

Capacity limitations between the Nordic countries and Germany

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Introduction

The Swedish Energy Markets Inspectorate's (Ei's) terms of reference state that the authority is to monitor and analyse developments in the electricity and natural gas markets.¹ Ei is also to work to promote a harmonisation of regulatory frameworks, so that equal conditions are created in the electricity and natural gas markets within the Nordic countries (the Nordics) and the EU.

This report, which Ei has written at its own initiative, is intended to survey and quantify limitations to the cross-border connections between the Nordics and Germany. It has been a known fact in the industry, and a subject of discussion for a number of years, that TSOs limit the transmission capacity between the Nordics and Germany due to internal bottlenecks.

The report is made up of four parts intended to provide the informed reader with a background to and an understanding of the regulatory framework, an overview of the considerable scope of the limitations. In an additional chapter, we will use an energy market model to simulate the welfare effects of the limitations. In conclusion, Ei will present views on how these problems should be managed.

The report is based partly on a consultant's report compiled by Gunnar Lundberg EEManagement on commission by Hagman Energy and Ei. Gunnar Lundberg has also conducted a series of interviews with central actors within the EU cooperation. This report was written by Björn Klasman, Johan Leymann and Sigrid Colnerud-Granström, all at the Department for Market Surveillance.

¹ Ordinance (2007:1118) with terms of reference for the Swedish Energy Markets Inspectorate

Summary

Background and regulatory framework

The Nordic power system is strongly interlinked, both within the Nordics and with neighbouring markets. Sweden's SE4 bidding area (southernmost Sweden) is linked to Germany and to Poland via two DC links of 600 MW each (Baltic Cable and SwePol link). At the end of 2015 a further 700 MW DC link between SE4 and Lithuania (Nord Balt) will become operational.

The German power system is still dependent to a great extent on thermal power, which in turn is primarily based on fossil fuels. This is despite the considerable expansion of renewable energy which has taken place since the turn of the century. As a result, average prices in Germany remain higher than in the Nordics, where the share of fossil fuel-based power production is small. These structural price differences between the Nordics and Germany, together with the fact that transmission capacity is limited, mean that capacity allocation in the transmission links between the countries have direct and considerable consequences for producers and consumers on both sides of the border.

The German power system is currently characterised by a significant power surplus in the country's northern parts, while the southern parts suffer from a shortage of power. There are a number of bottlenecks in the German transmission system today, most of them between northern and southern Germany. Despite these internal bottlenecks Germany, together with Austria, is not divided into several bidding areas in the way that Sweden and many other countries are.

The extent of capacity limitations

Ei looked at how large a share of the capacity of cross-border connections between Sweden and Germany was actually allocated to the day-ahead market (Elspot) between 2012 and 2014. Of the three cross-border connections between the Nordics and Germany, only the link between Sealand and Germany is not regularly limited.

The link worst affected by capacity limitations is the AC link between Jutland and Germany, in which only a third of the maximum transmission capacity of 1 780 MW was allocated to southbound power during 2014. Transmission in this link was limited at virtually all hours. The link between southern Sweden and Germany is also subject to extensive capacity limitations, primarily on northbound power where only a little more than half the maximum transmission capacity was allocated to the market.

Most of the limitations in links between the Nordics and Germany are due to internal bottlenecks.

Ei also looked at why limitations are so extensive, and notes that capacity allocation is regularly limited due to internal bottlenecks.

In order to calculate the welfare effects that occurs as a result of capacity limitations between the Nordics and Germany, we used a power market model. Actual limitations, hour by hour for the years 2012 to 2014, were fed into the model. In the same way, actual wind power production figures for Germany, Denmark and Sweden were used. For fuels and costs of emissions rights, a price level on a par with current prices was used. This allowed us to calculate quite closely the effects of limitations on the total welfare.

The countries that lose the most on limitations are Sweden and Norway, both with a total loss of about EUR 20 million per year.

This is evident from looking at the changes to the welfare effects between a situation with limitations and one without. The net result for Sweden and Norway is a loss of approximately EUR 20 million per year. This net result comprises the sum of changes in consumer surplus, producer surplus and congestion rent. If we look at the consumer side of the situation, German consumers lose EUR -133 million per year, and Swedish and Norwegian consumers gain between EUR 110 and 220 million per year. Danish consumers gain between EUR 55 and 90 million per year, while producers in Denmark lose EUR 40 to 80 million per year.

Ei's view is that to the greatest possible extent transmission bottlenecks should be managed where they are physically located.

It is Ei's view that in the same way as the electricity price should reflect supply and demand, bottlenecks in the transmission system should be managed, to the greatest possible extent, where they are physically located. If one or several countries insist on having a single bidding area, this should be conditional on that customers and producers in other countries are not subject to additional costs or reduced profitability as a result. The current practice, in which Nordic producers are negatively affected by how Germany handles its bottlenecks, is not in line with EU ambitions for a common internal market for energy.

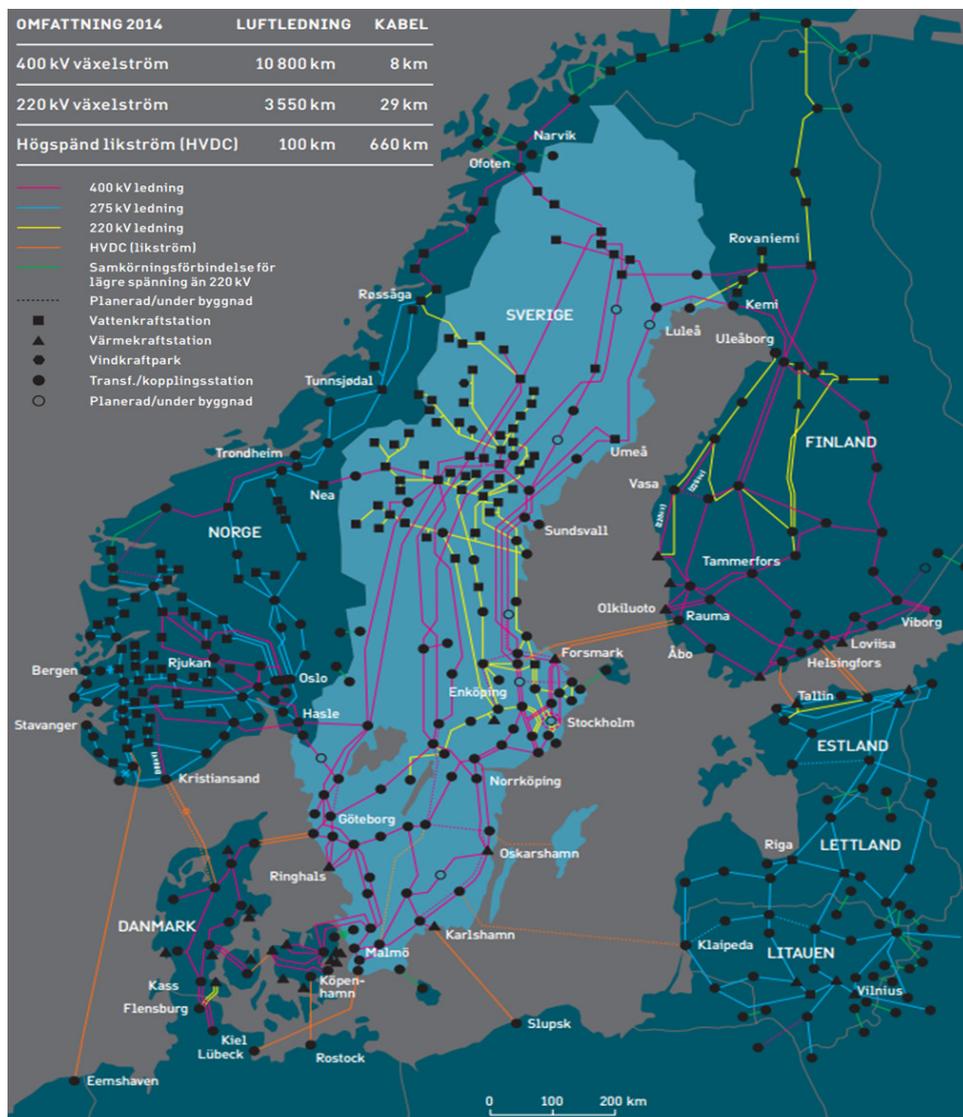
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1 Background

The transmission system, or national grid for transmission of high-voltage power has been built over a long period of time, and reflects how resources for power production have been linked to areas of consumption. In Sweden, the population and the consumption of power have been concentrated in the south, while power production in the form of hydropower has been in the north. From the 1970s onwards, nuclear power expanded in the south of the country, bringing production closer to where needs, i.e. power consumption, were. The extent of the Nordic transmission system is shown in Figure 1 below.

Figure 1 The transmission system in the Nordic and Baltic states



Source: Svenska Kraftnät

The capacity of the transmission system is generally determined on the basis of prognoses of future consumption as well as of added and discontinued power production. It is therefore unavoidable that parts of the grid will be used to its maximum capacity in certain situations, and that bottlenecks will therefore occur. The decommissioning of a major power plant, such as the nuclear power station Barsebäck, can also cause new bottlenecks.

These bottlenecks occur within a country as well as between countries. Since each country originally built its transmission system according to its own needs, it is usually between countries that capacity shortages become apparent. Normally, each country has one or several transmission system operator (TSO) responsible for operating the transmission system and for ensuring that there is always a balance between demand and power production at the national level. TSOs also coordinate their operation of the transmission system with TSOs in neighbouring countries.

The TSO can apply a number of measures to manage bottlenecks in its area of control, i.e. in the network it is responsible for. If capacity in one section is being fully used in one direction, the operator can buy power from a producer on the side of the section where the capacity limit has been reached, i.e. on the side to which the power is moving. The converse applies on the other side of the section, and the operator can instead sell power. And alternatively, a flexible consumer can reduce or increase its consumption on the side that relieves the section.

Another method is to limit the power being imported or exported to the control area of the TSO. This practice has been applied historically, and is still used today. However, it is questionable on purely principal grounds whether export and import limitations are in compliance with the third energy package and freedom of movement within the EU. In Chapter 2 is a brief description of the third energy package and an explanation of how Sweden was divided into bidding areas in order to better fulfil the goal of the package – a single energy market.

1.1 The Nordic and European power systems

The Nordic power system is strongly interlinked, both within the Nordics and with neighbouring markets, see Figure 2. The reason for this is that it was advantageous even before deregulation to link together the hydropower-dominated systems in Norway and Sweden with the systems in Finland and Denmark, which were dominated by thermal power.

The Swedish SE4 bidding area is linked to Germany and Poland via two DC links of 600 MW each. A further DC link, of 700 MW, between SE4 and Lithuania will become operational at the end of 2015.

Figure 2 Nordic and Baltic bidding areas and transmission links



Source: Nord Pool

Denmark's DK2 bidding area is also linked to Germany via a 600 MW DC link. Between the DK1 area and Germany is AC link that can run 1 780 MW in the southerly direction and 1 500 MW in the northerly direction².

1.2 Internal bottlenecks in Germany

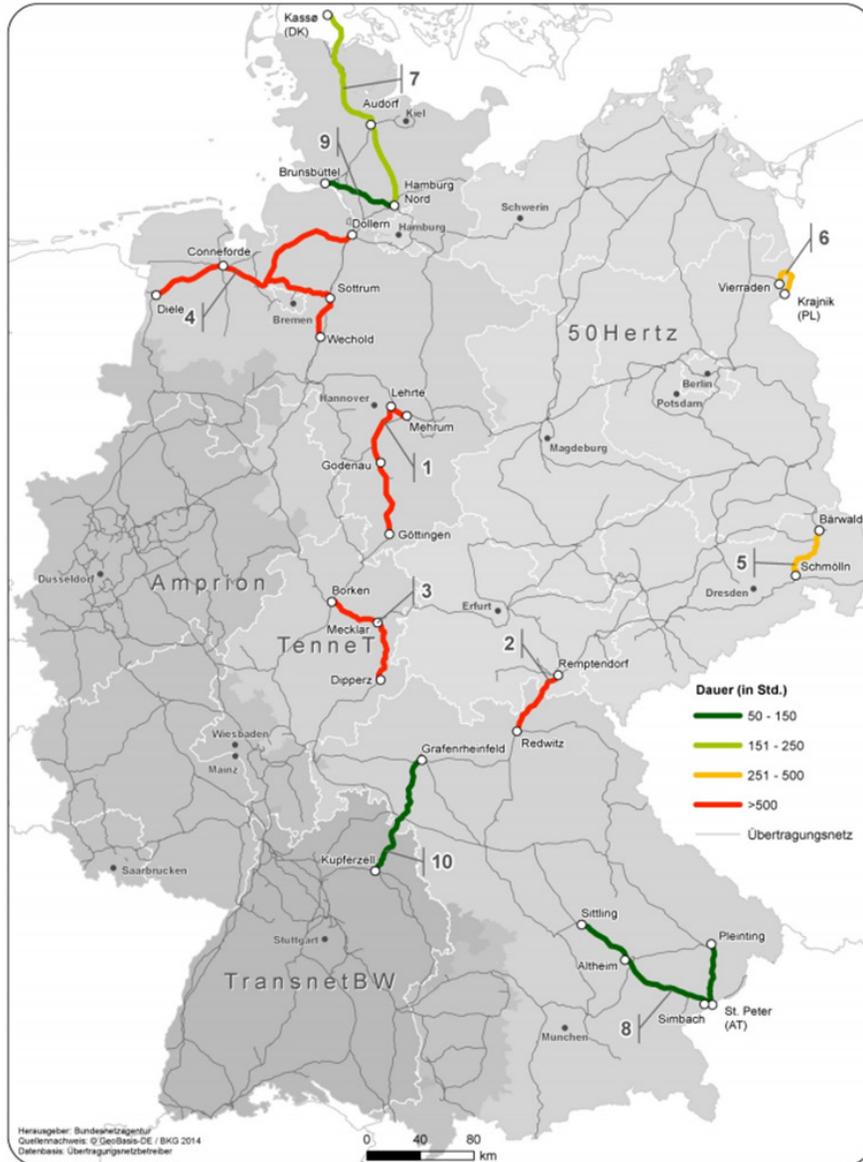
The German power system is currently characterised by a significant power surplus in the country's northern parts, while the southern parts suffer from a shortage of power. There are a number of bottlenecks in the German transmission system today, most of them between northern and southern Germany, see Figure 3 from the German supervisory authority, Bundesnetzagentur. These bottlenecks prevent the surplus in the north from reaching the consumers in the south. Despite internal bottlenecks, Germany is not divided into bidding areas in the way that the Nordics are, along with several other countries. Instead it consists of a single bidding area together with Austria.

There are several reasons for the bottlenecks. One is that Germany has decided, as part of its energy transition (Energiewende), to decommission the country's nuclear power plants – nine reactors with a total production capacity of 12 000 MW – by 2022. Most of the plants to be decommissioned are south of the bottleneck,

² The AC link between Jutland and Germany consists of four separate cables with a total capacity of 1 780 MW in the southerly direction and 1 500 MW in the northerly direction.

which is likely to exacerbate the internal bottleneck situation. Another contributing factor is that several fossil fuel-fired power plants in southern Germany have been shut down due to unprofitability, and further shutdowns have been announced by several actors³. Additionally, the sharp increase in renewable energy is placing higher demands on the transmission grid.

Figure 3 Internal bottlenecks in Germany



Source: Bundesnetzagentur

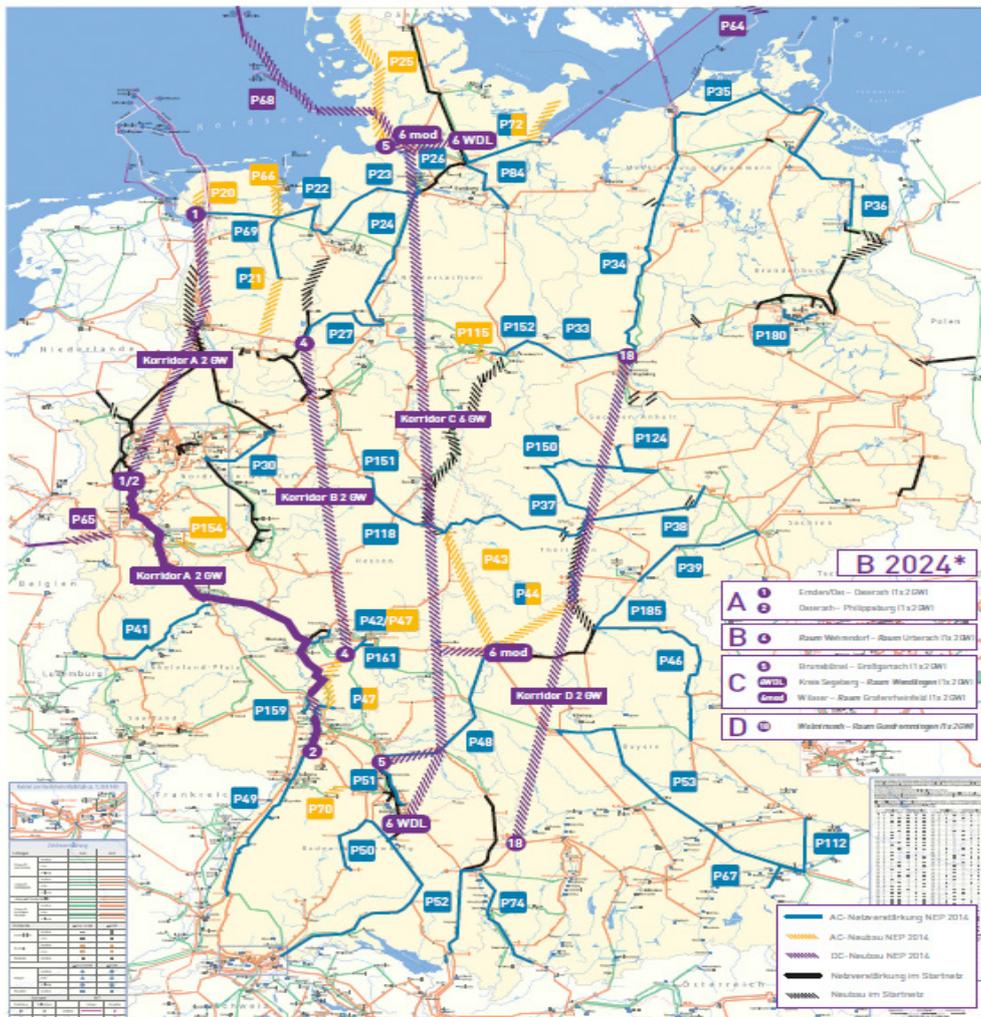
In order to meet the challenges posed by bottlenecks and planned shutdowns of power plants, the German supervisory authority (the Bundesnetzagentur) has drawn up a reinforcement plan for the grid. There are four TSOs (and grid owners) in Germany, and the country's federal system of governance gives considerable

³ Permission is now required to shut down power plants, and this has in some cases been refused with reference to system security. An agreement to continue operations at the gas-fired Irsching 4 (561 MW) and 5 (845 MW) plants, reached between a German transmission company, TenneT, and Eon, a power company, runs out in 2016. Eon has again announced its wish to shut down the plants.

powers to the states (Länder). These factors complicate the picture, and individual states have opposed parts of the plan.

In order to make a plan you need to form a conception of the future. This is done by means of a number of scenarios, of which there is generally one that you most believe in. In this case, the scenario is known as Scenario B. It assumes that the German policy goals will be fulfilled, but that slightly more renewable energy is developed. At the same time, it sees gas power capacity as increasing somewhat. It expects that gas power will be needed to maintain the flexibility required in the power system with further renewable energy. Scenario B extends ten years into the future, but also includes a time horizon which is another ten years into the future (as a separate scenario). Figure 4 below shows the planned reinforcements in Scenario B.

Figure 4 Planned reinforcements in Germany, Scenario B
 SZENARIO B 2024*



Source: www.netzentwicklungsplan.de

Additionally, current plans are contained in what is known as the starting plan, drawn up by the German TSOs. This plan, which reflects the current situation, contains a large number of projects of varying size which are either ongoing, in the process of obtaining permits, or planned.

Several projects relieve bottlenecks in individual transmission system areas, while others, such as the link between Thuringia and Bavaria also improve transmission capacity between the north and south. Grid expansion is also the measure advocated in a green paper⁴ from the Federal Ministry for Economic Affairs and Energy, in order to maintain Germany as one bidding area. The German supervisory authority and the TSOs thus regard the problem of bottlenecks to be temporary, which is to say absorbed by further expansion within a ten-year period.

However, in view of the considerable difficulties and long-time horizons associated with expanding a transmission system, it is doubtful if the problem can really be called temporary. For example, Svenska Kraftnät usually considers that it will take ten years, on average, to complete a new transmission line. Add to this the difficulties in expanding a transmission system in a country where the federal states have considerable autonomy, and the transmission system is divided between four separate grid operators. Regarding the bottlenecks in Germany as temporary or not depends on how you define “temporary”. There is no doubt, however, that the internal bottlenecks in Germany will remain for several years to come.

⁴ “Ein Strommarkt für die Energiewende” (Grünbuch), October 2014

2 Regulatory framework

Development of regulations within the European Union has been very extensive over the past few years. In this chapter we will give a brief background to selected parts of the regulatory framework that concern the capacity of transmission links between bidding areas.

2.1 An internal market for gas and electricity

On 25 June 2009, the third European legislation package about a single market for energy (also known as the third energy package or the third package) was adopted. Put simply, this third package aims to strengthen and liberalise Europe's internal market for energy. The objective is to achieve an integrated, competitive and efficient European electricity and gas market, with a secure and safe energy supply, and in which the customer encounters correct market prices.

One of the effects of the third package was to introduce a legal basis for developing new EU legislation, known as network codes. These are aimed at implementing the overall goals formulated in the third package. Network codes have been developed by several actors, including the European Commission, the European Network of Transmission System Operators for Electricity (ENTSO-E) and gas (ENTSO-G), European energy regulators within the framework of ACER (Agency for the Cooperation of Energy Regulators), and member states.

2.2 Methods for calculating capacity in cross-border connections

One of the network codes/guidelines controls how the capacity in transmission links between areas are to be allocated, and bottlenecks managed – it is known as Capacity Allocation and Congestion Management (CACM). There are two methods under CACM for calculating capacity allocation between bidding areas: a market-linked method with coordinated net transfer capacity (NTC), and a method of flow-based market coupling. Very briefly, the NTC method is based on pre-assessing and allocating a maximum level for power transmission between bidding areas. Calculations of available capacity in the flow-based method also consider what alternative routes that power can take through the grids, thus optimising available capacity in interlinked grids. One advantage of the flow-based method is that capacity allocation is market-driven, and calculated by means of the market-linking process, which can potentially increase total benefit.

CACM prescribes the flow-based method as the primary one for capacity calculation regarding day-ahead and intraday trading in geographical areas where capacity transmission between bidding areas is critical. CACM emphasises that the flow-based method should only be applied after the actors in the market in question have been consulted and given sufficient time to ensure a smooth introduction of the method. The NTC method is only recommended for regions where capacity within the bidding areas is less dependent on transmission

possibilities between them, and the flow-based method thus brings no added value.

2.3 How Sweden got four bidding areas

In 2006 Dansk Energi, the Danish trade body, reported Svenska Kraftnät to the Directorate-General for Competition of the European Commission (DG Comp). The complaint claimed that Svenska Kraftnät was in breach of EU competition rules in its management of internal bottlenecks in the transmission system. Dansk Energi's view was that Svenska Kraftnät's method of managing bottlenecks by reducing exports to Denmark amounted to prioritising Swedish customers over Danish ones. A short time later Energinet.dk, the Danish TSO, published a report claiming that Sweden's management of the connection between Sweden and Denmark had been costly for Danish customers, and this was followed by the Norwegian trade body, Energibedriftenes Landsforening (EBL) giving its support to Dansk Energi on the congestion management issue.

In April 2009 DG Comp decided to examine whether Svenska Kraftnät's export limitations amounted to an abuse of its dominant market position. At a meeting with Svenska Kraftnät on 25 May 2009, DG Comp proposed a settlement in which Svenska Kraftnät would undertake to change its procedures for congestion management in return for a dismissal of the case by DG Comp. In June 2009, DG Comp presented a preliminary assessment of the case in which it noted that Svenska Kraftnät's management of internal bottlenecks in the Swedish transmission network could be in breach of the competition rules in Article 82 (now 102) of the EC Treaty, now the Treaty on the functioning of the European Union. DG Comp asked Svenska Kraftnät to make a list of undertakings to remedy this. It would then be possible to dismiss the case. During the summer of 2009, DG Comp and Svenska Kraftnät discussed the form of these undertakings, and Svenska Kraftnät submitted a proposal to DG Comp in September 2009. DG Comp circulated the proposal for comment, and once market actors had provided feedback it was returned to Svenska Kraftnät with requests for minor adjustments. In January 2010 Svenska Kraftnät duly submitted an amended proposal for undertakings to DG Comp, and in April of the same year DG Comp determined to make Svenska Kraftnät's undertakings binding for a period of ten years.

DG Comp approved the exception of the so-called West Coast Section from Svenska Kraftnät's undertaking to manage internal bottlenecks. Svenska Kraftnät justified its request for an exception on the grounds that bottlenecks in this section cannot be effectively managed using a division into bidding areas as there are not enough production assets in the area. Neither are there sufficient production flexibility and possibilities for upward or downward adjustments within the West Coast Section. Svenska Kraftnät undertook to strengthen the West Coast Section with a new 400 kV link between Stenkullen and Strömma-Lindome, to be operational by 30 November 2011. However, the link did not become operational until the summer of 2012.

While DG Comp was examining the issue, in September 2008, the Nordic Council of Ministers adopted a plan of action to speed up the development of a single Nordic electricity market with a more target-oriented and effective approach. The plan included the statement that "the national authorities responsible for the

systems are requested to begin the process of dividing the Nordic power market into further potential bidding and/or price areas, to be established in 2010". This led the government to instruct Svenska Kraftnät in its 2009 spending authorisation to begin the process of dividing Sweden into further bidding areas for Nord Pool Spot AS. The new division into areas was to be implemented as soon as was deemed feasible considering the changes to IT systems that were necessary, as well as the financial markets' need for advance planning. In March 2009 Svenska Kraftnät announced in a progress report to the Ministry of Enterprise and Innovation that it intended to explore a zonal division along the sections that limit transmission capacity within the country.

The full report requested by the government in the spending authorisation was submitted to the Ministry of Enterprise and Innovation in October 2009. In the report, Svenska Kraftnät advocated dividing Sweden into four bidding areas. Several aspects had been considered in the study of how many bidding areas Sweden should have and where they should be located. One of the arguments for the proposal was that the fundamental market structure, including supply and demand, would create transparent prices and give long-term price signals which in turn would provide incentives for efficient localisation of production and consumption.

On 24 May 2010 Svenska Kraftnät formally decided to divide Sweden into four bidding areas as from 1 November 2011.

3 The extent of limitations

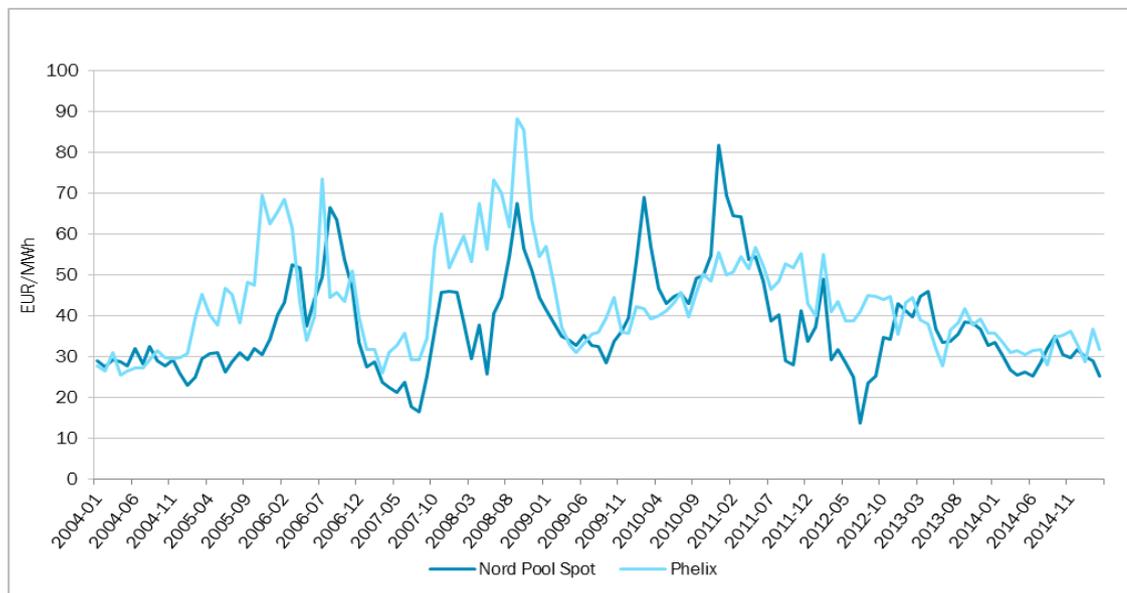
Sweden's and the Nordics' electricity systems are strongly interlinked with those of neighbouring countries. In practice, however, the full capacity of cross-border connections is not used. This chapter will describe the extent of limitations in cross-border connections. It will also illustrate the price differences between bidding areas, which are the basis for the incentive to transfer power between the areas.

3.1 Structural price differences between Sweden and Germany

Prices in the Nordic system are highly dependent on the hydrological balance and on the access to nuclear power. The German prices is dependent – more so than in the Nordics – on the prices of fossil fuels, primarily coal and gas.

During a typical year, Nordic prices are lower on average since hydro power has a lower marginal cost than thermal electricity production. Extended periods in which German prices are lower than Nordic ones are therefore due to a lower-than-normal hydrological balance, often in combination with low access to nuclear power. Average Nordic prices have been lower than German prices for a long time, see Figure 5.

Figure 5 Average prices on Nord Pool Spot and EEX (Phelix)



Sources: Nord Pool and EEX

The last few years have seen a major expansion of wind and solar power in Germany. This expansion has been significant enough that prices often drop below the Nordic system price on those days and hours when the production of wind and solar power is high. Negative prices are even noted in Germany on occasion –

particularly on windy public holidays – due to very high levels of wind production.

Price differences between German spot prices and spot prices in Nordic bidding areas with links to Germany are illustrated in Figure 6.

Figure 6 Price differences between Germany and the Nordics



Sources: Nord Pool Spot and EEX

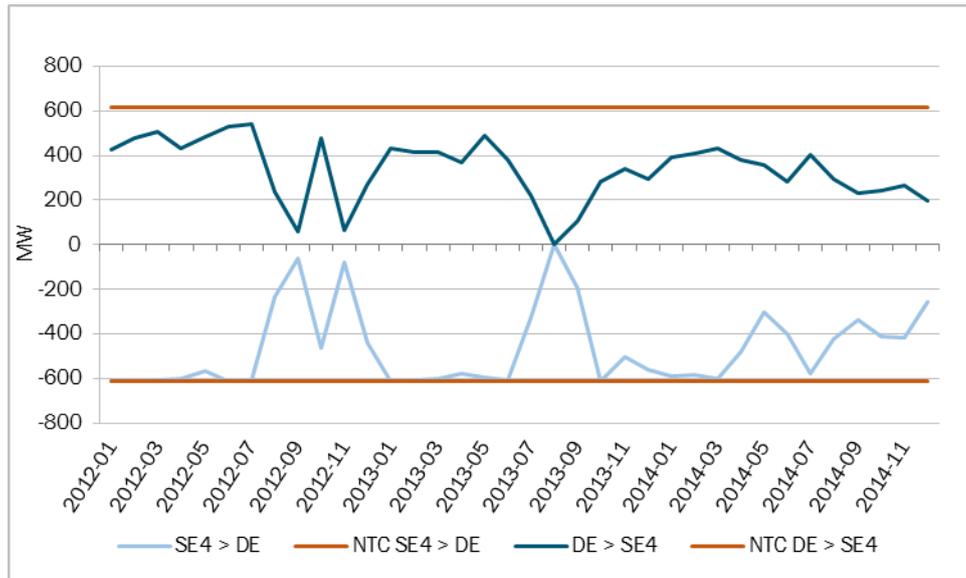
The elevated production of wind and solar power thus creates an incentive for exporting power even during periods when the hydrological balance in the Nordics is relatively favourable. Indeed, the trend over the last few years has been for what was mainly a north-south power flow between the Nordics and Germany to shift towards flowing increasingly in both directions.

3.2 Extensive limitations to cross-border connections

Since transmission capacity is not infinite, capacity allocation in transmission links are, together with the structural price differences that exist between the Nordics and Germany, decisive for pricing. Maintaining full capacity in cross-border connections is particularly important for making use of the storage possibilities of hydropower, and thus for balancing intermittent power.

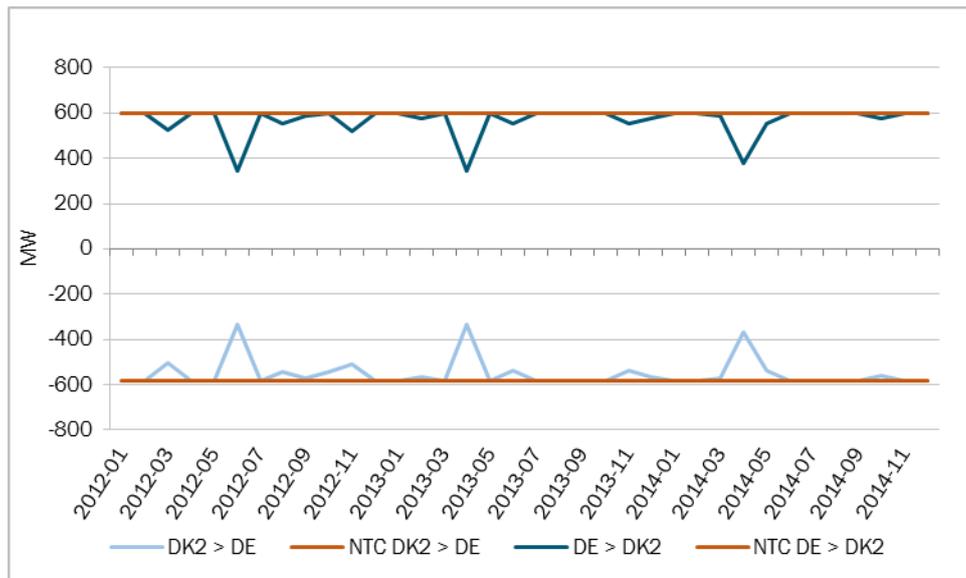
There are currently three cross-border connections between Germany and the Nordics, with a total transmission capacity of almost 3 000 MW. In reality, however, all the capacity is not used. Figures 7-9 show how large a share of the maximum capacity (NTC) has been allocated to the day-ahead market. The maximum capacities are illustrated in orange and the actual allocated capacities are depicted in blue.

Figure 7 Average capacity allocated in relation to maximum capacity (NTC), SE4-Germany



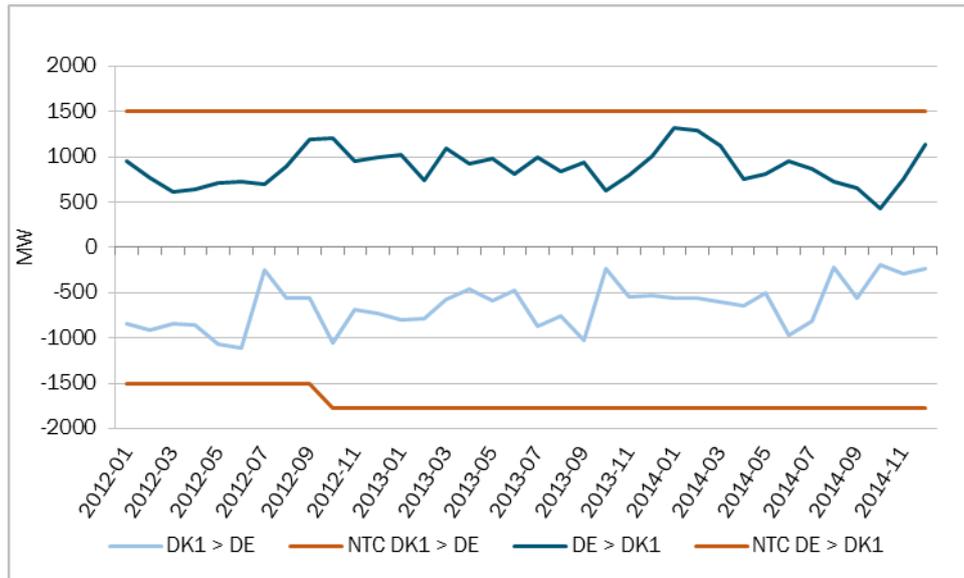
Sources: Nord Pool Spot and Ei processing

Figure 8 Average capacity allocated in relation to maximum capacity (NTC), DK2-Germany



Sources: Nord Pool Spot and Ei processing

Figure 9 Average capacity allocated in relation to maximum capacity (NTC), DK1-Germany



Sources: Nord Pool Spot and Ei processing

Of the three cross-border connections in Figures 7-9, only the one between Sealand and Germany is not limited on a regular basis. The limitations that do occur are largely due to technical faults and maintenance work.

Worst affected by capacity limitations is the AC link between Jutland and Germany, where only a third of the 1 780-MW maximum capacity was allocated in a southerly direction in 2014. Capacity in this link was limited during virtually all hours, see Tables 1-2.

The link between southern Sweden and Germany is also subject to extensive capacity limitations, principally in the northerly direction where only just over half of the maximum transmission capacity was allocated. Limitations there (measured in hours per year) are more the rule than the exception, see Table 1-2.

Table 1 Average capacity allocated 2012-2014

	SE4 > DE	DE > SE4	DK2 > DE	DE > DK2	DK1 > DE	DE > DK1
Max (MW)	615	615	585	600	1780	1540
Min (MW)	0	0	0	0	0	0
Average capacity (MW)						
2012	457	376	543	561	788	865
2013	482	310	553	567	636	900
2014	448	323	560	574	511	901

Table 2 Number of hours with limitations 2012-2014⁵

	SE4 > DE	DE > SE4	DK2 > DE	DE > DK2	DK1 > DE	DE > DK1
Number of hours with limitations						
2012	2586	5384	769	637	8531	8293
2013	2268	7337	642	642	8452	8165
2014	5095	7693	390	390	8742	7769
Number of hours without limitations						
2012	6198	3400	8015	8147	253	491
2013	6492	1423	8118	8118	308	595
2014	3666	1068	8371	8371	19	992

3.3 Who limits and why?

As part of the voluntary undertaking, Svenska Kraftnät pledged to report annually on who limits cross-border connections and what these limitations are due to⁶. Svenska Kraftnät's reports⁷ indicate that the extensive limitations, primarily in a northerly direction, in the Baltic Cable are due to the so-called West Coast Section. This is a bottleneck that occurs when the main flow is in a northerly direction – in other words, when Sweden and Norway are importing power from Denmark and Germany. This happens principally when wind power production is high.

As described above, Svenska Kraftnät obtained an exception in the agreement with DG Comp that allows it to limit the cross-border connections due to congestion in the West Coast Section. In the agreement, Svenska Kraftnät pledged to reinforce the power supply to the Gothenburg region with a 400 kV DC cable between Stenkullen and Lindome by 30 November 2011. Despite the fact that this reinforcement has now been in place for a number of years, limitations in the cross-border connections caused by the West Coast Section remain extensive. The reason

⁵ A limitation is defined as an hour in which the rate of use (actual capacity in relation to maximum capacity – NTC) is lower than 95%

⁶ SWEDISH INTERCONNECTORS - COMP CASE NO 39351

FINAL COMMITMENTS UNDERARTICLE 9 OF COUNCIL REGULATION NO 1/2003, January 26 2010.

⁷ Swedish Interconnectors, COMP Case 39351, Monitoring Report No 1-11.

for this is most likely the rapid growth in wind power in recent years, meaning that transmission capacity sometimes is insufficient even with the reinforcement.

The limitations in the link between Jutland and Germany are also caused by a high input of wind and solar power, particularly in Germany. In November 2014 Tennet, the German TSO, and its Danish counterpart, energinet.dk, published a market message about introducing, in 2015, more or less permanent limitations in the link Jutland-Germany precisely due to the elevated production of intermittent electricity⁸. The view of the two TSOs is that an expansion of transmission capacity will eventually solve these problems.

Ei has also studied urgent market messages (UMMs) published via the Nord Pool Spot platform, and we note that a very large share of capacity limitations between Germany and the Nordics are due to a high wind power input. It is not possible, in a consistent way, to separate cross-border limitations caused by technical problems and maintenance from those caused by internal bottlenecks. This is partly due to the fact that the formulation "...considerable wind power production and maintenance work..." is frequently used to describe the cause of limitations. Furthermore, Tennet states in the report referred to above that it intends to limit capacity more or less permanently during 2015.

One link that is not subject to regular limitations due to internal bottlenecks is Kontek, between Sealand and Germany. Limitations in this transmission link are almost exclusively due to technical problems or maintenance. It is reasonable to assume that Baltic Cable between SE4 and Germany would have the same high rate of use as Kontek if it were not for internal bottlenecks in Sweden and Germany. Based on this assumption, we chose to run the simulations described in Chapter 4 based on actual capacity limitations to the day-ahead market, even though some of the limitations had been caused by maintenance work or technical problems.

⁸ Market Information on the capacity on the border between Denmark West and Germany for 2015, Tennet and Energinet.dk, 2014-11-27.

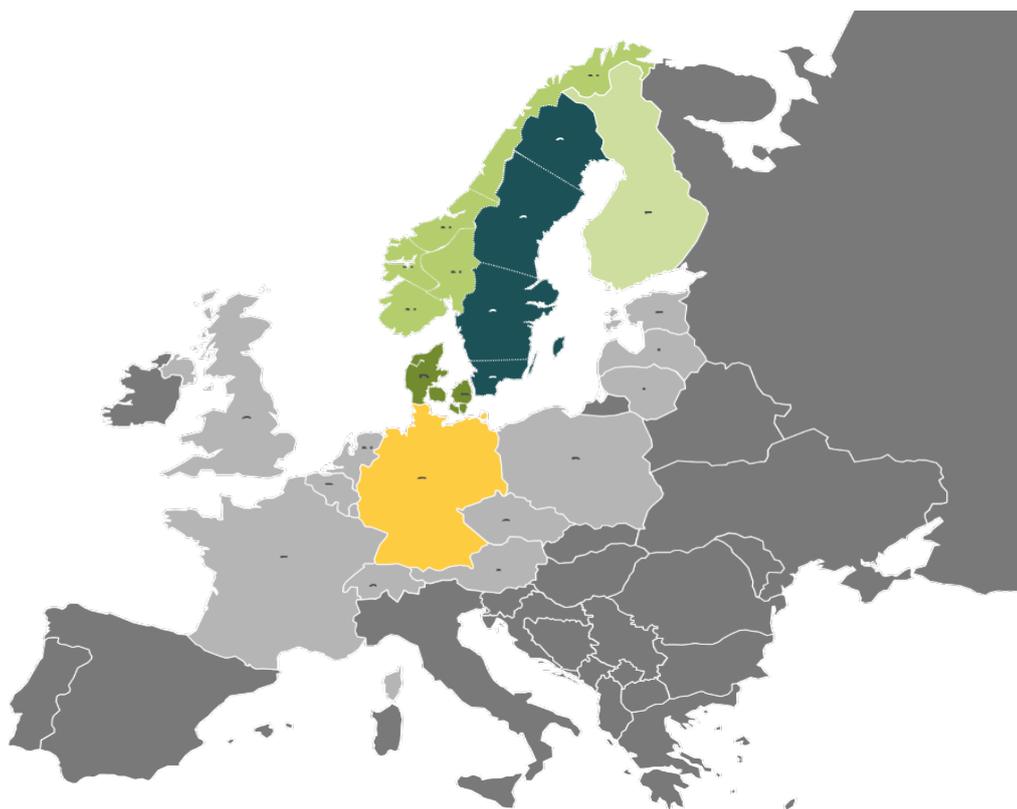
4 Welfare effects of limitations

In order to calculate the welfare effects occurring as a result of limitations in transmission links between the Nordics and Germany, we used a power market model⁹. In this chapter we will begin by briefly describing the model and the underlying assumptions of the simulations, and then present the results of the simulations. The primary aim of these was to look closely at how limitations in transmission links between the Nordics and Germany affect prices, and the welfare effects that arise as a result.

4.1 Brief description of the simulation model

Figure 10 shows the countries included in the simulations, in colour and light grey.

Figure 10 Scope of the simulations (countries in dark grey are not included in the model)



Source: Thema Consulting

⁹ The TheMA model from THEMA Consulting AS

The power market model includes data from 16 countries in Europe, covering production plants, transmission links and consumption. These countries also have exchanges with external power systems, in links where a fixed exchange price determines the direction of power. These links are with Russia, Spain, Italy and the rest of Europe. The model also takes the Nordic bidding areas into account.

The model optimises the welfare for the entire simulated system using linear programming. The level of detail is high for the Norwegian hydropower system, which plays a decisive role in pricing. For the other countries wind, solar and hydropower are aggregated, so that all production plants are presented jointly per bidding area. Hydropower is divided into power plants with reservoirs and power plants on rivers without reservoirs. There are also small-scale power plants which cannot be regulated to any considerable degree. Nuclear power is represented per plant, while other thermal power is divided into fuel and efficiency level – i.e. how efficiently the thermal power plants converts the fuel into power.

The model takes ramping into account, i.e. the stepwise ramping up or down of cables, demand flexibility and also the possibility of running hydropower optimisation step by step on a weekly basis. This is to better reflect the uncertainty inherent in hydropower resource use.

The simulations carried out for this report were made with an hourly resolution, meaning that every hour of the year was included in the model’s calculations.

4.2 General assumptions

The power system is represented by a typical year, corresponding to the current (2015) power system. This means that the power plants and transmission links that exist today are available. There are prognoses for consumption, and inflow into reservoirs is within normal values. The primary purpose of the simulations is to compare how limitations in transmission links between the Nordics and Germany affect pricing, and the welfare effects that arise as a result. Prices used for fuels and CO2 emission rights are listed in Table 3.

Table 3 Price assumptions

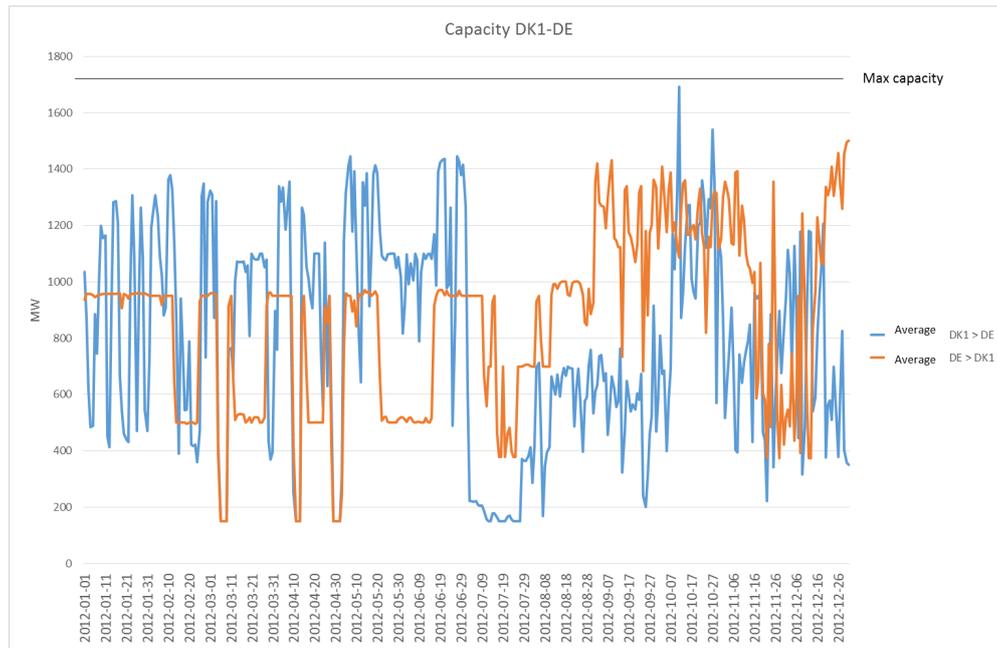
Coal	6.8 EUR/MWh
Gas	19.7 EUR/MWh
CO2	6.9 EUR/ton

4.3 Limitations between the Nordics and Germany

The simulations used actual limitations, hour by hour, as they occurred from 2012 to 2014. Figure 11 below exemplifies how great the variations in how much capacity is allocated to the market can be. The figure shows average available capacity per 24h between DK1 (Jutland) and DE (Germany) during 2012. It indicates the considerable variations, and also limitations, compared with the total capacity in the transmission link. At times, available capacity is far less than half of full capacity.

Simulations were made for all limitations, regardless of their cause. As mentioned earlier, it is reasonable to assume that the majority of limitations can be attributed to elevated wind power production, even if a number are due to a combination of elevated wind power production and maintenance work. However, it is not possible to separate the respective contributions to limitations of maintenance and wind power surplus.

Figure 11 Average capacity allocated between Jutland and Germany 2012, (DK1->DE blue; DE->DK1 brown) 2012

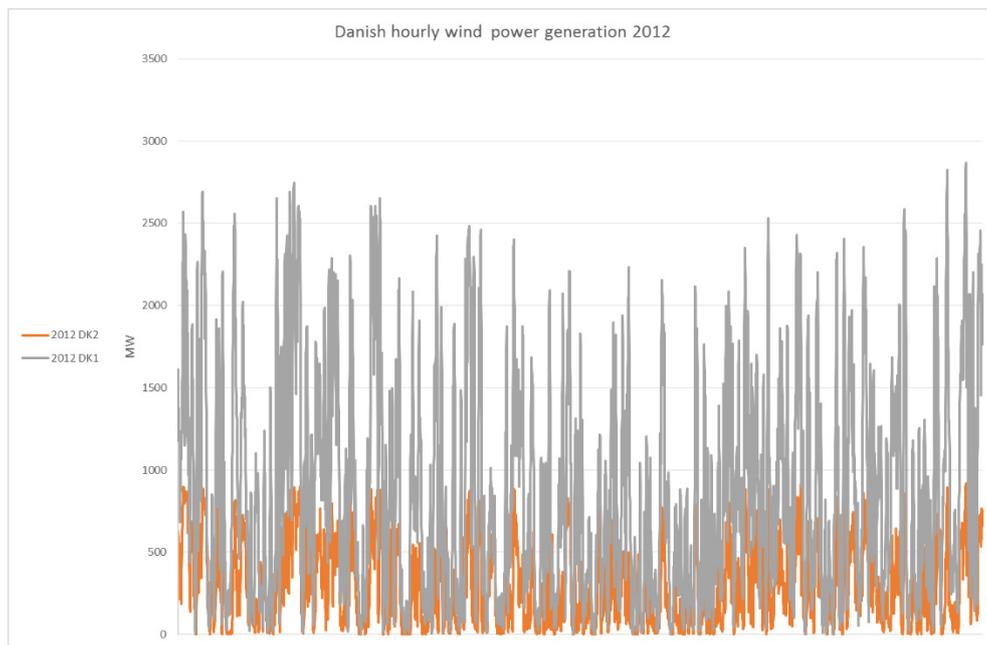


Source: Nord Pool

4.4 Wind power in the Nordics and Germany

For wind power, actual wind power production between 2012 and 2014, hour by hour, was used. Figure 12 below shows Danish wind power production, hour by hour, in 2012. Wind power production is characterised by considerable differences between low and high levels of production.

Figure 12 Wind power in Jutland (grey) and Sealand (brown) 2012



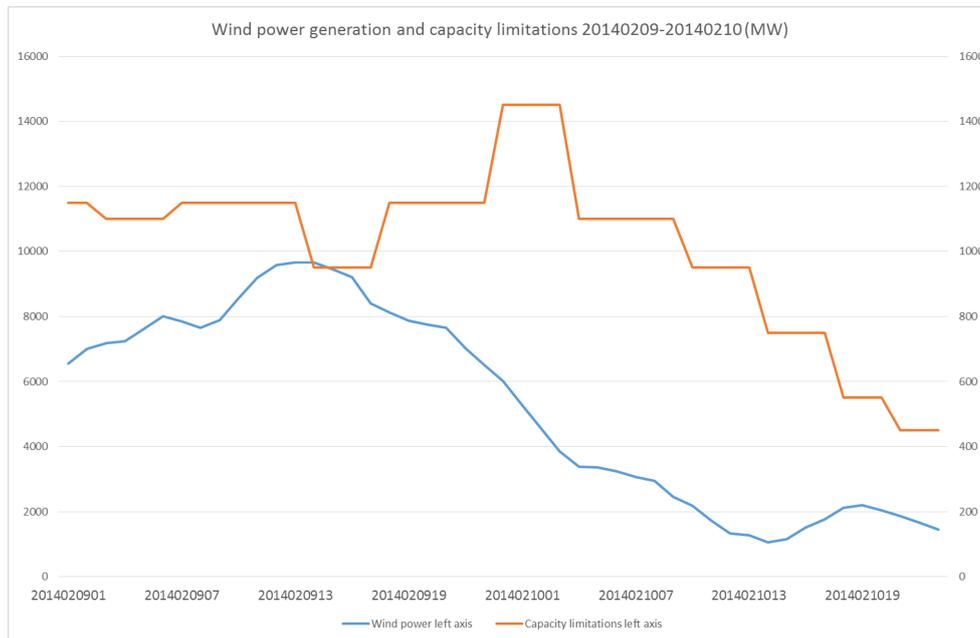
Source: Energinet.dk

On average, wind force is higher during the period from October to March than during the summer period. Winds are slightly stronger in the daytime than during the night.

4.5 Correlation between limitations and wind power production

Figure 13 below shows examples of how limitations are affected by wind power production in northern Germany. When production drops, so do the limitations.

Figure 13 Wind power in Germany (control area TenneT, blue) and limitations Jutland -> Germany (TenneT, brown) 2014-02-09 - 2014-02-10



Sources: Energinet.dk and TenneT

Figure 13 shows the strong correlation between wind power production in northern Germany and the size of southerly limitations from Jutland to Germany. Calculations of the correlation coefficient between southerly limitations from Jutland and wind power production in northern Germany (TenneT's area) indicate correlations of 0.38, 0.45 and 0.50 for 2012-2014. There is thus a clear relation between wind power production and capacity allocation.

There are also periods in which limitations are considerable without wind power production in northern Germany being very elevated. A large proportion of these limitations are likely due to maintenance work. In 2014, average available southerly capacity in the link between DK1 (Jutland) and northern Germany was 29 per cent of NTC.

5 Results

Changes in total welfare, between when limitations are in force and when they are not, are measured in terms of welfare effect. This welfare loss is calculated as the sum of consumer and producer surpluses, and congestion rent. Congestion rent is the revenue that arises as a result of price differences on either side of bidding zone. This revenue accrues 50/50 to the TSOs on either side of the boundary. For Sweden, the simulated welfare effect for the time period 2012 through 2014 is shown in Table 4.

Table 4 Welfare effects in Sweden due to capacity limitations, MEUR

	2012	2013	2014	Total
Producer surplus	-126	-134	-221	-481
Consumer surplus	115	121	199	434
Congestion rent	-9	-8	-4	-20
Total	-20	-21	-25	-66

In Sweden, as in Norway, losses are on the producer side and in the same order of magnitude. Consumers are the winners instead, but the net effect is a loss for Sweden of EUR 20 to 25 million per year. Table 5 makes it clear that the big net losers are Sweden and Norway, both with losses on the order of EUR 20 million per year.

Table 5 Welfare effects in the Nordics and Germany due to capacity limitations, MEUR

	2012	2013	2014	Total
Germany	-3	-5	-3	-11
Sweden	-20	-21	-25	-66
Denmark	-4	-6	-14	-25
Norway	-18	-18	-22	-58
Total	-45	-50	-64	-160

Table 5 also shows that the net effect is small for Germany. Thus Germany has little to gain from a change to the current situation, as the net effect of limitations is small. If we look on the consumer side instead, we see that German consumers are the losers (EUR 133 to 196 million each year). The winners are the German producers, who gain between EUR 135 and 210 million annually from limitations.

In Norway the producers are the losers, by between EUR 120 and 220 million per year. Norwegian consumers instead gain between EUR 110 and 200 million annually. Danish consumers gain between EUR 55 and 90 million each year, while the country's producers lose between EUR 40 and 80 million annually.

6 Conclusions

The transmission links between the three Nordic bidding areas SE4, DK1 and DK2 and Germany are frequently subject to limitations due to a surplus of renewable energy in northern Germany. This is because internal bottlenecks are moved to the border.

In this report, Ei has looked at the welfare effects of limitations in the links between Germany and the Nordics in 2012-2014. The period was characterised by considerable limitations in transmission link capacity between Sweden and Germany and between Jutland and Germany. Although price differences were relatively small during the period, the accumulated welfare losses were fairly large – EUR 160 million. Since domestic producers in Germany are favoured at the expense of producers in another country, these kinds of import restrictions are in breach of the Treaty on the functioning of the European Union¹⁰. In this context, import restrictions are equally as damaging to the internal energy market as were the export restrictions between Sweden and Denmark. DG Comp found that these limitations were in breach of the internal market directive and that led to the introduction by Svenska Kraftnät of bidding areas in Sweden.

Ei's view is that just as the price of electricity should reflect supply and demand, congestion in the transmission system should be managed, to the greatest extent possible, where they are physically located. If one or several countries insist on having a single bidding area, this should be conditional on that customers and producers in other countries are not subject to additional costs or reduced profitability as a result. The current practise, in which Nordic producers are negatively affected by how Germany handles its bottlenecks, is not in line with EU ambitions for a common internal market for energy.

German and Danish transmission system owners believe that congestion problems will eventually be solved by means of increased investments in the expansion of infrastructure. Projects currently in the planning phase will likely contribute to reduced congestion, but it is questionable whether they will be sufficient to meet the demands that intermittent power and nuclear decommissioning in Germany will make on the infrastructure. A further circumstance is that it will take a very long time before the new projects are in place. Merely referring to expansion as the solution to the problem is therefore not appropriate, since the problem of limitations will continue for some time, and likely cause considerable welfare effects in the future as well.

Limitations are necessary *per se* in order to maintain system reliability, but they raise the question of whether consumers in northern Germany and producers in the Nordics should suffer from the way Germany manages its internal bottlenecks – a situation that could be rectified by dividing the country into bidding zones.

¹⁰ Article 102 of the TFEU (Treaty on the functioning of the European Union)

