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# Nordic bidding zones

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## Brief summary

This report presents a study of bidding zone delimitation in the Nordic power market

The analysis concludes that the best candidates for merger are the three northernmost bidding zones in Sweden, and in particular SE1 and SE2. This result emerges when we look at historical as well as future (modelled) prices.

The two northernmost bidding zones in Norway, NO3 and NO4, constitute the second group of merger candidates. Historical data identify NO1 and NO2 as merger candidates, but with investments in external interconnectors to Denmark and Germany, the cost of merging NO2 with other bidding zones increases. Historical prices show that the cost of merging NO5 with other bidding zones is relatively high, but investments in internal transmission capacity reduce the cost.

The cost of merging the northern Swedish-Norwegian bidding zones seem quite small, although to some extent the costs depend on the investments in interconnector capacities.

## About THEMA Consulting Group

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| Øvre Vollgate 6<br>0158 Oslo, Norway<br>Company number: NO 895 144 932<br>www.t-cg.no | THEMA Consulting Group is a Norwegian consulting firm focused on Nordic and European energy issues, and specializing in market analysis, market design and business strategy. |

# CONTENT

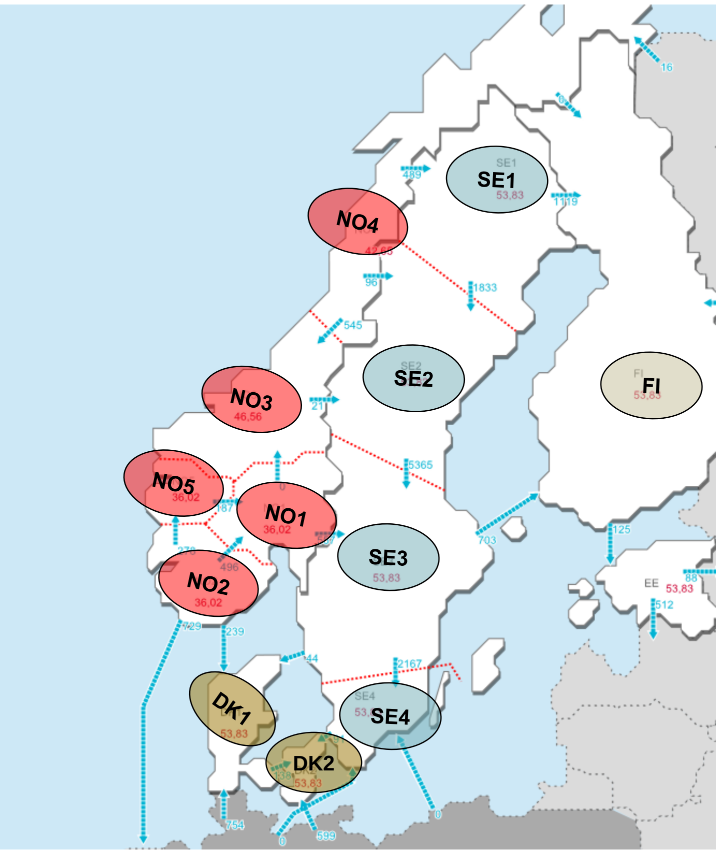
# SUMMARY AND CONCLUSIONS

This report presents a study of bidding zone delimitation in the Nordic power market.

## Background and topic of the study

The Nordic power market is currently (since November 2011) split into twelve bidding zones: Norway is split into five bidding zones, Sweden into four and Denmark into two bidding zones. Finland is operated as one bidding zone. The current bidding zone delimitation is shown in the figure below.

***Current bidding zone delimitation in the Nordic market***




Source: Nord Pool Spot

The countries apply different principles for bidding zone delimitation and national borders always constitute bidding zone borders. The report discusses whether the market efficiency may be increased by merging pares or groups of bidding zones in the Nordic market both within countries and across national borders:

- What are the pros and cons of today's bidding zone delimitation compared to fewer and larger bidding zones, possibly across national borders?

We discuss the alternative perspectives of bidding zone delimitation of society, TSOs and market participants, and to what extent it represents a challenge to have different principles for bidding zone delimitation within the Nordic region and between the Nordic region and Continental Europe.



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## Costs and benefits of bidding zone mergers

Bidding zone delimitation is a method of congestion management in the electricity grid: When the transmission capacity between bidding zones is congested, zonal prices are adjusted in order to balance the power system and relieve the congestion. The benefit of bidding zone delimitation is that congestions are handled in the market, and that all market participants are faced with a price signalling the correct marginal value of electricity in their location. Zonal pricing ensures least-cost congestion management and provides proper investment incentives as well. Without bidding zone delimitation the TSO must handle the congestion outside the market by redispatching or countertrading.

Consumers and generators use forward contracts to manage future price risks. In the Nordic market the Nordic System Price (NSP) is the common reference price for forward contracts. The NSP is the common price that would apply for the entire Nordic market if there were no congestions. As the price in any zone is likely to differ from the NSP, the forward contract provides incomplete hedging. Contracts for Differences (CfDs) may be used to hedge zonal price risks. However, as zones get smaller, the liquidity in CfDs declines and the cost of efficient risk management increases.

Hence, bidding zone delimitation implies the following trade-off:

- Finer bidding zone delimitation yields more efficient spot price signals, lower costs of redispatching and countertrading, but may reduce efficient hedging opportunities and the cost of hedging.
- Cruder bidding zone delimitation yields more efficient hedging due to increased liquidity in forward contracts, but reduce spot market price signals and increase the cost of redispatching and countertrading.

The value of more efficient hedging opportunities is difficult to estimate since we do not have data or indicators for the willingness to pay for hedging.

The more severe the congestions are, the more frequently will prices differ between zones and the larger will price differences be. Hence, merging bidding zones that rarely experience congestions and where price differences are small may prove beneficial due to efficiency gains of more liquid forward markets.

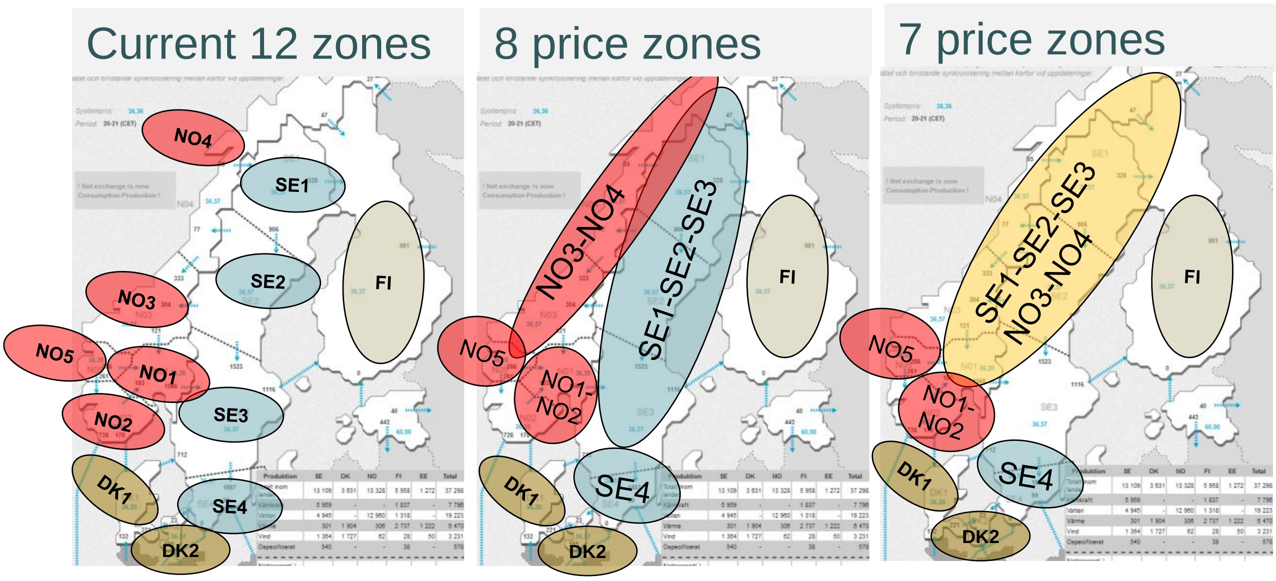
## Analysis of empirical price data

Analysis of zonal price differences with today’s bidding zones reveal that prices are frequently equal in some groups of bidding zones, i.e. the transmission capacity is not congested and no congestion costs occur. The magnitude of price difference in hours with congestion indicates the cost of redispatching/countertrade if bidding zones were merged. The main results are:

- *Within Sweden* prices in the three northern bidding zones, SE1, SE2 and SE3, are often equal. Prices in all zones have been equal in more than 95 % of all hours. Prices in the southern bidding zone, SE4, are equal to prices in SE3 in 90 % of the hours. Prices in all the Swedish zones are equal in about 87 % of all hours. The analysis of the price differences shows the price differences between SE1 and SE2 are negligible, while the average difference between SE3 and SE4 is 1,6 €/MWh.
- *Within Norway* prices in the northernmost bidding zones, NO3 and NO4, are equal in 92 % of all hours. In addition prices are equal in NO1 and NO2 in 90 % of all hours. The average price differences are 0,4 and 0,5 €/MWh respectively. Prices in the adjacent zones NO1 (to the south) and NO3 (to the north) are only equal in 60 % of the hours and the average price difference is 3,6 €/MWh.
- *Cross-border* prices are equal in the northern zones, i.e. SE1, SE2, and SE3, plus NO3 and NO4 around 80 % of the hours. The average price difference is around 1 €/MWh in hours with congestions.

Hence, based on the frequency and magnitude of price differences, the most obvious candidates for merger are SE1, SE2 and SE3, NO3 and NO4 plus NO1 and NO3, and all the northern bidding zones SE1-SE3 and NO3-NO4. The three alternatives are shown in the figure below.

***Alternatives for merger of bidding zones based on historical findings***




## Modelling of future market conditions

Bidding zones are commonly defined for a prolonged time period. One reason for this is the need for stable framework conditions for forward price hedging and provision of long term investment signals. The power markets are in a period of transition, with new investments in renewable generation and interconnectors to markets outside the Nordics as well as in the internal Nordic transmission grid changing flows and congestion patterns. In order to test the three alternative configurations towards expected future market developments, we have run a number of model simulations for the market in 2018. An important reason for bidding zone delimitation in a hydro system is the variation in inflow levels and patterns. Therefore, we have simulated the market with four different inflow assumptions. In addition we take into account expected developments in demand, generation and transmission.

The main results from the simulations are:

- *Within Sweden*: Zonal prices show similar patterns as the analysis of empirical price data: SE1, SE2 and SE3 have equal prices in almost all hours, whereas prices in SE4 deviate more.
- *Within Norway*: Prices in NO3 and NO4 are mostly equal. However, due to investments in Norway, including new interconnectors, even NO5 and NO1 prices are now frequently equal to NO3 prices. NO2 prices deviate more from the prices in the other Norwegian bidding zones.
- *Cross-border*: Across the Swedish-Norwegian border, prices are now more equal within the zones NO3-NO5 and SE1-SE3.

In order to uncover the most important determinants for price convergence across zones, we carried out a number of sensitivity analysis as well:

- *Internal grid investments:* Without investments in the internal transmission grid the frequency of congestion and price differences increase. The capacity between the northern zones is however still largely uncongested. The frequency of congestion between SE4 and

SE3 increase markedly, however, as do congestions between NO5 and adjacent bidding zones.

- *External interconnectors*: New interconnectors influence the internal flows and congestion pattern in the grid. If SK4 between Norway and Denmark and NordLink between Norway and Germany are not built, the frequency of congestions between bidding zones within Sweden and within Norway is reduced. However, congestions occur more frequently between Sweden and Norway as the demand for exports from Norway via Sweden increases.
- *Inflow variations*: Deviations from normal year inflows are important, particularly for price differences within Norway.

### Conclusions and concluding remarks

The quantitative empirical analysis based on historical price data and modelled prices indicate the magnitude of system costs associated with merger of bidding zones. The more frequently the transmission zones are congested and the higher the associated zonal price differences, the higher are the costs of merging the bidding zones.

The analysis concludes that the best candidates for merger are the three northernmost bidding zones in Sweden, and in particular SE1 and SE2. This result emerges when we look at historical as well as future (modelled) prices.

The two northernmost bidding zones in Norway, NO3 and NO4, constitute the second group of merger candidates. Historical data identify NO1 and NO2 as merger candidates, but with investments in external interconnectors to Denmark and Germany, the cost of merging NO2 with other bidding zones increases. Historical prices show that the cost of merging NO5 with other bidding zones is relatively high, but investments in internal transmission capacity reduce the cost.

The cost of merging the northern bidding zones across the Swedish-Norwegian borders also seem quite small, although to some extent the costs depend on the investment in interconnector capacities.

The Pompe study suggests that northern Finland could be a candidate for merger with the northern bidding zones in Sweden and Norway. Since Finland is currently not divided into bidding zones we do not have historical data to study this alternative. The market model employed also reflects the current bidding zones.

We do not have any basis to assess the costs associated with low liquidity in forward markets with the current bidding zone delimitation, nor a model to calculate the possible gains in risk hedging with fewer and larger bidding zones. Hence, we cannot make a clear conclusion as to the optimal trade-off between efficient congestion management and price signals in the physical power market and a more liquid market for CfDs. The analysis merely points out that the cost of merging some groups of bidding zones seems to be fairly low.

# 1 INTRODUCTION AND BACKGROUND

Bidding zone delimitation is used as a method to handle congestions in the electricity grid. The basis for bidding zone delimitation is that the transmission capacity is limited and that the cost of generating electricity may differ between the bidding zones.

The Nordic power market currently consists of 12 bidding zones. The utilisation of the transmission capacities between the zones is optimised in one joint market algorithm operated by Nord Pool Spot (implicit auction). The algorithm determines prices for each bidding zone subject to congestion between the zones. In addition Nord Pool Spot calculates a Nordic System Price (NSP) which is a common market price for the region assuming no congestions. The NSP is a pure reference price for forward contracts whereas bidding zone prices are the prices for physical energy traded in the day-ahead market (spot market).

The market prices provide incentives on when to consume/generate and where to invest in consumption, generation and grid. Bidding zone delimitation affects the efficiency of these price signals and thus the efficiency of both operations and investments (welfare economic efficiency).

Bidding zone delimitation affects forward markets as well; both the way products are defined and the level of competition and liquidity. Consumers and generators in the Nordic region use forward contracts with reference to the NSP to hedge forward price risks. However, the hedge is not complete since prices in the relevant bidding zones may differ significantly from the NSP. To this end Contracts for Differences (CfD) are used to make a forward contract with reference to the NSP relevant for a given bidding zone. Due to the large number of bidding zones, however, the liquidity in CfD trading is low. The low liquidity creates concerns about market power and the efficiency of risk management in the market.

Although the Nordic market is highly integrated across national borders, the principles and methods for bidding zone delimitation vary between the countries. Thus far, the division into bidding zones has been based on proposals from the national TSOs, with national borders perceived as “natural” borders for bidding zones as well.

This study investigates bidding zone delimitation from a Nordic perspective. The focus of the study is:

- *What are the pros and cons of today’s bidding zone delimitation compared to fewer and larger bidding zones, possibly across national borders?*

The report is organized as follows:

- Chapter 2 describes the principal criteria and perspectives of society, consumers, generators and TSOs on the issue of bidding zone delimitation.
- Chapter 3 describes methods of congestion management chapter 4 the solutions and practices currently applied
- Chapter 5 presents an analysis of the impact of the current Nordic bidding zone delimitation based on historical price data and identifies candidates for merger.
- Chapter 6 presents a model based analysis focussing on the robustness of the alternative bidding zone configurations in view of future market developments.

The project is to some extent continuing the discussion from the Pompe study of 2007. The Pompe study recognises the trade-off between the two views on bidding zones. One view emphasises the significance of price signals for efficient short-term resource utilisation and long-term incentives for investments in generation and consumption, and thus prefers delimitation into many bidding zones. The other view focuses on the significance of competition and market integration for an efficient market, and thus prefers delimitation into as few bidding zones as possible.



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The Pompe study recommended further analysis of a delimitation of the Nordic market into two bidding zones, a hydro zone and a thermal zone:

- Sweden is divided into two zones (cut 2)
- Finland is divided into two zones (north-south)
- North Sweden and north Finland is one bidding zone together with (most of) Norway
- South-east Norway is structurally connected to south and mid Sweden and should be included in the thermal bidding zone

Since we do not have price data for a division of Finland into two bidding zones, and the applied model is set up with the current bidding zone delimitation, the analysis focus on possible mergers of the Swedish and Norwegian bidding zones.

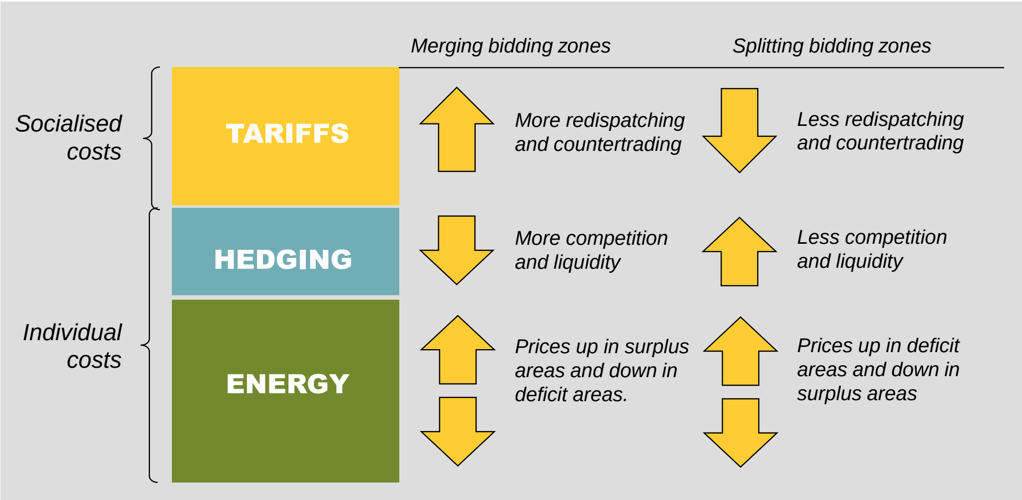
# 2 PERSPECTIVES ON BIDDING ZONE DELIMITATION

The various stakeholders in the power market may have very different perspectives on whether bidding zone delimitation is attractive to them or not. Figure 1 illustrates in principle how alternative bidding zone delimitation affects the costs of consumers. High granularity of bidding zones may e.g. be desirable from a system optimisation perspective (TSO and society); however a large number of small bidding zones might increase risk and hedging costs to market participants.

From the perspective of a market participant, fewer bidding zones will have the immediate effects illustrated in Figure 1:

- Larger bidding zones imply increased redispatching and balancing costs for the TSO as congestions must be handled outside the spot market. Hence, transmission tariffs increase.
- Fewer and more aggregated bidding zones promote liquidity in forward markets which may reduce risk management costs for market participants.
- The cost of energy increases for participants located in a surplus are and decreases for participants located in deficit areas as prices are evened out across the larger bidding zone.

***Figure 1 Bidding zone delimitation affecting perceived costs of market participants***




Consumers and generators have individual perspectives on bidding zone delimitation depending on the answer to the following two questions:

1. Is the market participant located in a surplus area or in a deficit area?
2. Is the market participant engaged in hedging activity or not?

Figure 2 sums up pros and cons (plus and minus) of merging bidding zones to market participants given alternative answers to the two questions above. Zero indicates that the market participant is indifferent.

***Figure 2 Merging bidding zones – perspectives of market participants***

| | | Hedging | No hedging |
|---|---|---|---|
| **Surplus area** | *Consumer* | - + - | - 0 - |
| | *Generator* | + + | 0 + |
| **Deficit area** | *Consumer* | - + + | - 0 + |
| | *Generator* | + - | 0 - |

*Tariffs* *Hedging* *Energy*

Merging bidding zones is beneficial to consumers located in deficit areas since both energy and hedging cost are likely to go down. The tariff is expected to go up due to higher TSO costs but this cost is socialized across all bidding zones. Merging bidding zones is however less attractive to consumers in surplus areas since both energy costs and tariffs are expected to increase – and in particular unattractive if the consumer is not engaged in hedging activity.

If the merger of bidding zones obscures market signals, however, the total cost of the energy system is likely to increase both in the short and the long term. When congestions are managed within the market algorithm, zonal prices reflect the marginal cost of energy in each bidding zone. Zonal pricing thus ensures cost-efficient resource allocation to manage the congestion. Moreover, zonal prices provide incentives for investments in generation in the deficit area and in consumption in the surplus area.  With larger bidding zones, these price signals are obscures, distorting both short- and long-term market decisions, and increasing the overall costs to society. These costs are ultimately borne by consumers.

A socioeconomic perspective on bidding zone delimitation is reflected in ACER's Framework Guidelines on Capacity Allocation and Congestion Management (CACM) for Electricity and ENTSO-E's Network Code on CACM, focusing on network security, market efficiency and stability/robustness of bidding zones delimitation as overall targets.[1] However, in the presence of bottlenecks, there is a trade-off between efficiency in the physical market and efficiency in the forward market when it comes to the granularity of bidding zones.

- High granularity of bidding zones promotes an efficient utilisation of resources both short-term and long-term
- Larger bidding zones promotes for more efficient opportunities for hedging since hedging is concentrated in a few forward contracts (one reference price is relevant to more market participants increasing liquidity).

It is worth noting that while merging bidding zones is likely to increase competition and liquidity in forward markets; this is not necessarily the case for the physical market. The bottlenecks remain and the lack of competition, and the related costs, is simply "moved" to the less developed, less integrated and less transparent markets for redispatching and countertrading.

The TSOs are regulated monopolies and have an obligation to serve the interests of society and of their customers, i.e. both consumers and generators. The system operator provides and schedules transmission services, and ensures that the grid is operated in a reliable manner, providing security of supply. The tasks include congestion management, procurement/provision of

[1] We are not going into depth on the Network Codes in this report. It is however worth noting that the Network Codes are in the process of being developed and that the current versions are likely to be revised.

ancillary services, and ensuring balance between supply and demand at all times. The TSO wants to be able to manage congestions efficiently and to keep system costs down.

The main perspective of the society is to have efficient bidding zone delimitation promoting efficient price signals for efficient short-term utilization and long-term development of the power system as well as limiting system costs to TSOs.

# 3 BIDDING ZONE DELIMITATION AND CONGESTION MANAGEMENT

Bidding zone delimitation is the main congestion management method used in the Nordic region. Congestions indicate constraints in the transmission system – that the demand for transport capacity exceeds available capacity. Congestion management aims to efficiently allocate the transmission capacity when there is a constraint.

Congestions between two bidding zones leading to price differences and are likely to occur when there are:

1. Differences in generation technology that makes the costs of generating electricity different in the two adjacent areas
2. Differences in the resource situation for renewable energy in two adjacent areas, like the amount of precipitation and inflow to hydro plants and the amount of wind for windmills
3. Differences related to the demand side – the profile of the consumption and the degree of flexibility

In this chapter we define bidding zone delimitation as a method in congestion management. We further discuss the alternative method of redispatching and countertrading.

## 3.1 Bidding zone delimitation

A *bidding zone* is the largest geographical area within which market participants are able to exchange energy without capacity allocation.[2] The delimitation of bidding zones aims to identify possible or persistent constraints in the transmission system, and to ensure that regional market conditions are reflected in the price. Whenever the transmission capacity between two zones is congested, market prices are adjusted so that prices are lower in the surplus area and higher in the deficit area, until the congestion is relieved.

In the long term, adding more capacity between the two areas or investments in demand and supply may reduce congestions and cause prices to converge.

Efficiency in this context implies that the underlying value of power in different locations is reflected when allocating the scarce transmission capacity to ensure that the resources in the overall system are utilised in an optimal way.

Trade within and between the Nordic bidding zones takes place in the day-ahead market (Elspot) and in the intraday market (Elbas). Both markets are operated by Nord Pool Spot. The Elspot market is organized as a one-off auction where market players provide hourly bids and offers. Nord Pool Spot aggregate the bids and offers into a supply and demand curve that determines a market price (spot price) for each hour one day-ahead. After Elspot is settled, market players can balance their portfolios in Elbas. Elbas is organized as a market for continuous trading of hourly energy products and the market closes one hour prior to the hour of operation.

The principles used for bidding zone delimitation have to a large extent been defined at the national level. The Nordic countries have addressed the issue of bidding zone delimitation differently. In principle there are three dimensions to consider:

[2] ENTSO-E Network Code on Capacity Allocation and Congestion Management of 27 September 2012

1. *Number of zones*: One can decide to have one bidding zone for a country or to have two or more bidding zones (zonal pricing) that closer reflect congestions in the national power system. Ultimately each node in the grid could be represented in the market solution (nodal pricing[3]).
2. *Flexibility of zone delimitation*: Bidding zones can be fixed or they can be dynamic in order to account for bottlenecks that are more short term to medium term of nature due to changes in renewable resources (e.g. hydrological situation) or due to investments that temporarily may affect balances in the power system.
3. *Geographical scope*: Bidding zones can be defined within national borders or they can span national borders (cross-national bidding zones). It is a clear ambition to integrate markets across Europe and that national borders should not constitute barriers to trade.

## 3.2 Redispatching and countertrading

From a market perspective there are no congestions within a bidding zone, and the zone has one uniform price. However there may very well be physical bottlenecks within zones. An alternative to bidding zone delimitation is thus to manage the congestion using redispatching or countertrading.

Redispatching means that the TSOs pay for generation to increase (or demand to decrease) in the deficit area of the bidding zone and for generation to decrease (or demand to increase) in the surplus area of the bidding zone. Hence, the market price within the zone is not altered. In the Nordic market redispatching is usually referred to as countertrading. ENTSO-E defines countertrading somewhat differently in the Draft Network Code on Capacity Allocation and Congestion Management (Sept. 2012), where “Countertrading means a cross zonal energy exchange initiated by System Operators between two Bidding Zones to relieve a Physical Congestion” and “Redispatching means a measure activated by one or several System Operators by altering the generation and or load pattern, in order to change physical flows in the grid and relieve a Physical Congestion”.

[3] Nodal pricing is a method of determining prices in which market clearing prices are calculated for a number of locations on the transmission grid called nodes. Each node represents the physical location on the transmission system where energy is injected by generators or withdrawn by loads. The  rice at each node represents the locational value of energy, which includes the cost of the energy and the cost of delivering it, i.e. losses and congestion.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# 4 CURRENT SOLUTIONS, FUTURE SOLUTIONS AND CHALLENGES

In this chapter we describe congestion management methods used by the Nordic countries and by some of the other countries in our region. We further discuss the European target market solutions and the process of electricity market integration in Europe and to what extent having somewhat different solutions for congestion management, and in particular bidding zone delimitation, is challenging.

## 4.1 Bidding zones and market solutions in the Nordic region and beyond

Bidding zone delimitation is used differently in the Nordic region. Finland is one bidding zone. The other three Nordic countries have implemented zonal pricing, but their situations differ. Sweden and Denmark are split into four and two fixed bidding zones. Denmark has always been split in two bidding zones (Jutland has not been part of the Nordic synchronous area, until 2010 there was no interconnection between the two bidding zones and the connection is congested most of the time. Sweden currently consists of four bidding zones, introduced in November 2011 and Svenska Kraftnät (SvK) is committed to keep the Swedish electricity market divided into two or more bidding zones until April 2020.

Norway is currently split into 5 bidding zones. However, the bidding zones in Norway are dynamic in order to account for strained regional energy situations. Fluctuations in the hydrological balance make the Norwegian power system different from the rest of the region. Dynamic bidding zones create incentives for generators to optimise the use of storage capacity and ensures import when the hydrological situation is weak. Congestions on the borders between control areas, i.e. national borders, are handled within the market algorithm, as all national borders are simultaneously bidding zone borders.

Estonia, Lithuania and Latvia constitute one bidding zone each, all part of Nord Pool Spot. The TSOs also have agreed to define cross-border exchange with Russia and Belarus as new bidding zones.

Most countries in Europe have one uniform price, including the countries bordering the Nordic region like Poland, the Netherlands and the UK. Germany and Austria have one uniform price and is a unique example in Europe of a cross-national bidding zone. Italy has zonal pricing with fixed bidding zones

Russia applies nodal pricing due to the differences in the generation costs and the insufficient transmission capacities across their regions. Power prices in hydro-dominated Siberia tend to be lower than the price in the European part of Russia.

The Nordic countries use *market splitting* with *implicit auctions* as the method for congestion management in the day-ahead market allocation implying that one power exchange (Nord Pool Spot) is covering all the bidding zones in the region, simultaneously calculating prices and flows for all zones. The algorithm used by Nord Pool Spot also optimises the capacity on interconnections to Poland and the Baltic states. The capacity on the interconnections between the Nordics/Baltics and Russia (and Belarus) are all having explicit auctions, but the TSOs have agreed to implement the connections as bidding zones in Nord Pool Spot.

Potential challenges related to having cross-national bidding zones in the Nordic region should be further investigated. Cross-national bidding probably require closer operational cooperation between TSOs on redispatching and countertrading in their joint bidding zone. Other issues include distribution of costs related to redispatching and the distribution of congestion rent on the borders of the bidding zone. Discussions of closer cooperation between TSOs may become more relevant with cross-national bidding-zones.

The CWE (Central West Europe) region uses *market coupling* with implicit auction as the method for congestion management in the day-ahead market allocation. Market coupling implies that several power exchanges (APX in the Netherlands, Belpex in Belgium and EPEX Spot in Germany/France) share one common algorithm used to optimise prices and flows in the coupled markets. The algorithms used in market coupling and market splitting may be identical, thus realising the same flows and the same optimal utilisation of resources.

Since 2011 the CWE and Nordic regions have been *volume coupled*. Volume coupling implies that a separate implicit auction algorithm has been run for the combined CWE-Nordic region. This calculation is performed in order to determine the flow on the interconnections between the two regions. The calculations are done by the European Market Coupling Company (EMCC), a company jointly owned by the TSOs and power exchanges. The flows calculated by EMCC are used by the power exchanges in the two regions as an input in their calculations of prices and flows within and between the respective bidding zones. Volume coupling has improved the efficiency of the utilisation of the capacity on the interconnections between the regions, making the combined region closely integrated in the day-ahead timeframe.

Poland has implemented a market based mechanism for allocation of a transmission capacity among market players. Since 2005 a coordinated congestion management mechanism, based on an agreement with the neighbouring TSOs, in the form of explicit cross-border capacity auction is used to allocate interconnector capacity on the borders. According to the new Energy Act, Poland is planning to introduce nodal pricing. Bidding zone delimitation has been considered unsuitable for the Polish grid.

Part of the market splitting in the Nordic region implies publishing a Nordic system price. The system price reflects the price if there were no constraints. The system price is used as a reference price for financial contracts only. Similarly does the French-German spot exchange (EPEX Spot) publish Elix which is a system price for Germany, France, Switzerland and Austria. The Nordic market has a quite liquid market for forwards on the system price while the CWE market mainly trade forwards with reference to the bidding zones (in each country). The forwards with reference to the German price (Phelix) have become liquid and are used for hedging also for market players located in the adjacent countries. The Nordic market use CfDs swap the hedge done towards the NSP “home” to the relevant bidding zone. Zonal price risk in CWE is not an issue if hedging is available in the relevant bidding zone. TSOs in CWE are in addition selling cross-zonal transmission rights. These contracts provide TSOs with opportunities to hedge congestion rent, but they are also to some degree able to be used for hedging purposes by market participants.

## 4.2 Congestion management in the EU target market model

The EU aims to integrate the European power markets into one efficient Internal Energy Market (IEM). This involves establishing best practise market solutions in the various market timeframes) and integrating national markets into regional markets and ultimately into a pan-European market. The market solutions are being defined in the Framework Guidelines and the Network Codes.

The day-ahead market and the intraday market are the two market timeframes used by the market players to buy and sell physical energy (manage energy positions of market players). The target model defines implicit auction and flow-based allocation[4] to be the future solutions for Europe. The European Target Model is set out in the Framework Guidelines and in the Network Codes mentioned above.

The forward market provides opportunities to manage forward price risk. The target model (also described in the Framework Guidelines and the Network Codes) is for TSOs to sell transmission rights unless there are viable/liquid alternatives available in financial derivatives (e.g. CfDs). The transmission rights are defined to have the Use-It-or-Sell-It provision or be purely financial in order to ensure efficient allocation in the day-ahead market.

[4] Flow-based allocation refers to a market algorithm where capacity calculation, price setting and scheduled flows are determined implicitly.



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During the last 4-5 years, the Nordic region and CWE (Central West Europe) have accelerated their effort in integrating their markets into a Northwest European day-ahead (from November 2013) and intraday market (to be launched in 2015). This market will provide market coupling and implicit auction for an area covering Belgium, Denmark, Estonia, Finland, France, Germany, Austria, Great Britain, Lithuania, Luxembourg, the Netherlands, Norway, Poland (via the SwePol Link), Sweden and Latvia, as well as the interconnections between these countries. Other regions are expected to connect to the solution in Northwest Europe, and South West Europe (SWE), including Portugal and Spain, are likely to join first. There is also regional market coupling initiatives in the regions of Central East Europe (CEE), South East Europe (SEE) and Central South Europe (CSE) aiming to be connected to the solution in Northwest Europe over time.

Similar initiatives to create a joint intraday market in Northwest Europe (also expandable) are taking place, and Network Codes are being established to guide integration and cooperation also in the balancing markets.

## 4.3 Nordic vs. Continental Europe differences may not be such a problem

We have identified significant differences in principles used for bidding zone delimitation and in the chosen market solutions both within the Nordic region and between the Nordic region and Continental Europe. In this section we discuss to what extent these differences represent challenges or problems. We are in particular considering the following two differences:

1. *Bidding zone delimitation*. Different principles are applied within the Nordic region and between the Nordic region and Continental Europe.
2. *Managing zonal price risk*. The products used in the Nordic region differ from those used in Continental Europe.

We have concluded that efficient bidding zone delimitation promotes spot market and congestion management efficiency, important from the perspectives of society and market participants. Efficiency is realised when the bidding zones are reflecting the physical bottlenecks in the grid. Having a mix of dynamic bidding zones in Norway and fixed bidding zones in Sweden and Denmark promotes efficiency, reflecting that bottlenecks in Norway are more dynamic by nature due to shifting hydrology, while the bottlenecks in Sweden and Denmark are more long-term and predictable. The algorithms used by the power exchanges for day-ahead capacity allocation are flexible and able to add new bidding zones and merge old ones. Thus, a prerequisite for efficient bidding zone delimitation in the Nordic region is to allow both dynamic and fixed bidding zones. The core principle that bidding zone borders should follow bottlenecks in the grid remains however the same across the countries applying bidding zone delimitation.

It could however be challenging if some countries apply bidding zone delimitation and others do not. One example is Germany. Germany does not have bidding zone delimitation while the Nordic countries with interconnections with Germany do. Northern Germany is a surplus area within Germany but congestions within Germany are not reflected in the price. As the German "system" price, that determines the trade between the Nordics and Germany, may reflect marginal costs in the south of Germany, there may be exports from the Nordics to Germany even if the marginal cost of generation in north Germany is low or even close to zero. Hence, trade may flow in the opposite direction to the efficient solution with exports from north Germany. Bidding zone delimitation would improve efficiency. On the other hand, even if Germany keeps one bidding zone for the entire country, efficiency would not be helped by the Nordic region applying on bidding zone as well, in order to harmonize solutions with Germany. Thus, from an efficiency point of view, bidding zone delimitation should continue to be the main congestion management tool in the Nordic region. Another argument for the Nordic region to stick to bidding zone delimitation is that bidding zone delimitation, nodal pricing and flow-based market coupling are part of the target model and that these solutions also may be implemented in Germany and in Continental Europe in the years to come.


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We have also identified differences in the solutions applied in the forward markets. Generators and consumers are exposed to the price risk of the bidding zone where they are located. Market players in the Nordic region hedge this risk using forwards with reference to the NSP and they use CfDs to swap this hedge making, it an efficient hedge for generation and consumption within their bidding zone. Transmission rights used for cross-national trading in Continental Europe is a bet on the future congestion rent between two bidding zones and is thus not an efficient hedge for consumption and generation. From the perspective of consumers and generators in the Nordic region the CfDs as a product provides an efficient hedge together with a forward on the NSP. The Nordic TSOs may however still sell transmission rights if they want to hedge congestion rent. The transmission rights would have limited value for hedging purposes but consumers and generators could potentially benefit indirectly if speculative traders get access to purchase transmission rights and if this in turn promoted the liquidity of the CfDs.

Market players in Continental Europe hedge their zonal price risk using forwards with reference to the bidding zone where they are located. The liquidity of the German forward market is strong and German forwards are used for hedging also by players in the neighbouring markets. Forwards with reference to the Nordic bidding zones will duplicate the combination of buying a forward on the NSP and buying a CfD. The scarce liquidity will then be distributed across more products and the liquidity of the forwards on the NSP may suffer.

Forwards on the German Phelix price is to some extent filling the same role in Continental Europe as forwards on the NSP do in the Nordic region. It is not the perfect hedge, but to many players it is good enough. Some players may however want a contract to manage the price difference between the German price and the price in their zone. A contract similar to the Nordic CfD would provide such an hedge.

It is not a problem to the Continental European market participants that the Nordic region has CfDs. On the contrary, CfDs provide all suppliers in Europe with an opportunity to efficiently manage zonal price risk and to compete on a level playing field in the Nordic region if they want to establish a business as a supplier of electricity.

Liquidity of the markets for managing zonal price risk, be it CfDs, forwards with reference to the bidding zone or transmission rights, is limited if the bidding zones are small. In the following we will discuss the bidding zone delimitation in the Nordic region and to what extent bidding zones could be considered merged.



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# 5 HISTORICAL PRICE DIFFERENCES

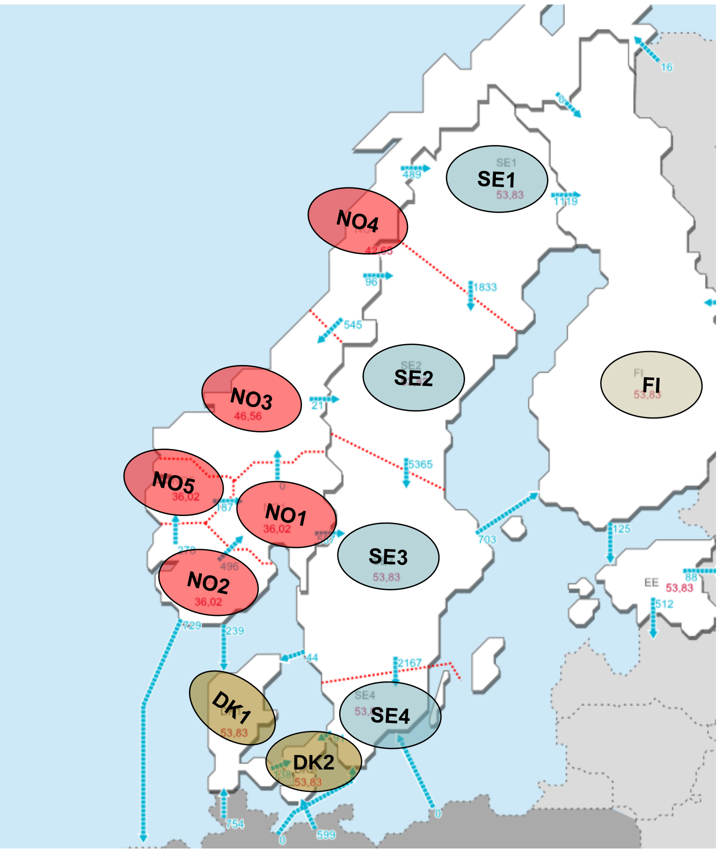
This chapter provides an historical analysis of price differences between the Nordic bidding zones. The aim is to identify zones that may be potential candidates for merger. Equal prices imply that there are no congestions between bidding zones. Hence, bidding zones with equal prices may be potential candidates for merger.

We find that some zones in Sweden and some zones in Norway have had fairly equal prices in the studied period from November 2011 to September 2013. These areas are in particular located in the North. The prices in the two Danish bidding zones and .in Finland are to a limited degree in line with prices in their respective adjacent areas.

## 5.1 Observed price differences

In this section we present hourly spot price differences in the Nordic bidding zones for the time period November 2011 until September 2013. This is the time period for which the current bidding zone delimitation has applied. Figure 3 gives an illustration of today's bidding zone delimitation.

***Figure 3: Current bidding zone delimitation in the Nordic market***




*Source: Nord Pool*

Table 1 summarizes the results and shows the share of the hours for which prices in two bidding zones were identical. The colour indicates the degree of similarity of prices with the darkest colour signifying the highest share of equality.

***Table 1: Percentage of hours with same price (for time period November 2011 - September 2013)***

| | SE1 | SE2 | SE3 | SE4 | NO1 | NO2 | NO3 | NO4 | NO5 | FI | DK1 | DK2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SE1 | *100.0 %* | *98.8 %* | *95.5 %* | *86.6 %* | *60.7 %* | *53.6 %* | *87.8 %* | *82.9 %* | *56.1 %* | *73.1 %* | *57.8 %* | *65.4 %* |
| SE2 | *98.8 %* | *100.0 %* | *96.7 %* | *87.7 %* | *61.7 %* | *54.6 %* | *86.6 %* | *81.6 %* | *57.1 %* | *73.2 %* | *58.5 %* | *66.0 %* |
| SE3 | *95.5 %* | *96.7 %* | *100.0 %* | *90.0 %* | *62.3 %* | *55.0 %* | *84.2 %* | *79.7 %* | *57.6 %* | *74.5 %* | *60.8 %* | *68.1 %* |
| SE4 | *86.6 %* | *87.7 %* | *90.0 %* | *100.0 %* | *57.8 %* | *50.7 %* | *76.6 %* | *72.9 %* | *54.1 %* | *67.0 %* | *63.0 %* | *75.5 %* |
| NO1 | *60.7 %* | *61.7 %* | *62.3 %* | *57.8 %* | *100.0 %* | *89.6 %* | *58.7 %* | *56.2 %* | *86.5 %* | *47.9 %* | *44.5 %* | *46.5 %* |
| NO2 | *53.6 %* | *54.6 %* | *55.0 %* | *50.7 %* | *89.6 %* | *100.0 %* | *51.8 %* | *49.3 %* | *80.0 %* | *42.7 %* | *45.0 %* | *44.4 %* |
| NO3 | *87.8 %* | *86.6 %* | *84.2 %* | *76.6 %* | *58.7 %* | *51.8 %* | *100.0 %* | *91.8 %* | *54.6 %* | *64.1 %* | *51.3 %* | *58.6 %* |
| NO4 | *82.9 %* | *81.6 %* | *79.7 %* | *72.9 %* | *56.2 %* | *49.3 %* | *91.8 %* | *100.0 %* | *52.3 %* | *61.4 %* | *48.7 %* | *56.2 %* |
| NO5 | *56.1 %* | *57.1 %* | *57.6 %* | *54.1 %* | *86.5 %* | *80.0 %* | *54.6 %* | *52.3 %* | *100.0 %* | *43.7 %* | *41.6 %* | *43.2 %* |
| FI | *73.1 %* | *73.2 %* | *74.5 %* | *67.0 %* | *47.9 %* | *42.7 %* | *64.1 %* | *61.4 %* | *43.7 %* | *100.0 %* | *47.9 %* | *53.6 %* |
| DK1 | *57.8 %* | *58.5 %* | *60.8 %* | *63.0 %* | *44.5 %* | *45.0 %* | *51.3 %* | *48.7 %* | *41.6 %* | *47.9 %* | *100.0 %* | *83.0 %* |
| DK2 | *65.4 %* | *66.0 %* | *68.1 %* | *75.5 %* | *46.5 %* | *44.4 %* | *58.6 %* | *56.2 %* | *43.2 %* | *53.6 %* | *83.0 %* | *100.0 %* |

*Legend:* *above 95 %* *above 90 %* *above 80 %* *below 80 %*

We make the following observations:

- Prices in the three northernmost bidding zones in Sweden, SE1-SE2-SE3, have been very similar. In over 95 % of all hours, prices in any two of the bidding zones have been identical.
- Price alignment of prices between Southern Sweden (SE4) and the other Swedish zones was much lower, in the region of 85-90 %.
- Prices in NO3 and NO4 in the Northern part of Norway have been quite similar, with equal prices in around 92 % of all hours. Prices in the North and the South of Norway are much less aligned.
- There is some price alignment between prices in Northern Sweden (SE1-SE2-SE3) and NO3 and NO4 in Northern Norway, with prices in any two of the zones being equal around 85 % of all hours.

For the other areas, there has been less price alignment. Prices in Finland and Denmark are less in line with prices in Sweden and Norway. Bidding zone delimitation in Finland could have changed this picture, possibly having prices in one Finnish bidding zone more in line with prices of northern Sweden and Norway. The prices in Denmark are more influenced by prices in Continental Europe than the other Nordic bidding zones.

The above analysis focusses on the amount of hours where prices were equal. In the remaining hours prices were different, but the numbers do not reveal the magnitude of the price differences. Indicators of the size of price differences are given in Table 2, showing the average price difference between two areas *in those hours when prices differed.* The average price difference between two zones over the entire observation period is hence lower.

The table supports the conclusions presented above. Prices between the three bidding zones in Northern Sweden are very similar. So are prices in Northern Norway and between NO1 and NO2 in the South of Norway. But even prices in the North of Sweden and the North of Norway are fairly equal. Interestingly, also prices between NO5 and NO1 and NO2 are fairly similar, even though hours of price alignment for NO5 are much fewer. Thus, although prices are often different, the price differential is not very large.

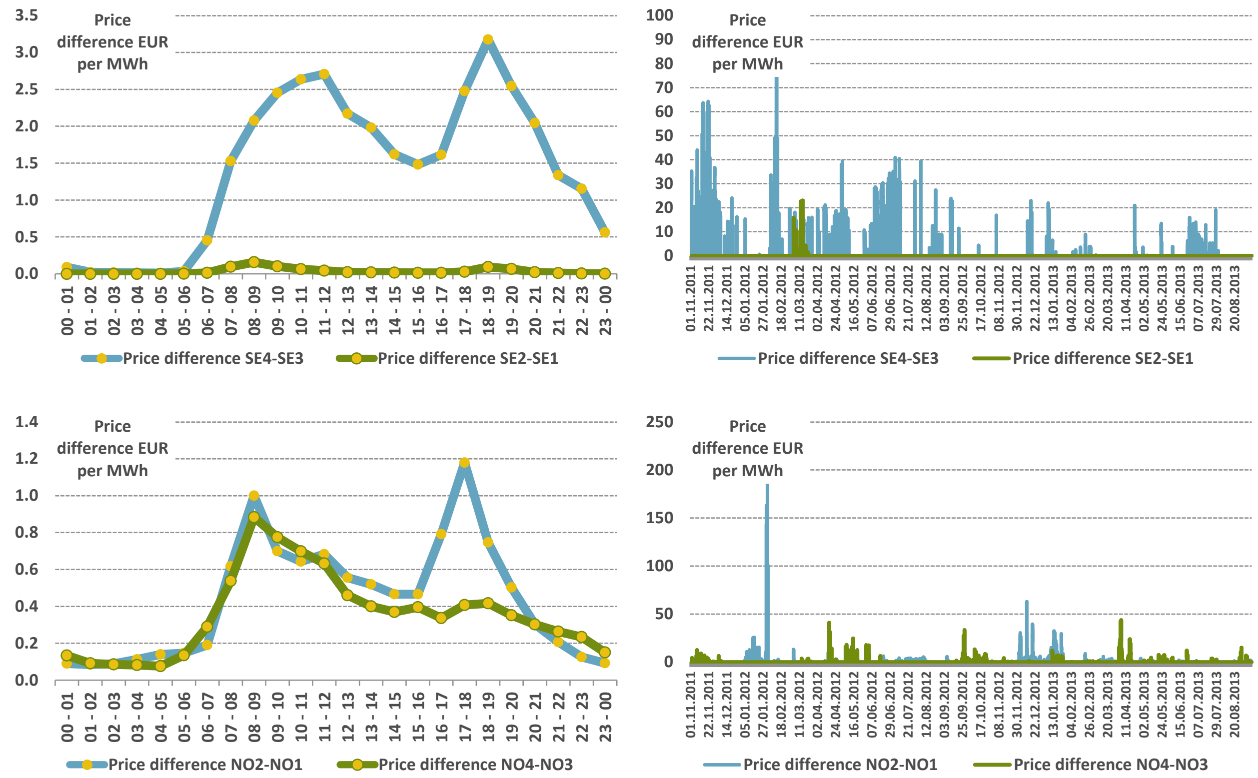
***Table 2: Average price difference in hours with price differences (€/MWh)***

| | SE1 | SE2 | SE3 | SE4 | NO1 | NO2 | NO3 | NO4 | NO5 | FI | DK1 | DK2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SE1 | - | 0.0 | 0.5 | 2.2 | 4.1 | 5.3 | 0.7 | 1.0 | 5.2 | 4.4 | 9.2 | 7.6 |
| SE2 | 0.0 | - | 0.4 | 2.1 | 4.1 | 5.2 | 0.8 | 1.1 | 5.1 | 4.4 | 9.0 | 7.5 |
| SE3 | 0.5 | 0.4 | - | 1.6 | 4.4 | 5.7 | 1.3 | 1.6 | 5.4 | 4.0 | 8.1 | 6.6 |
| SE4 | 2.2 | 2.1 | 1.6 | - | 7.2 | 9.0 | 3.2 | 3.7 | 8.4 | 6.1 | 6.8 | 4.1 |
| NO1 | 4.1 | 4.1 | 4.4 | 7.2 | - | 0.5 | 3.6 | 3.6 | 0.5 | 11.6 | 16.3 | 15.5 |
| NO2 | 5.3 | 5.2 | 5.7 | 9.0 | 0.5 | - | 4.7 | 4.7 | 0.7 | 13.8 | 16.3 | 16.9 |
| NO3 | 0.7 | 0.8 | 1.3 | 3.2 | 3.6 | 4.7 | - | 0.4 | 4.5 | 6.0 | 11.5 | 9.5 |
| NO4 | 1.0 | 1.1 | 1.6 | 3.7 | 3.6 | 4.7 | 0.4 | - | 4.6 | 6.6 | 12.6 | 10.3 |
| NO5 | 5.2 | 5.1 | 5.4 | 8.4 | 0.5 | 0.7 | 4.5 | 4.6 | - | 13.7 | 18.2 | 17.6 |
| FI | 4.4 | 4.4 | 4.0 | 6.1 | 11.6 | 13.8 | 6.0 | 6.6 | 13.7 | - | 12.8 | 10.4 |
| DK1 | 9.2 | 9.0 | 8.1 | 6.8 | 16.3 | 16.3 | 11.5 | 12.6 | 18.2 | 12.8 | - | 2.3 |
| DK2 | 7.6 | 7.5 | 6.6 | 4.1 | 15.5 | 16.9 | 9.5 | 10.3 | 17.6 | 10.4 | 2.3 | - |

*Legend: less than 0.5 €/MWh less than 1.5 €/MWh less than 3 €/MWh above 3 €/MWh*

We also find that price differences mostly appear in peak hours. Figure 4 shows the price difference over the entire observation period (right hand panel), and the average price difference by hour of the day (left hand panel). We also observe that the price differences between SE1 and SE2 (upper part of the figure) are limited to a certain period, while price differences between SE3 and SE4 are a more permanent phenomenon. The figure also includes a corresponding picture for Norwegian price zone differences (lower part of the figure), confirming that price differences occur mostly in peak hours. Severe differences are limited to a few hours.

***Figure 4: Observed hourly average price differences for Swedish bidding zones SE4-SE3 and SE1-SE2 and for Norwegian bidding zones NO2-NO1 and NO4-NO4***




*Source: THEMA Consulting Group, based on Nord Pool data*


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***Table 3: Share of hours with common prices across three adjacent zones (Nov. 2011-Sept. 2013)***

| | SE1<br>SE2<br>SE3 | NO1<br>NO2<br>NO5 | SE1<br>SE2<br>NO4 |
|---|---|---|---|
| First two | *98.8 %* | *89.6 %* | *98.8 %* |
| Last two | *96.7 %* | *80.0 %* | *81.6 %* |
| All three | *95.5 %* | *51.1 %* | *81.6 %* |

*Legend:* *above 95 %* *above 90 %* *above 80 %* *below 80 %*

An important aspect in the potential merger of bidding zones is that the price alignment is largely affected by the number of bidding zones that one compares. The prices may be aligned when comparing one-on-one, but may be much less aligned when considering several bidding zones. This is illustrated by the figures in Table 3, showing the percentage of hours when prices are aligned in two and three bidding zones respectively. For the three Swedish bidding zones SE1-SE2-SE3 prices are aligned in all three areas at the same time. However, when looking at NO1-NO2 and NO5, we find that prices between NO1 and NO2 as well as NO2 and NO5 are fairly aligned, but prices are to a much lesser extent aligned in all three areas at the same time.

## 5.2 Reasons for price differences

The observed price differences are a consequence of factors discussed in chapter 3.

First, differences in generation technology makes costs of generating electricity different between northern Nordic zones dominated by hydro and southern zones of Sweden and Denmark dominated by thermal, nuclear, and wind. This picture is further strengthened by connections from Denmark, Southern Sweden and Southern Norway towards Continental European markets characterized by a volatile price structure due to a mix of thermal capacity and high shares of wind power.

Second, we experience regional hydrology variations. Thus, a year may be a dry year in Western Norway, while other regions experience normal or high inflow levels. This is also illustrated in Figure 5, showing the historical inflow variations between areas in Norway and Sweden, expressed as the percentage of normal inflow for the respective regions (100 % = normal inflow levels).

***Figure 5: Historical inflow variations for the three reservoir regions in Norway and Sweden (100 % = normal inflow)***

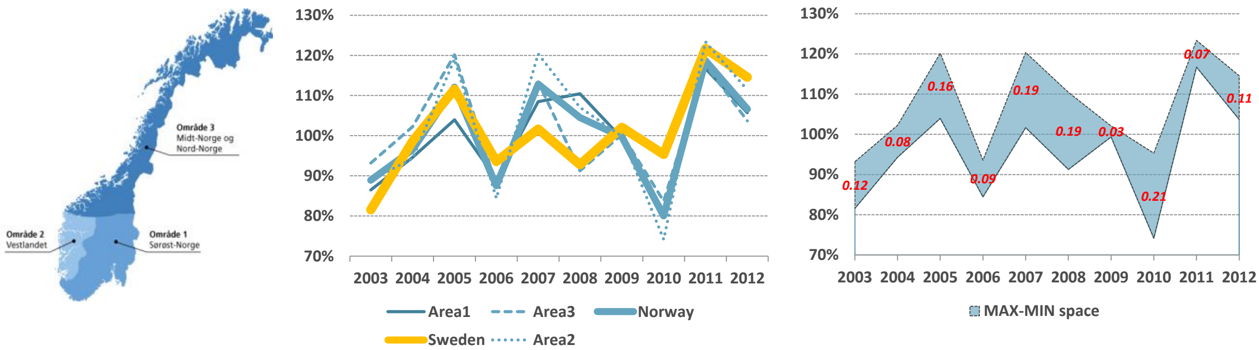
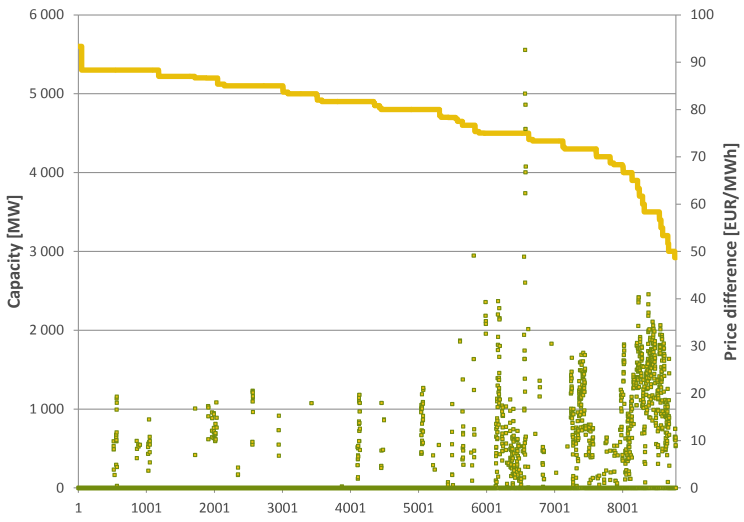



Figure 6 shows the capacity limitations in the cut between SE3 and SE4 and observed price differences in relation to available capacity. The observed price differences and their frequency correlate well with capacity reductions between bidding zones in southern direction. The lower the available capacity, the more frequent and severe are the price differences between SE3 and SE4. The main reasons for capacity reductions are stability issues in this cut and planned outages.

***Figure 6 Price differences in SE3-SE4 and ATC from SE3->SE4 (left) and reasons for capacity reductions (right), 2012***




*Source: THEMA Consulting Group, based on Nord Pool data*

## 5.3 Conclusions from the analysis of historical data

Bidding zones are the result of transmission bottlenecks and local imbalances. Some bidding zones do however frequently have similar prices and are hence identified as possible candidates for merger. These potential candidates are

- SE1, SE2 and SE3
- NO3 and NO4
- Potentially NO1 and NO2 as one “Southern zone”
- Potentially SE1-SE2-SE3 and NO3-NO4 as one cross-national “Northern zone”

An illustration of potential new bidding zone delimitations according to the historical analysis is shown in Figure 7. We have thus identified one potential cross-national bidding zone. Bidding zone delimitation in Finland could potentially have contributed to expanding this cross-national bidding zone further to also include Northern Finland, but this has not been analysed in this study.

It should, however, be emphasised that the proposed candidates for mergers are very preliminary. Firstly, the analysed time period only covers 22 months, and may therefore not be representative for a longer time period, particularly when we take the natural variations in inflow levels and patterns into account. Secondly, the power system will develop further and change over time. The bottlenecks of the past may therefore not be the bottlenecks of the future, old bottlenecks may be resolved and new bottlenecks become apparent.

We have therefore also conducted a model based analysis of the year 2018 to analyse how price differences may evolve in the future. The findings from the model analysis are presented in the next chapter.



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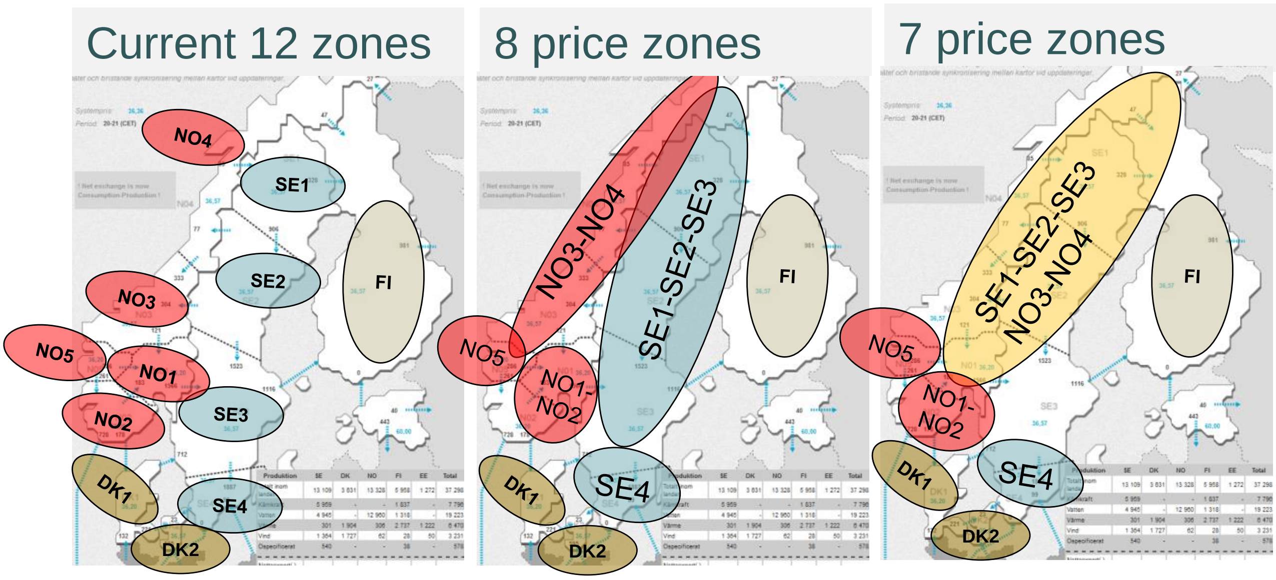
***Figure 7: Potential for merger of bidding zones based on historical findings***



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# 6 FUTURE BOTTLENECKS AND PRICE DIFFERENCES

This chapter provides a model based analysis for the future development of price differences, given today's bidding zones. We have modelled the year 2018, given expected developments for transmission, demand, and generation, taking historical inflow variations into account.

The analysis indicates the possibility of aggregating the northern hydro-dominated bidding zones, while leaving the bidding zones with strong interconnections to the continent separately. We see that the Nordic power market is sensitive to variations in inflow levels and patterns. Bidding zones are an efficient tool to handle local imbalances that result from inflow variations. Investments in transmission reduce bottlenecks between zones, but can at the same time increase or decrease bottlenecks elsewhere in the system.

## 6.1 Price differences for the year 2018

The analysis of prices in 2018 is based on prices obtained by using the The-MA power market model. The model simulations take account of expected demand, transmission, and generation developments in the Nordic countries and power markets in North-West Europe. In order to also account for inflow variations, we modelled the year 2018 with different inflow series reflecting local imbalances. Local inflow data for the years 2005, 2007, 2008 and 2010 were incorporated in the model. Those were the years with the largest annual inflow spread – expressed in percentage of normal year inflow – across regions over the time period 2003-2012 (cf. Figure 5). For example, in 2010, inflow in reservoir Area 2 was about 75 % of normal year inflow, while it was almost normal at around 96 % in Sweden.

In the analysis of historical data we saw that the availability of transmission is crucial. To account for variations in ATC values we implemented hourly availability of transmission based on observed availability of transmission for 2012. A more detailed description of the assumptions can be found in the appendix.

The results of the model analysis are summarized in Table 4. As the inflow assumptions are very different than for the years for which we conducted the historical analysis, the results here cannot be directly compared with the results from Table 1.

***Table 4 Percentage of hours with same price (2018; modelled prices over four inflow scenarios)***

| | SE1 | SE2 | SE3 | SE4 | NO1 | NO2 | NO3 | NO4 | NO5 | FI | DK1 | DK2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SE1 | *100.0 %* | *100.0 %* | *99.4 %* | *93.3 %* | *93.2 %* | *87.2 %* | *93.6 %* | *93.6 %* | *93.2 %* | *82.2 %* | *35.9 %* | *56.2 %* |
| SE2 | *100.0 %* | *100.0 %* | *99.4 %* | *93.3 %* | *93.2 %* | *87.2 %* | *93.6 %* | *93.6 %* | *93.2 %* | *82.2 %* | *35.9 %* | *56.2 %* |
| SE3 | *99.4 %* | *99.4 %* | *100.0 %* | *93.8 %* | *92.6 %* | *86.6 %* | *93.0 %* | *93.0 %* | *92.6 %* | *82.5 %* | *36.0 %* | *56.3 %* |
| SE4 | *93.3 %* | *93.3 %* | *93.8 %* | *100.0 %* | *86.4 %* | *80.8 %* | *86.9 %* | *86.9 %* | *86.4 %* | *80.3 %* | *36.5 %* | *57.3 %* |
| NO1 | *93.2 %* | *93.2 %* | *92.6 %* | *86.4 %* | *100.0 %* | *93.7 %* | *99.6 %* | *99.3 %* | *100.0 %* | *75.7 %* | *32.6 %* | *50.9 %* |
| NO2 | *87.2 %* | *87.2 %* | *86.6 %* | *80.8 %* | *93.7 %* | *100.0 %* | *93.5 %* | *93.4 %* | *93.7 %* | *72.8 %* | *35.6 %* | *49.1 %* |
| NO3 | *93.6 %* | *93.6 %* | *93.0 %* | *86.9 %* | *99.6 %* | *93.5 %* | *100.0 %* | *99.7 %* | *99.6 %* | *76.1 %* | *32.4 %* | *51.3 %* |
| NO4 | *93.6 %* | *93.6 %* | *93.0 %* | *86.9 %* | *99.3 %* | *93.4 %* | *99.7 %* | *100.0 %* | *99.3 %* | *76.1 %* | *32.4 %* | *51.3 %* |
| NO5 | *93.2 %* | *93.2 %* | *92.6 %* | *86.4 %* | *100.0 %* | *93.7 %* | *99.6 %* | *99.3 %* | *100.0 %* | *75.7 %* | *32.6 %* | *50.9 %* |
| FI | *82.2 %* | *82.2 %* | *82.5 %* | *80.3 %* | *75.7 %* | *72.8 %* | *76.1 %* | *76.1 %* | *75.7 %* | *100.0 %* | *34.0 %* | *52.8 %* |
| DK1 | *35.9 %* | *35.9 %* | *36.0 %* | *36.5 %* | *32.6 %* | *35.6 %* | *32.4 %* | *32.4 %* | *32.6 %* | *34.0 %* | *100.0 %* | *75.8 %* |
| DK2 | *56.2 %* | *56.2 %* | *56.3 %* | *57.3 %* | *50.9 %* | *49.1 %* | *51.3 %* | *51.3 %* | *50.9 %* | *52.8 %* | *75.8 %* | *100.0 %* |

We make the following observations:

- The three bidding zones SE1-SE2-SE3 in Northern Sweden have very similar prices.
- SE4 in Southern Sweden still has distinct prices from the other Swedish and Nordic bidding zones
- The bidding zones in Northern Norway (NO3-NO4) mostly have similar prices. With the planned grid investments even the Bergen area (NO5) and the Oslo area (NO1) will be very aligned with NO3 and NO4.
- Prices in Northern and Western Norway (NO3-NO4-NO5) and Northern Sweden (SE1-SE2-SE3) are somewhat aligned
- Southern Norway (NO2) has more distinct prices from the other zones. It is mostly aligned with the Oslo area (NO1)
- There is very little price alignment for Finland and the Danish bidding zones with the other zones.

## 6.2 Explaining factors and sensitivities

In order to test the importance of the assumptions regarding internal transmission capacity, new interconnectors, and inflow, we have simulated a number of sensitivities. These sensitivities address the following questions:

- What are the price differences if internal grid developments do not take place? We addressed this by modelling the year 2018 with today's internal grid capacities in the Nordic countries.
- How do price differences develop if the internal grid is developed, but if there are no new interconnectors? We addressed this by modelling the year 2018 without new interconnectors to Germany, and without the SK4 interconnector between Norway and Denmark.
- What is the impact of hydrological imbalances? We addressed this by running the model with a normal inflow year.

### *The role of the internal transmission grid*

The results from the sensitivity addressing the internal grid are summarized in Table 5. As in the reference case, we have modelled the year 2018 with different hydrological imbalances and availability of transmission capacity, but with today's internal grid.

It can easily be observed that the frequency of price differences increases. Across some areas, however, prices are still identical for the vast majority of hours. This is the case for the areas in Northern Sweden SE1-SE2-SE3 and for the areas in Northern Norway NO3-NO4. Prices between Northern Sweden and Northern Norway remain also identical in most hours. Also, NO5 (the Bergen area) has very different prices from the rest, unlike in the reference case.

An interesting observation is that without new internal grid investments, prices in Finland are more often identical with prices in Sweden than in the references case. Thus, internal grid investments reduce the frequency of bottlenecks between Norway and Sweden, but increase the frequency of bottlenecks between Finland and Sweden. In other words, if the grid between Norway and Sweden is re-enforced, the load on the link between Sweden and Finland increases.



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***Table 5: Percentage of hours with same price (2018 with today's internal grid; modelled prices over four inflow scenarios)***

| | SE1 | SE2 | SE3 | SE4 | NO1 | NO2 | NO3 | NO4 | NO5 | FI | DK1 | DK2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SE1 | 100.0 % | 98.6 % | 98.2 % | 51.4 % | 73.2 % | 48.7 % | 92.3 % | 92.9 % | 73.0 % | 92.4 % | 19.4 % | 39.9 % |
| SE2 | 98.6 % | 100.0 % | 99.6 % | 51.7 % | 74 .6 % | 49.0 % | 92.2 % | 91.5 % | 74.4 % | 92.8 % | 19.5 % | 40.1 % |
| SE3 | 98.2 % | 99.6 % | 100.0 % | 51.8 % | 74.7 % | 49.2 % | 91.8 % | 91.1 % | 74.5 % | 92.9 % | 19.6 % | 40.2 % |
| SE4 | 51.4 % | 51.7 % | 51.8 % | 100.0 % | 31.9 % | 26.2 % | 44.8 % | 44.5 % | 31.7 % | 50.1 % | 30.1 % | 60.3 % |
| NO1 | 73.2 % | 74.6 % | 74.7 % | 31.9 % | 100.0 % | 74.0 % | 76.3 % | 75.3 % | 99.8 % | 68.9 % | 15.0 % | 24.7 % |
| NO2 | 48.7 % | 49.0 % | 49.2 % | 26.2 % | 74.0 % | 100.0 % | 51.6 % | 51.0 % | 74.2 % | 46.6 % | 22.5 % | 21.6 % |
| NO3 | 92.3 % | 92.2 % | 91.8 % | 44.8 % | 76.3 % | 51.6 % | 100.0 % | 98.6 % | 76.2 % | 86.4 % | 15.4 % | 34.3 % |
| NO4 | 92.9 % | 91.5 % | 91.1 % | 44.5 % | 75.3 % | 51.0 % | 98.6 % | 100.0 % | 75.2 % | 86.0 % | 15.1 % | 34.1 % |
| NO5 | 73.0 % | 74.4 % | 74.5 % | 31.7 % | 99.8 % | 74.2 % | 76.2 % | 75.2 % | 100.0 % | 68.7 % | 15.2 % | 24.5 % |
| FI | 92.4 % | 92.8 % | 92.9 % | 50.1 % | 68.9 % | 46.6 % | 86.4 % | 86.0 % | 68.7 % | 100.0 % | 18.5 % | 38.6 % |
| DK1 | 19.4 % | 19.5 % | 19.6 % | 30.1 % | 15.0 % | 22.5 % | 15.4 % | 15.1 % | 15.2 % | 18.5 % | 100.0 % | 65.1 % |
| DK2 | 39.9 % | 40.1 % | 40.2 % | 60.3 % | 24.7 % | 21.6 % | 34.3 % | 34.1 % | 24.5 % | 38.6 % | 65.1 % | 100.0 % |

*Legend:* *above 95 %* *above 90 %* *above 85 %* *below 85 %*

In Sweden we observe that the three northernmost price zones, SE1-SE2-SE3, have almost identical prices, even without any new internal grid investments in Sweden. SE4 on the other hand experiences different prices in about half of the hours modelled.

The bottleneck between SE3 and SE4 is reduced when the capacity on the South West link is increased according to the planned 1400 MW upgrade: The share of hours when SE4 has equal prices with the other Swedish bidding zones increases from only 50 % (cf. Table 5) to 93 % with the planned South-West link in place (cf. Table 4).

In a sensitivity simulation where we increased the interconnection between SE3 and SE4 by another 600 MW, we find that prices in SE4 and SE3 are identical in 98 % of the hours.

### *The role of interconnectors*

Substantial investments in new interconnectors affect internal flows in the Nordic region. These investments include the NordLink interconnector to Germany (planned for 2018), the SK4 interconnector to Jutland (planned for 2016), and the NSN interconnector to the UK (planned for 2021). These interconnectors will influence internal flows and congestions within the Nordic countries.

We therefore simulated the year 2018 with identical inflow and ATC availability assumptions as in the reference case, but without the planned NordLink interconnector and the SK4 interconnector. The results from the simulations are summarized in Table 6.



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***Table 6: Percentage of hours with same price (2018 without SK4 and NordLink; modelled prices over four inflow scenarios)***

| | SE1 | SE2 | SE3 | SE4 | NO1 | NO2 | NO3 | NO4 | NO5 | FI | DK1 | DK2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SE1 | 100.0 % | 100.0 % | 99.1 % | 91.5 % | 71.0 % | 71.0 % | 71.7 % | 71.7 % | 71.0 % | 77.6 % | 26.6 % | 51.4 % |
| SE2 | 100.0 % | 100.0 % | 99.1 % | 91.5 % | 71.0 % | 71.0 % | 71.7 % | 71.7 % | 71.0 % | 77.6 % | 26.6 % | 51.4 % |
| SE3 | 99.1 % | 99.1 % | 100.0 % | 92.3 % | 70.4 % | 70.4 % | 71.1 % | 71.1 % | 70.4 % | 78.1 % | 26.7 % | 51.5 % |
| SE4 | 91.5 % | 91.5 % | 92.3 % | 100.0 % | 66.5 % | 66.5 % | 67.1 % | 67.1 % | 66.5 % | 75.5 % | 27.1 % | 52.5 % |
| NO1 | 71.0 % | 71.0 % | 70.4 % | 66.5 % | 100.0 % | 100.0 % | 98.9 % | 98.9 % | 100.0 % | 58.7 % | 21.4 % | 42.3 % |
| NO2 | 71.0 % | 71.0 % | 70.4 % | 66.5 % | 100.0 % | 100.0 % | 98.9 % | 98.9 % | 100.0 % | 58.7 % | 21.4 % | 42.3 % |
| NO3 | 71.7 % | 71.7 % | 71.1 % | 67.1 % | 98.9 % | 98.9 % | 100.0 % | 99.9 % | 98.9 % | 59.3 % | 21.7 % | 42.7 % |
| NO4 | 71.7 % | 71.7 % | 71.1 % | 67.1 % | 98.9 % | 98.9 % | 99.9 % | 100.0 % | 98.9 % | 59.2 % | 21.6 % | 42.7 % |
| NO5 | 71.0 % | 71.0 % | 70.4 % | 66.5 % | 100.0 % | 100.0 % | 98.9 % | 98.9 % | 100.0 % | 58.7 % | 21.4 % | 42.3 % |
| FI | 77.6 % | 77.6 % | 78.1 % | 75.5 % | 58.7 % | 58.7 % | 59.3 % | 59.2 % | 58.7 % | 100.0 % | 24.3 % | 46.9 % |
| DK1 | 26.6 % | 26.6 % | 26.7 % | 27.1 % | 21.4 % | 21.4 % | 21.7 % | 21.6 % | 21.4 % | 24.3 % | 100.0 % | 68.5 % |
| DK2 | 51.4 % | 51.4 % | 51.5 % | 52.5 % | 42.3 % | 42.3 % | 42.7 % | 42.7 % | 42.3 % | 46.9 % | 68.5 % | 100.0 % |

*Legend:* *above 95 %* *above 90 %* *above 85 %* *below 85 %*

The results illustrate a very important point: Without interconnector investments, prices within Norway and within Sweden are more frequently equal, but price differences between Norway and Sweden increase. Thus, new interconnectors from Norway to Denmark, Germany and the UK contribute to alleviating bottlenecks between Norway and Sweden. The reason for this is simple. With new interconnectors in place, Norway can export directly, without going via Sweden. Thus, lines between Norway and Sweden are relieved from flow. At the same time, however, interconnectors increase bottlenecks within Norway.

### *The role of inflow deviations*

To analyse the impact of inflow deviations, we conducted the same analysis as in the references case, assuming a normal hydrological year, see summary of results in Table 7.

***Table 7: Percentage of hours with same price (2018; modelled prices for a normal year)***

| | SE1 | SE2 | SE3 | SE4 | NO1 | NO2 | NO3 | NO4 | NO5 | FI | DK1 | DK2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SE1 | 100.0 % | 100.0 % | 99.4 % | 93.7 % | 93.6 % | 92.4 % | 93.7 % | 93.6 % | 93.6 % | 87.7 % | 38.3 % | 60.3 % |
| Nodal<br>SE2 | 100.0 % | 100.0 % | 99.4 % | 93.7 % | 93.6 % | 92.4 % | 93.7 % | 93.6 % | 93.6 % | 87.7 % | 38.3 % | 60.3 % |
| SE3 | 99.4 % | 99.4 % | 100.0 % | 94.2 % | 93.0 % | 91.8 % | 93.1 % | 93.0 % | 93.0 % | 88.0 % | 38.3 % | 60.4 % |
| SE4 | 93.7 % | 93.7 % | 94.2 % | 100.0 % | 87.3 % | 86.1 % | 87.3 % | 87.3 % | 87.3 % | 86.6 % | 38.9 % | 61.3 % |
| NO1 | 93.6 % | 93.6 % | 93.0 % | 87.3 % | 100.0 % | 98.8 % | 99.9 % | 99.7 % | 100.0 % | 81.6 % | 35.2 % | 55.5 % |
| NO2 | 92.4 % | 92.4 % | 91.8 % | 86.1 % | 98.8 % | 100.0 % | 98.7 % | 98.5 % | 98.8 % | 80.5 % | 36.0 % | 54.4 % |
| NO3 | 93.7 % | 93.7 % | 93.1 % | 87.3 % | 99.9 % | 98.7 % | 100.0 % | 99.7 % | 99.9 % | 81.7 % | 35.1 % | 55.5 % |
| NO4 | 93.6 % | 93.6 % | 93.0 % | 87.3 % | 99.7 % | 98.5 % | 99.7 % | 100.0 % | 99.7 % | 81.6 % | 35.0 % | 55.5 % |
| NO5 | 93.6 % | 93.6 % | 93.0 % | 87.3 % | 100.0 % | 98.8 % | 99.9 % | 99.7 % | 100.0 % | 81.6 % | 35.2 % | 55.5 % |
| FI | 87.7 % | 87.7 % | 88.0 % | 86.6 % | 81.6 % | 80.5 % | 81.7 % | 81.6 % | 81.6 % | 100.0 % | 36.9 % | 58.4 % |
| DK1 | 38.3 % | 38.3 % | 38.3 % | 38.9 % | 35.2 % | 36.0 % | 35.1 % | 35.0 % | 35.2 % | 36.9 % | 100.0 % | 74.2 % |
| DK2 | 60.3 % | 60.3 % | 60.4 % | 61.3 % | 55.5 % | 54.4 % | 55.5 % | 55.5 % | 55.5 % | 58.4 % | 74.2 % | 100.0 % |

*Legend:* *above 95 %* *above 90 %* *above 85 %* *below 85 %*

We see that less hydrological imbalance decreases the price differences between the Nordic areas. In particular prices within Norway are more aligned. Also NO2 (Southern Norway) is now more similar to the remaining Norwegian bidding zones countries.

Southern Sweden (SE4) remains an area with distinct prices, also for a normal year. Danish prices also remain distinct, while Finish prices are closer to the Swedish prices.

*Costs and benefits of merging Swedish bidding zones*

As pointed out in Chapter 2 there is a trade-off between costs of hedging and costs of re-dispatching/countertrading when we merge bidding zones. Since we do not have a way to model the cost of hedging, we cannot calculate the optimal bidding zone delimitation, however. Comparing the market solution with and without bidding zone delimitation, we can however illustrate the impact on the cost of counter trade of removing the bidding zone delimitation.

Modelling the 2018 scenario with prices over four inflow scenarios (reference scenario as explained in 6.1) we estimate a yearly increase in the cost of counter trade in Sweden around 4 EUR million. We would like to emphasize, however, that this is only a very rough estimate and is likely to be an underestimation of actual costs. As we do not employ a full grid model, the estimate does not capture changes in counter trade within the original bidding zones. Moreover, the model does not capture possible effects of strategic behaviour in the balancing market, which would increase the cost of counter trading.

On average the prices will increase in SE1, SE2 and SE3, while SE4 will experience lower prices. Consequently, the producers in Northern Sweden and consumers in Southern Sweden would benefit from a bidding zone merger. Since most of the consumption is in SE4 the total consumer surplus increases in Sweden, as well as the total producer surplus for all of Sweden. At the same time, counter-trade costs are typically passed on to consumers, thus whether consumers will eventually benefit from this measure is not clear.

An interesting observation in this context is that if Sweden is to become one price zone, spot prices in Sweden would increase, not decline, in most hours. The reason for the price increase is that the water values in Northern Sweden increase as the elimination of price zones effectively increases spot market interconnection between the Swedish zones. This result illustrates that removal of bidding zone delimitation affects the operation of generation, and thus the efficiency of the market. The generally higher water values in the North feed back into prices in Southern Sweden, at least in hours which already had identical prices. On the other hand, the previously observed spot price spikes in SE4 are reduced.

***Table 8 Average price in each bidding zone with and without merged price zones (€/MWh)***

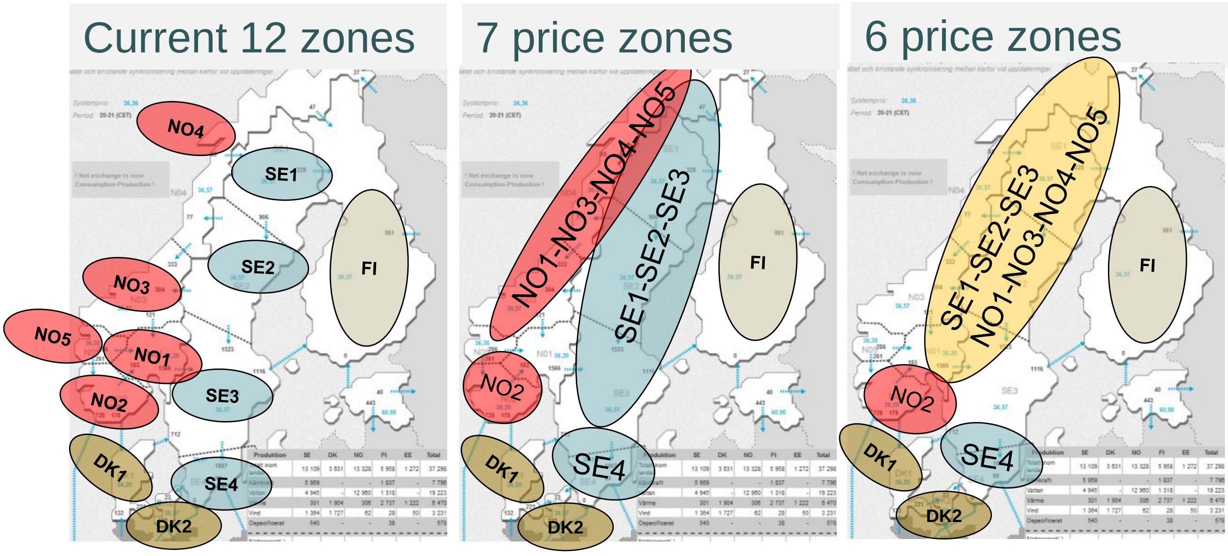
| | SE1 | SE2 | SE3 | SE4 |
|---|---|---|---|---|
| Four bidding zones | 33.79 | 33.79 | 33.83 | 34.22 |
| One bidding zone | 33.87 | 33.87 | 33.87 | 33.87 |

## 6.3 Conclusions from the model analysis

The results from our model based analysis are in line with the observations from the analysis of historical data. The prices in the bidding zones in Northern Sweden (SE1-SE2-SE3) are likely to remain fairly similar in the future, and so will prices in Northern Norway (NO3-NO4). With new grid investments in place, the Bergen area (NO5) and the Oslo area (NO1) will be very similar to NO3 and NO4. Also prices across Northern Sweden and Northern Norway are more frequently equal, although prices are more frequently equal within each of the bidding zones.

Southern Sweden (SE4) will remain a zone with distinct prices, and new interconnectors from Norway will increase the frequency of congestions between Southern Norway (NO2) and the other zones. Figure 8 summarizes the findings.

***Figure 8: Potential bidding zones based on model simulations for 2018***




We would like to emphasize that the analysis can only identify potential candidates for bidding zone merger, and the presented results can only give an indication of effects. Whether merging bidding zones is in fact efficient or not would require further analyses with a proper grid model. Also, bidding zone delimitation is an important instrument for handling of local imbalances that result from uneven inflow across the region.

The results also depend on the development of the internal grid. Without new investments in the internal grid, bottlenecks will remain or increase. In fact, some new bidding zones may even have to be created if new bottlenecks occur.

# APPENDIX

Key input variables in the power market model:

| | | Norway | | | Sweden | | | Finland | | | Denmark | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Units* | 2013 | 2018 | *Δ* | 2013 | 2018 | *Δ* | 2013 | 2018 | *Δ* | 2013 | 2018 | *Δ* |
| Price | *€ per MWh* | 29.3 | 36.1 | *24 %* | 29.5 | 35.4 | *20 %* | 30.2 | 35.7 | *18 %* | 29.9 | 36.8 | *23 %* |
| Coal | *$ per ton* | 74.8 | 100.6 | *35 %* | 74.8 | 100.6 | *35 %* | 74.8 | 100.6 | *35 %* | 74.8 | 100.6 | *35 %* |
| Gas | *$ per MBtu* | 10.1 | 9.0 | *-11 %* | 10.1 | 9.0 | *-11 %* | 10.1 | 9.0 | *-11 %* | 10.1 | 9.0 | *-11 %* |
| CO2 | *€ per ton* | 4.5 | 4.9 | *9 %* | 4.5 | 4.9 | *9 %* | 4.5 | 4.9 | *9 %* | 4.5 | 4.9 | *9 %* |
| SRMC Coal | *€ per MWh* | 24.4 | 31.9 | *31 %* | 24.4 | 31.9 | *31 %* | 24.4 | 31.9 | *31 %* | 24.4 | 31.9 | *31 %* |
| SRMC Gas | *€ per MWh* | 51.2 | 45.8 | *-11 %* | 51.2 | 45.8 | *-11 %* | 51.2 | 45.8 | *-11 %* | 51.2 | 45.8 | *-11 %* |
| Demand | *TWh* | 127.3 | 131.5 | *3 %* | 141.8 | 146.3 | *3 %* | 84.9 | 89.6 | *6 %* | 36.0 | 37.0 | *3 %* |
| Generation | *TWh* | 135.1 | 136.8 | *1 %* | 153.8 | 164.7 | *7 %* | 71.7 | 79.0 | *10 %* | 41.5 | 40.0 | *-4 %* |
| *Water* | *TWh* | 131.1 | 132.3 | *1 %* | 65.4 | 66.8 | *2 %* | 12.9 | 12.8 | *0 %* | 0.0 | 0.0 | *0 %* |
| *Nuclear* | *TWh* | 0.0 | 0.0 | *0 %* | 63.3 | 65.7 | *4 %* | 21.0 | 33.8 | *61 %* | 0.0 | 0.0 | *0 %* |
| *Wind* | *TWh* | 2.2 | 2.5 | *16 %* | 10.6 | 14.6 | *37 %* | 0.7 | 4.5 | *525 %* | 12.9 | 11.9 | *-8 %* |
| *Coal* | *TWh* | 0.0 | 0.0 | *0 %* | 2.1 | 1.6 | *-23 %* | 19.1 | 9.2 | *-52 %* | 20.9 | 20.4 | *-2 %* |
| *Gas* | *TWh* | 0.0 | 0.0 | *0 %* | 1.3 | 1.3 | *1 %* | 1.7 | 2.1 | *24 %* | 3.5 | 3.5 | *1 %* |
| *Other*[5] | *TWh* | 1.9 | 1.9 | *2 %* | 11.2 | 14.6 | *31 %* | 16.2 | 16.5 | *2 %* | 4.2 | 4.2 | *0 %* |
| *Capacity* | *MW* | 23400 | 32850 | *40 %* | 28500 | 34180 | *20 %* | 0 | 0 | *0 %* | 1190 | 1190 | *7 %* |

Renewable power generation will grow significantly due to the common green certificate support scheme in Norway and Sweden. Feed-in tariffs in Finland will also lead to a significant increase in renewable power generation in the Nordic area towards 2020. In Finland, Olkiluoto 3 will further strengthen the supply side.

- In Norway, we expect moderate investments in wind power up to 2018, before accelerating from 2020.
- In Sweden, the biggest short-term changes in the generation mix are wind power investments. We expect much of the increased capacity in 2018 in Northern Sweden, but also in SE4.
- In Finland, we assume the Olkiluoto 3 nuclear reactor currently under construction in Southern Finland to be operational by 2016, improving the power balance and decreasing the need for import.
- In Denmark we expect changes in installed wind capacity over the next decades. In total 1500 MW more wind capacity are expected to come online as tender processes for new offshore wind farms are carried out. However, in the period up to 2018 we expect small changes in installed capacity.

Within the Nordic market area we expect significant internal grid re-enforcements in north-south direction in Norway and Sweden as well as new cables to the continent. As for major new transmission investments we assume the following:

- Norway
    - Internal Norwegian upgrades 2014-2020

[5] Includes energy from peat, heavy fuel oil, light fuel oil, bio and combined heat and power

  - SK4 in operation by 2016 (600 MW Norway-Denmark)
  - NordLink in operation by 2018 (1400 MW Norway-Germany)
- Sweden
  - Internal Swedish upgrades until 2016
    - Southwest Link in operation by 2015 (1440 MW in internal Swedish capacity increase between SE3-SE4, deferred western branch of Southwest link)
    - Serial upgrade SE1-SE2 by 2016 (900 MW)
    - Shunt compensation SE2-SE3 by 2016 (500 MW)
  - NordBalt in operation by 2016 (700 MW Sweden-Lithuania)
- Finland
  - Estlink2 in operation by 2014 (650 MW Finland-Estonia)
- Denmark
  - Danish-German upgrades by 2014 and 2018
  - SK4 in operation by 2016 (600 MW Norway-Denmark)
  - COBRA by 2017 (700 MW Denmark-Netherlands)



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