to other countries outside the Baltic Sea region, for example the United K and the Netherlands. How can the

energy systems and the regulation of the energy markets evolve to enjoy the possible benefits?

Next steps:

- Improve the quality of Russian data used in the model. A contact has been established with the Energy Forecasting Agency in St. Petersburg.
- Develop analyses of different concepts for a common interconnection at Kriegers Flak and for other regional offshore wind farms.
- Develop analyses of how to ensure the most efficient use of the heat production from the new power plants in the region, including a dialogue with the central and local decision makers.
- Evolve the energy markets in the Baltic Sea Region.
- Evolve the markets for biomass in the Baltic Sea Region.

Conducting the study on Energy perspectives for the Baltic Sea Region has been an ongoing dialogue process. The establishment of the energy database by using modeling tools STREAM and Balmorel enables a further dialogue between the stakeholders with possibilities to detail the above-mentioned questions as well as other questions related to the development of a sustainable energy system in the Baltic Sea Region.

# 2 Scenarios and policy targets

One Baseline scenario and three alternative policy scenarios are put together to shed light on the future energy situation in the Baltic Sea Region.

The *Baseline scenario* is developed in order to comply with the European Union's targets of reducing $CO_2$-emissions by 20 % in 2020 and increasing the share of renewable energy to 20 %.

The scenario variations comprise:

- a scenario with *regional targets* for increasing the share of renewable energy instead of national targets
- an *Improved efficiency scenario* where electricity consumption is expected to be reduced considerably compared to the baseline projection
- a *30%@COP15 scenario* showing a situation where the EU commits itself to additional $CO_2$-reductions at the COP 15 meeting in December 2009.

The means of achieving the policy targets are to a large extent determined by the modelling tool based on a least cost analysis of supply side measures.

$CO_2$-targets

The targets mean that in 2020 $CO_2$-emissions from the electricity generators in the region should be reduced by 21 % compared to 2005 as this is the general requirement for the companies encompassed by the EU Emissions Trading Scheme (ETS).

The EU ETS covers the majority of fossil fuel power plants in the EU as well as the energy intensive industry. 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[6] as a means to comply with the targets. All things considered, it was chosen to apply 21 % as a realistic reduction target for 2020 for the electricity and district heating sector in the Baltic Sea Region.

For 2030 a project target to reduce 50 % of $CO_2$-emissions compared to 1990 was implemented. However, compared to 2005 the target is only a 38 % reduction because of the significant reduction in $CO_2$-emissions that took place in the Eastern part of the region following the transition to democracy after 1990.

RE targets

In addition to the $CO_2$-targets a RE target is included for the electricity sector towards 2020. In all scenario variations, except "Regional RE target", the RE

6 The Clean Development Mechanism (CDM) is an arrangement under the Kyoto Protocol allowing industrialised countries with a greenhouse gas reduction commitment (called Annex A countries) to invest in projects that reduce emissions in developing countries as an alternative to more expensive emission reductions in their own countries.

targets are treated as individual targets for each of the countries in the region. The RE targets are set in line with the RE directive endorsed at the summit in December 2008.

The RE directive provides a target for the share of RE of final energy in each member state, but not a separate target for the electricity sector.

Renewable energy in the electricity sector

The level of renewable energy that will have to be introduced in the electricity sector will, among other things, depend on the economical and technical opportunities compared to increasing renewables in other sectors such as the transport sector and the industry. The EU Commission's renewable energy road map[7] foresees that the penetration of renewable energy in the electricity sector will have to increase to 34 % in 2020 in order to comply with a general target of 20 % renewable energy in energy consumption. Compared to 2005 this means a 20 percentage point increase in the share of RE in electricity generation (from 14 % in 2005) compared to only a 13 percentage point increase of renewable energy in overall energy consumption (from 7 % in 2005). In other words, the absolute share of renewable energy in electricity consumption should increase 1.5 times more than the overall share of renewable energy.

In the present analyses we chose to operate with a target for the electricity sector corresponding to: RE share of electricity in 2005 + 1.5 * required increase in RE in overall final energy demand in the directive. As an example, 28 % of electricity consumed in Denmark in 2005 was supplied from renewable energy. The RE directive requires Denmark to increase its share of RE in final energy demand by 13 percentage point from 17 % in 2005 to 30 % in 2020. Hence, we set the RE target for the Danish electricity sector at 48 % in 2020 (i.e. 28 % + 1.5 * 13 %).

For the Baltic Sea Region as a whole renewable energy electricity corresponded to 26 % of total electricity supply in 2005. For 2020 the target for the region is 38 % based on the approach outlined above (see Table 8).

Pertaining to the modelling of the energy systems it is assumed that the RE targets do not become binding until after 2010. Moreover, to simplify the analyses in the model, the renewable energy targets do not apply to district heating.

| **Final energy** | **Germany** | **Denmark** | **Estonia** | **Finland** | **Lithuania** | **Latvia** | **Poland** | **Sweden** | **Norway** | **NW Russia** | **REGION** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 RE share | 6% | 17% | 18% | 29% | 15% | 35% | 7% | 40% | 60% | 3% | 14% |
| 2020 target | 18% | 30% | 25% | 38% | 23% | 42% | 15% | 49% | 60% | 0% | 25% |
| Increase 2005-2020 | 12% | 13% | 7% | 10% | 8% | 7% | 8% | 9% | 0% | 0% | 11% |
| **Electricity** | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2005 RE share | 11% | 28% | 1% | 27% | 4% | 48% | 3% | 54% | 100% | 19% | 26% |
| Expected increase in electricity sector | 18% | 20% | 11% | 14% | 12% | 11% | 12% | 14% | 0% | NA | 15% |
| 2020 target | 29% | 48% | 12% | 41% | 16% | 59% | 15% | 68% | 100% | NA | 37% |

Table 8: Renewable energy targets. No renewable energy target has been included for North West Russia; it assumed though that the present renewable generation will continue at least the same level towards 2030

In Table 9, the renewable energy targets are expressed in TWh of renewable energy electricity generation.

7 http://www.europa-kommissionen.dk/upload/application/89eba319/03_renewable_energy_roadmap_en.pdf (2009-02-04), see p. 11.

| TWh | Germany | Denmark | Estonia | Finland | Lithuania | Latvia | Poland | Sweden | Norway | Russia | REGION |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **2005** | 57 | 10 | 0 | 23 | 0 | 3 | 3 | 76 | 118 | 17 | 308 |
| **2010** | 97 | 13 | 0 | 30 | 1 | 4 | 8 | 88 | 127 | 17 | 386 |
| **2015** | 140 | 16 | 1 | 36 | 2 | 6 | 15 | 98 | 135 | 17 | 465 |
| **2020** | 177 | 19 | 1 | 41 | 2 | 6 | 20 | 105 | 135 | 17 | 525 |
| **2025** | 182 | 19 | 1 | 43 | 2 | 7 | 23 | 108 | 142 | 17 | 546 |
| **2030** | 186 | 20 | 1 | 44 | 3 | 8 | 25 | 109 | 147 | 17 | 562 |

Table 9: Renewable energy requirements (TWh of electricity generation) in the Baseline scenario. In the sensitivity scenario with improved energy efficiency the absolute values are lower because the RE target is measured as a share of final energy consumption.

Norway

Even though Norway is not a part of the EU, the renewable energy directive will also be applicable to Norway by virtue of the 1994 European Economic Area (EEA) Agreement, to which Norway is a party[8]. The electricity generation from renewables was 108 % of domestic electricity consumption in Norway in 2005, because of a greater than usual inflow to the Norwegian hydro power plants. However, for the present analyses it was chosen to use 100 % RE share in the electricity as the starting point for Norway and it is assumed that Norway will stay at this level until 2030.

Russia

The policy framework in Russia is very different compared to the other countries in the region, which are all members of the European Union, except Norway.

Obviously the EU targets on renewable energy and the EU ETS regulation do not apply to Russia. However, Russia is a party to the Kyoto Protocol and this provides Russia with incentives to reduce greenhouse gas emissions. Russia's commitment under the Kyoto Protocol is to stabilise its emissions at 1990 levels during the five year period from 2008 to 2012. The economic recession after the break-up of the Soviet Union, as well as structural changes to the economy, have resulted in a massive reduction of Russia's energy-related $CO_2$-emissions. Therefore it is expected that Russia will have considerable surplus of quotas (so-called AAU) in the period from 2008-2012. Potentially, this surplus could be exported to other countries under the Kyoto framework. Moreover, studies show that Russia has a large cost-effective potential for further reducing energy related $CO_2$-emissions mainly through energy-efficiency improvements in a range of industrial activities and end-use sectors[9].

For North West Russia we have included a target of 10 % $CO_2$ reduction in 2020 and a 30 % reduction in 2030. These targets assume that an international agreement is reached at COP15 in December 2009, which will provide incentives for ambitious reductions. Because of the lack of statistical data on $CO_2$ emissions, the targets are measured against a model based on the simulation of North West Russia in 2005 using the available data set.

It is assumed that from 2015 a market for $CO_2$-quotas will be formed allowing Russian power and heat producers to trade quotas with their counterparts in the rest of the Baltic Sea Region.

8 "Europe agrees on much-anticipated renewable energy deal", http://www.bellona.org/articles/articles_2008/europe_energy_deal, 10/12-2008

9 http://www.iea.org/textbase/nppdf/free/2006/russiangas2006.pdf, 2009-03-17. IEA, 2006: "Optimising Russian Natural Gas - Reform and Climate Policy"

## 2.1 One Baseline scenario and three policy scenarios

In addition to the Baseline scenario a number of scenario variations are prepared. These variations differ in the way policy targets are complied with and whether common solutions or national solutions are put in play.

By examining the results of the various scenario variations it is possible to examine the costs and benefits of pursuing different policies. Moreover, the value of implementing specific projects in the region can be examined under different scenarios for the future development of the sector.

The table below shows the policy targets for the scenario, the variations, as well as key assumptions with regard to interconnectors and development in electricity demand.

| | **Regional CO2-target for electricity sector (compared to 2005)** | | **RE target** | **Inter-con-nections** | **Electricity demand** | **New Generation** |
|---|---|---|---|---|---|---|
| Scenario | 2020 | 2030 | 2020 | 2005-2030 | 2005-2030 | 2005-2030 |
| Baseline | - 21 % | - 38 % | Country specific | BAU | BAU | Model decides (-nuclear, hydro) |
| *Scenario variations* | | | | | | |
| Regional RE target | - 21 % | - 38 % | Regional | BAU | BAU | Model (-nuclear, hydro) |
| Improved efficiency | - 21 % | - 38 % | Country specific | BAU | - 22 % in 2030 | Model (-nuclear, hydro) |
| 30%@COP15 | - 31 % | - 38 % | Country specific | BAU | BAU | Model (-nuclear, hydro) |

Table 10: Scenarios and variations towards 2030

Further description of the scenario variations:

Regional RE target

The EU has set out national targets for increasing the share of renewable energy in final energy consumption towards 2020. However, the renewable energy directive allows Member States that are in surplus to sell renewable energy credits to other countries.  These so-called ‘statistical transfers’ of RE can also be applied in cases where member states cooperate on joint projects. This sensitivity scenario explores a situation where the countries around the Baltic Sea cooperate on achieving their national targets.

Improved efficiency

In the Baseline scenario a business-as-usual projection of the development in the electricity demand is used based on data from the European Commission (EU, 2008). This projection reflects existing policies at the EU level and in the different Member States. In the “Improved efficiency scenario”, as a result of firmer policies, electricity consumption is expected to be reduced considerably compared to the Baseline projection. As such in 2030 the general electricity consumption is approximately 20 % below the Baseline level. Moreover, the use of electricity for heating is reduced, resulting in total electricity savings at 22 %.

30%@COP15

A separate scenario variation, “30%@COP15”, is developed showing an additional reduction of $CO_2$ emissions by 10 percentage point from the power sector in 2020. This variation reflects a situation where an ambitious international agreement is obtained at the Copenhagen summit in December 2009 committing the EU Member States to cut their overall $CO_2$-emissions by 30 % in 2020.

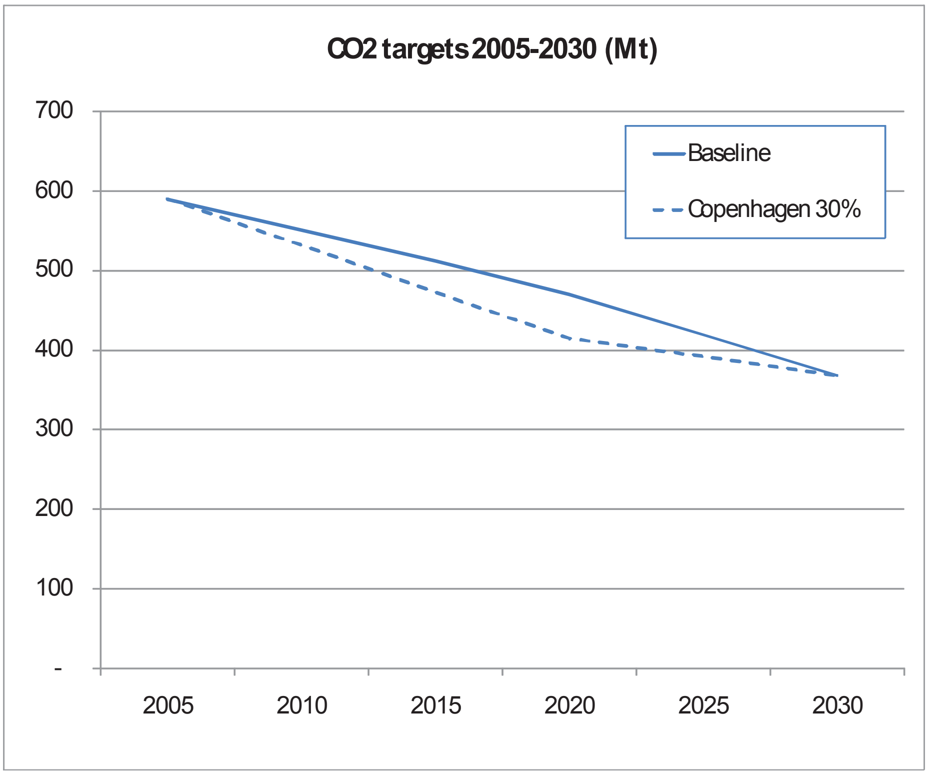



Figure 16: Targets for reducing CO2 emissions from the electricity and district heating sectors in the period 2005-2030 for the Baltic Sea Region. A linear development is assumed between 2005 and 2020 and between 2020 and 2030.

## 2.2 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.

The present study focuses on the least-cost ways of achieving the targets from a socio economic point of view. The existing policy measures for promoting RE are not considered in the study, because they would tend to divert investments in renewable energy technologies to the countries with the most favourable support scheme, rather than the countries with the best renewable energy resources.

# 3 Modelling tool

The Balmorel model

The analyses are carried out by the use of the Balmorel model, which is an economic/technical partial equilibrium model that simulates the power and heat markets.

The model optimises the production at existing and planned production units (chosen by the user) and allows new investments in the scenarios, chosen by the model on a cost minimising basis.

More information about the model can be found on the model's website, [10] www.balmorel.com[11].


Figure 17: Map of the transmissions grid in the Baltic Sea Region (Source: Nordel)

Geographical scope

The original version of this model contains data for the electricity and Combined Heat and Power (CHP) system in the Nordic countries (Denmark, Finland, Norway and Sweden), the Baltic countries (Estonia, Latvia and Lithuania), Poland and Germany.

The model considers the most important bottlenecks in the electricity systems. Norway consists of four electric areas with capacity constraints between them Sweden consists of three areas, Denmark two and Germany three whereas Poland, the Baltic countries and Finland consist of one area each.

Data collected for this study and used in the simulations include data from North West Russia. To be specific, the following regions were included: Republic of Karelia, Kola Peninsula, Pskov Region, Kaliningrad, Arkhangelsk Region, Leningrad Region incl. St. Petersburg, Novgorod Region and Republic of Komi.

Due to the lack of exact data about the Russian electricity and heating systems crude approximations have been made in some cases[10].

10 The main sources of information are the reports "Distributed Energy Production in the North-West Region of Russia" (Efimov, A, 2007) and "Scenarios for electricity power sector development in the North-West of Russia" (Abdurafikov R., 2007).

# 4 Key assumptions for the scenarios

The following section describes the most important assumptions underlying the analyses, including:

- Fuel prices
- $CO_2$ price
- Electricity and heat demand prognoses
- Technology costs and investments
- Renewable energy potentials

## 4.1 Fuel prices

The development in prices of fossil fuels is based on the latest forecast from International Energy Agency's (IEA) World Energy Outlook 2008 (WEO-2008). According to this projection the real term price of crude oil will increase from an expected 100 $/bbl in 2010 to 122 $/bbl in 2030.

The prices of different types of biomass are based on information from the Danish Energy Agency. The biomass prices represent the marginal prices of biomass delivered at a large power plant. These prices are not necessarily equal to the cost of procurement, because the market price of biomass is defined in competition with other fuels.

For municipal waste a negative cost, - 3 € per GJ -, is used to represent the alternative costs of treatment.

| (Euro08/GJ) | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| Coal | 2.4 | 3.7 | 3.6 | 3.5 | 3.4 |
| Lignite | 1.5 | 2.3 | 2.2 | 2.1 | 2.1 |
| Fuel oil | 6.6 | 9.7 | 10.5 | 11.1 | 11.7 |
| Light oil | 11.6 | 17.0 | 18.6 | 19.6 | 20.6 |
| Nuclear | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Natural gas | 5.6 | 8.7 | 9.5 | 10.0 | 10.6 |
| Biogas | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| Wood Waste | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| Straw | 5.5 | 6.2 | 6.3 | 6.4 | 6.6 |
| Wood | 5.8 | 6.4 | 6.7 | 6.9 | 7.2 |
| Wood pellets | 8.7 | 9.4 | 9.8 | 10.1 | 10.5 |
| Import Biomass | 7.2 | 7.9 | 8.2 | 8.5 | 8.8 |
| Municipal Waste | -3.1 | -3.1 | -3.1 | -3.1 | -3.1 |

Table 11: Fuel price assumptions used in the study (real terms).

Gas prices in Norway and Russia

Because Norway 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 here. In Norway a 10 % discount is assumed. In Russia it was included a 6 % discount plus a deduction of 0.4 €/GJ from the forecasted European gas import price. This relationship between European and Russian gas market prices has been estimated based on the correlation between the so-called netback price at the Russian-Ukrainian border and the price at the EU border[11]. The difference represents transport costs through Ukraine, Slovakia and the Czech Republic in the period 2004-2007.

Currently the gas prices in Russia are state-capped; however the Russian government is planning to increase gradually local gas prices until 2011 in order to achieve a level of equal profitability of sales on both local and export markets.[12]

$CO_2$-price

No external $CO_2$-price is applied in the calculations. In its place the model finds optimal solutions for reducing the emissions of $CO_2$ to the targets included in the scenarios, i.e. a 21 % reduction in 2020[13] (compared to 2005) and a 50 % reduction in 2030 (compared to 1990). The model is able to compute the marginal cost of reducing $CO_2$ in each scenario. This can be interpreted as the price of $CO_2$-quotas if the Baltic Sea Region formed a closed market for $CO_2$.

With the EU Emissions Trading Scheme as it is implemented today, it is possible to trade quotas across the whole EU and to import credits from Clean Development Mechanism (CDM) projects as a means to comply with the targets set out. This will of course have an impact on the price of $CO_2$-quotas in the Baltic Sea Region. However, to simplify the interpretation of the results no link is assumed to the rest of the EU ETS.

## 4.2 Transmission capacity

The starting point of the analyses is the existing interconnectors in the Baltic Sea Region.

In addition, it is assumed:

Five prioritized Nordic cross sections

That the five prioritized Nordic cross sections have all been established by 2015. The five prioritized Nordic cross sections are:

- Fenno - Skan II linking Finland and Sweden (800 MW)
- Great Belt in Denmark (600 MW)
- Nea - Järpströmmen between Sweden and Norway (750 MW)
- South Link in Sweden (600 MW)
- Skagerrak IV between Denmark and Norway (600 MW)

11 Russian Analytical Digest 53/09
12 See, Reuters article from November 6, 2009. http://www.reuters.com/article/rbssEnergyNews/hidUSL628742520081106 "Russia clears 20 pct domestic gas price rise in '09"
13 Except in the Copenhagen 30% scenario where the target for 2020 is 31 % reduction. This is not clear

Reinforcement of German grid

That a significant reinforcement of the internal grid between the North West and Central parts of Germany will take place (7000 MW) to accommodate for the planned expansion of wind power in the northern parts of Germany particularly off-shore.

Poland-Lithuania and Estonia-Finland

That by 2020 Poland and Lithuania are connected by a 1000 MW connection.

That a second connection between Estonia and Finland at 650 MW will be implemented by 2020.

Norway-Norway Norway-Sweden

That connections between the central part of Norway and neighbouring areas in South and North Norway and North Sweden are upgraded by 1200 MW.

No further interconnectors are assumed to be established in the Baseline scenario.

## 4.3 Electricity demand

In all scenarios except the scenario called "improved efficiency" the demand for electricity develops as anticipated in the most recent projection from the European Commission[14]. Table 12 shows the development in electricity demand in the business as usual projection.

| TWh | Denmark | Sweden | Finland | Norway | Germany | Poland | Lithuania | Estonia | Latvia | NW Russia |
|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 35,3 | 141,9 | 89,0 | 118,0 | 575,0 | 113,9 | 9,7 | 7,2 | 6,6 | 90,9 |
| 2010 | 36,9 | 151,4 | 98,1 | 127,4 | 615,4 | 130,0 | 11,7 | 8,8 | 8,6 | 102,4 |
| 2015 | 38,5 | 157,6 | 104,0 | 134,5 | 649,6 | 149,6 | 13,6 | 10,2 | 10,2 | 110,9 |
| 2020 | 38,5 | 157,6 | 104,0 | 134,5 | 649,6 | 149,6 | 13,6 | 10,2 | 10,2 | 120,0 |
| 2025 | 39,8 | 161,0 | 108,5 | 141,7 | 667,1 | 170,4 | 15,4 | 11,4 | 11,7 | 129,9 |
| 2030 | 40,8 | 163,0 | 111,5 | 147,3 | 682,1 | 185,1 | 17,1 | 12,5 | 13,2 | 140,7 |

Table 12: The BAU development in electricity demand, 2010-2030, including grid losses.

According to the EU Baseline projection, in the short-term electricity consumption is projected to increase at a rate similar to that observed in the recent past. In the longer term the Baseline scenario "takes the view that energy efficiency improvements in appliance design and the housing stock are exerting a downward pressure on demand which is moderating the growth of electricity consumption in all sectors" (EU Commission, 2008, p. 58).

Improved efficiency scenario

In the "Improved efficiency scenario" electricity consumption is expected to be reduced considerably compared to the Baseline projection. This is a result of stringent policies to make consumers use electricity in a more rational manner. In 2030 the general electricity consumption is approximately 20 % below the baseline level. The same relative level of energy savings is assumed to take place in all countries across the region.

14 EUROPEAN ENERGY AND TRANSPORT
TRENDS TO 2030 — UPDATE 2007, European Commission 2008.

| All countries | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Savings in general electricity consumption relative to baseline | 0% | 2 % | 7 % | 10 % | 15 % | 20 % |

Reducing electricity for direct heating

In addition to the general effort to reduce electricity consumption, a specific focus is put on reducing electricity demand for conventional electric heating - through improved insulation of buildings and by converting to other forms of heating with lower marginal $CO_2$-emissions, such as electric heat pumps, district heating, solar heating and boilers fuelled by biomass or natural gas.

Particularly in Norway, Sweden and Finland, electricity is a very important source of heating. Today's high consumption of electricity in these countries should be seen in relation to the history of the energy systems, particularly the access to cheap hydro power and base-load nuclear power. However, as the electricity markets are opened, and considering that the electricity may alternatively be exported to neighbouring countries where the marginal generation comes from thermal power plants, using electricity for direct heating becomes relatively expensive. In the "Improved efficiency scenario" it is assumed that the demand for electricity for heating in Finland, Norway and Sweden is reduced by 50 % towards 2030.

| Country | Electricity demand for heating 2005 | Share of total final electricity demand 2005 |
|---|---|---|
| Finland | 9 TWh | 11% |
| Norway | 30 TWh | 27% |
| Sweden | 21 TWh | 16% |

Table 13: Electricity demand for heating in Finland, Norway and Sweden.

When including the additional effort to reduce electricity demand for direct electric heating, the total electricity savings in 2030, in the improved efficiency scenario are 22 % for the region as a whole compared to the baseline scenario.

## 4.4 Existing generation capacity

The Balmorel model holds an inventory of the existing power plants in the Baltic Sea Region. In some countries like the Baltic Countries and Denmark all large power plants are modelled individually, whereas a more aggregated representation is used for others, e.g. Germany and Poland.

This inventory forms the starting point for the analyses. However, as time moves forward existing plants are commissioned and new sources of generation will have to be brought online.

A number of assumptions on the rate of decommissioning of existing plants are assumed for the individual countries. These assumptions are based on, among other things, the expected technical life time of power plants, and in certain cases information about the conditions of specific power plants.

## 4.5 New generation capacity

Apart from investments in new nuclear and hydro power, and a minimum level of investments in wind power and some thermal power plants (power plants that will be commissioned with a very level of certainty within the coming years), investments in new generation capacity are decided upon by the model's investment module.

Investment approach

The Balmorel model is myopic in its investment approach, and thereby 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 11.75%, which is equivalent to 10% internal rate for 20 years. 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.

Technology data catalogue

The model has a data catalogue with a set of new power station 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 plant, power plants with CCS and wind power (on and off-shore). Thermal power plants can be condensing unit – producing only electricity, or combined and power plants. The model may also invest in heat generation capacity such as coal, biomass and gas boilers, as well as large-scale electric heat pumps and electric boilers.

Basic technical and economic data for the power generation technologies that the model may invest in can be viewed in the table below. The same technology assumptions are used throughout the period from 2010 to 2030; however the CCS technology is not assumed to be commercially available until 2020.

Wave power and solar power technologies are not considered in the analysis, because – without special subsidies – they are not expected to be competitive with wind power and biomass technologies within the time-frame of the study. However, the technological development may evolve differently than assumed here. This is one of the questions that are foreseen to address in connection with future sensitivity analyses.

| **Technology** | **Investment cost (mil. €/MW)** | **Fixed O&M (€1000/ MW)** | **Variable O&M (€/ MWh)** | **Electric efficiency** *Condensing mode* | **Electric efficiency** *CHP mode* | **Total efficiency** *( Elec. + heat)* |
|---|---|---|---|---|---|---|
| Natural Gas fired Back Pressure CC | 0.8 | 11 | 3 | NA | 49% | 94% |
| Natural Gas fired Extraction CC | 0.6 | 13 | 2 | 60% | 55% | 90% |
| Biogas fired Back Pressure CHP | 3.5 | 0 | 29 | NA | 39% | 90% |
| Straw fired Back Pressure CHP | 2.6 | 92 | 2 | NA | 30% | 90% |
| Municipal Waste fired Back Pressure CHP | 6.2 | 248 | 24 | NA | 32% | 95% |
| Coal fired Condensing Power with CCS | 2.0 | 32 | 15 | 39% | 0% | 39% |
| Wood fired Condensing Power | 1.5 | 29 | 3 | 45% | 0% | 45% |
| Coal fired Condensing Power | 1.2 | 32 | 2 | 48% | 0% | 48% |
| Coal fired Extraction Power Plant CCS | 2.1 | 34 | 15 | 39% | 32% | 74% |
| Lignite fired Extraction CHP | 1.2 | 50 | 2 | 41% | 34% | 82% |
| Natural Gas fired Extraction CHP | 1.2 | 31 | 2 | 48% | 40% | 92% |
| Coal fired Extraction CHP | 1.4 | 34 | 2 | 48% | 41% | 85% |
| Straw fired Extraction CHP | 1.9 | 29 | 5 | 47% | 39% | 90% |
| Wood fired Extraction CHP | 1.9 | 53 | 3 | 45% | 38% | 87% |
| Wind Turbine, On-shore | 1.3 | 16 | 2 | NA | NA | 100% |
| Wind Turbine, Off-shore | 2.0 | 41 | 3 | NA | NA | 100% |

Table 14: Electricity generation technologies, which the model can invest in.

## Nuclear power

As opposed to letting the model make "optimal" investments in nuclear power, it has been chosen to describe a development based on best available information about the future role of nuclear power in the different countries in the region.

The reason for this approach is twofold: first of all the direct costs of new nuclear power plants are associated with a high degree of uncertainty. For example, the 5th Finish nuclear reactor of 1600 MW, which is currently under construction, was projected to cost EUR 3.2 billion, but a EUR 2.3 billion cost overrun is reported[15]. 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.

15 Danish Newspaper "Information" 09 09 05.

The table below shows the expected development of nuclear power in the individual countries in the Baltic Sea Region towards 2030.

Nuclear outlook

The nuclear Baseline scenario is made with the intention to form a compromise between the very strong views against or in favour of nuclear power.

| MW | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Denmark | - | - | - | - | - | - |
| Sweden | 9,372 | 9,372 | 9,372 | 9,372 | 9,372 | 9,372 |
| Finland | 2,656 | 2,656 | 4,256 | 4,256 | 4,256 | 4,256 |
| Norway | - | - | - | - | - | - |
| Germany | 20,264 | 20,264 | 20,264 | 20,264 | 17,870 | 9,256 |
| Poland | | - | - | - | 2,089 | 4,385 |
| Lithuania | 1,200 | - | - | 1,500 | 1,500 | 1,500 |
| Estonia | - | - | - | - | - | - |
| Latvia | - | - | - | - | - | - |
| NW Russia | 5,760 | 5,760 | 5,760 | 5,760 | 5,760 | 5,760 |
| **Total** | **39,252** | **38,052** | **39,652** | **41,152** | **40,847** | **34,529** |

Table 15: Expected development in nuclear capacity in the Baltic Sea Region. This development is applied in all scenarios.

In Germany and Sweden nuclear power has been high on the political agenda for a long time, with continuing debates about whether or not the technology should be phased out or advanced.

Nuclear in Sweden

In Sweden the Parliament decided in 1980 that no further nuclear power plants should be built, and that a nuclear power phase-out should be completed by 2010. In 1999 Barsebäck block 1 was shut down, and in 2005 block 2 was shut down. However, the energy production from the remaining nuclear power plants has been considerably increased in recent years to compensate for the shutting down of Barsebäck. The current conservative-led coalition is positive towards nuclear power and has decided to cancel the Nuclear Phase-Out Act. In addition, it will be possible to grant permits for successively replacing current reactors as they reach the end of their technological and economical life. For the present analyses we assume that the existing nuclear power plants either remain operational to 2030, or are replaced by new nuclear power plants of the same capacity.

Nuclear in Germany

In Germany a decision was made in 2000 on the gradual shut down of the country's nineteen nuclear power plants. This decision was based on a 32 year life-time of the existing plants. However, the current German chancellor Angela Merkel is opposing a phase-out, and therefore depending on the outcome of the next German federal election it is not unlikely that the nuclear phase-out will be postponed or abandoned. For the present analyses it has been assumed that the life-time is increased 50 years on average. This means that in 2020 all existing plants are operating, but in the period between 2020 and 2030 more than 50 % of the nuclear capacity is taken out. No new nuclear power plants are anticipated in Germany.

Lithuania

In Lithuania a new nuclear power plant is foreseen to come online in 2020 as a substitution for the Ignalina power plant, which is assumed to be taken out of operation by 2010 in accordance with the agreement between Lithuania and the EU.

Poland

In Poland the government sees nuclear power as part of the solution to reduce $CO_2$-emissisons and diversify energy sources. In accordance with the Baseline projection from the EU Directorate - General Energy and Transport (DG TREN) scenario, 2.1 GW of nuclear power capacity is expected to be commissioned by 2025, and a further 2.4 GW by 2030[16].

Finland

In Finland the 5th reactor is expected to be producing by 2015. No further expansion with nuclear power is assumed in Finland in the scenario despite current discussions about the 6th reactor.

Russia

In 2007 16% of total Russian electricity demand was supplied by nuclear power. Rosatom, the State Atomic Energy Corporation running all nuclear assets of the Russian Federation, announced in 2006 a target for nuclear power providing 23% of electricity by 2020 and 25% by 2030, but since then plans have been scaled back by the government[17].

Almost 6,000 MW of nuclear power capacity is installed in North West Russia and a number of new nuclear power stations are being proposed, including plants in Kaliningrad and St. Petersburg. On the other hand the existing plants, among others in St. Petersburg, are scheduled to be closed or renovated within the next 15 years.

Because of the uncertainty related to the future policy decisions about new nuclear capacity in this part of Russia it has been assumed to keep the nuclear capacities in NW Russia unchanged towards 2030.

Denmark, Estonia, Latvia, Norway

In Denmark, Estonia, Norway and Latvia it is assumed that there will not be built any nuclear power plants.

## Hydro power

A number of countries around the Baltic Sea Region hold a significant potential to increase the generation of electricity from hydro power. To a higher degree many other sources of electricity generation, the costs of and possible barriers to hydro power projects are site specific. Hence, investments in new hydro power capacity are not decided by the model's investment module.

In the analyses it is assumed that the generation from hydro power is increased somewhat beyond today's production. However, the full technical economical potential, as identified in various studies, is not utilised.

The greatest potential for expanding hydro power generation is in Norway. According, to the Norwegian Water Resources and Energy Directorate (NVE)

16 http://www.world-nuclear.org/info/inf102.html(2009-02-03).
17 http://www.world-nuclear.org/info/inf45.html, 25 June 2009.

the total potential for large-scale hydro power in Norway is approx. 205 TWh[18], including 18.5 TWh from small-scale hydro power. These numbers should be compared to today's generation, i.e. the current utilization of the potential, which in a year is 122 TWh of average inflow.

Around 46 TWh of the total hydropower potential is located in protected watercourses, which gives remaining potential of around 56 TWh per year that is not protected against the development of power stations. However, it should be noted that the potential for small-scale hydro power is based on a theoretical assessment that does not take into consideration environmental impacts and other factors that reduce development opportunities.

For the present analyses it is assumed that the total generation from Norwegian hydro power is increased by 1 TWh annually, leading to a 25 TWh increase from 122 TWh in the base year 2005 to 147 TWh in 2030. This development includes a higher level of generation from existing power plants due to expected climate change.

The table below shows the assumed development in annual generation from hydro power, country by country in the period 2005-2030.

| TWh | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| **Denmark** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Sweden** | 72.5 | 73.0 | 74.0 | 75.0 | 75.0 | 75.0 |
| **Finland** | 13.8 | 13.8 | 13.8 | 14.0 | 15.0 | 16.0 |
| **Norway** | 121.8 | 126.8 | 131.8 | 136.8 | 141.8 | 146.8 |
| **Germany** | 26.7 | 26.9 | 28.4 | 28.5 | 29.2 | 29.9 |
| **Poland** | 2.0 | 2.1 | 2.5 | 3.0 | 3.2 | 3.5 |
| **Lithuania** | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| **Estonia** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Latvia** | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 |
| **Russia** | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |

Table 16: Assumed development in annual generation from hydro power, country by country, 2005-2030. Note that no division is made between small and large-scale hydro power.

## Wind power

A minimum development in investments in wind power is assumed in all scenarios. This mainly reflects wind power plants that are already under construction, and projects where firm decisions have been made. National objectives like the Swedish target to expand to 30 TWh of wind power production in 2020, or the Danish target to increase wind power generation to 50 % of electricity consumption in 2025 are not reflected in the minimum development.

The table below shows the minimum wind power development country by country in the period 2005-2030. In some countries the DG TREN forecast for 2010 is used as the minimum. No wind power expansion is included in Russia in the minimum development.

18 NVE (2008): "Facts 2008. Energy and Water Resources in Norway", p 24ff.

Table 17: Minimum wind power development. No wind power expansion is included in Russia in the minimum development.

| Onshore | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Denmark | 2.600 | 2.750 | 3.100 | 3.100 | 3.100 | 3.100 |
| Sweden | 493 | 1.612 | 1.612 | 1.612 | 1.612 | 1.612 |
| Finland | 82 | 250 | 500 | 1.500 | 1.750 | 2.000 |
| Norway | 274 | 508 | 940 | 1.380 | 1.600 | 1.990 |
| Germany | 18.428 | 24.351 | 24.351 | 24.351 | 24.351 | 24.351 |
| Poland | 83 | 600 | 600 | 600 | 600 | 600 |
| Lithuania | 6 | 98 | 204 | 210 | 225 | 230 |
| Estonia | 32 | 201 | 203 | 220 | 230 | 235 |
| Latvia | 24 | 171 | 180 | 195 | 198 | 200 |

| Offshore | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Denmark | 423 | 600 | 1.200 | 1.200 | 1.200 | 1.200 |
| Sweden | - | 500 | 500 | 500 | 500 | 500 |
| Finland | - | 60 | 60 | 60 | 60 | 60 |
| Norway | - | - | - | - | | - |
| Germany | - | 140 | 800 | 800 | 800 | 800 |
| Poland | | | | | | |
| Lithuania | - | | | | | |
| Estonia | | | | | | |
| Latvia | - | | | | | |

The model's investment module can choose to invest in additional wind power capacity based on the technical/economical potentials in each country. These are not the theoretical potentials for wind, but an estimate of a possible potential taking into consideration constraints related to access to sites, the economics of developing different sites and the available wind resources.

These potentials have mainly been deduced from the EU financed project TradeWind, "Wind Power Scenarios"[19]. In some cases however, the data has been supplemented by other sources of information. The values for 2030 are a best estimate of a long-term technical/economical potential. The model is not allowed to invest beyond the long-term potential.

Table 18: Technical/economical wind power potential (total cumulative maximum).

| Onshore | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Denmark | 2.600 | 2.750 | 3.500 | 3.500 | 3.500 | 3.500 |
| Sweden | 493 | 1.612 | 4.806 | 8.000 | 8.000 | 8.000 |
| Finland | 82 | 280 | 500 | 900 | 2.100 | 2.100 |
| Norway | 227 | 3.000 | 5.000 | 7.000 | 7.000 | 7.000 |
| Germany | 18.428 | 26.786 | 30.134 | 32.029 | 33.600 | 33.630 |
| Poland | 83 | 1.500 | 4.000 | 7.000 | 11.000 | 14.000 |
| Lithuania | 6 | 250 | 650 | 1.050 | 1.200 | 1.370 |
| Estonia | 32 | 307 | 800 | 935 | 1.500 | 1.805 |
| Latvia | 27 | 140 | 400 | 550 | 800 | 800 |

| Offshore | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| Denmark | 423 | 600 | 3.000 | 6.000 | 9.000 | 12.000 |
| Sweden | 23 | 550 | 2.600 | 5.500 | 10.000 | 11.000 |
| Finland | - | 500 | 2.500 | 6.500 | 10.000 | 10.000 |
| Norway | - | - | 2.500 | 5.000 | 7.300 | 7.300 |
| Germany | 165 | 1.680 | 12.479 | 24.611 | 27.284 | 29.957 |
| Poland | | | 1.000 | 2.000 | 2.000 | 2.000 |
| Lithuania | - | - | 200 | 200 | 200 | 200 |
| Estonia | | | 500 | 1.500 | 2.000 | 2.000 |
| Latvia | - | | 150 | 150 | 150 | 150 |

19 http://www.trade-wind.eu/fileadmin/documents/publications/D2.1_Scenarios_of_installed_wind_capacity__WITH_ANNEXES.pdf, (2009-02-04)

With respect to Russia a crude estimate has been made that the total long-term potential for on-shore wind power in the North West region is 14,500 MW (including 3000 MW in reach of the areas Karelia, Komi Peninsula, Arkhangelsk and Komi and 625 MW each in Pskov, Kaliningrad, Leningrad Region and Novgorod).

Full load hours

The table below shows the assumed number of full load hours for wind power in each country. 1 MW wind turbine with 2600 full load hours will produce 2600 MWh of electricity during one year – this corresponds to a 30 % capacity factor.

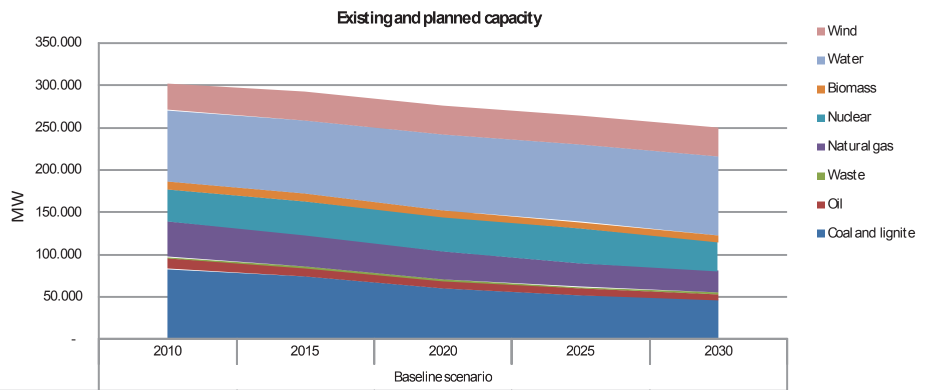
Table 19: Number of full load hours for wind power.

<table>
<tr><th></th><th>Onshore</th><th>Offshore</th></tr>
<tr><td>Germany</td><td>2200</td><td rowspan="9">3500</td></tr>
<tr><td>Denmark, East</td><td rowspan="9">2600</td></tr>
<tr><td>Estonia</td></tr>
<tr><td>Finland</td></tr>
<tr><td>Latvia</td></tr>
<tr><td>Lithuania</td></tr>
<tr><td>Poland</td></tr>
<tr><td>Sweden</td></tr>
<tr><td>Russia</td></tr>
<tr><td>Denmark, West</td><td rowspan="2">4145</td></tr>
<tr><td>Norway</td><td>3000</td></tr>
</table>

## Existing and planned capacity by fuel

Figure 18 summarizes the so-called exogenously specified power generation capacity for all countries in the years 2010-2030, i.e. the existing power plants – which are gradually phased out – as well as planned investments in new nuclear power, wind power and hydro power as described above.

The total existing and planned capacity decreases from approx. 300,000 MW in 2010 to 250,000 MW in 2030. The capacity of the thermal power plants fired with coal, oil, natural gas or biomass is reduced from approx. 150,000 MW in 2010 to 90,000 MW in 2030.




| | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| Wind | 31.747 | 34.298 | 34.297 | 34.297 | 34.295 |
| Water | 84.529 | 87.555 | 89.419 | 91.602 | 93.796 |
| Biomass | 9.407 | 9.036 | 7.999 | 7.817 | 7.639 |
| Nuclear | 38.051 | 39.651 | 41.151 | 40.847 | 34.529 |
| Natural gas | 41.569 | 36.805 | 32.196 | 27.989 | 24.812 |
| Waste | 1.962 | 1.969 | 1.976 | 1.976 | 1.976 |
| Oil | 12.750 | 10.488 | 9.195 | 8.046 | 7.060 |
| Coal and lignite | 82.514 | 73.201 | 59.339 | 51.238 | 46.209 |

Figure 18: Existing and planned capacity by fuel for all countries [MW]

## Biomass resources

Expansion with biomass fired power plants and boilers may to some extent be limited by the availability of resources locally.

The table below provides an overview of possible biomass resources in 2030 in each of the countries in the region divided into five general categories:

- Energy crops and grass cuttings
- Forestry residues from felling and complementary felling
- Biogas from manure
- Biowaste (mainly agricultural residues)
- Municipal waste

The municipal waste resource also includes the non-renewable energy fraction of the waste.

| PJ | Energy crops and grass cuttings | Forestry residues | Biogas from manure | Biowaste (mainly agricultural residues) | Municipal waste | Total |
|---|---|---|---|---|---|---|
| Germany | 980 | 201 | 190 | 223 | 657 | 2250 |
| Denmark | 4 | 40 | 39 | 40 | 50 | 173 |
| Finland | 54 | 75 | 15 | 234 | 32 | 411 |
| Sweden | 59 | 100 | 22 | 364 | 62 | 607 |
| Estonia | 54 | 8 | 5 | 34 | 9 | 111 |
| Lithuania | 331 | 17 | 9 | 54 | 11 | 422 |
| Latvia | 63 | 25 | 6 | 2 | 15 | 111 |
| Poland | 1273 | 50 | 93 | 150 | 254 | 1820 |
| Norway | 0 | 160 | 0 | 17 | 40 | 217 |
| BALTIC SEA | 2818 | 677 | 379 | 1117 | 1130 | 6121 |

Table 20: Available bioenergy resources in the Baltic Sea Region. The figures are derived from the report "How much bioenergy can Europe produce without harming the environment?" (EEA 2008), the Green-X database on dynamic cost-resource curves and a projection of the municipal waste resource from RISØ DTU[20]. Data for Russia is lacking. For the purpose of modelling no limitation has been implemented on the access to biomass resources in Russia.

The total identified bioenergy potential will not be to the disposal of the electricity and district heating sector as the bioenergy will also be used in industry, households and for the transport sector. Previous long-term scenario studies for the EU suggest that it is reasonable to assume that roughly 60 % of the total bioenergy resource will be available for the power and district heating sector. This assumes that the share of bioenergy used for transportation fuels is rather low (approx. 5%).

The table below gives an estimate of the bioenergy resource available for the power and district heating sectors. It is assumed, that 90 % of municipal waste, manure and biowaste is used here – since these fuels are the most difficult to handle and incinerate - whereas only 40 % of energy crops and forestry residues will be used for power and district heating generation. In total, for the Baltic Sea Region, this means that 61 % of the total bioenergy resource is available for the power and district heating sectors.

| PJ | Energy crops and grass cuttings | Forestry residues | Biogas from manure | Biowaste (mainly agricultural residues) | Municipal waste | Total |
|---|---|---|---|---|---|---|
| Germany | 392 | 80 | 171 | 200 | 591 | 1435 |
| Denmark | 2 | 16 | 35 | 36 | 45 | 133 |
| Finland | 22 | 30 | 14 | 211 | 29 | 305 |
| Sweden | 23 | 40 | 20 | 327 | 56 | 467 |
| Estonia | 22 | 3 | 5 | 31 | 8 | 68 |
| Lithuania | 132 | 7 | 8 | 49 | 10 | 206 |
| Latvia | 25 | 10 | 5 | 1 | 14 | 56 |
| Poland | 509 | 20 | 84 | 135 | 229 | 977 |
| Norway | 0 | 64 | 0 | 15 | 36 | 115 |
| BALTIC SEA | 1127 | 271 | 341 | 1005 | 1017 | 3762 |

Table 21: Available bioenergy resources in the Baltic Sea Region for the electricity sector and for district heating. Data for Russia is lacking. For the purpose of modelling no limitation has been implemented on the access to biomass resources in Russia.

20 Norwegian data is based on the following source,
http://www.fornybar.no/imagecache/43.OriginalImageData.20070320085549.jpg
http://www.fornybar.no/sitepageview.aspx?articleID=37
http://www.avfallnorge.no/fagomraader/energiutnyttelse/nyheter/energiutnyttelse_2008, 22.05.2009

## Interpretation of the biomass categories to the model

For the purpose of modelling, the two biomass categories "Energy crops and grass cuttings" and "Forestry residues" are merged into one fuel category termed "Wood".

The domestic wood is limited according to the available resources, whereas there is not assumed any limit on the possibilities for using imported biomass. For domestic wood a price of wood chips is used. For imported biomass a higher price is applied, reasoned upon higher transportation and handling costs (see previous section). Wood pellets are more expensive than wood chips, but easier to transport and handle.

For all other types of biomass only the domestic resources can be used.
The biowaste resource is generally termed "Straw" in the model. It is recognized that part of this resource is cheaper "Wood waste" used at existing power plants in Sweden and Finland. For this fraction a price close to zero is used.

For the purpose of modelling it is assumed that biogas may be used in connection with all local district heating schemes. This is a simplification of the actual possibilities for utilization of biogas. A negative $CO_2$-factor (-43 kg/GJ) is used for biogas in order represent the abated fugitive emissions (methane and nitrous-oxide) related to the alternative use of the manure in the agricultural sector.

# 5 Scenario analyses

This section presents the results from the simulation of the Baseline scenario as well as the three scenario variations:

- **Regional RE target**. Cooperation on achieving EU renewable energy targets.
- **Improved efficiency**. Lower demand for electricity than in the Baseline scenario.
- **30%@COP15**. Stricter $CO_2$-reduction target in 2020.

The Baseline scenario is described with a quite high level of details, whereas the presentation of the scenario variations mainly focuses on the differences compared to the Baseline scenario.

## 5.1 Baseline scenario

As previously mentioned, the Baseline scenario is developed to comply with the EU targets for 2020, as well as the target of 50 % $CO_2$ reduction in 2030 compared to 1990.

Investments in new generation capacity

The investments in new technologies for all countries are shown in Figure 19. In the figure the investments in new generation capacity are also compared to the development in existing and planned capacity, thus providing an outlook of the development in the total generation portfolio.

It appears that the mainly chooses to invest in wind power plants and new coal power plants.

The coal power plants that the model invests in are a new very efficient technology with electric efficiencies of 48 % when running in condensing mode. The coal fired power plants are primarily established in the beginning of the period – where the targets for reducing $CO_2$ emissions and increasing the share of renewable are not so strong – while the wind power plants are established more evenly during the whole period from 2015 to 2030.

The model also chooses to make some investment in new biogas based generation capacity; new biomass fired capacity and by the end of the period in coal fired capacity equipped with CCS. Though the level of investments is fairly small compared to the investments in e.g. wind power, it indicates that these technologies are competitive.

No investments are made in electricity generation capacity based on municipal solid waste. This may reflect that the alternative cost of treatment, estimated to be -3.1 €/GJ, is too low. This is an issue that deserves attention in connection with further analyses.

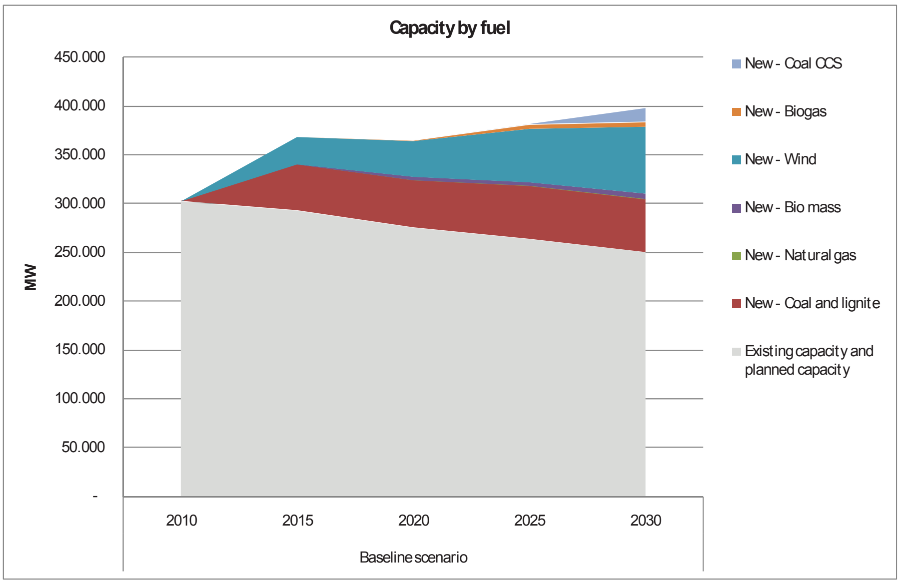



Figure 19: Total electrical capacity (MW) for Baseline scenario distributed on new and existing capacities.

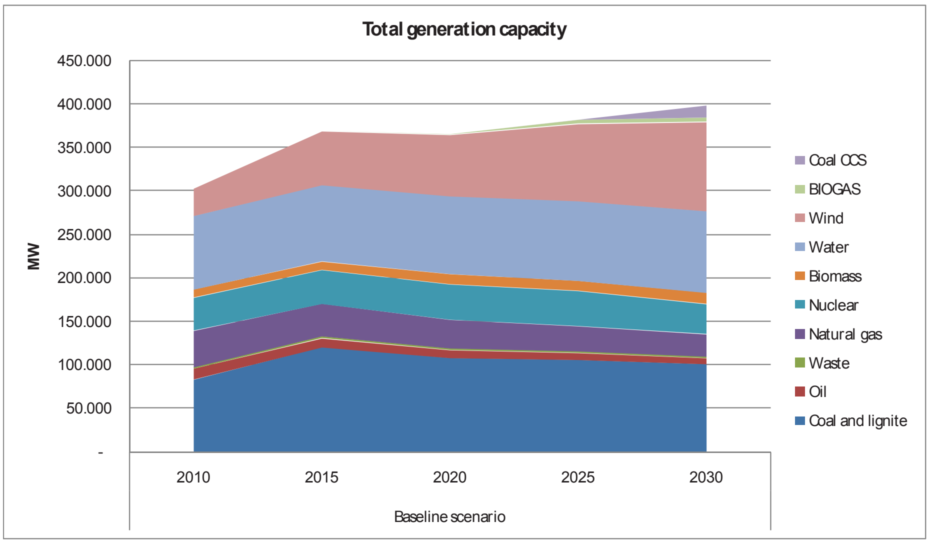


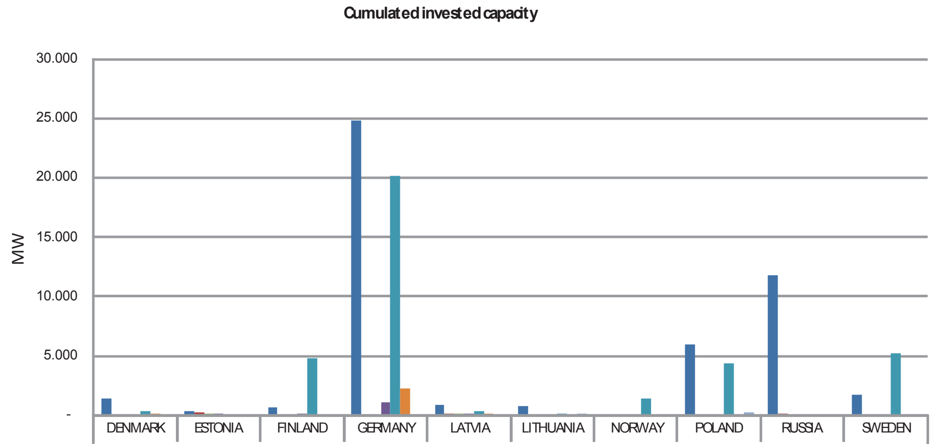

Figure 20: Total electrical capacity (MW) for Baseline scenario distributed on fuels.

In the following figures the cumulative investments for each country (grouped by fuel) are shown for the years 2020 and 2030. It should be remembered that these investments are in addition to existing and planned capacities.

Investments in new efficient coal power plants are made in all countries except Norway. It can of course be questioned if these investments will be politically acceptable. However, according to the model simulation, and given the input assumptions used, they are attractive from an investor point of view. This finding points to the fact that considering the assumed development in fuel prices and the need for $CO_2$-reductions, the existing portfolio of power plants is not sufficiently energy efficient. Moreover, the investment in new coal power is a result of the relationship between the projected coal and natural gas prices, which favour the former fuel. This fuel price link also explains why the model chooses to make only very few investment in new natural gas fired capacity in spite of the target to reduce $CO_2$-emissions.

Towards 2020 wind power is increased significantly in all countries except in Russia, Lithuania and Estonia. The most notable expansion takes place in Germany, where total installed wind power capacity is increased to almost 45,000 MW, of which 20,000 MW is commissioned in the period 2010-2020. The majority of this investment, 12,000 MW, is in off-shore capacity.

The relatively moderate wind expansion in Denmark should be seen in the light of the 800 MW off-shore capacity already scheduled to come online 2010-2015 in the Baseline development. These are plants that are already under construction or have been approved by the authorities[21].




| 2020 Baseline scenario | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Coal and lignite | 1.385 | 312 | 711 | 24.818 | 836 | 769 | | 5.924 | 11.767 | 1.767 |
| Natural gas | | 195 | | | 62 | | | | 53 | |
| Peat | | 80 | | | 46 | | | | | |
| Straw | | 2 | 61 | 1.125 | 10 | | | | | |
| Wind | 342 | | 4.813 | 20.158 | 299 | 26 | 1.437 | 4.400 | | 5.198 |
| Wood | 7 | | | 2.206 | 116 | | | | | |
| Biogas | | | | | | 76 | | 231 | | |

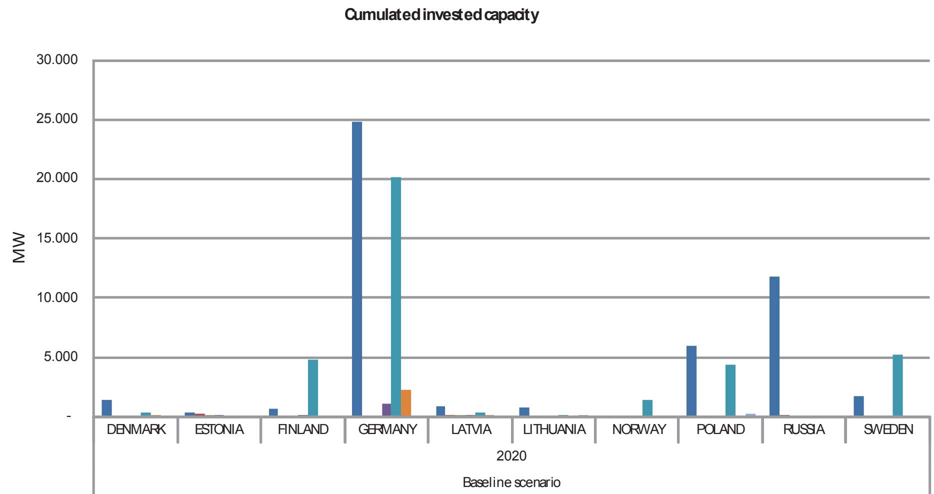
Figure 21: Cumulated invested capacity (MW) from 2010-2020 for Baseline scenario.

Between 2020 and 2030 considerable investments are made in biogas capacity and coal power plants with CCS. Most of the new coal power plants with CCS are located in Germany, whereas the investments in biogas capacity are distributed more evenly across the region consistent with the identified fuel potentials. Both technologies become more attractive by the end of the period where the commitment to reduce $CO_2$-emissions turn out to be increasingly important relative to the obligation on new renewable energy. In the case of biogas because the model takes into account the additional reduction of greenhouse gases ($CO_2$-equivalents) in the agricultural sector.

More than 10,000 MW of wind power capacity is installed in both North West Russia and Denmark between 2020 and 2030. The investments in Denmark mainly concern off-shore wind power, whereas the investments in North West Russia are in on-shore capacity. In this respect it should be mentioned that the model does not include a limitation on the amount of generation that can be installed within a given time period. In practice there may be bottlenecks in the manufacturing industry or in relation to planning or grid connection,

21 Horns Rev II and Rødsand II (200 MW each), which are currently being developed, as well as Anholt (400 MW), which is undergoing a tender procedure.

which could defer a rapid development in installed capacity over a short period of time.




| | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Coal and lignite | 1.385 | 312 | 711 | 24.818 | 836 | 769 | | 5.924 | 11.767 | 1.767 |
| Natural gas | | 195 | | | 62 | | | | 53 | |
| Peat | | 80 | | | 46 | | | | | |
| Straw | | 2 | 61 | 1.125 | 10 | | | | | |
| Wind | 342 | | 4.813 | 20.158 | 299 | 26 | 1.437 | 4.400 | | 5.198 |
| Wood | 7 | | | 2.206 | 116 | | | | | |
| Biogas | | | | | | 76 | | 231 | | |

Figure 22: Cumulated invested capacity (MW) from 2010-2030 in the Baseline scenario.

## Electricity generation by fuel

The electricity generation by fuel for all countries is shown in Figure 23. The utilisation of natural gas decreases dramatically between 2010 and 2015 as a result of the investments in wind power and new efficient coal power plants. This development is particularly profound in Russia where approximately half of the electricity is produced from natural gas in the 2010 simulation. It should be mentioned that such a sharp drop in the demand for natural gas is likely to result in a drop in the regional natural gas price. A drop in the gas price will to some extent cancel out the reduction in gas demand. However, this relationship has not been quantified in the simulation.

The role of wind power is gradually increased over the period and by 2030 wind power is the largest source of electricity next to coal power and hydro power. Biomass and biogas only gain significance by the end of the period. Co-firing of biomass at existing coal fired power plants is not considered an option in the model. Therefore the model may underestimate the use of biomass.

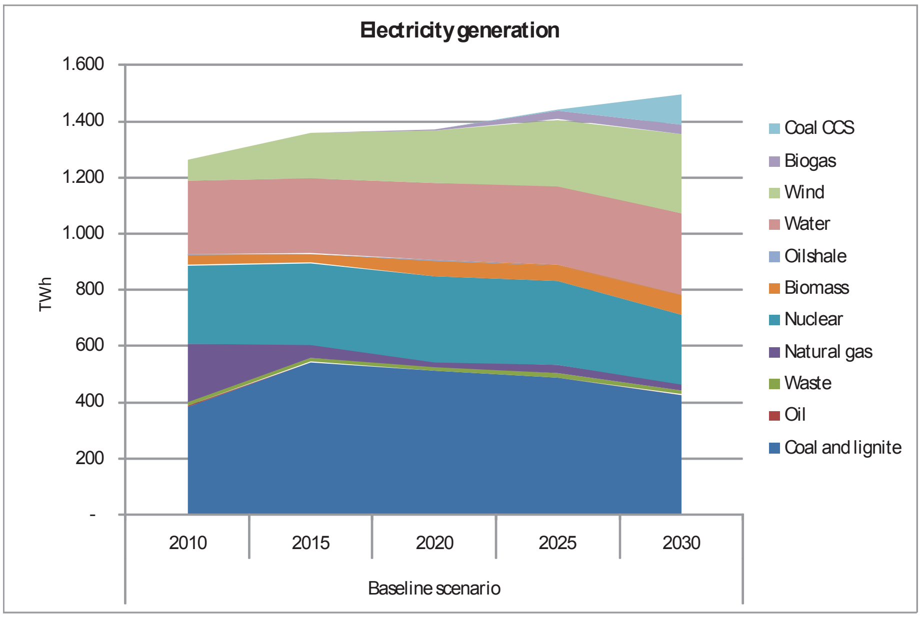
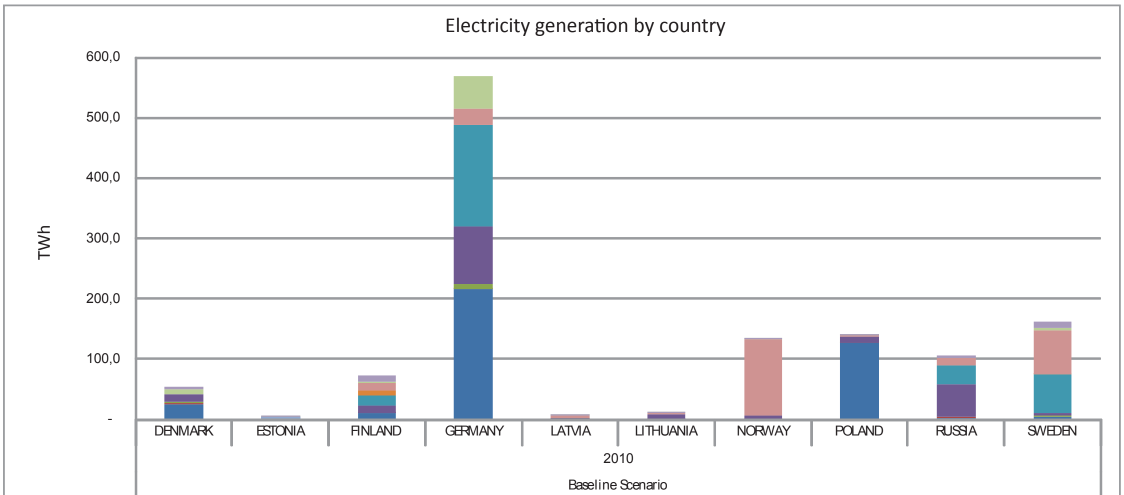


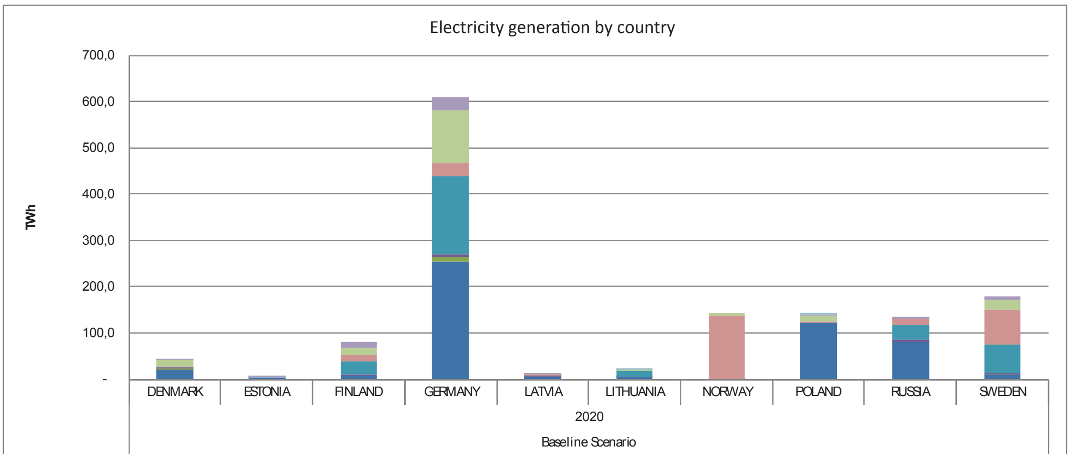

Figure 23: Total electricity generation (TWh) by fuel for Baseline scenario.

The distribution of electricity generation for each country grouped by fuel is shown in Figure 24, Figure 25 and Figure 26 for the years 2010, 2020 and 2030, respectively.



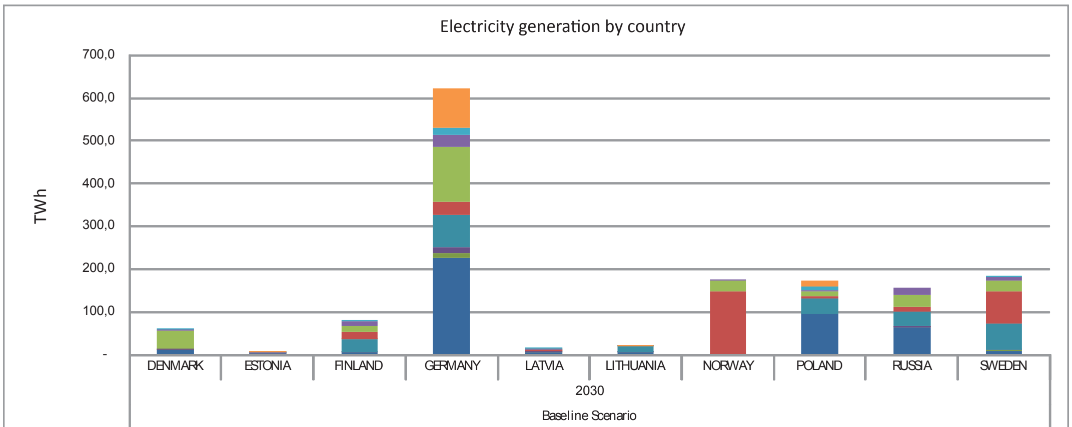

| 2010 Baseline Scenario | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Biomass | 2,8 | 0,4 | 10,8 | | 0,3 | 0,1 | 0,1 | 0,9 | 5,1 | 10,5 |
| Wind | 9,4 | 0,5 | 0,9 | 54,1 | 0,4 | 0,3 | 1,5 | 1,6 | 0,0 | 5,6 |
| Water | | | 13,8 | 26,8 | 3,3 | 0,8 | 126,8 | 2,1 | 12,3 | 73,0 |
| Shale | | 3,2 | | | | | | | | |
| Peat | | | 6,8 | | | | | | | 0,1 |
| Nuclear | | | 18,0 | 166,8 | | | | | 31,2 | 63,3 |
| Natural gas | 12,4 | 0,7 | 11,8 | 95,8 | 2,3 | 8,6 | 5,2 | 9,7 | 53,3 | 5,4 |
| Waste | 1,9 | 0,1 | | 9,9 | 0,1 | | 0,2 | 0,3 | | 0,9 |
| Oil | 0,7 | | 1,0 | 0,0 | | 0,4 | | | 1,9 | |
| Coal and lignite | 26,0 | | 9,7 | 215,3 | | | | 126,8 | 2,3 | 4,5 |

Figure 24: Electricity generation (TWh) for each country in 2010 grouped by fuel in the Baseline scenario.




| 2020 Baseline Scenario | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Biogas | | | | | | 0,6 | | 1,9 | | |
| Biomass | 1,9 | 0,6 | 10,9 | 26,8 | 1,1 | 0,3 | | 1,9 | 5,1 | 8,7 |
| Wind | 15,8 | 0,5 | 16,0 | 115,7 | 1,5 | 0,3 | 5,8 | 13,0 | 0,0 | 21,2 |
| Water | | | 14,0 | 28,4 | 3,3 | 0,8 | 136,8 | 3,0 | 12,3 | 74,9 |
| Shale | | 0,9 | | | | | | | | |
| Peat | | 0,5 | 0,3 | | 0,2 | | | | | 0,0 |
| Nuclear | | | 28,8 | 166,8 | | 12,3 | | | 31,2 | 63,3 |
| Natural gas | 2,4 | 0,9 | 1,4 | 5,8 | 0,6 | 0,4 | 1,0 | 0,1 | 4,9 | 0,5 |
| Waste | 1,9 | 0,1 | | 10,8 | 0,1 | | 0,2 | 0,3 | | 0,9 |
| Oil | 0,0 | | | | | 0,2 | | | 0,0 | |
| Coal and lignite | 20,8 | 2,3 | 8,2 | 254,6 | 6,1 | 5,6 | | 120,9 | 81,1 | 10,8 |

Figure 25: Electricity generation (TWh) for each country in 2020 grouped by fuel in the Baseline scenario.




| 2030 Baseline Scenario | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Coal CCS | | 1,8 | | 92,3 | | 0,7 | | 13,9 | | |
| Biogas | 2,5 | 0,5 | 1,5 | 18,5 | 0,5 | 0,9 | | 9,1 | | 1,4 |
| Biomass | 2,3 | 0,7 | 10,9 | 26,5 | 2,0 | 0,5 | 0,2 | 2,3 | 16,6 | 8,8 |
| Wind | 43,6 | 0,5 | 16,0 | 128,7 | 1,9 | 0,4 | 24,8 | 13,0 | 27,8 | 24,3 |
| Water | | | 16,0 | 29,8 | 3,2 | 0,8 | 146,8 | 3,5 | 12,3 | 74,9 |
| Shale | | 0,2 | | | | | | | | |
| Peat | | 0,1 | 0,2 | | 0,1 | | | | | |
| Nuclear | | | 28,8 | 76,2 | | 12,3 | | 36,1 | 31,2 | 63,3 |
| Natural gas | 0,9 | 0,5 | 1,4 | 13,3 | 1,4 | 0,5 | 0,8 | 1,1 | 3,8 | 0,1 |
| Waste | 1,9 | 0,1 | | 11,2 | 0,1 | | 0,2 | 0,3 | | 0,9 |
| Oil | 0,0 | | 0,0 | | | 0,2 | | | 0,0 | |
| Coal and lignite | 10,4 | 2,7 | 5,4 | 227,2 | 5,8 | 5,3 | | 94,7 | 64,6 | 9,5 |

Figure 26: Electricity generation (TWh) for each country in 2030 grouped by fuel for Baseline scenario.

## District heating generation

In Figure 28 the generation of district heating for all countries can be seen for the years 2010 and 2030. The generation of district heating is grouped by fuel

In Russia there is a notable change from gas to coal based heat production. The coal based heat is surplus heat from the coal fired power plants, which the model choses to invest in in 2015.

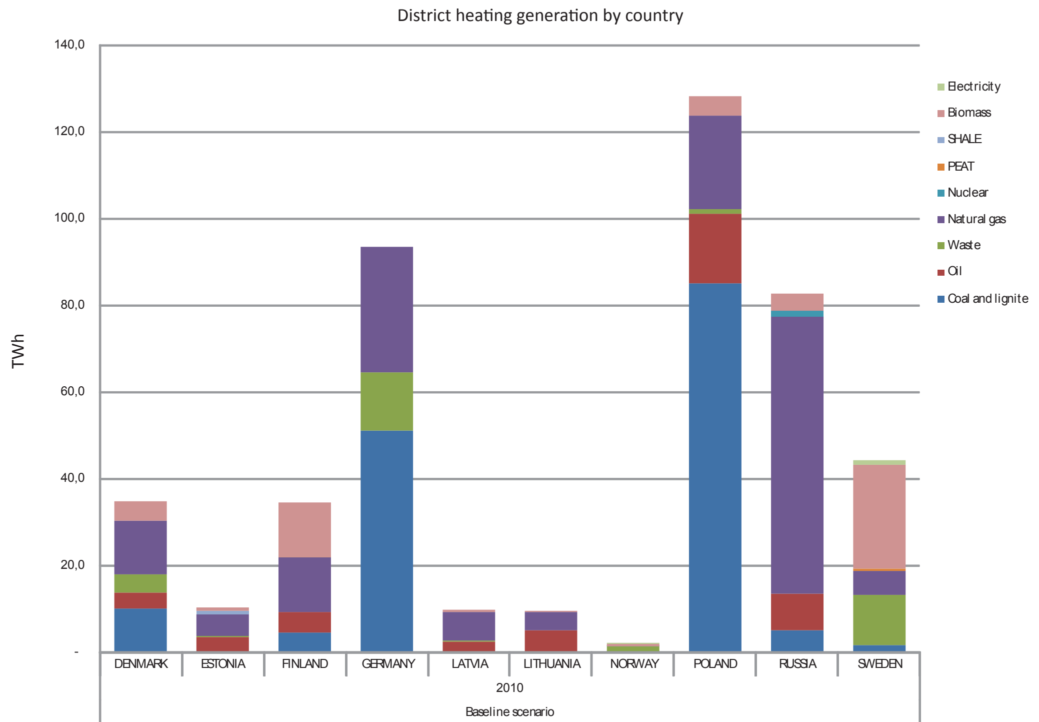
In Germany the district heat is mainly generated from coal and natural gas in 2010. By 2030 surplus heat from biogas and biomass gains increasing importance taking the role of natural gas, which is most completely phased out.

In Finland heat supply is changed to a high degree of electric based heating from heat pumps and very small share from electric boilers. The share of biogas and biomass based heating are increased as well. In Denmark a similar pattern is observed.

Coal is the dominant fuel in Poland in 2010. By 2030 municipal waste burned at heat only boilers becomes the most important source of district heating in combination with sizeable shares of biomass and biogas based heating as well as electric heating. The results illustrate, that from an economic point of view it is more attractive to treat the municipal waste at heat only boilers as opposed to using it at combined heat and power facilities.

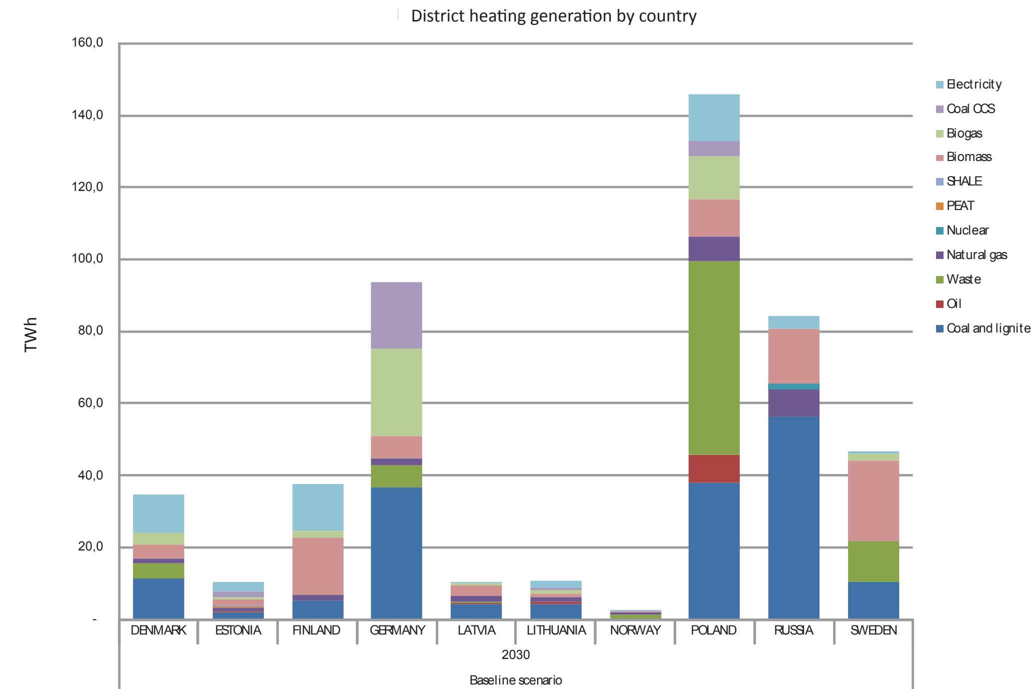
In Estonia, Latvia and Lithuania natural gas and oil based heating are replaced with surplus heat from coal and biomass power plants as well as electric heat pumps.

The competiveness of heat pumps using electric compressors should be seen in relation to the expansion with wind power, which has very low short run marginal costs. A Coefficient-Of-Performance (COP) of 3.0 is assumed for the heat pumps.




| | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Electricity | | | | | | | 0,0 | | | 0,9 |
| Biomass | 4,5 | 0,7 | 12,7 | | 0,6 | 0,3 | 0,3 | 4,7 | 3,9 | 24,0 |
| SHALE | | 0,8 | | | | | | | | |
| PEAT | | | 0,2 | | | | | | | 0,5 |
| Nuclear | | | | | | | | | 1,4 | |
| Natural gas | 12,4 | 5,0 | 12,6 | 29,0 | 6,5 | 4,3 | 0,2 | 21,4 | 64,0 | 5,6 |
| Waste | 4,1 | 0,3 | | 13,4 | 0,2 | | 1,2 | 1,2 | | 11,5 |
| Oil | 3,9 | 3,4 | 4,6 | | 2,4 | 4,9 | 0,1 | 16,0 | 8,3 | |
| Coal and lignite | 9,9 | | 4,5 | 51,2 | | | | 85,0 | 5,1 | 1,6 |

Figure 27: Total heat generation (TWh) for each country grouped by fuel in 2010 for baseline scenario. SHALE: Oil shale.




| | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Electricity | 10,8 | 2,5 | 13,1 | | 0,3 | 1,9 | 0,4 | 13,0 | 3,8 | 0,8 |
| Coal CCS | | 1,5 | | 18,5 | | 0,6 | | 4,2 | | |
| Biogas | 3,3 | 0,7 | 2,0 | 24,3 | 0,7 | 1,1 | | 11,9 | | 1,9 |
| Biomass | 3,9 | 1,7 | 15,8 | 6,1 | 2,7 | 0,9 | 0,4 | 10,3 | 15,3 | 22,4 |
| SHALE | | 0,2 | | | | | | | | |
| PEAT | | 0,2 | 0,1 | | 0,3 | | | | | |
| Nuclear | | | | | | | | | 1,4 | |
| Natural gas | 1,4 | 1,0 | 1,6 | 1,8 | 1,6 | 1,3 | 0,6 | 6,9 | 7,6 | 0,1 |
| Waste | 4,1 | 0,3 | | 6,1 | 0,2 | | 1,3 | 53,9 | | 11,5 |
| Oil | 0,1 | 0,1 | | | 0,1 | 0,7 | | 7,8 | 0,0 | |
| Coal and lignite | 11,4 | 2,1 | 5,1 | 36,8 | 4,4 | 4,2 | | 37,8 | 56,3 | 10,3 |

Figure 28: Total heat generation (TWh) for each country grouped by fuel in 2030 for baseline scenario. SHALE: Oil shale.

## $CO_2$ and RE prices

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 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.

It is assumed that $CO_2$ can be traded across all countries including North West Russia; consequently there is one common price of $CO_2$ for the whole region. Renewables, on the other hand, are taken care of by national policies in the Baseline scenario and therefore the prices are different for each country in the region.

As can be seen from Table 22 the simulations show that the marginal cost of abating $CO_2$ is approx. 7 € per ton in 2020 and approx. 50 € per ton in 2030.

The RE prices differ between the countries. In Russia there is no price of RE because there is not assumed any national RE target. In Norway the price of RE is zero because the expected development of new hydro power easily leads to compliance with the national RE target. In 2020, Finland, Lithuania, Latvia and Germany have the highest marginal costs of expanding renewable energy electricity generation.

The difference in compliance costs reflects 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

Between 2020 and 2030 the target for RE is kept constant, whereas the $CO_2$-target is tightened from a 21% to 38 % reduction compared to 2030. Therefore, in 2030 the $CO_2$-target becomes binding, whereas the RE target only binds in Latvia and Lithuania.

The simulations show that the shadow price of $CO_2$ is approx. 50 € per ton in 2030. 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.

| Shadow prices for $CO_2$ target and RE target | | | | |
|---|---|---|---|---|
| Country | 2020 | | 2030 | |
| | $CO_2$ EUR/ton | RE EUR/$MWh_{el}$ | $CO_2$ EUR/ton | RE EUR/$MWh_{el}$ |
| Denmark | 7 | 16 | 52 | - |
| Estonia | | 16 | | - |
| Finland | | 29 | | - |
| Germany | | 30 | | - |
| Latvia | | 31 | | 11 |
| Lithuania | | 31 | | 2 |
| Norway | | - | | - |
| Poland | | 24 | | - |
| Sweden | | 16 | | - |
| NW Russia | | - | | - |

Table 22: Shadow prices for $CO_2$ target and RE target for Baseline scenario.

$CO_2$-emissions

Figure 31 below shows the total $CO_2$ emissions in each country from 2010 to 2030. It appears that the $CO_2$ emissions are highest in Germany and Poland; however both countries see large decreases from 2020 to 2030.

Emissions in North West Russia increase significantly between 2010 and 2020. This is consequence of investments in new coal power plants substituting existing natural gas fired capacity. Between 2020 and 2030 emissions in North West Russia decrease somewhat as new wind generation and biomass fired power plants come online.

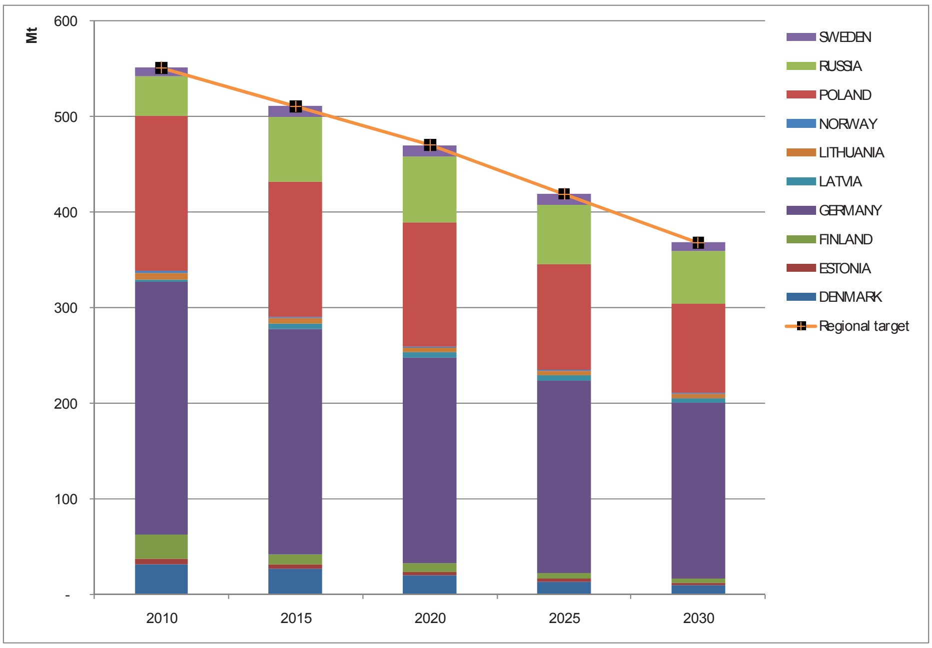



Figure 29: Total $CO_2$-emission (megatons) by country from 2010 to 2030 for Baseline scenario.

Figure 30 shows the total $CO_2$ emissions for all countries grouped by fuel. Coal is by far the greatest source of emissions. The emissions from biogas are negative due to the abated methane and nitrous oxide emissions in the agricultural sector.

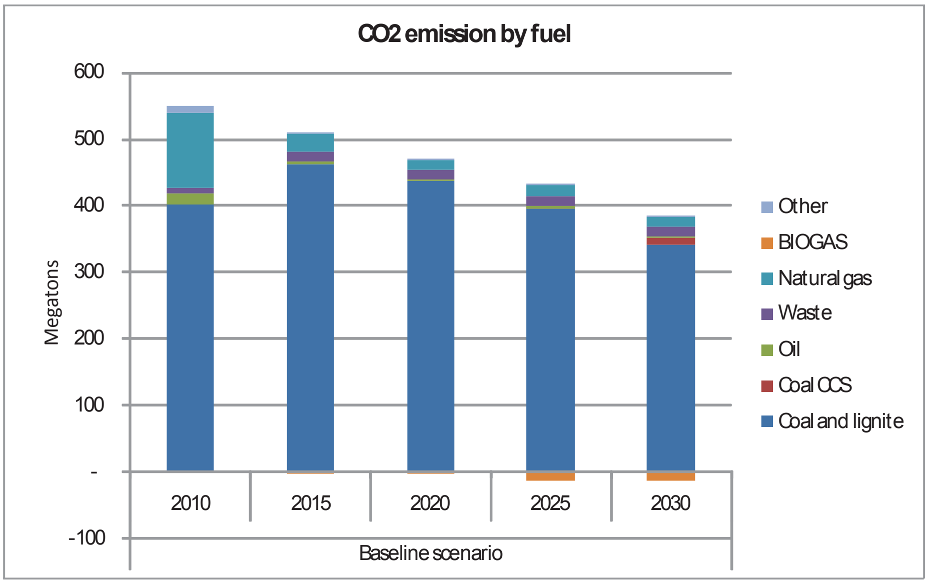



Figure 30: Total $CO2_2$-emission (megatons) from 2010 to 2030 grouped by fuel for Baseline scenario.

Electricity market prices

The following figure shows the development in the annual electricity prices from 2010 to 2030 for each country as computed by the model. The notable decline in prices between 2010 and 2015 must be viewed in light of the massive investments in new wind and coal based generation capacity. These new power plants have relatively low marginal generation costs and hence push electricity market prices down.

Between 2020 and 2030 electricity market prices increase as the $CO_2$-target becomes an increasing constraint causing the $CO_2$-price to increase significantly.

Poland has the lowest annual electricity market prices in 2010 according to the simulation, but this picture changes during the course of time and by 2030 prices in Poland and Germany are 10-15 € per MWh higher than in the other countries. This reflects the large share of coal power generation in these countries – a technology which has relatively high short run marginal costs when $CO_2$-prices are high.

It should be mentioned however, that the electricity market prices do not include the subsidies needed for supporting renewable energy in order to comply with the national RE targets.

To the consumer electricity prices should be added the costs of RE subsidies (assuming that the expansion with renewable energy is financed by the electricity consumers). In a situation with a market based RE certificate system the added cost to the consumer electricity price is the product of the price of a RE certificate and the share of RE. For example, in the case of Denmark in 2020, to the market price should be added: 48 % (RE share) * 16 €/MWh (RE price) = 7.7 €/MWh.

If only new renewable technologies are supported the RE share (and the costs to consumers) will be smaller. Other types of support schemes, for example feed-in-tariffs, where the support for renewables is tailored to the requirements of the individual technologies (or even to the individual power plants) may also lead to lower costs to the consumer if the support is customised well.

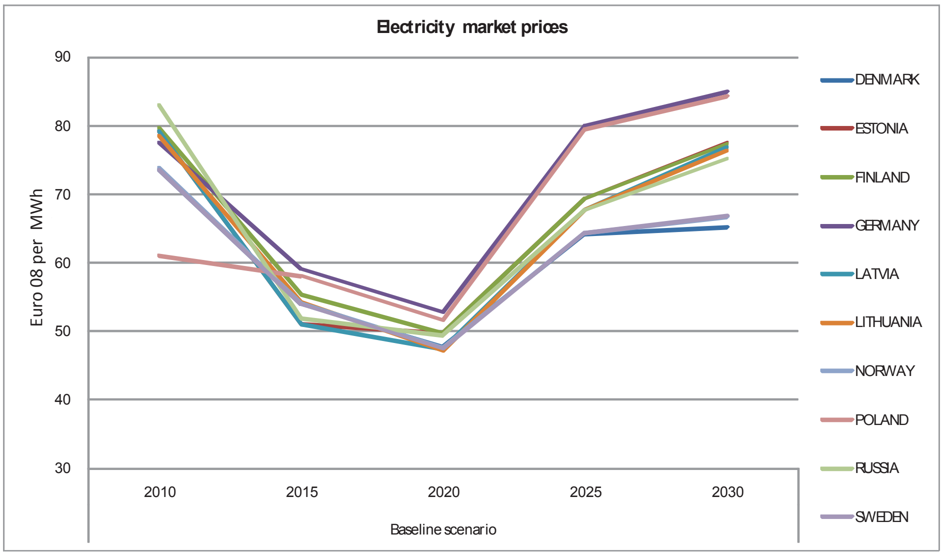



Figure 31: Annual electricity market price (EUR08/MWh) for Baseline scenario. The marginal power prices do not include the subsidies needed for supporting renewable energy targets

Exchange of electricity

The following table displays the total import and export from each country:

| GWh | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| **2010** | | | | | | | | | | |
| Export | 21.274 | 1.084 | 947 | 4.840 | 1.586 | 4.490 | 24.239 | 15.937 | 15.664 | 31.918 |
| Import | 5.592 | 5.324 | 22.099 | 19.266 | 4.521 | 6.215 | 17.887 | - | 23.308 | 17.768 |
| **Net export** | **15.682** | **-4.240** | **-21.152** | **-14.425** | **-2.934** | **-1.724** | **6.352** | **15.937** | **-7.644** | **14.150** |
| **2020** | | | | | | | | | | |
| Export | 15.797 | 2.487 | 2.548 | 8.919 | 4.348 | 11.094 | 25.369 | 2.949 | 13.936 | 39.031 |
| Import | 14.324 | 8.328 | 26.120 | 15.551 | 2.757 | 4.752 | 16.272 | 11.795 | 12.897 | 13.679 |
| **Net export** | **1.473** | **-5.841** | **-23.572** | **-6.633** | **1.591** | **6.342** | **9.096** | **-8.845** | **1.040** | **25.352** |
| **2030** | | | | | | | | | | |
| Export | 25.001 | 1.169 | 1.490 | 1.828 | 4.316 | 10.283 | 36.798 | 3.383 | 17.338 | 41.036 |
| Import | 8.142 | 7.726 | 31.803 | 24.527 | 3.962 | 6.492 | 11.508 | 11.779 | 18.591 | 18.108 |
| **Net export** | **16.859** | **-6.556** | **-30.313** | **-22.699** | **353** | **3.791** | **25.290** | **-8.397** | **-1.253** | **22.927** |

Table 23: Exchange of electricity between the countries in the region.

Sweden and Norway are net exporters of electricity in the beginning of the period and remain so until 2030, whereas Estonia, Finland and Germany are net-importers during the course of the period.

Poland starts out as net exporter but eventually become importer. Latvia, Lithuania and Russia follow more mixed patterns.

In the end of the period a significant export of electricity, approx. 64 TWh takes place from Scandinavia (Denmark, Norway and Sweden) toward the thermal based systems in Germany, Poland, where coal is still dominant, and to Finland. This reflects the relative high costs of coal based electricity in a situation with a high price of $CO_2$ – as well as the easier access to competitive RE sources in Scandinavia.

## 5.2 Regional RE target

In this sensitivity scenario the RE targets from every country are aggregated into one common target for the region. The total target for RE to be produced is the same as in the Baseline scenario.

This change in approach has rather significant implications for the investment made in new electricity generation capacity between 2010 and 2020, as indicated in Figure 32 and Figure 33 below.

The model still chooses to invest mainly in wind and coal power, but a large share of the investments in wind power are moved from Germany, Sweden and Finland to Denmark and particularly Norway, where wind conditions are anticipated to be somewhat better. Investments are moved to North West Russia as well because in the regional RE scenario Russia gets the same incentives to develop renewables as the other countries in the Baltic Sea Region.

Lower RE generation

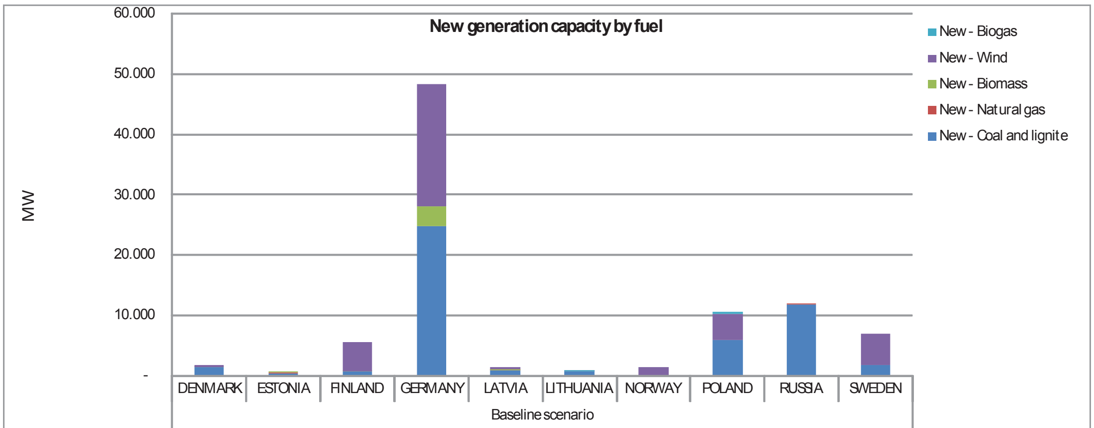
The total generation of renewable energy in the region is 8 TWh lower in the regional RE scenario compared to the Baseline scenario. This may appear surprising since the RE target is the same in the two scenarios. The reason is that

Norway over-complies in the Baseline scenario, due to the expected development of new hydro power plants. In the scenario with Regional RE target Norway's over-compliance contributes to achieving the Regional RE target.

Investments in new biomass fired capacity are reduced very considerably in the Regional Target Scenario compared to the Baseline scenario. This is because 1) Total RE generation decreases 2) Wind power becomes more attractive, because the RE target removes the geographical constraints related to the deployment of RE.

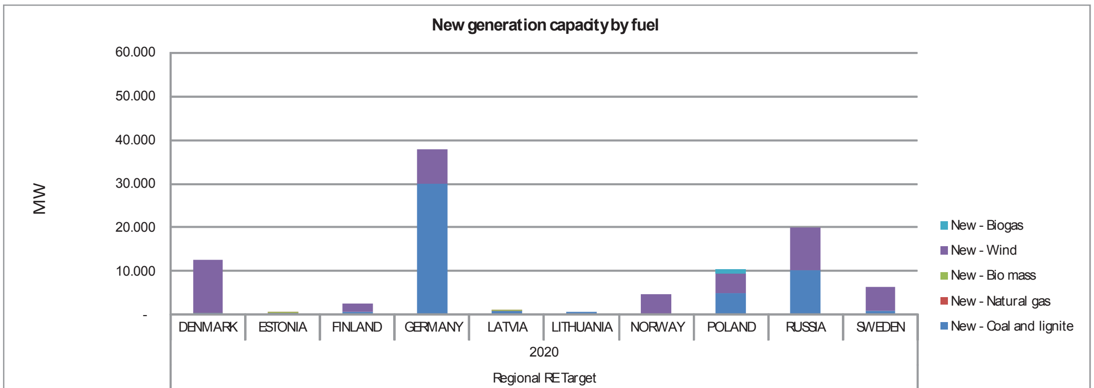
Figure 34 shows the electricity generation from all power plants in 2020 grouped by fuel.

In the situation with a common RE target the cost of increasing renewable energy becomes the same in all countries in the region, 19 € per MWh of renewable energy electricity in 2020.



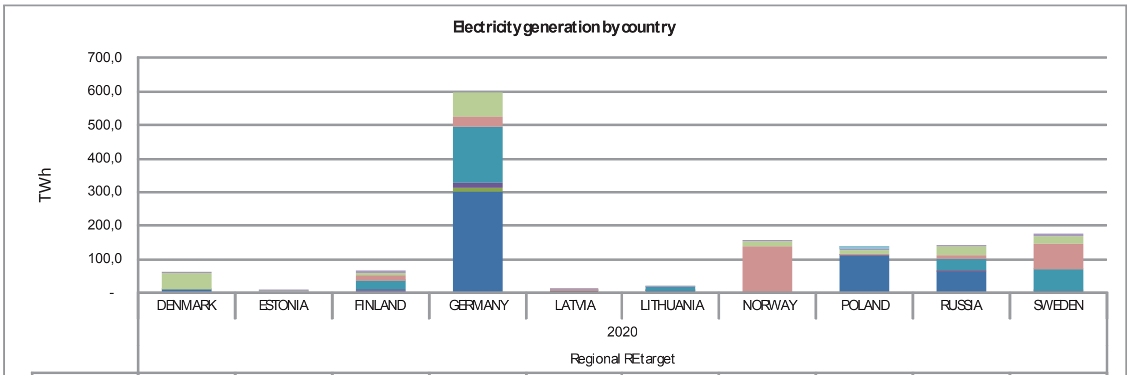

| Baseline scenario | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| New - Biogas | | | | | | 76 | | 231 | | |
| New - Wind | 342 | | 4.813 | 20.158 | 299 | 26 | 1.437 | 4.400 | | 5.198 |
| New - Biomass | 7 | 82 | 61 | 3.331 | 173 | | | | | |
| New - Natural gas | | 195 | | | 62 | | | | 53 | |
| New - Coal and lignite | 1.385 | 312 | 711 | 24.818 | 836 | 769 | | 5.924 | 11.767 | 1.767 |

Figure 32: Cumulated invested capacity from 2010 to 2020 grouped by fuel for the Baseline scenario




| 2020 Regional RE Target | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| New - Biogas | | | | | | | | 985 | | |
| New - Wind | 12.215 | | 1.850 | 7.949 | | | 4.695 | 4.400 | 9.847 | 5.456 |
| New - Bio mass | 6 | 89 | | | 167 | | | | | |
| New - Natural gas | | 200 | | | 91 | | | | | |
| New - Coal and lignite | 376 | 302 | 762 | 29.900 | 790 | 737 | | 4.986 | 10.111 | 984 |

Figure 33: Cumulated invested capacity (MW) from 2010 to 2020 grouped by fuel in the Regional RE target scenario.




| | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Biogas | | | | | | | | 7,8 | | |
| Biomass | 2,7 | 1,0 | 10,4 | | 0,8 | 0,2 | 0,1 | 1,9 | 5,1 | 8,9 |
| Wind | 46,6 | 0,5 | 5,7 | 73,0 | 0,4 | 0,3 | 15,6 | 13,0 | 25,6 | 21,9 |
| Water | | | 14,0 | 28,4 | 3,3 | 0,8 | 136,8 | 3,0 | 12,3 | 74,9 |
| Shale | | 0,7 | | | | | | | | |
| Peat | | 0,2 | 0,3 | | 0,5 | | | | | 0,0 |
| Nuclear | | | 28,8 | 166,8 | | 12,3 | | | 31,2 | 63,3 |
| Natural gas | 0,8 | 0,8 | 1,5 | 16,0 | 0,7 | 0,4 | 0,4 | 0,4 | 4,3 | 0,0 |
| Waste | 1,9 | 0,1 | | 10,8 | 0,1 | | 0,2 | 0,3 | | 0,9 |
| Oil | 0,0 | | | | | 0,2 | | | 0,0 | |
| Coal and lignite | 9,1 | 2,2 | 7,7 | 301,9 | 5,7 | 5,3 | | 112,0 | 63,7 | 6,2 |

Figure 34: Electricity generation (TWh) grouped by fuel in 2030 for Regional RE target scenario.

## Electricity market prices

The average electricity market prices from 2010 to 2030 can be seen in the Figure 35 below.

The marginal cost of reducing $CO_2$ is 14 €/ton in the Regional RE target scenario in 2020 compared to 7 €/ton in the Baseline scenario. The reason for this is that the RE targets are met with less efforts in the Regional RE target scenario; hence the $CO_2$ target is a more binding constraint than in the Baseline scenario. As a result the electricity market prices are also slightly higher in 2020 in some countries than in the Baseline scenario; this is particularly the case in German and Poland where the cost of $CO_2$ has a high impact on the short run marginal generation costs due to the high shares of coal power in the generation mix.

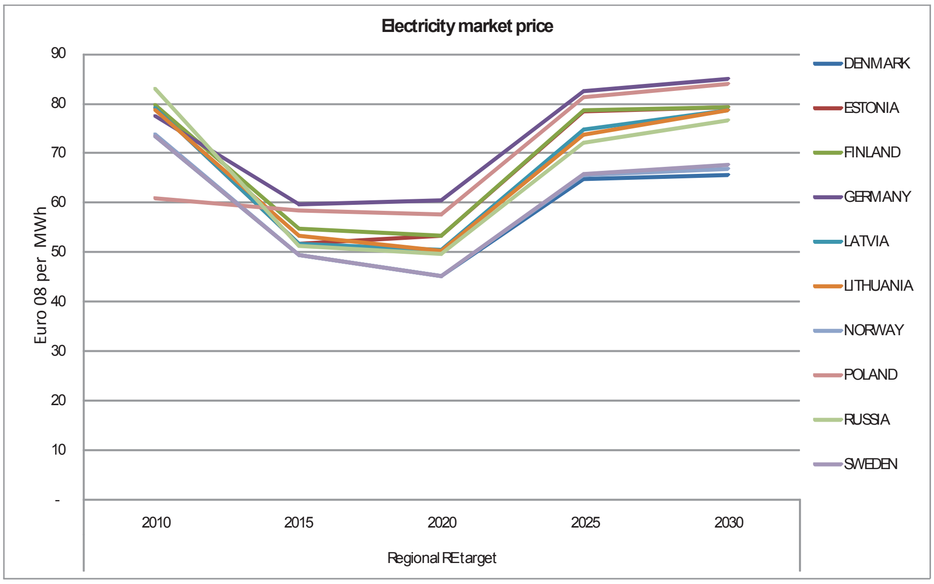



Figure 35: Average electricity price Euro 08 per MWh for each country from 2010 to 2030 in the regional RE target scenario.

As explained in the previous section, to the consumer electricity prices should be added the costs of RE subsidies assuming that the expansion with renewable energy is financed by the electricity consumers. With a market based RE certificate system the added cost to the consumer electricity price is the product of the price of a RE certificate (19 €/MWh) and the share of RE.

Economic consequences

The economic consequences of the regional RE target scenario variation are shown in the table below. All figures are compared to the Baseline scenario. The economics are distributed based on:

- **Generators.** Revenues from electricity and heat sales, minus fuel costs, $CO_2$, O&M and capital costs related to new investments.
- **Consumers.** Expenses for electricity and heat.
- **TSOs** (transmission system operators). Income from bottlenecks on interconnectors.
- **Public profit**. Expenses for support of RE.

The sum of these figures is the total socio-economic benefit.

Note, that in the economic calculations it is assumed the public (the state) supports the development of renewable energy. In many countries this commitment lies with the electricity consumers.

The simulations show that the benefit of this relocation of investments is approx. 5 billion € in net present value (2009). However, this figure should be interpreted with caution, because the country specific estimates of renewable energy potentials and costs are associated with a significant degree of uncertainty, particularly in the long-term.

From a socio-economic point of view Germany and Finland are the greatest beneficiaries from the common RE target. The main benefit here stems from improved public profit due to lower subsidies for renewable energy.

A 6 % discount rate is used to convert future revenue streams to Net Present Value.

| Mill. €, NPV | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN | Total: |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Generator profits: | -906 | 219 | 55 | 12.609 | -159 | 421 | 11.372 | 1.907 | 1.805 | -1.439 | 25.883 |
| Consumer surplus: | 871 | -364 | -2.766 | -14.659 | -320 | -298 | 2.759 | -3.062 | -1.417 | 2.891 | -16.365 |
| TSO profit: | 257 | 47 | 576 | -331 | 29 | 1 | 350 | 91 | 337 | 691 | 2.048 |
| Public profit: | -3.934 | -134 | 3.445 | 15.531 | 854 | 98 | -14.912 | -665 | -3.641 | -2.844 | -6.202 |
| **Socio economic benefit:** | -3.712 | -232 | 1.310 | 13.150 | 404 | 222 | -431 | -1.729 | -2.916 | -701 | 5.364 |

Table 24: Socio-economic consequences of the Regional RE target scenario compared to the Baseline scenario; expressed in min. € as Net Present Value (2009).

Table 25 displays the shadow prices for the $CO_2$ targets and the RE targets in 2020 and 2030.

| Shadow prices for $CO_2$ target and RE target | | | | |
|---|---|---|---|---|
| Country | 2020 | | 2030 | |
| | $CO_2$ EUR/ton | RE EUR/$MWh_{el}$ | $CO_2$ EUR/ton | RE EUR/$MWh_{el}$ |
| Denmark | 14 | 19 | 53 | 0 |
| Estonia | | | | |
| Finland | | | | |
| Germany | | | | |
| Latvia | | | | |
| Lithuania | | | | |
| Norway | | | | |
| Poland | | | | |
| Sweden | | | | |
| Russia | | | | |

Table 25: Shadow prices for $CO_2$ target and RE target for Regional RE target scenario.

## 5.3 Improved efficiency scenario

This scenario assumes a lower level of demand for electricity compared to the Baseline scenario. This development is assumed to take place as a result of active policies for reducing the demand for electricity, particularly electricity used for direct heating. However, it can also be interpreted as the result of lower than anticipated economic growth resulting in a reduced demand for electricity.

Figure 36 shows the investments in new generation capacity grouped by fuel, as well as the development in existing capacity. Wind and coal power are still the preferred choices by the model, but the level of investments is significantly lower than in the Baseline scenario.

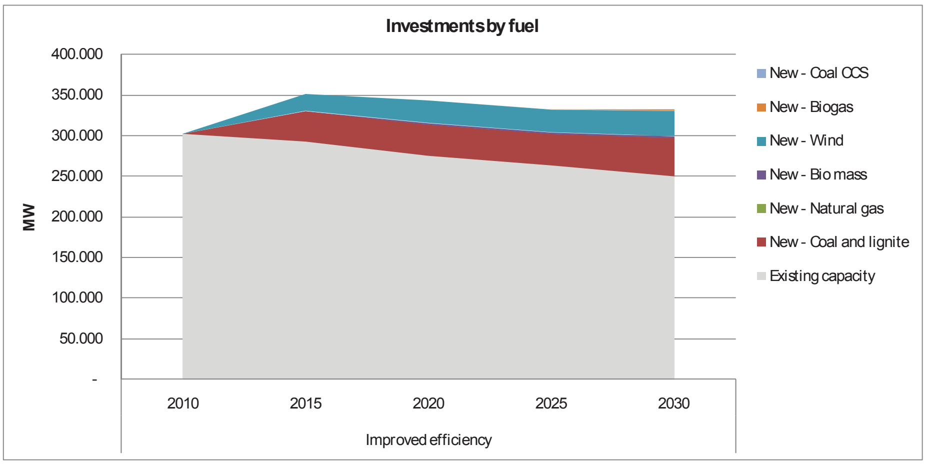



Figure 36: Development in existing capacity and investments in new generation capacity in the Improved efficiency scenario.

The development in electricity generation is shown for the period 2010-2030 in Figure 37, and in detail for each country for 2030 in Figure 38.

The development in total generation in the region remains more or less constant during the course of time, because of the demand side measures that are anticipated.

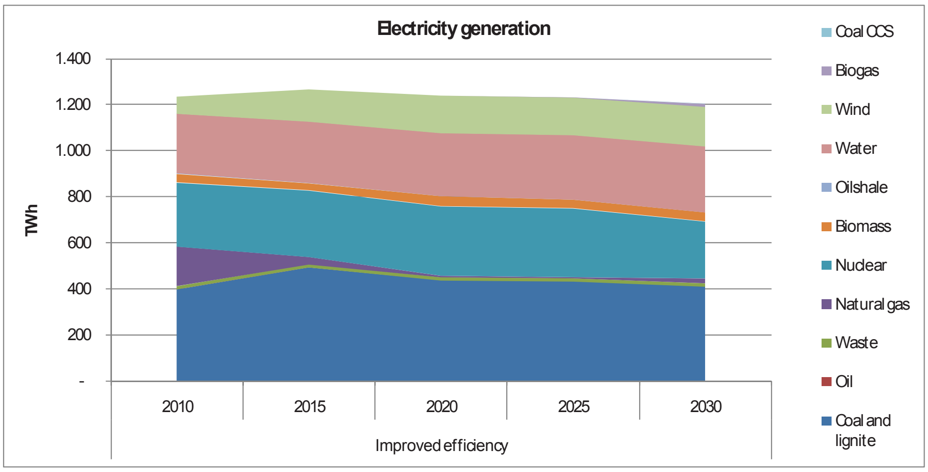
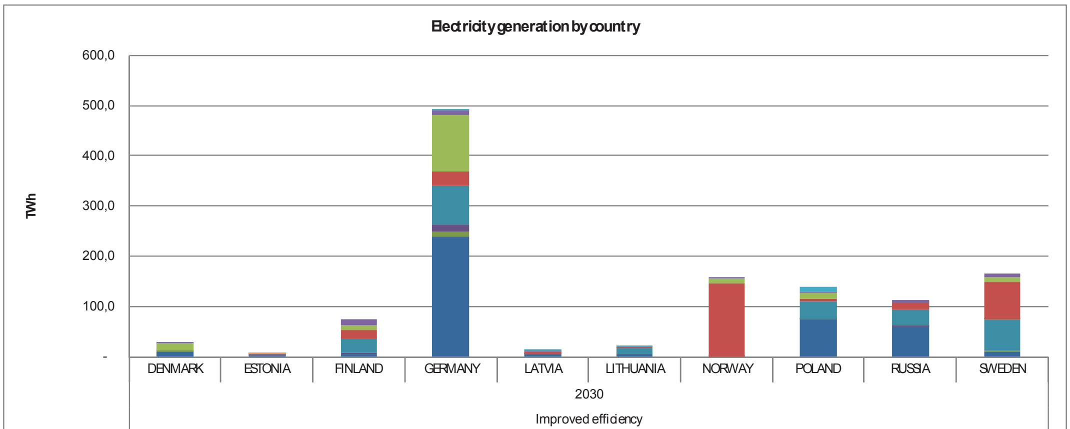



Figure 37: Electricity generation (TWh) grouped by fuel (2010-2030) in the Improved efficiency scenario.

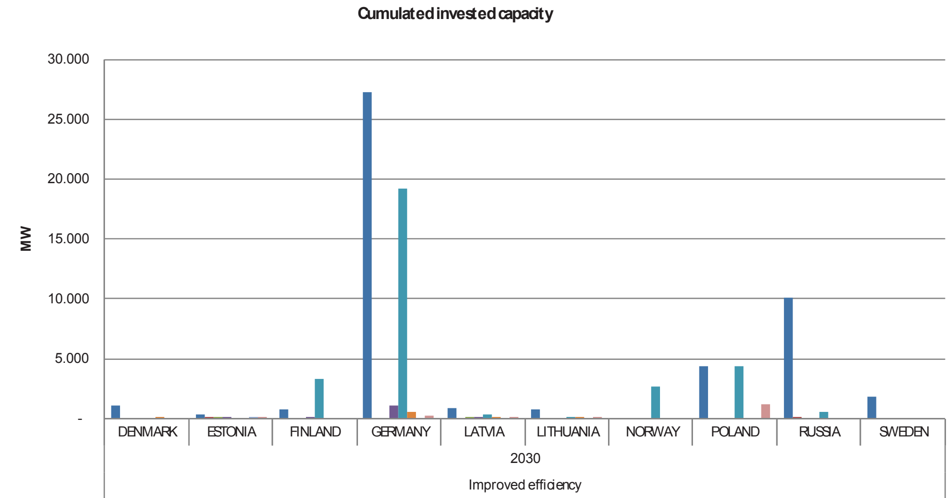
Investments in coal fired power plants with CCS are no longer economically attractive because the cost of only reaches 38 €/ton by the end of period.

Investments in new biogas and biomass capacity are also reduced very significantly compared to the baseline, leaving wind power as the only new renewable energy technology with a considerable role in 2030. Nevertheless, no new investments are made in wind power in either Sweden or Denmark until 2030.




| | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Coal CCS | | 0,9 | | | | | | | | |
| Biogas | | 0,5 | | 1,9 | 0,3 | 0,8 | | 9,1 | | |
| Biomass | 1,9 | 0,5 | 11,0 | 8,7 | 1,0 | 0,1 | 0,1 | 1,5 | 5,0 | 8,2 |
| Wind | 14,9 | 0,5 | 10,8 | 112,4 | 1,6 | 0,8 | 9,6 | 13,0 | 1,5 | 7,7 |
| Water | | | 16,0 | 29,8 | 3,2 | 0,8 | 146,8 | 3,5 | 12,3 | 74,9 |
| Shale | | 0,2 | | | | | | | | |
| Peat | | 0,3 | 0,1 | | 0,4 | | | | | 0,0 |
| Nuclear | | | 28,8 | 76,2 | | 12,3 | | 36,1 | 31,2 | 63,3 |
| Natural gas | 0,6 | 0,3 | 0,9 | 14,0 | 0,3 | 0,4 | 0,3 | 0,4 | 3,6 | |
| Waste | 1,9 | 0,1 | | 10,8 | 0,1 | | 0,2 | 0,3 | | 0,9 |
| Oil | 0,0 | | | | | 0,2 | | | 0,0 | |
| Coal and lignite | 9,9 | 2,1 | 6,0 | 238,9 | 4,9 | 4,7 | | 74,0 | 59,6 | 10,3 |

Figure 38: Electricity generation (TWh) grouped by fuel in 2030 for the Improved efficiency scenario.




| | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Coal and lignite | 1.051 | 353 | 735 | 27.223 | 837 | 737 | | 4.415 | 10.106 | 1.819 |
| Natural gas | | 67 | | | | | | | 9 | |
| Peat | | 80 | | | 116 | | | | | |
| Straw | | 4 | 105 | 1.056 | 10 | | | | | |
| Wind | | | 3.316 | 19.207 | 330 | 154 | 2.691 | 4.400 | 576 | |
| Wood | 14 | | | 515 | 92 | 0 | | | | |
| Coal CCS | | 126 | | | | | | | | |
| Biogas | | 64 | | 235 | 42 | 100 | | 1.172 | | |

Figure 39: Cumulated invested capacity (MW) from 2010 to 2030 grouped by fuel for Improved efficiency scenario.

The economic benefits of the Improved efficiency variation scenario compared to the Baseline are very considerable, as shown in Table 25. The Net Present Value of the scenario compared to the Baseline scenario is more than €100 billion higher. This amount should be compared to the cost of implementing the needed energy savings during the same course of time. It has been possible to make an assessment of these costs within the scope of the present study.

| Mill. €, NPV | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN | Total: |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Generator profits: | -7.147 | -763 | -10.108 | -80.169 | -946 | -2.014 | -24.040 | -20.912 | -17.920 | -28.140 | -192.160 |
| Consumer surplus: | 8.459 | 2.647 | 22.472 | 137.467 | 2.762 | 3.325 | 30.524 | 34.418 | 27.742 | 34.595 | 304.411 |
| TSO profit: | -17 | -60 | -68 | -434 | -45 | -55 | -40 | -53 | -113 | -39 | -923 |
| Public profit: | 600 | 5 | -922 | -3.401 | -388 | -339 | -5 | -889 | -336 | 1.030 | -4.644 |
| **Socio economic benefit:** | 1.895 | 1.829 | 11.375 | 53.463 | 1.383 | 917 | 6.440 | 12.564 | 9.373 | 7.446 | 106.683 |

Table 26: Socio-economic consequences of the Improved efficiency scenario vs. the Baseline scenario, expressed in min. € as Net Present Value (2009).

The average electricity market prices from 2010 to 2030, as computed by the model, can be seen in Figure 40.

Electricity market prices are around 10 € per MWh lower in the efficiency scenario than in the Baseline scenario, because the marginal generation technologies have lower short run marginal cost.

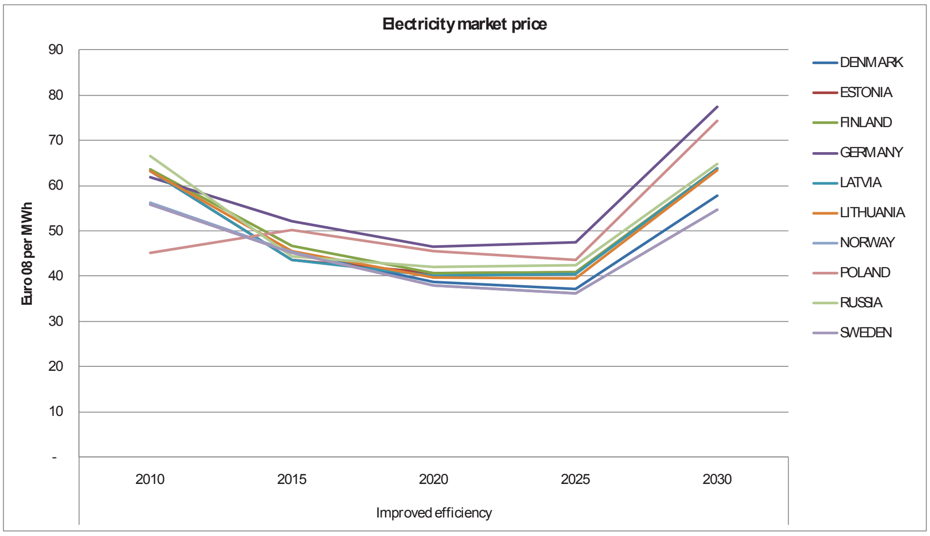



Figure 40: Average electricity market prices (Euro08 per MWh) for each country from 2010 to 2030 in the Improved efficiency scenario.

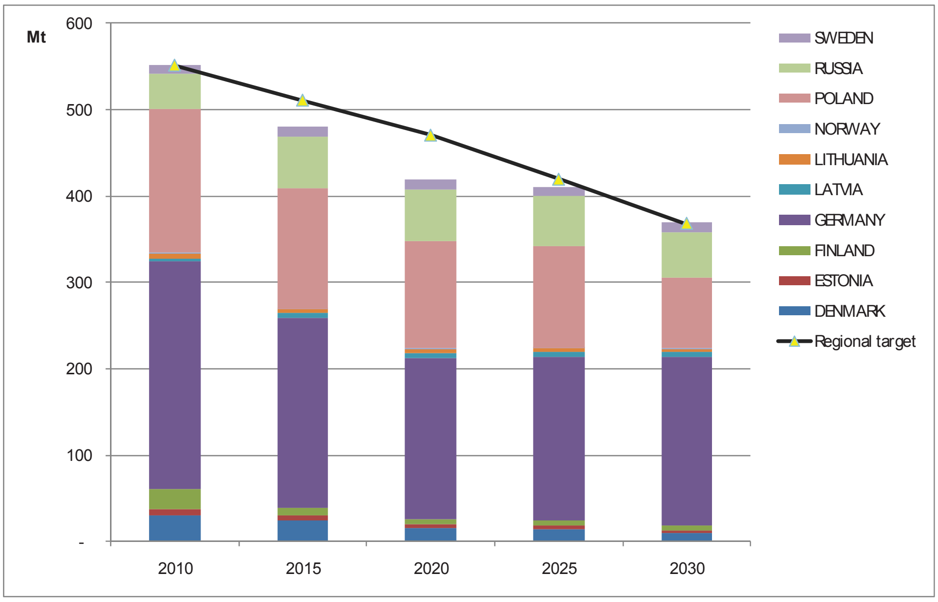



Figure 41: Total $CO_2$-emission (Megatons) by country in the Improved efficiency scenario.

The lower demand for electricity, in combination with the targets for increasing the share of renewable energy, results in an overachievement of the $CO_2$ targets in the period 2015 - 2025. Only by 2030 the target on $CO_2$ becomes binding. At that time the marginal cost of reducing $CO_2$ emissions is 38 € per ton in the scenario compared to 52 € per ton in the Baseline scenario.

This reflects that cheaper abatement measures are put into play at the supply side in this scenario. By combining demand and supply side measures it will be possible to achieve stronger $CO_2$ targets.

Denmark, Estonia and Norway over-comply with respect to the RE target, and hence there are no costs of RE. For the remaining countries the costs of compliance are between 20 and 40 €/MWh. As in the Baseline scenario, no target applies to Russia.

| Shadow prices for $CO_2$ target and RE target | | | | |
|---|---|---|---|---|
| Country | 2020 | | 2030 | |
| | $CO_2$ EUR/ton | RE EUR/$MWh_{el}$ | $CO_2$ EUR/ton | RE EUR/$MWh_{el}$ |
| Denmark | 0 | - | 38 | - |
| Estonia | | - | | - |
| Finland | | 38 | | - |
| Germany | | 36 | | - |
| Latvia | | 38 | | 12 |
| Lithuania | | 39 | | - |
| Norway | | - | | - |
| Poland | | 25 | | - |
| Sweden | | 21 | | - |
| Russia | | - | | - |

Table 27: Shadow prices for $CO_2$ target and RE target in the Improved efficiency scenario.

## 5.4 30%@COP15

The 30%@COP15 scenario explores a situation where $CO_2$-emissions from the power and district heating sectors are reduced by an additional 10 percentage points in 2020, in other words the target for reducing $CO_2$-emissions in 2020 is 31 % instead of 21 %. This reflects a situation where an ambitious international agreement is obtained at the Copenhagen Climate Summit in December 2009 committing the EU Member States to cut their overall $CO_2$-emissions by 30 % in 2020.

The target for 2030 remains at 50 % reduction compared to 1990 (38 % compared to 2005).
The two tables below show accumulated investments in the 30%@COP15 scenario and in the baseline.

| **30%@COP15 MW** | **Coal and lignite** | **Natural gas** | **Biomass** | **Wind** | **Biogas** | **Coal CCS** |
|---|---|---|---|---|---|---|
| 2020 | 45.992 | 4.058 | 2.780 | 38.102 | 3.258 | 33 |
| 2030 | 51.473 | 4.694 | 6.623 | 68.364 | 4.512 | 11.196 |

Table 28: Accumulated Investments in new electricity generation capacity (MW) in 30%@COP15 scenario

| **Baseline MW** | **Coal and lignite** | **Natural gas** | **Biomass** | **Wind** | **Biogas** | **Coal CCS** |
|---|---|---|---|---|---|---|
| 2020 | 48.260 | 310 | 3.653 | 36.673 | 306 | |
| 2030 | 54.195 | 541 | 5.506 | 68.710 | 4.455 | 13.651 |

Table 29: Accumulated Investments in new electricity generation capacity (MW) in the Baseline scenario

The stricter $CO_2$ target in 2020 leads to fewer investments in new coal fired power plants in 2020, but more investments in natural gas fired capacity, wind power and biogas based capacity. The investments in biogas capacity are to some extent made at the expense of a smaller amount of investments in biomass fired capacity.

Biogas is more attractive in the 30%@COP15 scenario, because the negative $CO_2$-emission factor of biogas becomes a greater benefit with the stronger $CO_2$-target. This should be viewed in the light of the $CO_2$-price, which is 30 €/ton in the 30%@COP15 scenario in 2020 compared to only 7 €/ton in the Baseline scenario.

The cumulated investments by 2030 also differ between the two scenarios even though the 2030-target is the same. The main difference is that higher level of investments in natural gas up to 2020 in the 30%@COP15 scenario leads to fewer investments in new coal power and coal power with CCS in the subsequent decade.

Figure 42 illustrates the cumulated investments in the region from 2015 to 2030.

Figure 43 displays the electricity generation by fuel for each country in the region.

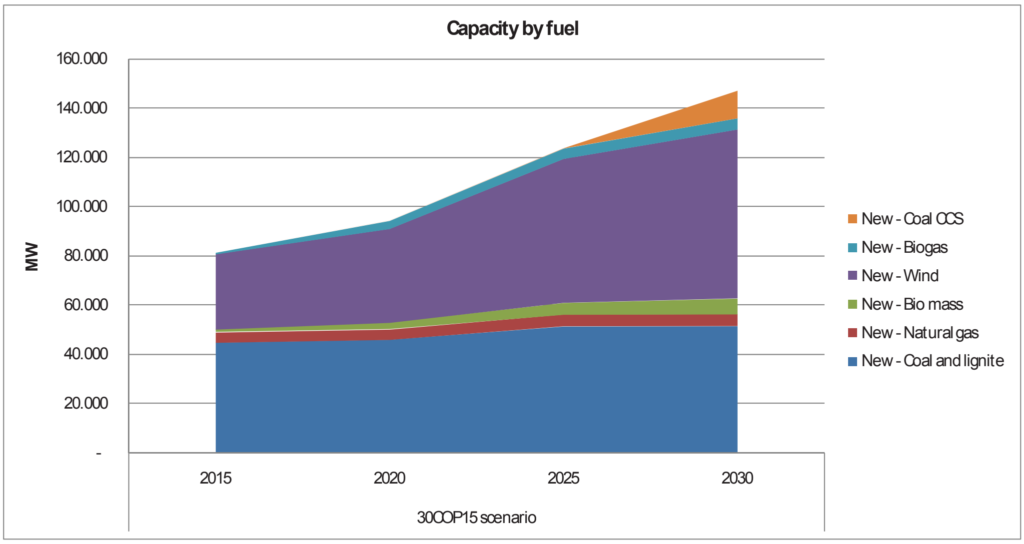
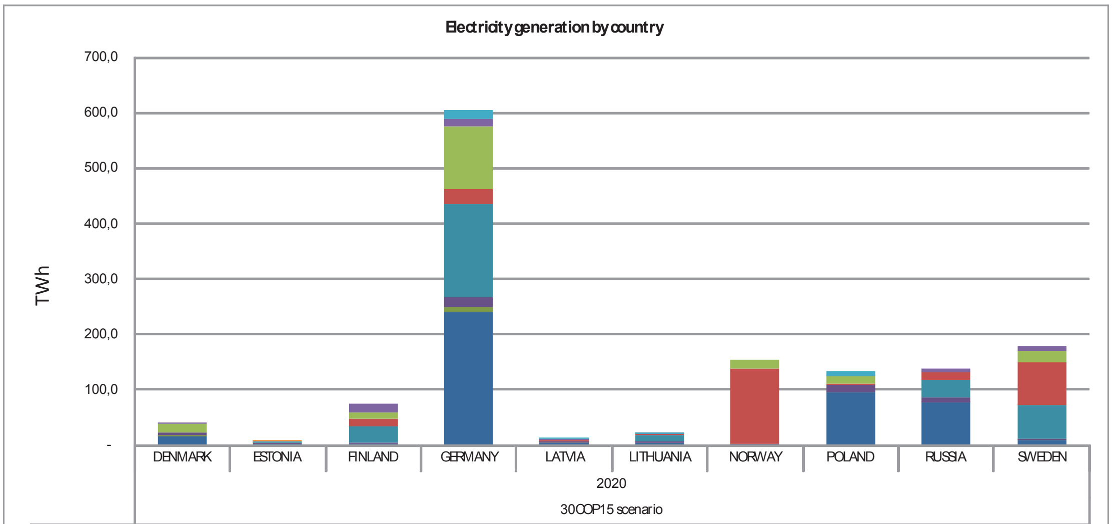



Figure 42: Cumulated invested capacity from 2010 to 2030 grouped by fuel for 30%@COP15 scenario.




| | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN |
|---|---|---|---|---|---|---|---|---|---|---|
| Coal CCS | | 0,2 | | | | | | | | |
| Biogas | | 0,5 | | 15,4 | 0,5 | 0,8 | | 9,1 | | |
| Biomass | 2,5 | 0,7 | 14,6 | 13,9 | 1,7 | 0,2 | | 1,9 | 5,1 | 9,1 |
| Wind | 15,2 | 0,5 | 12,4 | 113,1 | 0,5 | 0,3 | 15,6 | 13,0 | 1,7 | 20,8 |
| Water | | | 14,0 | 28,4 | 3,3 | 0,8 | 136,8 | 3,0 | 12,3 | 74,9 |
| Shale | | 0,4 | | | | | | | | |
| Peat | | | 0,0 | | | | | | | 0,0 |
| Nuclear | | | 28,8 | 166,8 | | 12,3 | | | 31,2 | 63,3 |
| Natural gas | 4,3 | 1,4 | 1,9 | 17,3 | 0,9 | 0,7 | 1,5 | 12,5 | 10,0 | 1,4 |
| Waste | 1,9 | 0,1 | | 10,9 | 0,1 | | 0,2 | 0,3 | | 0,9 |
| Oil | 0,0 | | | | | 0,2 | | | 0,0 | |
| Coal and lignite | 16,6 | 2,4 | 2,4 | 239,6 | 4,8 | 5,4 | | 95,1 | 77,2 | 8,2 |

Figure 43: Electricity generation (TWh) grouped by fuel in 2020 for the 30%@COP15 scenario.

As intended, the $CO_2$-emissions in the scenario follow a lower trajectory than in the Baseline. Figure 44 shows how $CO_2$-emissions are distributed on countries between 2010 and 2030.

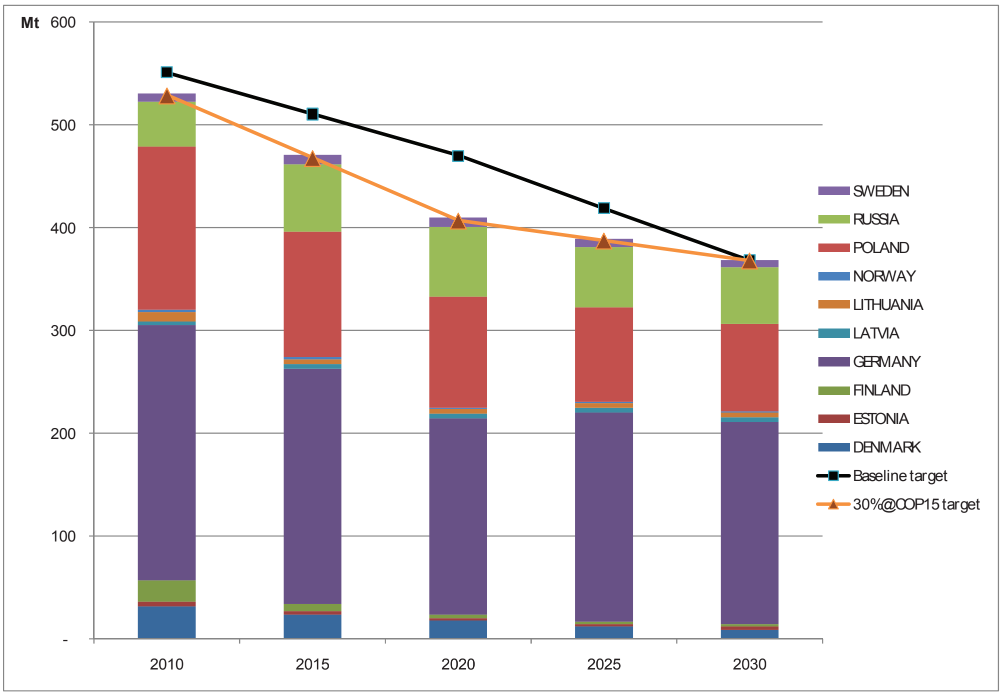



Figure 44: Development in $CO_2$-emissions (Mt) by country in the scenario 30%@COP15. The scenario specific $CO_2$ targets are shown by the orange line and the $CO_2$ target in the baseline by the black line

The average annual electricity market prices in the 30%@COP15 scenario are significantly higher between 2010 and 2020 compared to the baseline. This must be viewed in the light of the higher marginal $CO_2$-price. In 2025 and 2030 electricity market prices are at the same level as in the Baseline scenario.

The additional costs to electricity consumers for subsidising renewables will be lower in the 30%@COP15 scenario between 2010 and 2020, because the higher $CO_2$-price provides a great economic incentive for renewables.

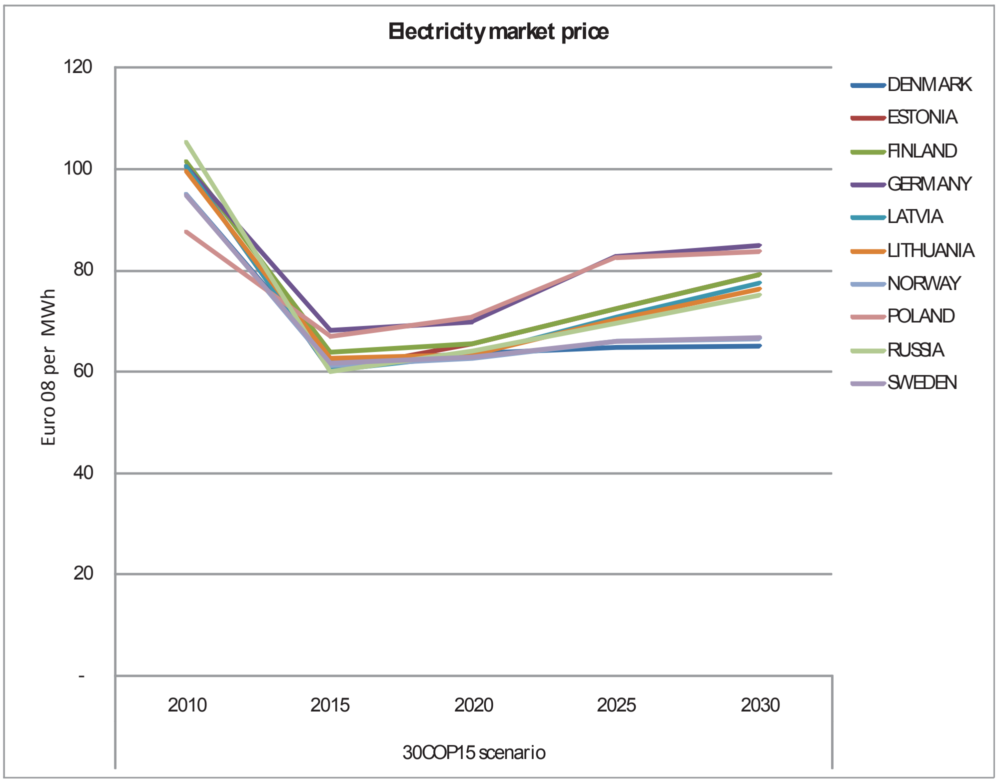



Figure 45: Average electricity price (Euro 08 per MWh) for each country from 2010 to 2030 for 30%@ COP15 scenario.

The total economic consequences for the region of following the lower $CO_2$-emission path are estimated to be approx. €16 billion, measured as net present value (2009).

Table 30 shows how the economic consequences are distributed on countries and stakeholders. The pattern is the same in almost all countries: generators have their profits increased as the higher $CO_2$-prices lead to higher electricity market prices; the costs of consumers are increased considerably as a results of the higher electricity prices; TSO profits (changes in bottleneck income on congested transmission lines) increase slightly; and public profits are improved, because the need for special support to renewables are reduced.

Looking across the different stakeholder groups, the scenario results in a net benefit for Denmark, Lithuania, Norway and Sweden, whereas the result is a net cost for the remaining countries in the region.

Table 30: Socio-economic consequences of the 30%@COP15 scenario compared to the Baseline scenario

| Mill. €, NPV | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | Sweden | Total: |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Generator profits: | 4.891 | 256 | 6.180 | 70.231 | 588 | 1.889 | 17.675 | 14.587 | 15.688 | 14.469 | 146.454 |
| Consumer surplus: | -4.902 | -1.407 | -13.410 | -87.080 | -1.447 | -1.716 | -16.437 | -21.253 | -15.856 | -19.502 | - 183.011 |
| TSO profit: | 85 | 16 | 124 | 221 | 5 | -13 | 138 | 35 | 46 | 137 | 795 |
| Public profit: | 535 | -54 | 2.517 | 9.072 | 468 | 272 | 3 | -302 | 3 | 6.886 | 19.399 |
| **Socio economic benefit:** | 610 | -1.189 | -4.589 | -7.557 | -385 | 431 | 1.379 | -6.933 | -119 | 1.989 | -16.363 |

The marginal cost of reducing $CO_2$ is significantly higher than in the Baseline in 2020. In 2030 it is slightly lower. The costs of new renewable energy is significantly lower than in the Baseline by 2020; in Denmark, Estonia, Norway and Poland there is no additional costs associated with new renewables because of the relatively high $CO_2$-price.

Table 31: Shadow prices for $CO_2$ target and RE target for the 30%@COP15 scenario.

| Shadow prices for $CO_2$ target and RE target | | | | |
|---|---|---|---|---|
| Country | 2020 | | 2030 | |
| | $CO_2$ EUR/ton | RE EUR/$MWh_{el}$ | $CO_2$ EUR/ton | RE EUR/$MWh_{el}$ |
| Denmark | | 0 | | 0 |
| Estonia | | 0 | | 0 |
| Finland | | 13 | | 0 |
| Germany | | 13 | | 0 |
| Latvia | 30 | 15 | 51 | 9 |
| Lithuania | | 2 | | 3 |
| Norway | | 0 | | 0 |
| Poland | | 0 | | 0 |
| Sweden | | 2 | | 0 |
| Russia | | 0 | | 0 |

## 5.5 Analysis: $CO_2$ and RE targets

Marginal costs to reach the targets

The scenarios are set up to meet both the $CO_2$-targets and the RE targets for the region. But what are the marginal costs of these targets, and which of the targets are the most binding in 2020 and 2030? These questions have been illustrated by letting the model calculate 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 by one MWh (the shadow prices). Respectively, these values can be interpreted as estimations of the $CO_2$-price in the emissions trading scheme and the marginal level of support needed for renewable energy.

It is assumed that $CO_2$ can be traded across all countries including NW Russia; consequently there is one common price of $CO_2$ for the whole region. Renewable energy targets, on the other hand, are national targets in the Baseline scenario, and therefore the prices are different for each country in the region.

Table 32 gives an overview the shadow prices for $CO_2$-targets for 2020 and 2030 for the different scenarios.

Table 32: Shadow prices for $CO_2$ targets in EUR/ton

| Scenario | 2020 | 2030 |
|---|---|---|
| Baseline | 7 | 52 |
| Regional RE Target | 14 | 53 |
| Improved Efficiency | 0 | 38 |
| 30% CO2@COP15 | 30 | 51 |

$CO_2$-targets in 2020

The table indicates that the $CO_2$-targets for the region in 2020 can be met at costs between zero and 30 € per tonnes depending on the reduction ambitions and the efforts to implement energy savings and to cooperate on the integration and implementation of renewable energy. In the Improved Efficiency scenario the $CO_2$-target can be met without additional costs. The reason for this is that the national renewable energy requirements become binding, but not the targets for $CO_2$. The findings show that the targets on renewable energy and on reducing $CO_2$ are to a very high complimentary. The target on renewable energy contributes to keeping the price of $CO_2$ down and the similar the targets to reduce $CO_2$ lower the direct cost of complying with the RE targets.

Trading outside the region

It should be stressed that the present analyses do not consider the possibilities for trading $CO_2$ quotas between the electricity companies in the region and companies in other sectors and/or countries. In practice, the Baltic Sea Region is part of the EU ETS and the cost of $CO_2$ quotas will be determined by the marginal reduction costs among all companies included in the EU market as well as by the price of credits from CDM projects. However, the means and dynamics in the EU market can be expected to resemble those modelled for the Baltic Sea Region in the present study.

Between 2020 and 2030 the target for RE is kept constant, whereas the $CO_2$-target is tightened from 21% to 38 % reduction compared to 2005. Therefore, in 2030 the $CO_2$-target becomes binding in all scenario variations and the $CO_2$ reductions costs are significantly higher. The RE target on the other hand is only binding in Latvia and Lithuania in the Baseline scenario.

The simulations show that the shadow price of $CO_2$ is just above 50 € per ton for all scenarios in 2030 except for the Improved Efficiency scenario that has a shadow price of 38 € per ton.

RE-prices

The shadow prices for the RE-targets are shown in Table 2 and 3.

Table 33: Shadow prices for RE targets in 2020 in the different scenarios (EUR/$MWh_{el}$).

| Country | Baseline scenario | Regional RE Target scenario | Improved Efficiency scenario | 30%@COP15 scenario |
|---|---|---|---|---|
| Denmark | 16 | 19 | - | - |
| Estonia | 16 | | - | - |
| Finland | 29 | | 38 | 32 |
| Germany | 30 | | 36 | 26 |
| Latvia | 31 | | 38 | 49 |
| Lithuania | 31 | | 39 | 13 |
| Norway | - | | - | - |
| Poland | 24 | | 25 | - |
| Sweden | 16 | | 21 | 2 |
| NW Russia | - | | - | |

Table 34: Shadow prices for RE targets in 2030 in the different scenarios (EUR/$MWh_{el}$).

| Country | Baseline scenario | Regional RE Target scenario | Improved Efficiency scenario | 30%@COP15 scenario |
|---|---|---|---|---|
| Denmark | - | - | - | - |
| Estonia | - | | - | - |
| Finland | - | | - | - |
| Germany | - | | - | - |
| Latvia | 11 | | 12 | 9 |
| Lithuania | 2 | | - | 3 |
| Norway | - | | - | - |
| Poland | - | | - | - |
| Sweden | - | | - | - |
| NW Russia | - | | - | |

In the Baseline scenario the RE prices differ quite substantially between the countries. In Russia there is no price of RE because no national RE target is assumed. In Norway the price of RE is zero, because the expected development of new hydro power easily leads to compliance with the national RE target. In 2020 Finland, Germany, Latvia, Lithuania and Poland and have the highest marginal costs of expanding renewable energy electricity generation.

In the Regional RE Target scenario the price of RE is common for the region. In 2020 it is 19 € per MWh of renewable electricity.

The total generation of renewable energy in the Baltic Sea Region is 8 TWh lower in the regional RE scenario compared to the Baseline scenario. This may appear surprising since the RE target is the same in the two scenarios. The reason for this is that due to the expected development of new hydro power plants, Norway over-complies in the Baseline scenario. In the scenario with Regional RE target Norway's over-compliance contributes to achieve the Regional RE target.

In the Improved Efficiency scenario Denmark, Estonia and Norway over-comply with respect to the RE target in 2020, and hence the marginal cost of increasing the RE target is zero. For the remaining countries the costs of compliance is up to 10 €/MWh higher than in the baseline scenario. This may appear surprising since the requirement for renewables – measured in absolute energy - is lower in the efficiency scenario compared to the Baseline scenario, because the RE targets are measured as a percentage of final energy consumption. The reason is that in 2020 electricity market prices are around 10 € per MWh lower in the efficiency scenario than in the Baseline scenario, because the marginal generation technologies have lower short run marginal cost. Therefore, the need to subsidise new renewable energy increases similarly.

# 6 Case analysis of Kriegers Flak

In addition to the overall scenarios a case analysis has been made to illustrate the costs and benefits of concerted planning for wind power plants in the shallow waters of Kriegers Flak in the Baltic Sea. Germany, Sweden and Denmark are all planning to build off-shore wind farms at Kriegers Flak (400, 600 and 600 MW respectively).

The case explores the consequences of a developing a common integrated off-shore grid, which could also serve as a link between the Nordic and German electricity markets.

The area and a possible common international connection are sketched in the figure below.

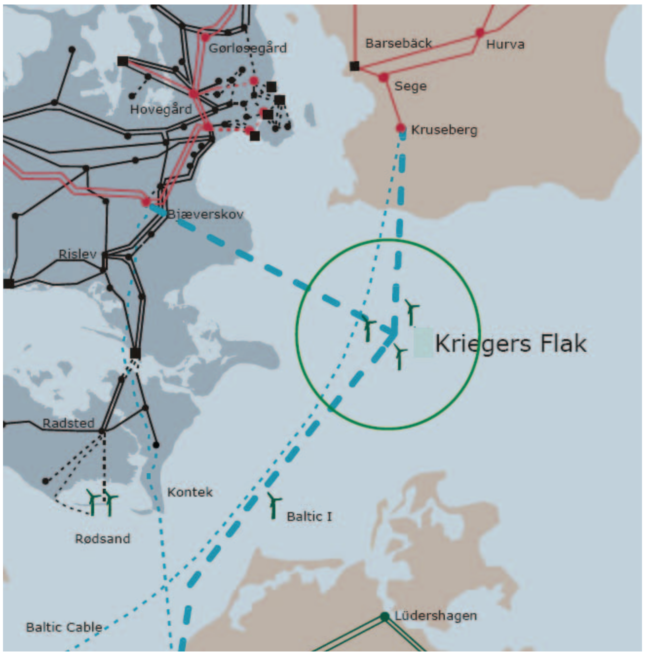



Figure 46: Location and sketched connection of Kriegers Flak. The thinner dashed lines indicate the existing connections between Denmark and Germany (Kontek) and Sweden and Germany (Baltic Cable). Source: Energinet.dk

An integrated off-shore wind grid could serve a twofold purpose by connecting the wind farms to the transmission grid at shore, as well as by linking the electricity markets in the region. Kriegers Flak could serve as a pilot project for an integrated offshore grid.

The figure below shows a duration curve of the transmission between the off-shore wind farms in Kriegers Flak and their respective countries in the Baseline scenario[22] without a common international connection (dotted lines) and a

22 A few minor changes have been made to the Baseline scenario since the Kriegers Flak analysis was carried out. However, these changes are not expected to have noteworthy influence on the results.

situation with common interconnection (full lines). In the first situation the cables are only used to transmit power from the wind farms to land. In the second case, the off-shore grid is also used as a mean to transport electricity to and from the three countries. This leads to a significant higher utilisation of the cables.

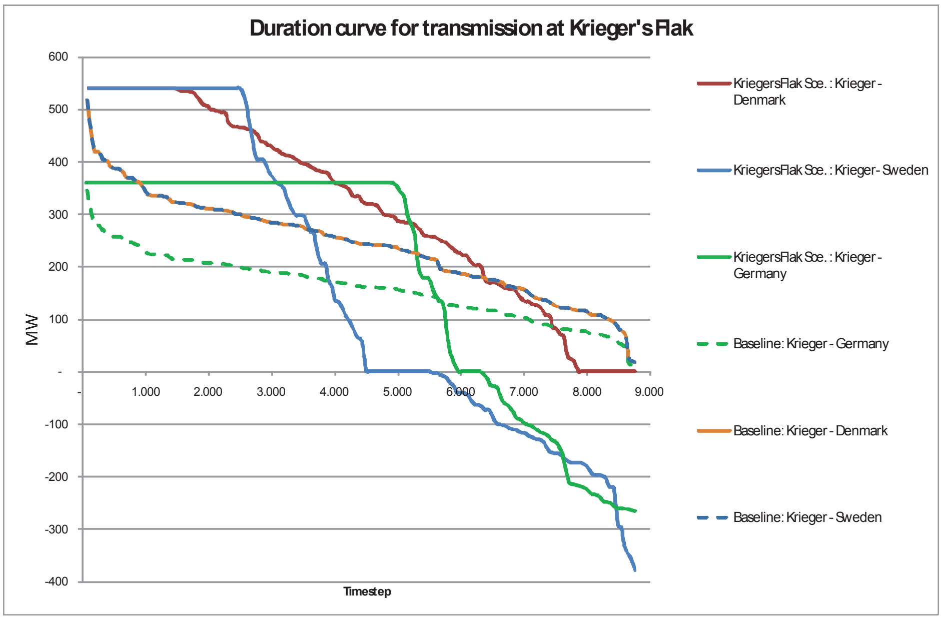



Figure 47: Duration curves showing the utilisation of the connections to Kriegers Flak in the Baseline Scenario with individual on-shore connection and in the situation with a common interconnection at Kriegers Flak.

The common interconnection at Kriegers Flak compared to a situation with no common interconnection shows a benefit a Net Present Value of €17 million for the region. This figure does not include the possible higher capital cost associated with the common solution.

The above calculation assumes only 400 MW of transmission between Germany and Kriegers Flak. This is sufficient to connect the 400 MW of expected wind power capacity at the German part of Kriegers Flak; however in connection with an integrated offshore grid it may appear more economic to establish a stronger connection to Germany, particularly considering that the connections from Kriegers Flak to Denmark and Sweden are 600 MW each.

It will be relevant to carry out further analyses explore the costs and benefits of different concepts for a common interconnection at Kriegers Flak.

| Mill. €, NPV | DENMARK | ESTONIA | FINLAND | GERMANY | LATVIA | LITHUANIA | NORWAY | POLAND | RUSSIA | SWEDEN | Total: |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Generator profits: | -33 | -0 | 40 | -65 | 0 | 7 | -59 | 74 | 22 | 1 | -12 |
| Consumer surplus: | 15 | -2 | -29 | -92 | -8 | -12 | 59 | -92 | -70 | 115 | -117 |
| TSO profit: | 56 | -3 | 8 | -1 | -0 | 2 | -10 | 10 | 1 | 47 | 109 |
| Public profit: | -26 | -0 | -14 | 268 | 1 | 1 | 0 | -16 | -5 | -172 | 37 |
| **Socio economic benefit:** | **13** | **-6** | **5** | **110** | **-7** | **-2** | **-10** | **-24** | **-52** | **-10** | **17** |

Table 35: Socio-economic consequences of a common interconnection at Kriegers Flak compared to individual interconnections. Min. €, Net Present Value.

# 7 Screening of new interconnectors

A screening has been made of the most attractive new interconnectors in the electricity system in the Baltic Sea area.

The model considers the most important bottlenecks in the electricity systems and is able to assess the utility to the electricity market (including the different stakeholders in the market) of expanding transmission capacity between the different electrical areas in models.

Socio-economic benefit of adding one MW of transmission capacity

The table below shows the total socio-economic benefit of adding one MW of transmission capacity between the different transmission areas in the model in the Baseline scenario for 2020[23]. With regards to Russia only two areas have been included: Ru_STP (St. Petersburg area) and Ru_Kal (Kaliningrad Area). The table includes all possible direct connections, including connections that do not make sense in the real world (e.g. between Norway and Kaliningrad).

It should be stressed, that an expansion of the existing transmission capacities in the region has been included in the Baseline scenario (see Chapter 4.2). The expansions, which are examined here, are therefore in addition to this assumed baseline development.

Linking thermal and hydro system is most attractive

Connections linking the thermal power based systems in Germany and Poland and the Nordic power system dominated by hydro power have the highest value, as well as internal connections in Germany. Linking the Baltic countries / Russia with Scandinavia also appears attractive.

The table only serves as a screening of the benefits of the interconnections. A satisfactory evaluation of the different interconnection requires more simulations, taking into consideration for example the impact of situations with high/low hydro inflow as well as simulations with higher time resolution. Moreover, the capacities should be evaluated according to their full possible capacity, for example 600 MW or 1000 MW, and not the marginal change (1 MW).

Furthermore, the tables only show the value for the electricity market. To that, additional benefits can be derived from improved security of supply, improved competition and saved costs of auxiliary services. These benefits can be significant.

The benefits indicated in the table should be compared to the capital costs of the connections. These costs are site specific and have not been quantified as part of the present study. However, for comparison it could be mentioned that the capital cost of the 600 MW Great Belt connection linking Denmark East and

23 A few minor changes have been made to the Baseline scenario since the transmission screening was carried out. However, these changes are not expected to have noteworthy influence on the results.

Denmark West has been projected to be approx. 20,000 €/MW per year. For the 600 MW Skagerrak IV between Denmark and Norway the capital cost have been estimated to be approx. 35,000 €/MW and for NordBalt linking Lithuania and Sweden the costs are anticipated to be between 60,000 €/MW and 80.000 €/MW depending on the capacity of the interconnector (500/1000 MW). These cost estimates assume an economical lifetime of 30 years and a real interest rate of 6 %.

| | DE_CS | DE_NE | DE_NW | DK_E | DK_W | EE_R | FI_R | LT_R | LV_R | NO_M | NO_N | NO_O | NO_S | PL_R | RU_KAL | RU_STP | SE_M | SE_N | SE_S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DE_CS | - | 37.422 | 65.737 | 87.810 | 87.064 | 73.717 | 73.882 | 81.810 | 80.531 | 93.407 | 93.496 | 90.175 | 91.085 | 62.473 | 80.218 | 82.226 | 90.332 | 92.913 | 90.126 |
| DE_NE | 37.422 | - | 28.330 | 69.981 | 69.307 | 73.861 | 73.834 | 78.736 | 80.653 | 75.620 | 75.660 | 77.248 | 78.052 | 73.901 | 78.930 | 82.187 | 72.587 | 75.086 | 72.303 |
| DE_NW | 65.737 | 28.330 | - | 94.216 | 93.605 | 98.272 | 98.246 | 101.504 | 102.877 | 98.984 | 98.986 | 102.059 | 102.799 | 100.658 | 101.718 | 102.408 | 95.970 | 98.453 | 95.705 |
| DK_E | 87.810 | 69.981 | 94.216 | - | 1.173 | 21.432 | 21.243 | 37.526 | 43.150 | 5.733 | 5.829 | 9.537 | 10.204 | 47.680 | 38.999 | 46.111 | 2.667 | 5.232 | 2.486 |
| DK_W | 87.064 | 69.307 | 93.605 | 1.173 | - | 21.468 | 21.258 | 37.527 | 43.274 | 6.524 | 6.673 | 8.496 | 9.240 | 46.713 | 38.993 | 46.258 | 3.481 | 6.044 | 3.295 |
| EE_R | 73.717 | 73.861 | 98.272 | 21.432 | 21.468 | - | 414 | 25.588 | 22.793 | 23.653 | 23.776 | 24.544 | 25.356 | 38.141 | 27.209 | 26.219 | 20.563 | 23.183 | 20.517 |
| FI_R | 73.882 | 73.834 | 98.246 | 21.243 | 21.258 | 414 | - | 25.853 | 23.052 | 23.439 | 23.607 | 24.324 | 25.202 | 38.142 | 27.439 | 26.249 | 20.306 | 23.046 | 20.300 |
| LT_R | 81.810 | 78.736 | 101.504 | 37.526 | 37.527 | 25.588 | 25.853 | - | 6.004 | 39.059 | 39.059 | 39.977 | 40.725 | 54.438 | 1.837 | 9.557 | 36.274 | 38.804 | 36.179 |
| LV_R | 80.531 | 80.653 | 102.877 | 43.150 | 43.274 | 22.793 | 23.052 | 6.004 | - | 44.581 | 44.575 | 45.749 | 46.486 | 60.435 | 7.815 | 3.588 | 41.824 | 44.331 | 41.750 |
| NO_M | 93.407 | 75.620 | 98.984 | 5.733 | 6.524 | 23.653 | 23.439 | 39.059 | 44.581 | - | 278 | 13.068 | 12.070 | 52.931 | 40.614 | 46.655 | 3.162 | 571 | 3.375 |
| NO_N | 93.496 | 75.660 | 98.986 | 5.829 | 6.673 | 23.776 | 23.607 | 39.059 | 44.575 | 278 | - | 13.246 | 12.300 | 53.098 | 40.614 | 46.630 | 3.348 | 654 | 3.466 |
| NO_O | 90.175 | 77.248 | 102.059 | 9.537 | 8.496 | 24.544 | 24.324 | 39.977 | 45.749 | 13.068 | 13.246 | - | 1.150 | 44.681 | 41.401 | 48.462 | 10.093 | 12.711 | 10.164 |
| NO_S | 91.085 | 78.052 | 102.799 | 10.204 | 9.240 | 25.356 | 25.202 | 40.725 | 46.486 | 12.070 | 12.300 | 1.150 | - | 45.735 | 42.173 | 49.155 | 10.688 | 11.924 | 10.882 |
| PL_R | 62.473 | 73.901 | 100.658 | 47.680 | 46.713 | 38.141 | 38.142 | 54.438 | 60.435 | 52.931 | 53.098 | 44.681 | 45.735 | - | 52.689 | 63.995 | 49.813 | 52.549 | 49.780 |
| RU_KAL | 80.218 | 78.930 | 101.718 | 38.999 | 38.993 | 27.209 | 27.439 | 1.837 | 7.815 | 40.614 | 40.614 | 41.401 | 42.173 | 52.689 | - | 11.389 | 37.824 | 40.368 | 37.724 |
| RU_STP | 82.226 | 82.187 | 102.408 | 46.111 | 46.258 | 26.219 | 26.249 | 9.557 | 3.588 | 46.655 | 46.630 | 48.462 | 49.155 | 63.995 | 11.389 | - | 44.336 | 46.801 | 44.316 |
| SE_M | 90.332 | 72.587 | 95.970 | 2.667 | 3.481 | 20.563 | 20.306 | 36.274 | 41.824 | 3.162 | 3.348 | 10.093 | 10.688 | 49.813 | 37.824 | 44.336 | - | 2.760 | 346 |
| SE_N | 92.913 | 75.086 | 98.453 | 5.232 | 6.044 | 23.183 | 23.046 | 38.804 | 44.331 | 571 | 654 | 12.711 | 11.924 | 52.549 | 40.368 | 46.801 | 2.760 | - | 2.824 |
| SE_S | 90.126 | 72.303 | 95.705 | 2.486 | 3.295 | 20.517 | 20.300 | 36.179 | 41.750 | 3.375 | 3.466 | 10.164 | 10.882 | 49.780 | 37.724 | 44.316 | 346 | 2.824 | - |

Table 36: Screening of new interconnectors. **Baseline scenario, 2020**. The table shows the total socio-economic benefit of adding one MW of transmission capacity between the different transmission areas in the model. For Russia only two areas have been included: Ru_STP (St. Petersburg area and Ru_Kal (Kaliningrad Area).

| | DE_CS | DE_NE | DE_NW | DK_E | DK_W | EE_R | FI_R | LT_R | LV_R | NO_M | NO_N | NO_O | NO_S | PL_R | RU_KAL | RU_STP | SE_M | SE_N | SE_S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DE_CS | - | 87.112 | 135.118 | 243.613 | 261.336 | 173.874 | 182.330 | 156.486 | 162.861 | 285.194 | 285.264 | 256.046 | 277.117 | 90.753 | 156.162 | 182.085 | 261.264 | 281.008 | 260.987 |
| DE_NE | 87.112 | - | 48.160 | 171.946 | 179.430 | 136.141 | 135.680 | 145.695 | 141.045 | 213.611 | 213.620 | 191.906 | 212.774 | 153.559 | 145.631 | 135.852 | 189.811 | 209.450 | 189.408 |
| DE_NW | 135.118 | 48.160 | - | 183.106 | 168.309 | 162.596 | 160.426 | 174.777 | 169.979 | 223.233 | 223.197 | 202.373 | 223.075 | 200.623 | 174.837 | 160.774 | 199.541 | 219.125 | 199.144 |
| DK_E | 243.613 | 171.946 | 183.106 | - | 18.560 | 80.377 | 71.301 | 104.518 | 91.961 | 41.682 | 41.715 | 20.876 | 41.560 | 254.042 | 104.951 | 72.585 | 17.876 | 37.526 | 17.492 |
| DK_W | 261.336 | 179.430 | 168.309 | 18.560 | - | 98.314 | 89.202 | 121.783 | 109.899 | 55.101 | 55.127 | 34.551 | 54.844 | 271.765 | 122.244 | 90.500 | 31.693 | 51.143 | 31.333 |
| EE_R | 173.874 | 136.141 | 162.596 | 80.377 | 98.314 | - | 9.309 | 28.926 | 12.294 | 116.207 | 116.270 | 92.283 | 113.227 | 182.948 | 29.494 | 8.887 | 92.277 | 112.007 | 91.987 |
| FI_R | 182.330 | 135.680 | 160.426 | 71.301 | 89.202 | 9.309 | - | 38.099 | 21.547 | 106.956 | 107.018 | 83.550 | 104.488 | 192.036 | 38.617 | 1.452 | 83.004 | 102.755 | 82.719 |
| LT_R | 156.486 | 145.695 | 174.777 | 104.518 | 121.783 | 28.926 | 38.099 | - | 16.771 | 142.203 | 142.265 | 114.751 | 135.741 | 154.022 | 578 | 37.743 | 118.272 | 138.002 | 117.982 |
| LV_R | 162.861 | 141.045 | 169.979 | 91.961 | 109.899 | 12.294 | 21.547 | 16.771 | - | 128.420 | 128.461 | 103.822 | 124.779 | 170.783 | 17.301 | 21.067 | 104.505 | 124.219 | 104.215 |
| NO_M | 285.194 | 213.611 | 223.233 | 41.682 | 55.101 | 116.207 | 106.956 | 142.203 | 128.420 | - | 421 | 29.378 | 9.722 | 295.624 | 142.725 | 107.428 | 23.959 | 4.214 | 24.257 |
| NO_N | 285.264 | 213.620 | 223.197 | 41.715 | 55.127 | 116.270 | 107.018 | 142.265 | 128.461 | 421 | - | 29.458 | 10.114 | 295.693 | 142.787 | 107.464 | 24.015 | 4.270 | 24.313 |
| NO_O | 256.046 | 191.906 | 202.373 | 20.876 | 34.551 | 92.283 | 83.550 | 114.751 | 103.822 | 29.378 | 29.458 | - | 21.071 | 266.475 | 115.202 | 84.055 | 5.728 | 25.222 | 5.731 |
| NO_S | 277.117 | 212.774 | 223.075 | 41.560 | 54.844 | 113.227 | 104.488 | 135.741 | 124.779 | 9.722 | 10.114 | 21.071 | - | 287.546 | 136.207 | 104.971 | 26.098 | 12.068 | 26.389 |
| PL_R | 90.753 | 153.559 | 200.623 | 254.042 | 271.765 | 182.948 | 192.036 | 154.022 | 170.783 | 295.624 | 295.693 | 266.475 | 287.546 | - | 153.481 | 191.754 | 271.693 | 291.437 | 271.416 |
| RU_KAL | 156.162 | 145.631 | 174.837 | 104.951 | 122.244 | 29.494 | 38.617 | 578 | 17.301 | 142.725 | 142.787 | 115.202 | 136.207 | 153.481 | - | 38.311 | 118.773 | 138.524 | 118.488 |
| RU_STP | 182.085 | 135.852 | 160.774 | 72.585 | 90.500 | 8.887 | 1.452 | 37.743 | 21.067 | 107.428 | 107.464 | 84.055 | 104.971 | 191.754 | 38.311 | - | 83.519 | 103.233 | 83.257 |
| SE_M | 261.264 | 189.811 | 199.541 | 17.876 | 31.693 | 92.277 | 83.004 | 118.272 | 104.505 | 23.959 | 24.015 | 5.728 | 26.098 | 271.693 | 118.773 | 83.519 | - | 19.751 | 491 |
| SE_N | 281.008 | 209.450 | 219.125 | 37.526 | 51.143 | 112.007 | 102.755 | 138.002 | 124.219 | 4.214 | 4.270 | 25.222 | 12.068 | 291.437 | 138.524 | 103.233 | 19.751 | - | 20.042 |
| SE_S | 260.987 | 189.408 | 199.144 | 17.492 | 31.333 | 91.987 | 82.719 | 117.982 | 104.215 | 24.257 | 24.313 | 5.731 | 26.389 | 271.416 | 118.488 | 83.257 | 491 | 20.042 | - |

Table 37: Screening of new interconnectors. **Baseline scenario, 2030**. The table shows the total socio-economic benefit of adding one MW of transmission capacity between the different transmission areas in the model. For Russia only two areas have been included: Ru_STP (St. Petersburg area and Ru_Kal (Kaliningrad Area).

# Annex 1: The consultation and presentation process

An important part of the study is a consultation and presentation process where the most relevant stakeholders were involved in formulating relevant topics and discussing preliminary results of the analyses.

This annex gives a short description of the process from May 2008 to June 2009.

## Energy conference: Energy and Climate change: Global Challenges, Regional Solutions, 21 May 2008 in Warsaw, Poland

The conference was organised together with demosEUROPA – Centre for European Strategy and the Royal Danish Embassy in Poland. Over 250 participants, representing stakeholders from the private and public sector and international organisations were participating at the conference. Polish Minister of the Environment Maciej Nowicki and the EU Commissioner Danuta Hübner were among the speakers. The outline of the study and approach of developing two main scenarios for the energy system in the Baltic countries were presented. Furthermore, an article on current situation and future opportunities for the energy sector in the Baltic Sea Region (BSR) was distributed.

It was agreed that the BSR has the potential to become a showcase in energy efficiency for the rest of the world. The region should show leadership and integrity by setting and following examples. The aim is to look at the challenges and opportunities of the Region's energy market and define the added value of regional co-operation. The climate and energy challenges need to be addressed jointly in the region and globally. And the BSR is in a unique position right now to set the agenda and outline solutions as regards to the COP -14 in Poznan and COP-15 in Copenhagen.

## 2nd meeting of the Baltic Sea Parliamentary Conference (BSCP) Working Group on Energy and Climate Change (WG), 22 May 2008 in Tallinn

At this meeting the scope and approach of the study were presented.

During the presentation, the parliamentarians called for closer Baltic Sea regional energy cooperation and supported further development of the scenarios of the Energy Perspectives for the BSR. There was unanimous decision that the region will benefit from the enhanced energy cooperation and it was agreed that concrete scenarios have to be presented during the next meeting of the Working Group. The Working Group encouraged Nordic Council to support the first phase of the study financially as a supplement to the funding from Baltic Development Forum and Fabrikant Mads Clausens Fond, Danfoss.

## 3d meeting of the Baltic Sea Parliamentary Conference (BSPC) WG on Energy and Climate Change and Dinner Debate on the Baltic Sea Region Scenarios for the Transformation to Renewable Energy Sources, co-hosted 20 October 2008 by Nordic Council (NC) and BSPC in the Danish Parliament.

At the meeting the Working Group and specially invited guests, including Mr. Ferreira of the European Parliament welcomed preliminary findings from phase I and expressed a strong support for the further development of scenarios for enhanced energy cooperation in the BSR.

The conclusion of the debate was that in order to become the number one region in the world in energy efficiency, there is a need to have a common understanding, reliable data and trust, as essential preconditions for the energy cooperation in the BSR. Through closer cooperation, the BSR will be able to show how it is possible to provide greater security of energy supply, better use of energy capabilities, greater energy efficiency, more integrated and competitive energy markets, lower $CO_2$ emissions and more renewable energy.

## Meeting of the Joint Platform on Energy and Climate (JPEC), 22 October 2008 in Copenhagen

JPEC was created in 2008 and represents 11 organisations in the BSR such as Baltic Development Forum (BDF), Baltic Sea Parliamentary Committee (BSPC), Council of the Baltic Sea States (CBSS), Union of Baltic Cities (UBC), Baltic Sea States Sub-regional Co-operation (BSSSC), Nordic Council (NC), Nordic Council of Ministers (NCM), CPMR Baltic Sea Commission Energy Workgroup, Baltic Metropoles (BaltMet), Baltic Islands Network B7 and Baltic Assembly (BA) with a view to endorse a joint coordination of activities in the field of energy and climate in the BSR. At the meeting preliminary findings from phase I was presented and discussed.

JPEC supported the ongoing study and the development of different scenarios as a basis for finding ways to improve regional cooperation on Energy and Climate issues in the BSR. According to the views expressed among the members of JPEC, this region is heterogeneous in terms of energy-mix and energy resources. If the different competences and resources are exploited and combined in a clever way the region has a huge energy potential. The study is an instrument for mobilizing different stakeholders to agree on a common agenda. The study can also serve as a tool for strengthening co-operation and implementation of specific projects. It is solid testing ground in providing a common understanding of the challenges, possibilities and added value of the cooperation in the BSR.

## BDF Summit Copenhagen-Malmö, 30 November – 2 December 2008

During the BDF 2008 Summit the results from phase I of the study was discussed at the workshop: *Future scenarios of energy cooperation: combining intelligent regional solutions*. The analyses were presented as two different scenarios for the development of the energy system in the BSR – a Small-tech scenario and a Big-tech scenario. The Small-tech scenario focuses on distributed energy generation, energy savings and efficient utilisation of energy through combined heat and power generation, whereas the Big-tech scenario explores the opportunities of more centralised solutions such as nuclear power and carbon capture and storage (CCS). Wind power is an important part of the energy production in both scenarios and both scenarios comprise a more energy efficient transport sector.

The representatives from the European Commission, Baltic Sea Region Energy Cooperation (BASREC) (represented by the Danish Energy Agency), UBC, BSPC, Vestas, Gasunie, Eestia Energia and Swedbank took part in the discussions. There was an overall agreement that deepening regional cooperation and energy planning can provide a wide range of benefits from technology development, transfer of best practice and benchmarking. The BSR has a potential in becoming a testing ground and frontrunner in innovative solutions and thus to serve as a helpful benchmark for multi-stakeholders in identifying the added value from enhanced regional cooperation. The efficiency improvement and savings, the need to map the potential renewable sources and setting binding targets are very important. The existing, skills, complementarities and resources in the BSR, make this region one of the best regions regarding energy issues and in reaching the 20/20/20 targets. The Danish Prime Minister, Anders Fogh Rasmussen proposed at the Summit that the vision for regional cooperation should be to develop a “Green Valley” of Europe.

## Meeting of the Baltic Sea Region Energy Cooperation (BASREC) Group of Senior Energy Officials (GSEO), 3 December 2009 in Copenhagen.

The focus of this meeting was the discussions about two developed scenarios: Small-tech and Big-tech.

The GSEO called for a combination of small- and big-tech scenarios that take into consideration the policies of different countries around the region. By including existing measures the scenarios could contribute to show what additional measures may be needed. The GSEO also emphasised the importance of showing possible benefits of closer regional cooperation within areas such as wind power planning, interconnectors, demonstration of new technologies and energy markets.

## Baltic Sea Region Energy Cooperation (BASREC) Energy Ministers conference, 17 - 18 February 2009 in Copenhagen.

During the conference it was agreed that energy cooperation in the BSR should be strengthened in order to contribute to the growth and stability in the region, by promoting a sustainable and competitive energy system. In his speech, the Secretary General of the NCM, Mr. Halldor Asgrimsson, informed the energy ministers about the ongoing study on enhanced energy cooperation, which was positively welcomed among the participants. BDF's proposal to convene a multi stakeholders energy conference in the region was favourably received by the chair.

## Breakfast meeting with the European Commissioner for Energy, Mr. Piebalgs, 18 February 2009 in Copenhagen

A short memo on the results of phase I of the study and an outline of phase II was distributed to the Commissioner before the meeting.

Commenting on the study, the Commissioner saw the most interesting regional perspective in the small tech scenario. Still, Carbon Capture and Storage - that is part of the Big Tech scenario - might be necessary in order to utilise the fossil fuel reserves without jeopardising the climate. Mr. Piebalgs expressed his hope that the ongoing work on the study would continue. The positive experience and the best practice of the BSR could even be transferred to other regions in Europe, the Commissioner mentioned.

## The last (5$^{th}$) meeting of the Baltic Sea Parliamentary Conference (BSPC) WG on Energy and Climate Change, 18 May in Berlin

At the meeting the preliminary results from phase II of the study was presented and discussed.

The final report of the WG states that strengthening the capacity to support and coordinate the Baltic Sea regional energy cooperation, as well as developing of an integrated and optimized regional approach to energy issues is more than needed. It is important to take into account the various energy mix of the respective countries and the possibilities for developing cross-border power links.

The final report refers to the study on Energy Perspectives for the BSR and supports the achieved progress. On the basis of the comprehensive hearing of experts and parliamentary discussions, the BSPC WG recommends the following initiatives and measures: Develop a Coherent Energy Strategy for the BSR, launch Action Plans for CHP and Housing Innovation, use the Economic Crisis as an Opportunity, and establish a Regional Educational Approach.

## Energy and Climate seminar: ***Creating a "Green Valley" on top of Europe - Different Scenarios*** with participation of regional ministers, 4 June 2009, Elsinore

The Energy and Climate seminar was organized in connection with the CBSS Ministerial meeting that attracted different stakeholders from the private sector, including energy companies, such as Vestas, Gasunie, E.ON, Dong Energy, consultancy companies: Nidab, Grontmij Carl/Bro and international organisations: NCM, Nordic Energy Research, UBC Energy Commission, BASREC, Nordic Investment Bank.

The preliminary results from phase II of the study was presented and discussed.

Ministers for Foreign Affairs of Denmark, Norway, Finland and Ukraine actively participated in the discussions and gave a strong support for the ongoing study.

The overall conclusion and recommendation of the energy study were that the BSR could benefit both economically and environmentally from closer co-operation in energy planning. Development of a common interconnector strategy for the region would be important to harvest the potential benefits. Similarly, an action plan for efficient and sustainable heating would be important since there were many benefits within these areas. Regional projects in R&D and demonstration projects could also benefit the region as a global showcase. Finally there is a need to establish a common regional training programme in order to promote learn to benefits from better regional energy planning.

A shared regional energy agenda is not easily set and the benefits are not easily exploited. Most stakeholders in the region share, however, the same objectives regarding reduction of Green House Gasses, increase of renewable energies and energy efficiency, as well as the promotion of clean tech solutions. There is a need to develop a shared vision of a Green Valley of Europe and the establishment of an energy stakeholders' forum that includes different cross-border, cross-sector and cross-level actors could be a useful way to proceed.

## Energy workshop: ***Energizing Sustainable Growth***, 10-11 June 2009 in Kaliningrad, Russian Federation

The workshop was organised together with BASREC, NCM Information Office in Kaliningrad and the Government of the Kaliningrad Region of the Russian Federation. Energy Commission of the UBC, as well as Gasunie, took active part in the workshop. Following authorities and companies were representing Russian Federation at the workshop: Ministry of Infrastructure Development of the Kaliningrad Region, Kaliningrad Regional Centre for Energy Efficiency, Administration of the city district of Kaliningrad, State Technical University, INTER RAO (leading exporter and importer of electric power in Russia) and Energy Forecasting Agency in St. Petersburg.

The preliminary results from phase I and phase II of the study were presented.

The workshop welcomed the study as a very useful instrument for a dialogue on future possibilities for enhanced energy system in the BSR. The UBC representative pointed out the importance of common framework for the dialogue between the cities and found the Small-tech scenario very interesting in that context. Closer co-operation in energy planning and in energy grid development was needed. The framework of the EU's BEMIP provided very useful reference for specific projects that included Russia and Kaliningrad Region. Furthermore it came out clearly that there was a need for more information and data on the power generating facilities on the Russian side and energy consumption in Russian regions. This could be a topic in the third phase of the study. It also transpired that there was a need for a common methodology on energy data, including data on $CO_2$ emissions. During the workshop it was proposed to improve expert talks in order to exchange the views in collecting energy data from the North Region of the Russian Federation and common training sessions in energy planning were suggested.

## Meeting of the Baltic Sea Region Energy Cooperation (BASREC) GSEO, 29 June 2009 in Copenhagen.

At the meeting, the results from phase II were presented and a draft report from phase II was distributed for hearing. As a follow up of the meeting and as an input to the future BASREC working plan the following recommendations for phase III of the study have been disseminated to the members of the GSEO:

1. Scenario analyses
2. Baltic Ring of wind
3. Case analyses: Nuclear in the Baltic Sea Region, offshore wind etc.
4. Statistical data for the region
5. Show case Kaliningrad
6. District heating and CHP strategy
7. Financing
8. Education of new energy planners for region
9. Green jobs for the Baltic Sea Region

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