Ea Energy Analyses

Large Scale Wind Power in New Brunswick

- A regional scenario study towards 2025

Summary Report

Prepared by Ea Energy Analyses for the New Brunswick System Operator and the New Brunswick Department of Energy

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1 Summary and key findings

This study examines large-scale wind power development in the Maritimes Area in a regional context and examines how Danish experiences with deployment of large amount of wind power could be utilised in a Canadian context.

The study indicates significant benefits to New Brunswick as well as neighbouring jurisdictions from a deployment of 5,500-7,500 MW of wind power capacity in the Maritimes Area towards 2025. This includes 3,000-4000 MW in New Brunswick, 500-1,500 MW in Prince Edward Island and 2,000-2,500 MW in Nova Scotia. Exploiting this potential for wind power will bring economic benefits to the Maritimes provinces as well as New England. Québec may profit from providing balancing power. Furthermore, wind power deployment will contribute to the security of supply of the region, it will be part of a climate change strategy, and it may bring benefits to the local environment by reducing air pollution.

The reasons for these benefits are several:

- New Brunswick and the Maritimes Area have very good wind resources, yielding wind power capacity factors of up to 40 percent
- The current fuel price level provides a strong incentive to invest in technologies with low or no fuel costs. Wind power generation in the Maritimes will mainly replace production from existing oil or gas fired power plants with low efficiency in the region
- Carbon regulation and Renewable Portfolio Standards in the regions improve the competitiveness of wind power and provide security of demand for wind power and other non carbon emitting technologies
- Electricity demand is projected to continue to grow in the region in a situation where it is difficult to find sites for new generation capacity in New England, including coal power plants, nuclear power and wind power plants

The potential of 5,500-7,500 MW wind power is attractive to develop in a fuel price scenario of 120 USD per bbl crude oil, as well as a fuel prices scenario in the order of 60 USD per bbl. In the case of low fuel prices CO2-regulation and Renewable Energy Portfolio standards will become the main economic drivers for the wind development.

In order to maximise the value of wind power in the electricity market and to provide balancing power at reasonable costs, a high level of cooperation between the markets in the Maritimes Area and the neighbouring systems of New England and Québec is essential. This applies to the day to day operation of systems and markets as well as to the long-term planning for new wind power capacity and new infrastructure. Further studies of load flows and the dynamic behaviour of the electricity system will be needed as part of the deployment process.

Efficient utilization of the existing transmission grid in the region allows for large scale integration of wind power. However, with increasing wind power penetration the study indicates that it will be economically attractive to increase the transmission capacity between the electricity systems within the Maritimes Area as well as to load centres in New England.

Danish experiences from developing an energy system with a large amount of wind power show that the following measures are required in order to harvest the full benefits of a large-scale deployment of wind power:

- Preparing a comprehensive wind development plan for New Brunswick (and the Maritimes), including
  - long-term targets for wind power
  - proper physical planning to develop sites with good wind conditions
  - regulation ensuring that grid access is provided at reasonable costs not disfavouring wind power as a fluctuating energy source
  - a strategy on how to harvest industrial benefits of large-scale wind power
  - A strategy for incentives to invest in wind power, including a strategy for local involvement and ownership. A key question concerns what role the government of New Brunswick, the utilities and electricity consumers of New Brunswick should play with respect to stimulating investments in new wind power capacity. Looking at mechanisms whereby electricity consumers and wind power developers share the risks and benefits of the large investments required is recommended.
- Revising existing market design and restructure the market to allow for a higher level of competition and more efficient utilization of capacity within New Brunswick and across interconnectors.
- Improving the integration of the electricity markets in the Maritimes and the neighbouring systems of New England and Québec in order to maximise the value of the wind power in the region and to provide balancing power. The long term goal should be an efficient market coupling between the markets or even a common electricity market
- Continuing the restructuring process for the electricity sector in New Brunswick, including the evolvement of a strong system operator able to integrate wind power into the system and being engaged in comprehensive long-term system planning together with research, development and demonstration activities. As part of this process it should be considered to establish a transmission system operator with ownership of the transmission grid and interconnectors.
- Strengthening the efforts in development of the energy cooperation with neighbouring provinces and states, including development of a regional transmission expansion plan. A regional energy study could be one of the tools for evolving a common understanding of the challenges and possibilities for the future energy system in the North eastern part of North America.

These measures will not evolve by themselves. Strong political leadership and cooperation is needed throughout the region and particularly in Atlantic Canada. In New Brunswick, given the evolution of renewables, rising cost of fossil fuels and the experience to date with market re-regulation since 2004, the present situation calls for the political will to effect further restructuring in the electricity sector that supports the notions of the providing New Brunswickers with reliable, reasonably priced and environmentally sustainable supply of electricity and promoting the ability for the province to host additional generation development for the benefit of domestic and regional markets.

A firm strategy for a true market opening process will be needed, allowing for more market players, more liquidity in the market and more transparent electricity prices. Such strategy cannot be achieved without a regional consensus at the political level on the future path to evolve the whole energy system in the region.

The integration of large amount of wind power in the Maritimes is not possible without a close cooperation with the neighbouring systems on balancing, market rules, utilization of interconnectors and the establishing of new transmission lines. The development of the regional cooperation requires a strong effort from political level as well as from the system operators in the region. We recommend an open process with an extensive dialogue with all relevant stakeholders in New Brunswick and in the region as a whole with the New Brunswick Department of Energy as spearhead for this process.

The implementation of most of the above mentioned measures will not only benefit wind power integration. It will also facilitate the whole New Brunswick vision for an energy hub and help it realize its full potential.

At present a window of opportunity has emerged in the Maritimes area to benefit from the challenges in the energy supply and the need for changing the existing energy system. This window will not be open forever. Therefore firm strategies and quick response are needed at all levels to make it possible to harvest all the potential benefits from a large-scale wind power development.

2 Introduction

The government of New Brunswick has adopted a strategy to develop the province into an energy hub. This decision is among other things based on the abundant wind resource of the province, which could improve the security of supply of the province and meet the growing demand for electricity in neighbouring regions, especially the New England states.

This study was commissioned by the New Brunswick System Operator (NBSO) and the New Brunswick Department of Energy (DOE) from Ea Energy Analyses as part of a multi-phase process of examining the methods, impacts, costs and benefits of wind power integration in New Brunswick and the Maritimes. In the process, the Danish utility SEAS-NVE also participated.

This report consists of three main parts:

- A description of the regional scenario analyses exploring the opportunities for wind power in the analysed region, i.e., the Maritimes Area, New England and Québec.
- A presentation of the experience in wind power development in Denmark.
- A list of recommendations on wind power deployment to the NBSO and the New Brunswick DOE

More details on the scenario analyses are available in the scenario analysis report: "Scenario Analyses for the Electricity Markets of the Maritimes and New England".

First, a brief introduction to the electricity systems in the region is given.

Wind power status

Currently, wind power only plays a marginal role in the region consisting of the Maritimes Area and Québec in Canada and states of New England in the US. Some 150 MW of capacity is in place in the Maritimes at present, but existing policies and targets could increase this tenfold within the next decade. In Québec more than 400 MW of wind capacity were installed by May 2008 with a target of 4,000 MW for 2016. The region of New England holds about 50 MW of wind capacity now, but could see this amount increased very considerably in the years to come – in part as a response to the Renewable Portfolio Standard (RPS) requirements of the states in New England.

Generation mix and electricity demand

In New Brunswick, power generation consists of a mix of coal, oil, gas, hydro and nuclear capacity. In New England, natural gas is the dominant energy source for power generation, supplemented by coal, oil-fired capacity, nuclear and hydro. Electricity generation in Québec is close to 100 percent reliant on hydro power.

In terms of electricity demand, the provinces of the Maritimes Area are significantly smaller than Québec and New England (see Table 1).

TWh	New Brunswick*	Nova Scotia	Québec	New England
Annual electricity demand	17	13	188	127

Table 1: Present electricity demand (TWh). *Including Prince Edward Island and Northern Maine

New Brunswick has interconnections to Prince Edward Island, Nova Scotia, Québec and New England. New England and Québec are also interconnected. The differences in generation portfolios in the systems create potential benefits to be gained from regional electricity trade between the systems.

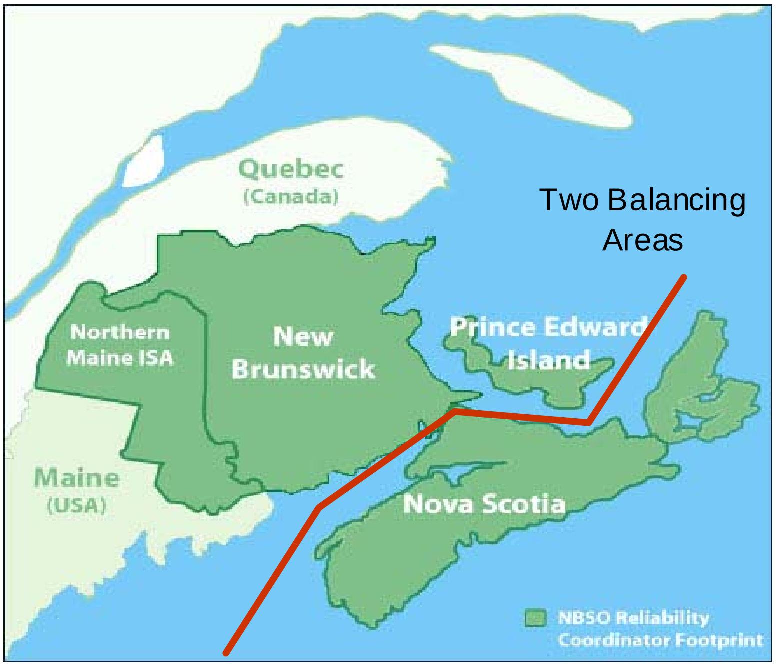


Figure 1: The Maritimes Area

Market setup

In principle, cross-border trade is driven by price differences. If the price in an adjacent area is higher, it is profitable for producers to export to that area. If the price in an adjacent area is lower, it is profitable for consumers to import from that area instead. At present the different markets of the region are not fully integrated and long term capacity reservations on the interconnectors to certain market players have the effect of limiting the exchange of electricity between the regions.

Moreover, in the case of New Brunswick the market for electricity is dominated by one company, NB Power owning almost all generation capacity (through NB GenCo/NB Nuclear Power), the transmission system (through NB TransCo) and the distribution and supply system (through NB Disco). This limits the access to the market for new players.

The independent company NBSO is responsible for system operation and market development and facilitation.

Large consumers (industry) have access to the market, but they have not yet exploited this opportunity.

Environmental regulation

In Canada it is being proposed that all major power producing entities will be required to reduce their CO_2 emissions intensity by 18 percent of the 2006 levels by 2010, with 2 percent continuous improvement every year after that, according to the federal Regulatory Framework for Industrial Greenhouse Gas Emissions.

As inter-firm trading is allowed, the scheme works on a similar basis as the RGGI (Regional Greenhouse Gas Initiative) cap and trade system, which will be in place in New England from 2009. RGGI limits CO_2 emissions to recent historic levels in the period 2009-2014 and requires 10 percent reduction towards 2018.

Renewable energy is promoted in all regions mainly through renewable energy portfolio standards. New Brunswick's Renewable Portfolio Standard requires that 10 percent of the province electricity must come from renewable sources by 2016. In New England, renewable energy policies are in place to increase the share of renewables from approximately 5 percent today to 14 percent in 2016.

3 Regional wind scenario analyses

As a key part of the present study, scenarios are developed towards 2025 exploring the development of the electricity markets in the region. The scenarios focus specifically on the perspective of large-scale wind power integration in New Brunswick and the Maritimes.

Since wind power integration and the development of the electricity system and market in New Brunswick are closely connected to the developments in the neighbouring regions, a simulation of the electricity systems in the Maritimes, New England and Québec areas is carried out.

The simulation considers all power generation capacity in the systems as well as important bottlenecks in the transmission grid. Generalised data on power plants and constraints in the transmission system was supplied by among others the NBSO, the US DOE and the Independent System Operator of New England (ISO-NE).

Modelling tool

For the quantitative analyses, the Balmorel model is applied[1]. In addition to simulating the electricity systems, the Balmorel model estimates electricity prices and is capable of assessing the impact of environmental regulation such as markets for green certificates and emission trading schemes.

The model takes a combined technical and economic approach. Balance between load and generation is ensured within each defined transmission sub region. It takes account of the most important transmission constraints. 624 time steps are used efficiently to represent seasonal, daily and hourly variations in load, intermittent generation etc. The system related costs of wind power intermittency are thus internalised in the model, but not the residual cost element due to forecast uncertainty.

The model does not replace the need for load flow and stability network analyses. This type of analyses require even more detailed information, such as to where specific turbines and farms are to be connected and as such is an activity which merits continuous attention by the responsible ISO or TSO, as system planning and operations activities.

In contrast to many other electricity system models, the Balmorel model makes suggestions for optimal investments in new generating capacity assuming well-functioning markets and full competition among power producers. In the present study, this feature of the model is used to analyse how the electricity systems may evolve in the future taking into consideration different framework conditions.

Four wind power policy scenarios

The quantitative analyses of the different development options in New Brunswick and the neighbouring regions have been approached by analysing four different wind power policy scenarios.

[1] Details on the model are available on www.balmorel.com.

Passive Scenario	Active Scenario	Transmission Scenario	Proactive Scenario
Passive wind power policies, e.g. with respect to physical planning, limits the usable wind power potential to 1,000 MW in the Maritimes Area.	An active policy to pursue wind power allows for exploitation of the physical potential of app. 16,500 MW in the Maritimes Area.	As the active scenario, plus increased transmission capacity within the Maritimes Area and to New England.	As the transmission scenario, plus harmonisation of environmental regulation and removal of trade barriers on interconnectors.

In the Passive Scenario it is assumed that wind power capacity in the Maritimes Area may not be developed beyond 1,000 MW e.g. due to planning constraints or grid access issues. In the Active Scenario policies are implemented allowing for the possible exploitation of up to 16,500 MW of wind capacity in the Maritimes Area, including 5,500 MW in New Brunswick[2].

In the Transmission Scenario the electric transmission capacity within the Maritimes Area and to New England is expanded to allow for more wind power. The transmission capacity from New Brunswick to the Boston area is assumed to be increased 1,500 MW by a HVDC connection passing through Maine. The AC interconnection to Nova Scotia is increased by 1,000 MW and to Prince Edward Island and Northern Maine by 600 MW. In the Proactive Scenario, in addition to the above, the environmental regulation is harmonised allowing renewable energy certificates and CO_2 quotas to be sold freely across systems. Moreover, existing tariffs on using interconnectors between New Brunswick and neighbouring areas are removed, thus stimulating more trade.

3.1 Key assumptions

The assumptions used in the study – regarding for example the development in electricity demand and fuel prices – have been determined in cooperation with the NBSO. Table 2 summarises the most important assumptions.

[2] The technical wind power potential – considering planning constraints and the available wind resource – has been identified to be 40,000 MW for New Brunswick only (Gagnon, 2008), but for reasons of conservatism we constrain the total potential to 16,500 MW for the Maritimes region in this study.

<table>
<tr><td>Fuel prices</td><td>Fuel prices are based on the prices observed in the first months of 2008, i.e. an oil price of just above 120 USD/barrel. Based on observed crude oil contracts from NYMEX, it is assumed that this price level will prevail over the period.

<table>
<tr><th></th><th>Oil (USD/barrel)</th><th>Natural gas (USD/Mbtu)</th><th>Coal (USD/ton)</th></tr>
<tr><td>2008</td><td>123</td><td>12.4</td><td>91</td></tr>
<tr><td>2015</td><td>116</td><td>11.1</td><td>86</td></tr>
<tr><td>2025</td><td>123</td><td>11.6</td><td>90</td></tr>
</table>
Fuel prices used in the study

Moreover, a sensitivity analysis is made with lower prices (60 USD/barrel of oil).</td></tr>
<tr><td>Electricity demand</td><td>For the region as a whole, the demand for electricity is expected to increase by 25 % from 2010 to 2025 as indicated by official projections. This corresponds to an annual increase of 1.3 %.
Electricity consumption is forecasted to grow slightly faster in New England than in the Maritimes Area.</td></tr>
<tr><td>Decommissioning of power plants</td><td>No decommissioning of power plants is assumed until 2015. In the period from 2015 to 2025, 5 percent of all thermal power plants are presumed to be decommissioned annually.</td></tr>
<tr><td>Environmental regulation</td><td>Existing and planned regulation regarding CO_2 and renewables is assumed to be enforced and prolonged to 2025 following current trends.</td></tr>
<tr><td>Sites for new power plants</td><td>Siting new coal and nuclear power plants is considered to be difficult. In New England, up to 2025, the model is only allowed to refurbish coal capacity which exists today and to establish 3.6 GW additional nuclear capacity. Wind power development in New England is confined to about 3,100 MW including two large-scale off-shore wind farms.</td></tr>
<tr><td>Wind power capacity factor (CF)</td><td>New Brunswick, Nova Scotia and Prince Edward Island: Each area has a potential of 500 MW with a capacity factor (CF) of 40%, 500 MW with a CF of 39 %, 500 MW with a CF of 38 % and etc. The total potential for each area is 5,500 MW. Therefore, there is a total wind potential of 16,500 MW with capacity factors ranging from 30 to 40%.
New England: Onshore: 32 % CF, Off-shore: 46 % CF.</td></tr>
</table>

Table 2: Key assumptions in the study

It should be noticed that investments in Québec are not explicitly modelled in the study. For Québec, a development in new hydro and wind power has been assumed; generating a surplus of 10 TWh per year from 2015 to be exported to New England and the Maritimes Area. This assumption is based on historical exports and prospective imports, but is less than the full potential. Actual annual volumes will depend upon market conditions (in Ontario, New

York and New England), load growth in Québec, and on the actual development of generation projects in Québec. On an hourly and daily basis the model allows Québec to be a net-importer or net-exporter depending on the benefits of trading with neighbouring countries.

Technology data is based on the New England scenario study published in August 2007 (ISO New England, 2008). Figure 2 compares the long-run marginal costs of six of the key technologies applying the above fuel prices and including a cost of CO_2 of 20 CAD/ton. An internal rate of return of 10 percent (real) is assumed in the calculation.

Due to the relatively high fuel prices – compared to the recent decades – nuclear power and wind power appear to be the most competitive technologies.

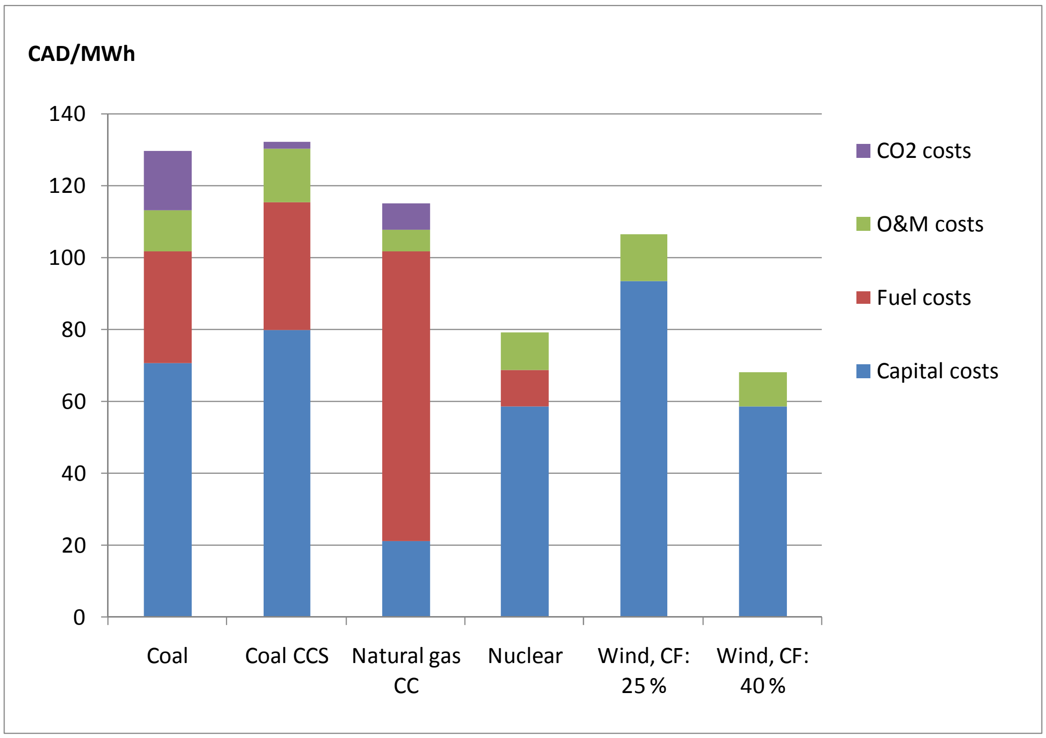


Figure 2: Comparison of long-run marginal costs of new power generation technologies (CAD/MWh). CCS: Carbon Capture and Storage, CC: Combined Cycle, CF: Capacity Factor. Two onshore wind power plants are included in the comparison with capacity factors of 25 percent and 40 percent respectively.

For the conversion from US dollars to Canadian dollars an exchange rate of 1:1 has been applied.

3.2 Results

In this section, the main results of the scenario analyses are summarized. We focus on the results from the Passive Scenario – where wind power in the Maritimes is restricted to 1,000 MW - and the Proactive Scenario, where it is possible to invest in a total of 15,000 MW of wind power capacity, additional transmission, harmonized environmental constraints, and removal of trade barriers.

More comprehensive results are available in the scenario background report, including details on operational issues.

Figure 3 shows the investments in new generation capacity in the two scenarios as selected by the optimization model.

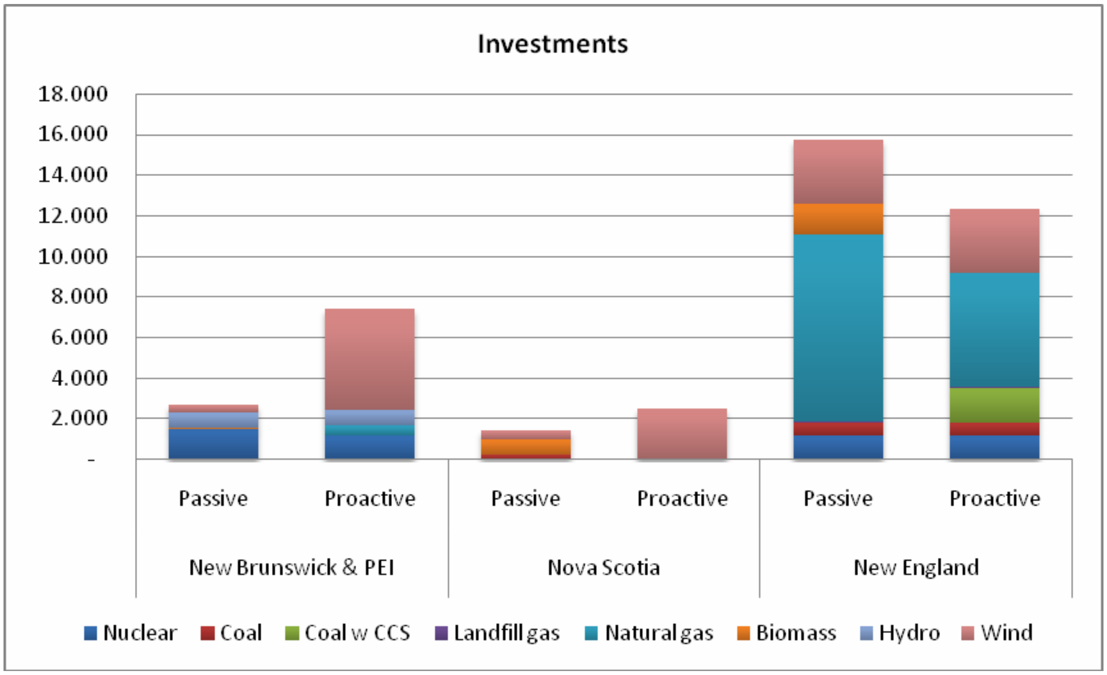


Figure 3: Investments in generation capacity in Maritimes Area and in New England in the period 2010 – 2025 (MW)

Investments in the Maritimes

In the Passive Scenario investments in the Maritimes consist of new nuclear power in New Brunswick (1,230 MW), significant amounts of biomass capacity, some gas capacity and wind power capacity up to 1,000 MW (the limit in the scenario).

Moreover, 740 MW of hydro power capacity is assumed to be imported into New Brunswick from Lower Churchill Falls in Labrador. This option is imposed on the model. The feasibility of the Lower Churchill Falls project has not been determined in the present study.

In the Proactive Scenario, the economic optimization model shows that it is feasible to invest in about 7,500 MW of wind capacity in the Maritimes Area. The remaining investments in the Passive scenario are unaltered in the Proactive scenario except for the biomass capacity, which is no longer feasible with the increasing penetration of wind power in the system. Because of the superior access to transmit power to New England, the majority of the investments in wind power, 5,000 MW, are made in the area of New Brunswick and Prince Edward Island and 2500 MW in Nova Scotia.

Investments in New England

In New England, siting issues are assumed to limit the growth of onshore wind by assumption to 1,100 MW and the offshore potential to 2,000 MW in total (1,000 MW off the coast of

Maine and 1,000 MW off South-eastern Massachusetts). Because of the high fuel prices, the model shows that it is attractive to upgrade and replace older and less efficient natural gas and oil-fired generation capacity with newer, more efficient combined cycle technology. These potentials are fully utilized in the passive as well as in the proactive scenario. Moreover, the model shows that it is attractive to invest in additional 3,600 MW nuclear capacity (the limit in the scenario).

All in all, around 3,000 MW fewer investments are made in the New England area in the proactive scenario compared to the passive scenario. The reason is that imports from the Maritimes Area are increased significantly due to the higher penetration of wind power and the fact that transmission capacity is increased and trade barriers between systems in the form of tariffs are removed in the Proactive Scenario.

Figure 4 shows the generation of electricity in the Maritimes and New England areas in 2025 compared to generation in 2010 (passive scenario). The major difference between the passive and the proactive scenario is less generation from natural gas and biomass in the proactive scenario and more wind generation. In the Proactive Scenario by 2025 18 percent of electricity generation in New England and the Maritimes is wind power.

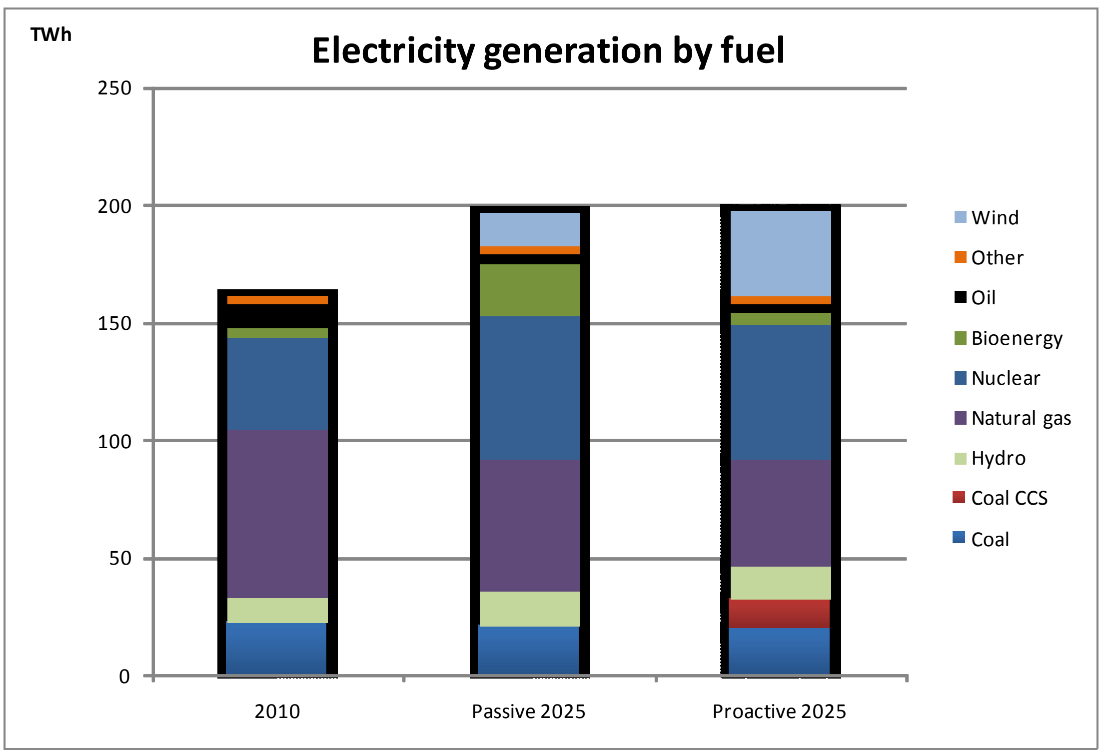


Figure 4: Total electricity generation by fuel source in the Maritimes Area and New England in 2010 (Passive Scenario) and the Passive Scenario and the Proactive Scenario for 2025

CO_2 emissions

The total sum of CO_2 emissions in the Maritimes and New England areas does not reach the total sum of the caps either in the Passive Scenario or the Proactive Scenario in the whole scenario period stretching from 2010 to 2025. However, in the passive scenario, where the CO_2 quotas are not traded across Canada and the US, of the years studied (2010, 2015, 2020 and 2025), the cap is binding in the Maritimes Area in years 2010 and 2015.

The relatively high fuel prices explain why the total CO_2 cap does not become more binding. With a price of oil above 120 USD/bbl it is attractive to shift to less carbon-intensive generation technology regardless of the CO_2 regulation.

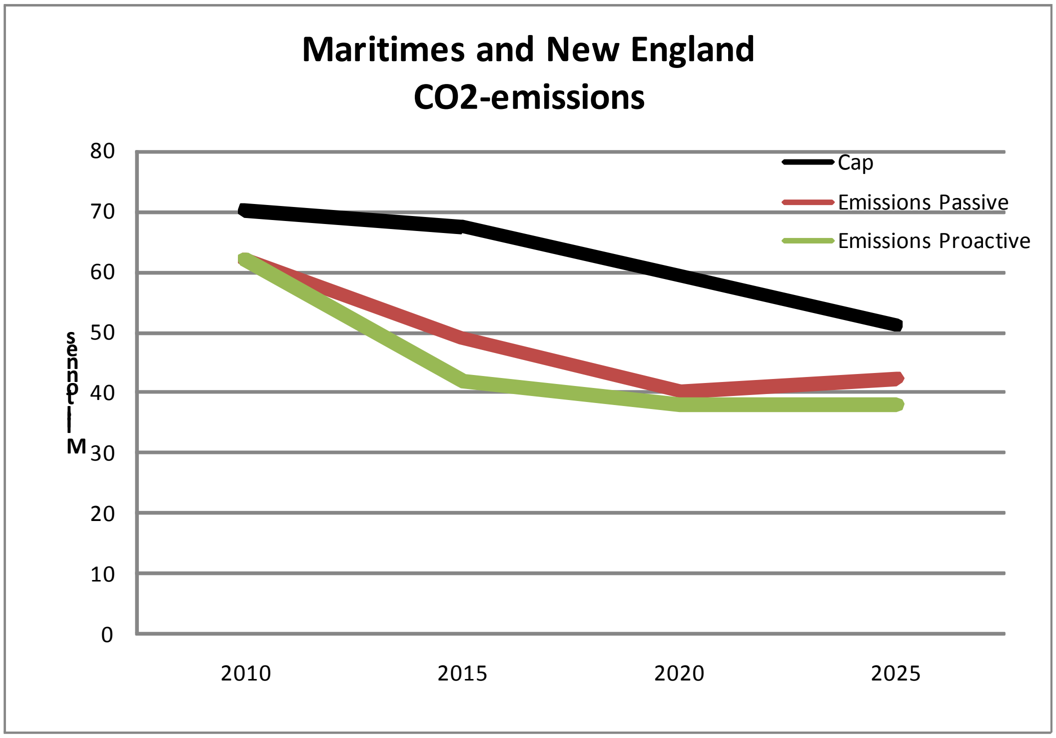


Figure 5: Total CO_2 emissions from power plants in the Maritimes Area and New England in the Passive Scenario and the Proactive Scenario compared to the total cap for the area.

Renewables requirements

In the Passive Scenario, the RPS requirements become binding in 2020 and 2025, but not in the Proactive Scenario, where the cost-competitive wind resources in the Maritimes are released to the market.

Electricity prices

Investing in new generation capacity will affect electricity prices in the long run. The current mix of generation facilities are not competitive in a world with oil prices at 120$/bbl. Wind power is particularly competitive where good sites are available. Wind power connected to hydro power is the strongest combination. Electricity prices in the Proactive scenario develop so that the prices are lowest where the wind power is generated. Therefore electricity prices in the Maritimes provinces can be expected to become lower in a future with much wind power than otherwise. Congestion in the system causes the prices in New England to find a level based on generation costs of old and new natural gas fired units. Gas remains on the margin in New England, but with higher average efficiency than today.

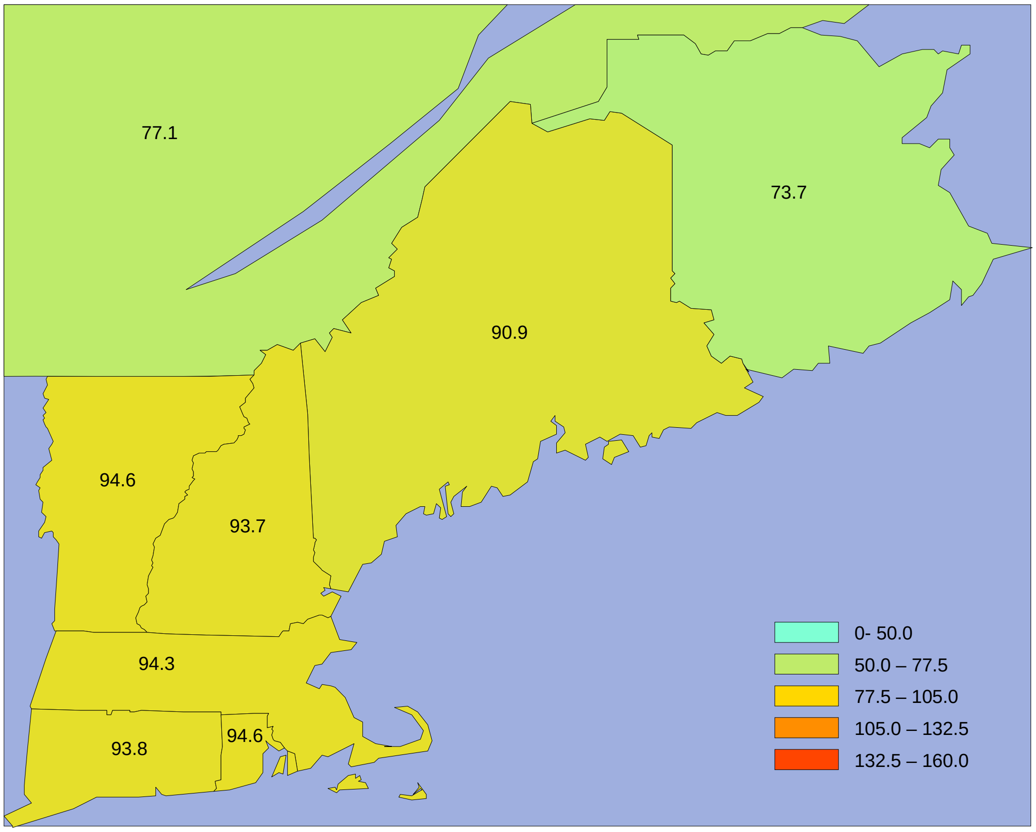


Figure 6: Consumption weighted average marginal electricity values (prices) in the Proactive scenario in 2025.

Economic results

In all three alternative policy scenarios, there is a total economic benefit for the region and for New Brunswick compared to the Passive Scenario. The benefit for the whole region is in the range of 4.0 to 6.5 billion CAD, and the benefit for New Brunswick is in the range of 1.1 to 2.1 billion CAD (highest in the Proactive scenario).

The table below shows the costs and benefits in the Proactive Scenario compared to the Passive Scenario. In order to calculate the net present value of the benefits to society of the investments and operations, all cost streams have been discounted to 2008 using a discount rate of 6 percent.

	New Brunswick & PEI	Nova Scotia	Quebec	New England	Total
Saved costs	-12.9	-1.1	0.0	20.9	6.9
- fuel	-3.3	1.5	0.0	16.3	14.4
- variable O&M	-0.5	-0.1	0.0	0.4	-0.1
- fixed O&M	-0.9	-0.1	0.0	0.8	-0.2
- capital costs	-8.2	-2.4	0.0	3.4	-7.2
Improved trade balance	15.0	2.9	0.4	-18.8	-0.4
Sum	2.1	1.9	0.4	2.1	6.5
Investment transmission					**-1.5**
Total					**5.0**

Table 3: Costs and Benefits of the Proactive Scenario in relation to the Passive Scenario in the period 2010-2025 (billion CAD) Future cost streams have been discounted to Net Present Value (2008) using a discount rate of 6 percent p.a. [1]Including Prince Edward Island.

The Proactive Scenario features higher capital costs than the Passive Scenario due to the investments in capital-intensive technologies, which on the other hand leads to a significant reduction in fuel costs.

The trade balance shows the value of the electricity which is exported/imported across the region. Had the model not included exchange of electricity with regions outside the analyzed system (New York is modelled by a price interface), the trade balance would sum to zero.

Nova Scotia and in particular New Brunswick improve their trade balances in the Proactive Scenario as they increase their exports significantly. On the other hand, the capital costs – to pay for investments in wind power capacity – are increased in these systems. In New England the situation is reverse.

Québec is not modelled as detailed as the other areas in the region. However, the simulations indicate that Québec is able to profit significantly from balancing wind power with hydro power.

Removing bottle-necks

The study indicates that there may be significant benefits from expanding the transmission capacity between New Brunswick and the load centres in the southern part of New England. Table 4 shows the estimated costs and benefits of the transmission expansions which are included in the Transmission Scenario and the Proactive Scenario. The cost-benefit analysis does not value potential additional benefits to the security of supply or synergies related to the acquisition of ancillary services between system areas.

	Costs	Benefits	Sum
New Brunswick <=> Boston + 1,500 MW, HVDC (600 km)	-1.05		
New Brunswick <=> Nova Scotia, + 1,000 MW, 345 kV AC (100 km)	-0.15		
New Brunswick <=> Northern Maine, + 600 MW, 345 kV AC (100 km)	-0.15		
New Brunswick <=> PEI, + 600 MW, 345 kV AC, (100 km)	-0.15		
Sum	-1.5	2.3	0.8

Table 4: Cost and benefits of extending the transmission system (billion CAD). Costs and benefits of the interconnectors are accounted for in period 2010-2025 and discounted to Net Present Value using a discount rate of 6 percent p.a. An economic life time of 30 years is assumed for the investments in the transmission system. The benefits are worked out as the total benefits of the two transmission expansions by comparing the economics of the Active Scenario and the Transmission Scenario.

Sensitivity analyses – low fuel prices

Fuel prices are a critical assumption in any scenario analysis of the electricity sector. For this reason, a sensitivity analysis where fuel prices are in line with the latest official projections from the International Energy Agency's World Energy Outlook (crude oil price decreasing to about 60 USD/bbl) has also been made.

Even in this case, the economic optimisation model shows that it is attractive to invest in significant amounts of wind power capacity in the Maritimes Area, approximately 6,100 MW until 2025. However, in the case of low fuel prices, the CO_2 regulation and the renewable energy portfolio standards will become the important economic drivers for the wind development.

3.3 Main conclusions from scenario analyses

The scenario analyses of the electricity systems in the Maritimes Area, New England and Québec demonstrate that it is economically feasible to develop 5,500-7,500 MW of wind power capacity in the Maritimes Area, including 3,500-5,500 MW in the area consisting of New Brunswick and Prince Edward Island and 2,000-2,500 MW in Nova Scotia. Exploiting this wind potential will bring economic benefits to New Brunswick as well as to Nova Scotia and New England.

Developing wind power in this order of magnitude is economically attractive with the current high fuel prices as well as with lower fuel prices in the order of 60 USD/bbl. In the case of low fuel prices, CO_2-regulation and Renewable Energy Portfolio standards will become the main economic drivers for the wind development.

4 Danish experience in wind power development

Since the 1980s there has been a steady growth in the wind power capacity in Denmark. At this point in time, more than 3,000 MW of wind power capacity is installed covering about 20 percent of total Danish electricity consumption. An additional 1,300 MW is planned to be installed within the next five years and in 2025 the government plans to increase the share of wind power to 6,000-6,500 MW corresponding to 50 percent of electricity demand.

At the same time Denmark has been able to build an extensive industry around wind power hosting companies such as Vestas, Siemens Wind Power and LM Glasfiber. In 2007, the exports of the Danish wind power industry totalled about seven billion CAD.

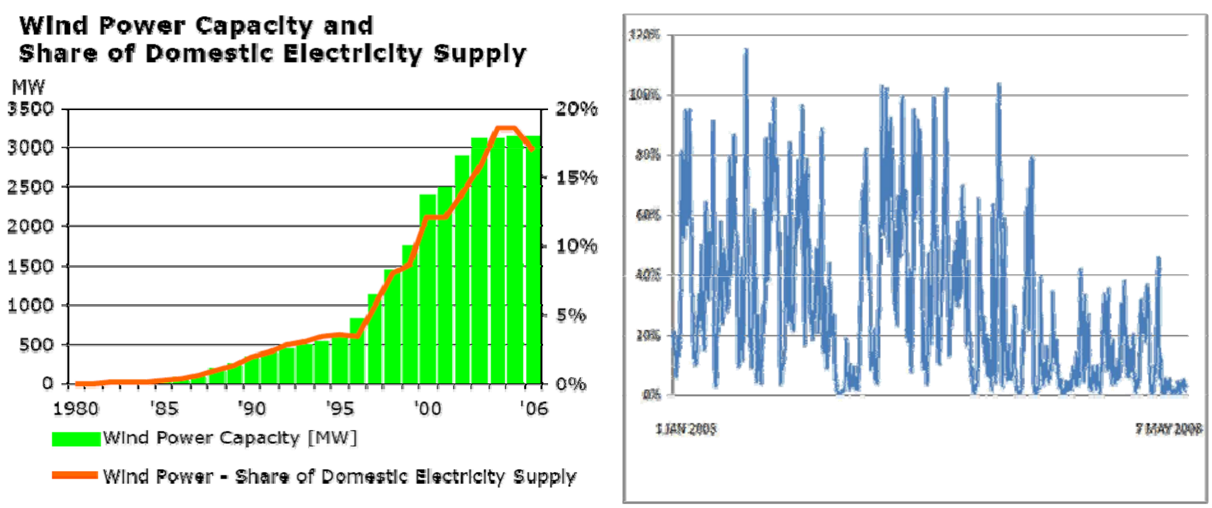


Figure 7: Left: Development in wind in Denmark 1980-2006 measured as installed capacity (MW) and generation as percentage of total electricity consumption. Right: Wind power's share of electricity consumption in the western part of Denmark in the period 1 Jan 2000 to 7 May 2008, hourly measurements.

The physical characteristics of the electricity systems in the Maritimes Area and in Denmark resemble each other to a high degree. Therefore Denmark provides a good learning case on wind power development and integration for New Brunswick and the Maritimes Area. The electricity consumption in the Maritimes Area is approximately the same size as in Denmark, both areas have access to neighbouring large-scale hydro power system (Québec and Norway/Sweden) and interconnections to large load centres (New England and Germany). Moreover both areas have good wind resources (see Figure 8).

4.1 The Danish lessons

Denmark has a long tradition – going back more than 30 years – for broad political alliances on energy policies. New policies have typically been negotiated in a transparent way including the majority of the political parties and with a high level of stakeholder involvement.

Wind power has had strong political support in Denmark since the oil crises in the 1970s. In the first phase, the key drivers were self-sufficiency and security of supply. In the two last decades wind power has been viewed as an important tool to reduce domestic CO_2 emissions as well.

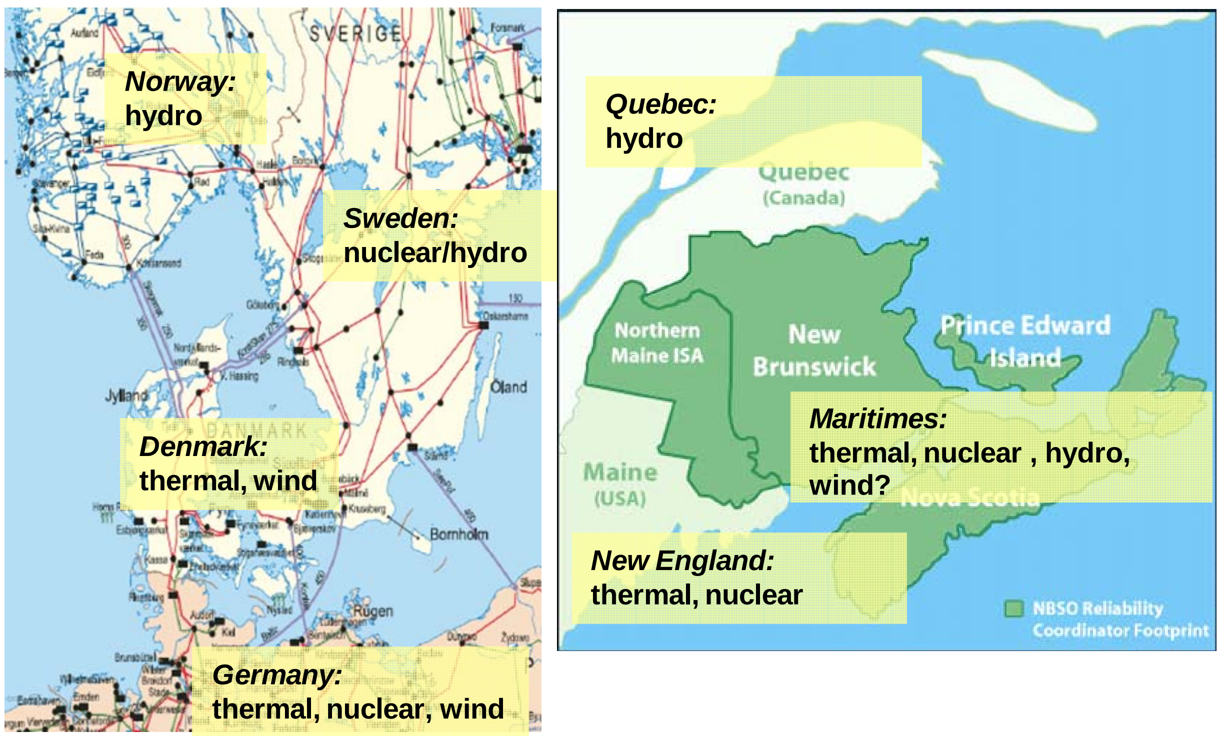


Figure 8: Maps of the Nordic-German electricity system and the Maritimes-Québec-New England area with indication of the dominant fuels for electricity generation.

A number of concrete measures have been essential for the development of wind energy in Denmark, including financial support schemes, grid access, physical planning, development of a well-functioning market, a pro-active system operator, local involvement and ownership and strong research development and demonstration efforts. The Danish experience on each of these issues is briefly dealt with in the following sections.

Financial support schemes

A range of different support schemes have been used to support wind power development in Denmark. In the 1980s, when wind power was still a rather immature technology, turbines were supported through investment subsides, feed-in tariffs and tax incentives. Subsequently, as the cost of wind power plants decreased, the investment subsidies were abandoned and the support schemes were revised to fit the framework of the liberalised electricity sector.

Today, onshore wind power receives a premium of 50 CAD/MWh on top of the price, which the owner of the turbine can obtain in the electricity market. Offshore wind farms are put up for tender on specific sites competing for the lowest fixed electricity price. The most recent off-shore tenders have yielded prices between 100 and 120 CAD/MWh.

The support for wind power is financed by the Danish electricity consumers and can be viewed upon as a risk sharing mechanism between producers and consumers. Though wind power is competitive with more conventional types of generation (compare with Figure 2, p. 14) its high capital costs poses a significant barrier taking into consideration the inherent risks in the electricity market. A fixed price for wind power generation gives producers certainty about future revenue and at the same protects consumers against high electricity prices in the future.

A well-functioning day ahead and real-time market

Denmark benefits from a high degree of cooperation with neighbouring countries. In the liberalised Nordic electricity market, power is traded on a common exchange, Nord Pool, to ensure optimal dispatching of generators. Denmark has strong interconnectors to neighbouring countries, and within the Nordic area all transmission capacity is made available to the electricity spot market.

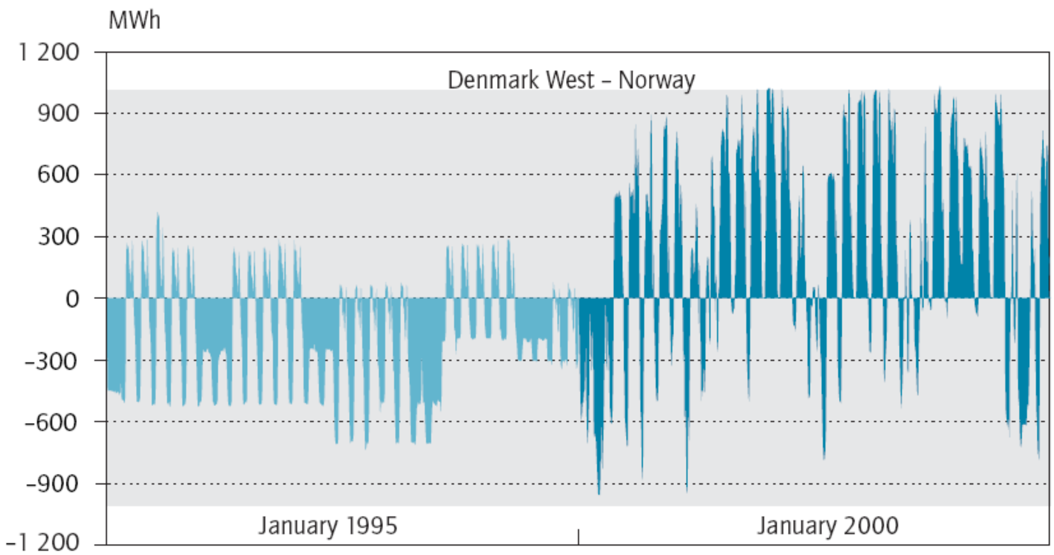
The market mechanism ensures that hydro power plants and thermal power plants have incentives to respond to the variations in wind power generation in a flexible manner.

Balancing power is traded on a least-cost basis across system areas in the hour of operation. This is done according to agreements between the Nordic transmission system operators. In Denmark, the actual balancing costs – based on the prices in the market for balancing power – are approximately 3.5 CAD/MWh

The common Nordic market has been of benefit to all the involved countries, not only regarding wind integration, but to the general electricity system and to the consumers as a whole. It has been developed during the recent 15 years as a long process with strong and sustained political commitment, extensive and detailed preparation, and continuous development to allow for necessary improvements.

One of government's most decisive roles was to establish a framework that allows for the development of effective competition. The first step was to break down the monopolies that existed in traditional vertically integrated utilities. Transmission network activities were separated from all commercial activities through true ownership unbundling. Networks and system operation are natural monopolies and should be subject to economic regulation, whereas generation and sales should be subject to competition.

In countries, where electricity markets have been liberalized, some of the consequences of have been a reduction in over capacity on the generation side (power plants being mothballed) and increased trade, resulting in increased utilization of the transmission system and interconnectors. Previously, power was mostly traded between utilities according to long-term contracts for so-called firm power. With the introduction of the market, the power flows according to short term price signals. This change is reflected in the figure below, showing the exchange of power between Western Denmark and Norway before and after the liberalization of the electricity market in Denmark.



Positive numbers are import and negative numbers are export; the shaded area marks the rated capacity of the interconnectors. (1,000 MW in 1995 and in 2000). (Source: Energinet.dk)

Creating a level playing field and developing effective, competitive market places requires establishing detailed market rules, design and regulation. There is one common feature of all successful markets: some sort of formal price quotation, conceived through formal market design. In this respect market operation is needed. Trading hubs may be organized by private companies, but in many jurisdictions the system operators are responsible for the daily market operation. In context of the Nordic countries, the common power exchange Nord Pool Spot, operating the Nordic day-ahead market, is jointly owned by the national transmission system operators.

Furthermore, with a decentralized decision-making process transparency is a prerequisite for achieving efficiency gains. Transparency improves the decision-making framework for all actors – policy makers, industry and consumers alike. Competitive market players do not voluntarily collect and publish fundamental market data and statistics. Therefore, it is important to redefine responsibility for this necessary task in liberalized markets. Increased transparency is a proven, strong instrument to ensure continuous development towards more effective markets. In the Nordic countries the transmission system operators have played an important role in ensuring the transparency in the electricity market.

Market concentration remains a serious concern in several electricity markets. Effective markets and transparency have been vital to easing access for new-comers. In addition, extending markets across countries and regions helps enable the “import of competition”; this is particularly important in smaller jurisdictions in which the need for consolidation limits the number of market players that can operate efficiently. In Europe the energy regulators have the role of monitoring the market concentration, assisted by the system operators.

Grid access and tariffs

In Denmark, grid connection costs are shared between the wind turbine developer and the electricity utility. Developers of onshore wind turbines pay for the low-voltage transformer as well as the connection to the nearest point in the distribution grid (10/20 kV), whereas the grid company covers the costs for reinforcement of the distribution and the transmission grid where needed.

Traditionally, wind turbines have not paid a network tariff. This has changed during recent years, however, and now new wind turbines are charged the same tariff as any other production facility. This tariff is rather small – less than 1 CAD per MWh of electricity that is generated – and it is not dependent on either peak production or the capacity of the generation facility. This is beneficial to wind power development, as individual wind turbines usually have relatively high peak production compared to average production.

Physical planning

Compared to New Brunswick, Denmark is rather densely populated. The population is around seven times higher and size of the country only 60 percent of New Brunswick. Therefore finding sites for wind turbines is a critical issue in Denmark – and one of the reasons why new wind power capacity in Denmark mainly will be located offshore.

For onshore planning there is a "one-stop-shop" approval procedure where the project developer collects all approvals (environmental, building, power production) from one entity: the local authority[3]. Also the local authorities are responsible for pointing out locations suitable for wind power production as part of their physical planning. Similarly for offshore projects, the Energy Authority is responsible the siting for wind power and is the one-stop-shop approval authority. Access to grid and ensuring reasonable grid costs is one criterion together with others in the siting of new wind power farms in Denmark. Therefore the TSO and the local distribution system operators also play a part in the physical planning for wind power.

The one-stop-shop procedures and pre-planning for wind power are of benefit to wind power developers, avoiding lengthy bureaucratic approval procedures, and to authorities and electricity companies. It ensures that new wind power plants are sited in coordination with other considerations of spatial planning and at locations with low grid connection costs.

[3] For wind turbines above 150 meters, the regions are the one-stop-approval authority.

Local involvement and ownership

The early expansion with wind power in Denmark was to a large extent started by cooperatives and private individuals. This development was among others things made possible by restricting the financial support for wind turbines to people living within some distance of the facilities.

In recent years utilities and professional private developers have become important investors as well and the locational requirements for receiving support have been abandoned. Even so, the Danish experience shows that joint local ownership of wind power in any form creates considerable economic interest and pride amongst the local population. This is also likely to lead to a higher level of public acceptance of wind power. Together with dialogue with the local population on new sites, local ownership has been essential to reduce the so-called NIMBY (Not In My Back Yard) effect in Denmark.

A strong system operator

Following the liberalisation of the electricity market in Denmark in the late 1990s, system operation and the ownership of the transmission system has been unbundled from generation and supply activities. Today, the high-voltage transmission system, as well as the gas transmission infrastructure, is owned by the Danish state through the Transmission System Operator, Energinet.dk.

Energinet.dk has the short and long-term responsibility for maintaining the security of supply of electricity and gas in both the short and the long-term, monitoring and developing energy markets and developing the Danish electricity and gas transmission infrastructure.

Moreover, the transmission system operator is responsible for carrying out coherent and comprehensive planning taking into account future transmission capacity requirements and the future security of supply. Developing the grid and the electricity in order to further large-scale introduction of wind power – particular off-shore – is probably the main issue of the Danish Transmission System Operator at this time.

Within Nordel, the associations of the Nordic transmission system operators, investments in interconnectors are coordinated between the Nordic countries.

Research, development and demonstration

In Denmark, the transmission system operator, as well as the energy authority, manages significant funds for the development and demonstration of technologies for environmentally friendly energy production. A large share of the Danish funds for R&D is placed with the TSO on the grounds that the TSO has a key insight into the future needs of the electricity system and the interplay between different technologies.

As the wind power technology is mostly commercial today the wind research programmes focus mainly on the integration and optimisation of wind energy and other renewable energy sources in the electricity system. Core research areas include the development of demand response, utilizing and strengthening the coupling between the electricity system and district heating systems using electric boilers and heat pumps, developing and exploiting the coupling to the transport sector (electric vehicles as price dependent demand) and examining energy storage technologies such as hydrogen, Compressed Air Energy Storage and batteries.

4.2 Change of mindsets

Traditionally, wind power was looked upon as a problem – and not as an opportunity – by the Danish utilities. However, during recent years, the mindsets of the power engineers and energy planners have changed. Today, the Transmission System Operator approaches wind power integration as a manageable challenge and makes an effort to deal with some of the myths that wind power is often faced with in relation to system integration, e.g. that wind turbines cannot contribute to ancillary services and that minimum generation capability of coal-fired power plants seriously limit wind power penetration.

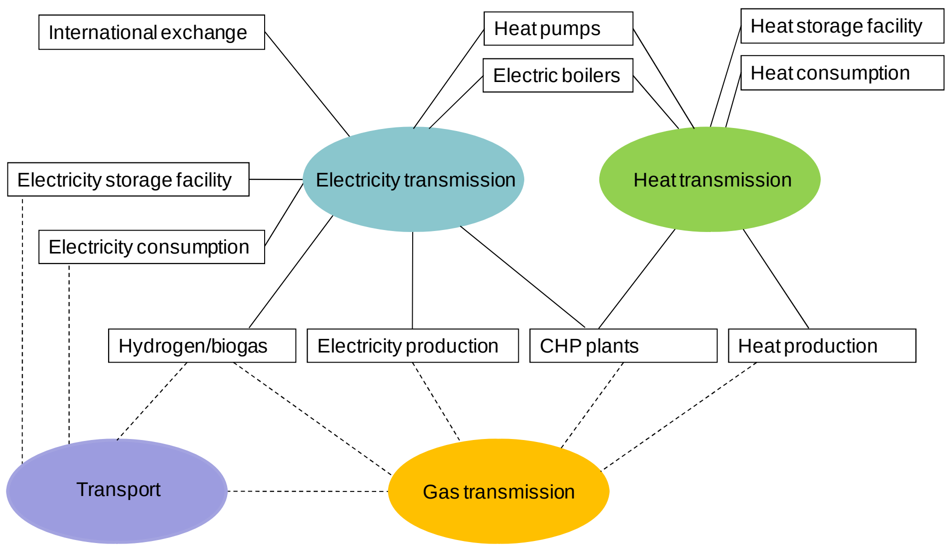


Figure 9: It is important to look at the whole energy system when integrating a large amount of fluctuating energy production. From Energinet.dk's system plan 2007

Cooperation is key

In Denmark it is generally recognised that in order to fulfil the vision of an efficient and flexible energy system with a large share of wind energy a high level of cooperation is required between politicians, energy industry, consumers and the players in the energy market.

Two activities have contributed to this need for cooperation: the project "The Future Energy System in Denmark" carried out by the Danish Board of Technology from 2004 to 2007 and the so-called energy camps initiated by the Danish Energy Association.

"The Future Danish Energy System"

The main aim of the project "The Future Danish Energy System" was to involve the politicians in the Danish Parliament and the players in the energy sector in a close dialogue on the future Danish energy system and to do it on a solid ground of knowledge.

The project was founded on a so-called Future Panel composed of members from the Danish Parliament. The Future Panel represented all political parties and was serviced from a

Steering Group with experts and stakeholders, researchers and representatives of NGOs and authorities in the energy field.

During the project five public hearings were held in the Parliament and a number of quantitative scenarios for the Danish energy future were developed. The hearings were led by politicians from the panel with experts from the energy field contributing knowledge and ideas for the future. A comprehensive collection of consultation documents and a short newsletter were produced after each hearing.

As part of the project, a publicly available modelling tool, STREAM, was developed. It is now used at Danish universities.

Energy camps

At energy camps a number of experts (from industry, organizations, universities and NGOs) and possible investors from the energy sector are gathered to solve a particular problem. The participants are divided into predefined groups of about 10 people dealing with issues such as how we make modern transportation or modern housing possible in a sustainable way without CO_2 emissions The participants are isolated at a resort for 24 or 48 hours, but provided with web-access and communication lines to the outside so that they easily can find information from ministries and other institutions.

At the end of the camp, the groups present their solutions in a very condensed form to the press and to the minister of energy, or other high levels persons, who join the camp for the last couple of hours.

The experience with the energy camps is that you often create new but realistic solutions to difficult problems – and you get a consensus between groups of people who used to work against each other.

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