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METHODOLOGY TO ESTIMATE THE IMPACT OF A BIDDING ZONE RECONFIGURATION ON MARKET LIQUIDITY AND TRANSACTION COSTS

Liquidity and transaction costs

ACER

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Applicable contract(s) governing the provision of this Report:

Objective:

The objective of this report is to provide an analysis of the potential impact of a bidding zone reconfiguration on i) market liquidity and ii) transaction costs and propose a methodology to quantify this impact and monetise it where relevant. It is written so as to provide guidance to the Agency in the context of its possible decision on the methodology and assumptions that are to be used in the bidding zone review process set in Article 15 of the recast Electricity Regulation.

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1 EXECUTIVE SUMMARY

To be written

2 BACKGROUND

Article 33 of the CACM Regulation[1] prescribes the minimum set of criteria for reviewing bidding zone configurations. Two of these criteria are market liquidity and transaction costs.

ACER has commissioned DNV GL to undertake an analysis of the potential impact of a bidding zone reconfiguration on market liquidity and transaction costs and propose a methodology to quantify this impact and monetise it where relevant. The study shall include an analysis and a conclusion on whether the above described impact can be considered as i) a (social) welfare gain (or loss), ii) welfare redistribution or iii) none of them.

The purpose of the study is to provide guidance to ACER in the context of its possible decision on the methodology and assumptions that are to be used in the bidding zone review process set out in Article 15 of the recast Electricity Regulation[2].

The DNV GL project team, Jørgen Bjørndalen and Björn Hagman, presented their findings to a selection of stakeholders at two regular meetings of the market stakeholders' committee (MESC) and to National Regulatory Authorities at two web-conference calls.

This report is structured in four sections. Part 1 after the Executive summary is an introduction and describes the background and the importance of liquidity. The next part analyses liquidity impacts in day-ahead and intraday markets. Part 3 analyses liquidity in forward markets. It starts with the need for hedging by fundamental participants. Sufficient correlation and transaction costs (risk premium and bid-ask spreads) are the key issues in assessing whether the forward market provides sufficient hedging opportunities in the concerned bidding zones. The issue of whether the impacts can be considered as changes in resource efficiency or as changes in distribution is analysed. Part 4 summarizes the proposed methodology to measure liquidity and transaction costs in a bidding zone review context.

[1] Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management

[2] Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity

3 THE IMPORTANCE OF LIQUID COMPETITIVE MARKETS

3.1 Interdependence between day-ahead and forward markets

Traditionally, bilateral physical contracts were used for buying and selling electricity. Fixed-price contracts protected customers from the risk of increasing prices and protected generators from the risk of reduced prices. Retail sales were often an integrated part of a vertically integrated utility. Utilities also enjoyed monopoly rights that effectively protected them from price risks and other types of risks. The drawback was that the electricity market was not efficient, transparent and non-discriminative.

The rise of organised day-ahead markets has opened opportunities for other buying and selling strategies. Consumers and retailers can buy their electricity in the day-ahead market and generators can sell electricity in the same market. Physical trading in the day-ahead market instead of longer-term bilateral physical contracts facilitates competition on equal terms and cost reductions for most participants since all participants in the day-ahead market meet the same price irrespective of their size. The drawback is that volatile day-ahead prices can lead to substantial price risks. Along with other risks, this may impede the core activities of all market participants.

A prerequisite for a well-functioning electricity market is thus that there are efficient hedging opportunities for consumers, retailers and generators. The demand for financial hedges from a market player varies with its overall risk exposure and with the terms in its physical contracts.

A fixed-price retail contract transfers the price risk from the customer to the retailer (however the customer is fully exposed to price risk when the contract period is ended). A retailer can choose to manage the price risk via a fixed-price bilateral contract with a generator. Another possibility is to buy the physical electricity in the day-ahead market and to combine the day-ahead purchase with a separate financial hedge of the price risk. In the same way, a generator has the possibility to reduce the price risk either via fixed-price bilateral contracts or via sales to the day-ahead market combined with separate financial hedges.

For large customers the choice is not only between variable-price or fixed-price retail contracts. They can also choose to combine with financial hedges if they buy in the day-ahead market or if they have variable-price retail contracts. Financial hedges and day-ahead purchases can be done directly by the customer or with assistance of a portfolio manager. Retailers and generators can of course also choose to use portfolio managers.

Financial long-term contracts are settled physically in most commodity markets. Physical settlement of a commodity contract implies that the market player has to arrange a physical receipt or delivery in a defined point or storage if the contract is not closed out before the delivery period. In this report, we will use the term *forward contracts* (or forward markets) for all contracts referring to any timeframe in the future beyond the single day-ahead coupling auction, including physical and financial settlement, exchange and over-the-counter (OTC) trading, cleared and non-cleared contracts, and including derivatives such as options and futures.

The major European forward markets for electricity have during the last decades changed from physical settlement to financial settlement. This has created a more level playing field between different categories of market participants and enabled a wider and increased use of the financial market. With financial settlement, there is only a cash settlement. Product specifications specify for the different contracts the reference price for the financial settlement. The reference price for base-load contracts is for each day during the delivery period calculated as the unweighted average of the day-ahead price for each hour.

A general acceptance of financial settlement requires that market participants have full trust in the formation of the reference price. A well-functioning day-ahead market is therefore a necessary prerequisite for a well-functioning financial market. Correspondingly, a well-functioning forward market is a necessary prerequisite for a well-functioning day-ahead market. Less market participants will buy or sell electricity in the day-ahead market if they find that the hedging opportunities are inefficient. They would instead rely on bilateral contracts for their electricity purchase or sales. There is thus a strong interdependence between the physical and financial markets.

3.2 Importance of liquidity

It is important that the electricity market is effective and competitive. Liquidity is an important feature of a well-functioning market. Liquid wholesale markets are important in creating competitive pressure in both the retail and wholesale markets.

Liquidity can be defined as the degree to which an asset can be bought and sold in the market without affecting the price of the asset and without incurring significant transaction costs. The bid-ask spread in a liquid contract should be fairly small. A small spread implies that there is a common view of the "correct" price. A high level of trading activity does not only reduce the bid-ask spread but also the risk for larger price movements when larger trades are done.

Poor liquidity in forward markets makes effective competition in generation and supply markets more difficult to achieve. It limits the ability of new entrants and small firms to buy and sell electricity in the wholesale market. Low levels of liquidity can increase their market risk as it becomes more difficult to hedge and to respond to changes in market conditions. This barrier limits the competitive pressure on incumbent firms.

Poor liquidity in day-ahead and intraday markets may result in mistrust in the wholesale market and may encourage business models (i.a. vertical integration or reliance on bilateral contracts) that reduce the need to trade in the wholesale market. Poor liquidity may also result in a less efficient price formation and a shakier basis for investment decisions.

On the other hand, liquid forward, day-ahead and intraday markets allow buyers and sellers to buy and sell electricity in a timely way at a reliable market price. They can pursue risk management strategies effectively. There is a lower risk for mistrust in the market. The more liquid markets, the easier it is for non-vertically integrated firms to compete with vertically integrated firms and the easier for new entrants to compete with incumbent firms.

Liquidity is thus an important characteristic of a well-functioning energy market. However, it is not an end in itself as it does not provide a guarantee that the market will operate efficiently. There are several other important characteristics of a well-functioning market.

3.3 Traders are essential for liquidity

An auction consolidates buy and sell bids into one market clearing. In European electricity markets, such consolidation of liquidity into an auction is done in the single day-ahead coupling (SDAC). In the single intraday coupling (SIDC), auctions are now implemented in addition to the current continuous trading.

Except for auctions of cross-zonal transmission rights in the form of FTRs or PTRs, there is only continuous trading in the forward market. Fundamental market participants as generators, retailers and industrial or commercial end-users submit bids and asks in order to achieve financial hedges and thereby reduce their risk exposure. Their aim is to reduce risks from market volatility – not to profit from market volatility.

Traders without any direct interest in production, supply or use of electricity, also participate in the markets. The aim for traders is to profit from market volatility – not to reduce risks from market volatility. Traders can be trading firms, funds, banks, utilities etc. They trade on their own account using their own capital. Their trading is based on technical (trend-following) or fundamental (price forecasting) analyses. Trading positions can relate to special contracts or to the spread between different contracts (delivery periods, zonal prices, fuels, carbon etc.).

Traders decide normally a time horizon when taking a position. Frequent time horizons are:

- The position shall not be kept overnight –day-trading.
- The position shall be closed when a target price is reached, a stop-loss limit is reached or a predefined date or incident is reached, whichever comes first.
- The intention is to keep the position until delivery. This is typically the case for transmission rights, as there is very little secondary trading in such rights in Europe, and for illiquid contracts.

Traders need to keep their open positions within decided risk limits. This means that short-term time horizons enable higher traded volumes.

The size of a possible open position in a contract is also dependent on the liquidity in the contract. High liquidity in the contract enables fast stop-loss of a larger volume without changing the price. Turnover, market depth and bid-ask spreads are important indicators when traders decide limits for open positions.

The liquidity offered from traders is an important lubricant for the forward market. Higher liquidity in the forward market improves the opportunities for fundamental market participants to rapidly perform their wanted hedging transactions. Traders buy when they think prices will go up and sell when they think prices will go down. Traders thus have an important role in adjusting prices quickly to new information. A higher frequency of trade reduces the bid-ask spread and creates a more efficient market.

4 LIQUIDITY IMPACTS IN DAY-AHEAD, INTRADAY AND BALANCING TIMEFRAMES

The recast Electricity Regulation states that bidding zones reflecting supply and demand distribution are a cornerstone of market-based electricity trading and are a prerequisite for reaching the full potential of capacity allocation methods including the flow-based approach[3]. The conclusion is that bidding zones therefore should be defined in a manner to **ensure market liquidity**, efficient congestion management and overall market efficiency.

It is further stated that bidding zone borders shall be based on long-term, structural congestions in the transmission network[4]. The configuration of bidding zones in the Union shall be designed in such a way as to maximise economic efficiency and to maximise cross-zonal trading opportunities while maintaining security of supply.

There are several liquidity impacts from a bidding zone reconfiguration (BZR) with bidding zone borders based on long-term, structural congestions in the transmission network.

A BZR resulting in a division of a bidding zone will divide the bids between the two zones. A BZR resulting in a merger of two bidding zones will merge the bids of the two zones.

However, the liquidity behind the price formation for a bidding zone in a market coupled auction is not limited to the bids in that bidding zone. In addition, bids in adjacent bidding zones affect the price formation in the concerned bidding zones depending on the available cross-border capacities. A BZR enabling increased cross-border capacities with adjacent bidding zones will thus in this respect result in some additional liquidity. The liquidity in adjacent bidding zones will in the same way also be increased if available cross-border capacities can be increased.

A structural congestion between two bidding zones means that the two zones repeatedly will have different prices. However, this will not necessarily mean a reduced liquidity behind the price formation in the two zones. A new zone may get common price with other adjacent zones and become a part of a larger price area and in this respect even get a higher liquidity. Also, adjacent zones with common price with a new bidding zone will get a higher liquidity behind the price formation.

Simulations of the day-ahead market can reveal to what extent the liquidity in different bidding zones will increase or decrease as a result of a BZR. One important issue is to what extent there will be an increase in available cross-border capacities with adjacent bidding zones and therefore a larger volume behind the price formation in the concerned bidding zone. Another important issue is to what extent the concerned bidding zone will have common price with adjacent bidding zones. In such a case will bids in adjacent zones be equally important for market clearing as bids in the concerned bidding zone.

Another liquidity effect of a BZR is that physical power transfer between market coupled bidding zones has to be done in the day-ahead market coupling or intraday market coupling. Company-internal transactions crossing a new bidding zone border has therefore to be done in the day-ahead or intraday market coupling.

Knowing that there are several causes for changes in traded volumes, we note that an increase in liquidity was observed after the separate Austrian bidding zone was implemented on 1 October 2018. The total EPEX SPOT day-ahead volume was 230 TWh for Germany, Luxemburg and

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[3] Preamble (19) of Regulation (EU) 2019/943

[4] Article 14(1) of Regulation (EU) 2019/943

Austria during the last 12 months before the division. The total day-ahead volume for the three countries increased thereafter by 13 % during the 12 months after the division to 261 TWh. Also, EXAA registered increased trading volumes. The total EXAA day-ahead volumes for Germany and Austria increased with 20 % from 8,3 TWh during the last 12 months before the division to 10,0 TWh during the first 12 months after the division.

A similar development was also observed in Sweden after the division 1 November 2011 of the Swedish bidding zone into four bidding zones. Nord Pool registered a 10 % increase from 2011 to 2012 in Swedish yearly day-ahead volumes.

A recent report prepared for the European Commission analyses how to integrate auctions in European intraday markets in order to meet the current CACM requirements for the single intraday coupling (Ehrenmann, et al., 2019). A general finding is that the requirements regarding congestion pricing based on actual bids and inclusion of flow-based market coupling constraints favour auctions over continuous trading. Liquidity concentration in auctions supports an efficient price discovery and a level playing field for smaller and larger market participants. The key question according to the report is not if auctions need to be introduced, but rather when to introduce them and how many are needed. Continuous trading between the auctions will enable market participants to react quickly to new information on plant outages, demand or weather.

It should also be noted that SDAC auctions are themselves a consolidation of liquidity since an auction pools buy and sell bids into one market clearing. Sufficient market liquidity to ensure efficient price formation in SDAC should therefore normally not be jeopardized if a BZR results in more bidding zones. The same goes for SIDC. Implementation of intraday auctions in addition to the current continuous trading will consolidate liquidity around the times when auctions take place. Hence, intraday liquidity becomes less critical than in a market based on continuous intraday trading only.

The guideline on electricity balancing states in preamble (5) that its rules will increase the liquidity of short-term markets by allowing for more cross-border trade and for a more efficient use of the existing grid for the purposes of balancing energy. Activation of balancing energy bids in a control area shall be based on a TSO-TSO model with a common merit order list. The common merit order list enables cost-effective use of bids in other control areas subject to available cross-border capacity.

Congestions within a bidding zone means that redispatch has to be used for balancing instead of the common merit order list. The liquidity benefit of a larger bidding zone is lost if intra-zonal congestions made some bids unavailable. In addition, cross-border intraday trade has now and then been closed when congestions arise within a bidding zone. A more efficient bidding zone configuration gives liquidity benefits in intraday and balancing timeframes if it eliminates the need to now and then close cross-border intraday trade and enables full use of the common merit order list.

5 HEDGING BY FUNDAMENTAL MARKET PARTICIPANTS

5.1 Hedging strategies

Hedging risks are an integrated part of all business. Companies tend to maximise profits within constraints, and risks are one group of constraints.

Risks can be dealt with in three different ways. They can be tolerated and thus kept. They can be transferred wholly or partly to another party. Such a transfer means normally an extra cost, an 'insurance premium'. The third possibility is to terminate or constrain the activity giving rise to the risk.

Perfect hedges that eliminate all risks are not sought. The 'insurance premium' would be too high if all risks are to be eliminated. The challenge is therefore to find an **acceptable level of risk at acceptable costs**. Risk management is a tool and not a goal per se.

There are numerous examples of potential hedges that are not used – simply because the costs are considered too high. 'Costs' here includes both an apparently high risk premium in a contract, that the hedge may reduce negative risks but at the same time foreclose attractive profit opportunities, and the internal administrative costs of managing a complex hedge portfolio. If a risk can't be transferred at acceptable costs, the company has to decide if the risk shall be tolerated or if the activity giving rise to the risk shall be terminated or constrained.

Hedging strategies are based on risk analysis, analysis of possible hedging instruments and correlation analysis. Retailers often make back-to-back hedging when concluding fixed-price contracts. A portfolio strategy for hedging is often used by producers and consumers meaning that the company gradually develop its wanted level of hedging by using standardized contracts with different maturities and volumes. A portfolio hedging strategy prescribes intervals for percentage of the volume to be hedged at different times before the delivery period. Such a strategy can be mechanical (the timing of the hedging transactions is not dependent on price expectations) or dynamic (the timing of the hedging transactions is dependent on price expectations).

A possible portfolio strategy for hedging is illustrated in the following figure. Whether the hedging starts years or months before delivery depends on risk analyses and relevant transaction and hedging costs.

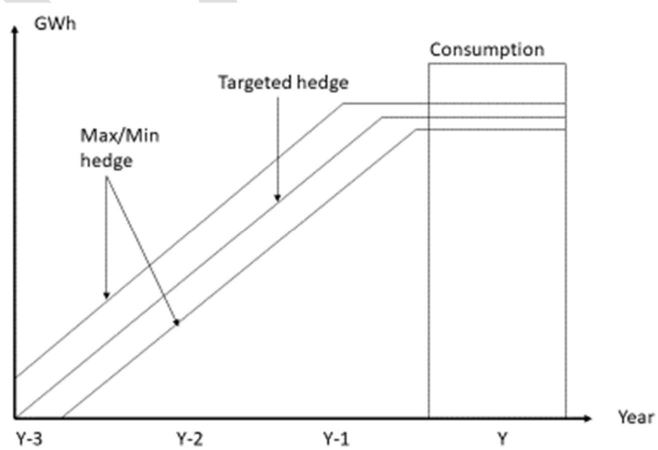

Figure 5-1 Illustration of gradually increasing hedging volume

5.2 Power purchase agreements

A power purchase agreement (PPA) is a direct bilateral agreement between a supplier and a consumer of power. A PPA was the traditional way to trade electricity before organised markets started to develop. Recently, there has been a growing trend internationally towards increased use of long-term PPAs. This development is driven by new types of buyers and sellers and is probably reflecting that these have long-term hedging demands that are not satisfied with the current organised markets.

On the buyer side, there has always been a demand by some electricity-intensive companies to achieve a more long-term hedging of power prices than is possible to achieve in organised forward markets. There is now also an increasing wish by companies to communicate sustainability and environmental goals and to prove that they contribute to an expansion of renewable electricity generation. New types of buyers of PPAs are data centres, global corporates and property owners. Some traditional PPA buyers as electricity-intensive companies have now the same focus on communicating that they contribute to an expanding renewable electricity generation.

On the seller side, there has traditionally been some interest in PPAs for hedging investment decision. Wind farm developers have now emerged as dominant sellers of long-term PPAs. Wind power has a high upfront investment. Certainty in the revenue stream is demanded from potential capital lenders. A certain return on the investment can be ensured by a long-term PPA. The wind farm owner has therefore an incentive to sign a long-term PPA even if the price of the power is lower than the expected day-ahead price.

There is a variety of long-term risks for both buyers and sellers of PPAs. PPAs are therefore tailored to fit for the specific circumstances. There are no standardized PPAs and the complexity gives a need to engage both legal and energy advisors. The high negotiation costs are a cost barrier for smaller size long-term PPAs. Open platforms for PPAs are now emerging.[5]

Bloomberg finds that over half of all PPA activity in Europe since 2013 has been in just three countries: the Netherlands, Norway and Sweden (Bloomberg New Energy Finance, 2018).

Large bidding zones are thus no requirement for a high PPA activity. The Netherlands is a mid-size bidding zone. Norway and Sweden have together a population of 15 million and 9 bidding zones. It is interesting to note that buyers and sellers in Norway and Sweden are most often in different bidding zones and there are also cross-border PPAs between the two countries. This means that the inherent cross-zonal price risk is not considered as a barrier to cross-border PPAs.[6]

5.3 Sufficient correlation and efficient hedging instruments

The guideline on forward capacity allocation (FCA GL) states in preamble (3) that efficient hedging opportunities should be developed for generators, consumers and retailers to mitigate future price risk in the area where they operate. Paragraph 4 in Article 30 describes what shall

[5] DNV GL's Instatrust (https://www.dnvgl.com/services/instatrust-128490) already has some 4 GW on offer from various developers.

[6] Cross-border PPAs place the cross-zonal price risks with one of the contracting parties; it is not eliminated.

be included in an assessment whether the forward market provides sufficient hedging opportunities in the concerned bidding zones.

A product or combination of products shall be considered as an appropriate hedge against the volatility of the day-ahead price of the concerned bidding zone if there is sufficient correlation between the day-ahead price of the concerned bidding zone and the underlying price against which the product or combination of products are settled (paragraph 4(a) in Article 30).

The assessment shall also include an analysis of whether the products or combination of products are efficient (paragraph 4(b) in Article 30).

The two relevant key issues are thus sufficient correlation and efficient hedging instruments. The correlation issue deals with the market participants' challenge to identify forward contract(s) that can be used to hedge price volatility, and to analyse if suggested contracts are suitable for hedging the price risk. The efficiency issue addresses the concern for market participants that hedging is associated with transaction costs and that hedges must not be too costly.

6 IDENTIFYING HEDGING OPPORTUNITIES - CORRELATION

If there are no local forward contracts available or if the local forward contracts are considered inefficient (e.g. illiquid), market participants with hedging demands can look for proxies. Proxies are other contracts, either by themselves or in combination, that potentially could provide appropriate hedges (Alexander, 2008). For any bidding zone, a proxy could be a forward contract for another bidding zone with comparable (not necessarily identical) behaviour of day-ahead prices. Alternatively, one could look for a combination of several contracts, e.g. for different bidding zones. Such combinations can potentially be complex, such that hedging a long position in zone z can be done by combining a short position in zone v and w with a long position in zone u.

It is not required that the proxy is for an adjacent bidding zone. The important issue is whether a short or long position in the proxy provide sufficient hedging for the market participant. As this is a financial matter, the physical location of the proxy is not an issue. It is the behaviour of the prices that matters.

Below, we discuss how to determine the appropriateness of proxies for hedging of a zonal price. We start with a mathematical approach to describe the volatility of the revenue for a market participant with different choice of hedging instruments. The relevant methods for quantitative assessments follow from the mathematics.

6.1 The risk level depends on correlation

A practical interpretation of price risk is to which extent the revenue varies with fluctuating prices. A common measure of such variations is the standard deviation of the revenue. If the revenue is fully determined by the prices in hedging contracts, the impact of price risk is eliminated, and the standard deviation is low.

To give a simple explanation of the mechanics of hedging price risks, we can use a power plant as example. To keep the example simple, we ignore the intra-day and real-time markets and assume that the only short-term market is day-ahead. Also, to avoid confusion with volume risk, we will assume the production volume is constant and 1 (MWh per hour).

The value of the output from this power plant is given by the local day-ahead prices. We can write the day-ahead price for hour t in bidding zone A as P_A^t. Let us also define the average day-ahead price over a longer period T, say a month, a quarter or a year, as P_A^T or simply P_A. The power plant is facing price risk because the actual value of P_A (and all the P_A^t) during the hedged period is unknown and volatile. The resulting revenue for the power plant is thus volatile.

If the local forward contract is liquid, the owner of the power plant can hedge the revenue from the power plant by taking a short position in the contract market (selling a forward contract) for the time period T. The settlement of the forward contract will be a payment equal to the contract price minus the average delivery price for the period (multiplied with the volume of course). If the contract price is higher than the delivery price, the seller will receive a payment; if the contract price is lower, the seller will pay the difference to the buyer.

Mathematically, we can write the resulting net cash flow over period T from the power plant and the hedge contract in the following manner, where $\hat{P}_A$ is the fixed contract price:

$$P_A + [\hat{P}_A - P_A] = \hat{P}_A \quad (1)$$

The cash flow in period T thus equals the price of the hedge; $\hat{P}_A$.

Assume the owner of the power plant considers hedging in zone B instead; using B as proxy for A. The net cash flow will now depend on the local day-ahead price in A (the sale of generation) and the settlement of the hedge arrangement in zone B (which is the difference between the contract price and the local day-ahead price in B):

$$P_A + [\hat{P}_B - P_B] = \hat{P}_B + (P_A - P_B) \quad (2)$$

The term $(P_A - P_B)$ is simply the cross-border price difference, here measured as the difference between the average of day-ahead prices over period T in zone A and B respectively. Hence, hedging a physical quantity in zone A by contracts in zone B results in a portfolio exposed to the cross-border price risk.

The efficiency of the proxy hedge depends on the size and statistical properties of this price risk. Let us therefore consider the variance of the net cash flow in Equation 2. Recall that the price of the hedge contract, $\hat{P}_B$, is a constant when the hedge is made. Hence, the variance of the revenue equals

$$Var\left(\hat{P}_B + (P_A - P_B)\right) = Var(P_A - P_B) = Var(P_A) + Var(P_B) - 2Cov(P_A, P_B) \quad (3)$$

The standard deviation of the net cash flow is the square root of the expression in Equation 3.

The correlation between the zonal prices in A and B is defined as the ratio of their covariance and the product of their individual standard deviations;

$$Corr(P_A, P_B) = \frac{Cov(P_A, P_B)}{\sigma^A \cdot \sigma^B} \quad (4)$$

This can be rearranged, such that $Cov(P_A, P_B) = Corr(P_A, P_B) \cdot \sigma^A \cdot \sigma^B$.

Then it is clear how a correlation metric is relevant when analysing hedging strategies and availability of hedging opportunities. Recall that P_A and P_B are the average day-ahead price over the relevant hedging horizon.

- If prices in A and B are perfectly correlated (correlation coefficient equal to one), the covariance equals the product of the individual standard deviations, which also are equal. In that case, the variance, and thus the standard deviation, of the portfolio cash flow in Equation 3 is zero, and the proxy hedge is perfect.
- If prices in A and B are not correlated at all (correlation coefficient and covariance equal to zero), the negative element on the right-hand side in Equation 3 is zero, which clearly makes the variance and standard deviation of the net cash flow larger than the variance of the price in B. Such a hedge would increase the price risk instead of reducing it.

Finding a good proxy thus implies searching for the B in the setup here that results in a sufficiently hedged portfolio. The aim is to reach an acceptable risk level at acceptable costs. This implies that the variance of the underlying for the proxy must be smaller than twice the covariance of the delivery price and the underlying, as shown in Equation 5.

$$Var(P_A) > Var(P_A) + Var(P_B) - 2Cov(P_A, P_B) \quad (5)$$

$$Var(P_B) - 2Cov(P_A, P_B) < 0$$

$$Var(P_B) < 2Cov(P_A, P_B)$$

6.2 Correlation between prices or price changes?

One of the key principles for EU listed companies is that derivatives shall be booked at mark-to-market value. Changes of mark-to-mark values between periods shall have immediate effect on the profit and loss account. The international accounting standard IAS39 allows for an exemption from this general rule if the mark-to-market values of the hedged item and a portfolio of hedging contracts are sufficiently correlated. The exemption implies that a decrease in the value of e.g. the hedge portfolio does not have to be booked against the profit and loss account because the loss also reflects a similar gain in the value of the hedged item (and vice versa). Without an exemption, the loss on the hedge portfolio must be booked immediately, while the corresponding gain in the hedged item cannot be booked due to the general principles of cautious accounting. Needed correlation tests for this purpose must therefore focus on comparing *the price changes* from one period to the next. The correlation tests in the accounting literature are thus comparing the changes in mark-to-market values of a hedged item and a portfolio of hedging contracts (Finnerty & Grant, 2003; Hailer & Rump, 2005).

The hedging decisions in the electricity market have a different perspective and objective. The objective is generally to reduce the volatility of revenue or costs due to the volatility of day-ahead prices. And with proper hedging contracts, the market participant can 'replace' the volatile day-ahead prices with fixed prices for longer periods. There will still be volatility in revenue or costs with such hedging, but the volatility will be lower, and the prices will be more predictable.

This objective or strategy for hedging decisions is reflected in the math section above. What matters is the correlation between the average delivery price of the hedging horizon and the average of the underlying for the hedging contracts over the same period.

Another way to explain this is that once the hedge is made, it does not matter if the market prices for the hedging period changes. If a market participant has sold at say 40 EUR/MWh for next year, and the market price for such contracts increases to 41 EUR/MWh the day after, this increase has no impact on the future revenue. The hedged volume will only receive 40 EUR/MWh. The increase from 40 to 41 EUR/MWh is relevant only for a mark-to-market valuation, not for predicting the future revenue.

The scope for the correlation analysis must therefore be to compare a given average zonal price with the average underlying for appropriate hedging portfolios. The concern is whether the prices in the delivery period are well correlated or not, and not whether changes in the value of the hedging portfolio and the hedged item during the hedging period are correlated. Thus, the approach in accounting tests is not relevant in this context.

6.3 Which proxies to compare?

The analytical problem is that there can be an infinite number of proxies, or potentially relevant hedge portfolios. The focus in the literature is on a mean-variance hedging with a minimum variance criteria (Alexander, 2008).

If we consider a hedge for e.g. Austria, one hypothetical alternative could be to use a combination of German and Italian forward contracts with x % of the volume hedged by the Italian contract and 100 minus x % hedged by the German contract. And we might as well consider including Hungary and the Netherlands in addition to Italy and Germany – or instead of Italy and Germany.

In practice, we can see only two realistic approaches for external analyses (e.g. by TSOs or regulators) when looking for potentially relevant proxies. One is to ask market participants which contracts they consider relevant in their hedge portfolios. The other is to search systematically through a limited set of alternative combinations. In doing so, the analytical challenge is 'reduced' to find the combination of contracts that demonstrates the best correlation with the local price to be hedged.

6.4 Time resolution and time horizon

Hedging strategies among producers often are flexible. Typically, the strategy states that between x and y % of the expected generation should be sold one year ahead, and further that between z and v % should be sold out two years ahead, etc. (x and y are then larger than z and v, respectively). As illustrated in Figure 5-1. Except for the long-term industries, like metals, industrial customers have somewhat similar hedging horizons, but frequently less flexible. Retailers also generally have a more mechanical approach and a hedging horizon corresponding to the duration of their fixed price sales contracts.

For those with a horizon of several years it is generally the average price per year that matters, while the quarterly and even monthly averages are more relevant for retailers. We cannot see any reason to study averages over shorter time periods, such as weeks. Hourly prices are anyway totally irrelevant.

A practical approach would be to study yearly, quarterly and monthly averages of hourly day-ahead prices. For a study of hedging horizons relevant for industrial end users and producers, the focus must be on yearly and perhaps quarterly averages. This requires, however at least either some simulated scenarios or some simulation years, or preferably some scenarios and some years.

For a bidding zone review, historical prices are not relevant. What is needed, are prices reflecting the potentially new bidding zone structure. This implies the correlation analysis must be prepared based on simulated prices. Luckily, other analyses relevant for a bidding zone review are likely to rely on modelling exercises applying numerical power market models which produce i.a. future hourly prices in different scenarios. Hence, we assume TSOs or regulators have access to price simulations reflected new potential bidding zones.

Ideally, such simulated prices should reflect a number of future years and different scenarios. If so, we would have more than sufficient 'observations' to study correlations between various monthly, quarterly and yearly average prices. A proper correlation analysis relies on a balance between not looking too far ahead and not too broad while at the same time not missing realistic but not frequent incidents.

6.5 What is "sufficient" correlation?

The next question is where to draw the limit to define an acceptable hedge. The beauty of the principles from hedge accounting (see section 6.2) is that there is a norm. To qualify for hedge accounting, the correlation coefficient must be at least 0,8. Market participants in the electricity sector may hedge at lower correlation rates without having to comply with the IAS39 if they do not apply hedge accounting.

For a market participant looking for a proper hedge, a ratio below 0,8 might also be acceptable. 0,7 is clearly better than e.g. 0,5, but is 0,5 sufficient or acceptable? And would hedging by a proxy with a correlation coefficient of 0,5 be worse than not hedging the zonal price risk at all?

We recommend that knock-out thresholds are not used. Possible thresholds should only be treated as indicators in the analysis. After all, it is the overall results from correlation analyses, efficiency analyses, other analyses and eventually a consultation that are important. The aim is to assess if there are contracts or combinations of contracts that enable a risk reduction to an acceptable risk level at acceptable costs.

6.6 Practical calculations

The quest for correlation metrics must, as already indicated, rely on simulated prices reflecting a new bidding zone configuration. Assuming simulation results are available, in terms of simulated hourly prices for multiple zones for preferably at least three years and for different scenarios spelling out the normal uncertainties in the market, the calculations are quite trivial.

1. Once the simulated prices are available, calculate the monthly, quarterly and yearly average prices separately for all bidding zones.
2. Suppose we are particularly concerned about the liquidity and hedging opportunities in zone X. Define all the other bidding zones as B1, B2, etc.
3. Calculate the correlation between average prices of X with similar average prices for B1, B2, etc., keeping the monthly, quarterly or yearly average prices separate:
    a. For monthly average prices, X vs B1, X vs B2, etc.
    b. For quarterly average prices, X vs B1, X vs B2, etc.
    c. For yearly average prices, X vs B1, X vs B2, etc.
4. Also consider 'blending' new proxies by different averages of B1, B2, etc. (e.g. 0.3B1 + 0.45B2 + 0.25B3) See also illustration below, where a simple regional arithmetic average is included.
5. The key question is how well the monthly, quarterly or yearly average prices for X are correlated with corresponding averages in any of the other bidding zones.

While the calculations are straight forward, making conclusions is more complicated. If we find that X and B4 are almost perfectly correlated, the only thing we know from the analysis so far is that fundamental positions in zones X and B4 can be hedged by the same forward contract. However, if we find that these zones are poorly correlated, we know that the fundamental positions in zones X and B4 can't be hedged by the same forward contract.

For illustration we include two tables showing historic correlation between yearly average day-ahead prices in four CWE countries; Germany, Belgium, the Netherlands and France. (For a bidding zone review we recommend simulated prices as explained above.) In the left half, the correlation coefficients are based on all yearly averages from 2008 to 2019; in the right half the correlation coefficients are based on the last six years only.

Table 6-1 Correlation between yearly average day-ahead prices in four CWE countries (Data source: ENTSO-E transparency platform)

	Yearly average prices (2008-2019)						Yearly average prices (2014-2019)				
	BE	NL	FR	DE	Average		BE	NL	FR	DE	Average
BE	1,00	0,95	0,94	0,88	0,97	**BE**	1,00	0,90	0,86	0,80	0,95
NL	0,95	1,00	0,90	0,92	0,97	**NL**	0,90	1,00	0,73	0,93	0,95
FR	0,94	0,90	1,00	0,95	0,97	**FR**	0,86	0,73	1,00	0,81	0,90
DE	0,88	0,92	0,95	1,00	0,97	**DE**	0,80	0,93	0,81	1,00	0,94

For the whole period, there is very good correlation between the yearly average day-ahead prices in the four countries. For the latest six years, the correlation is lower but still good.

The rightmost column in the two tables shows the correlation between each of the four bidding zone prices and the arithmetic average for all four zones. The numbers in the rightmost column indicate, not surprisingly, that for each of these bidding zones, a forward contract based on an index composed as an arithmetic average of all four day-ahead prices, would be the best alternative if local contracts were not attractive or available for hedging purposes.

7 ANALYSING HEDGING EFFICIENCY – RISK PREMIUM AND OTHER TRANSACTION COSTS

The availability of any contract type in forward markets is generally a result of supply and demand for various forms of derivatives.

To explain the supply and demand for contracts in forward markets, we will start with a very simple illustration to show that forward markets are markets for uncertainty, where the supply and demand functions reflect the various market participants' cost of being exposed to uncertainty (i.e. how risk-averse they are). We then continue by explaining how risk premium analyses can be performed.

Hedging efficiency is also dependent on other transaction costs, which could be explicit such as trading fees or implicit (such as potential transaction costs related to bid-ask spreads).

7.1 Forward markets are markets for uncertainty

The risk premium can be understood as the market value (cost)of replacing uncertainty with certainty. Consider the day-ahead price for electricity as a probability distribution. For simplicity, we assume that the price is normally distributed, with expected value p and standard deviation s. (A more realistic example would be more complicated to explain, but the logic and the implications are the same.)

In the diagram below the blue line represents a probability distribution with expected price 20 and a standard deviation of 6 (EUR/MWh). (Ignore the vertical, coloured lines until later.) For a start, let us assume that all market participants share the same expectations for the price. Hence, there is no doubt in the market about the expected price and its volatility. For a risk neutral end user, it would not matter if she signs a contract with a fixed price at 20 or simply pays the day-ahead prices whatever they turn out to be. The same would hold for a risk neutral producer. If both sides of the market were risk neutral, none of them would bother to require any sort of hedging contracts.

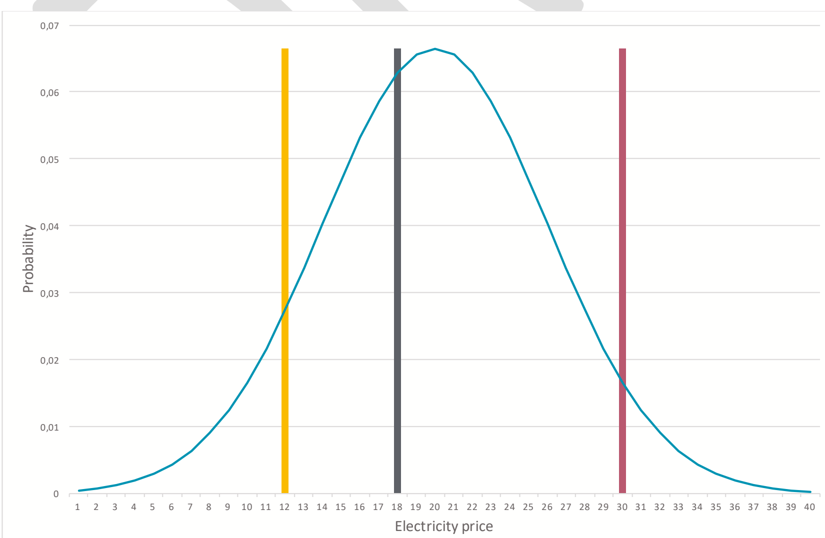

Figure 7-1 Illustration of a probability distribution for day-ahead price

Now, let us consider what happens if we assume at least one participant at the demand side is risk averse. A simple example is if prices above 30 (the red bar) is intolerable, and that prices are more attractive the more they are below 30. Thus, any fixed price up to 30 would be more attractive to this market participant than an unhedged position. And the lower the fixed price, the more attractive is the contract for this market participant.

There will be no contracts unless there is a counterparty. Assume therefore there is at least one producer that has concluded that at prices below 12 (the yellow bar), he will suffer an unacceptable loss. To ensure this will not happen to him, he is willing to sell at a fixed price provided it is above 12.

If these were the only risk averse market participants, all we would know ex ante is that an equilibrium price for a fixed price contract would exist and that it would be somewhere between 12 and 30.

Now, let us assume they (for reasons unknown to us) agree on a fixed price of 18 (the grey bar). What does this tell us?

a) Both the buyer and the seller get a contract that satisfies their demand for certainty. This is of course obvious, but it is important to recall that both had the option not to sign the contract, and both concluded that this contract was better than no contract.

b) The producer got 6 more than its final, ultimate limit, and the end user got 12 more than its limit. From such a perspective both have gained on the contract – even before the start of delivery.

c) From another perspective, we can observe that the producer has 'given away' an expected revenue of 2 (18 minus 20) while the end user has received the same expected revenue. This is in fact what we can describe as an ex-ante risk premium (minus 2 for the end user, plus 2 for the producer).

   However, in reality we cannot observe the probability distribution and thus we would not be able to do the calculation. As an alternative, it is at least possible to calculate the ex-post risk premium. The ex post risk premium depends, of course, on where the day-ahead price settle. 17 and 23 are equally likely prices, but with the former, the producer 'receives' an ex post risk premium of 1 (18 minus 17), while in the latter he pays 5 (18 minus 23).

d) We cannot interpret the observed equilibrium price (18) as the market participants' best guess of future day-ahead prices, unless we know (or have reason to assume) all market participants are risk neutral or have identical risk preferences. As we know for a fact that numerous market participants regularly hedge their assets and positions, we had better assume the opposite – that market participants have some degree of risk aversion. This likely varies between market participants.

e) The information provided so far does not explain why the equilibrium price for the contract ended at 18, and not just any other number between 12 and 30. However, we can deduce that in this example, the producer had higher, or stronger, risk aversion than the end user.

The last point is in fact a general result; market participants with the strongest risk aversion often pay the highest risk premiums for a specific contract. And market participants with the lowest risk aversion may get paid to avoid risk. Hence, **the risk premium is not necessarily a cost** – this depends on the risk aversion of all market participants.

Different market participants are typically concerned about hedging different timeframes, e.g. such that retailers dominate the market for the nearest months while producers dominate the market for the year products. There are studies that indicate that the risk premium may change as a function of time-to-maturity (Benth, Cartea, & Kiesel, 2008). In such a case, both producers and end-users might end up seeing their relevant risk premium as a cost.

Now, let us modify the assumptions one by one. First, assume all producers were risk neutral. The demand side would be willing to accept 30, and a risk neutral producer would accept 20. As e.g. 21 with certainty is more attractive than an expected but uncertain value at 20 also for a risk neutral producer, we conclude that the equilibrium outcomes would be between 20 and 30. It would, however, not be below 20 – a risk neutral producer would prefer 20 with uncertainty before 19 with certainty.

Next, assume there are no producers at all (and ignore the question about where the electricity would come from). First, if there is no one else, 'our' end user would not be able to contract. Second, if speculators operate in this market, an equilibrium solution might exist, provided these have risk capital and trading strategies that allows for selling fixed price contracts below 30 in this area.

Third, if we assume that the probability distribution for prices is stochastic, it would be much harder to interpret calculations of ex post risk premiums. It would be very hard to distinguish if the risk premium was high due to insufficient market participation (e.g. skewed bidding zones with more demand than supply, or vice versa), poor competition or high and/or changing volatility of day-ahead prices. Also, for the same reason, it can be expected that the ex-post risk premium varies from year to year. Additionally, a risk premium can indicate that the probability distribution for expected prices is asymmetric (Povh, 2009). Very high price spikes can be seen as possible but prices much below zero are in most bidding zones not seen as possible.

Fourth, if we relax the assumption that all market participants share the same expectations of future prices and the probability distribution for prices, virtually anything can happen. We would not be able to interpret how satisfied the various contract parties would be for an observed contract price (cf. point b) above). We would not come any closer to calculating the ex-ante risk premium; in fact, we would come further away (if possible). Any ex-post calculation of the risk premium would thus tell us very little about the state of the market.

Based on this simple example, we can conclude that what we would have preferred to know, is an estimate of future ex-ante risk premiums. However, there are no obvious way to estimate this.

The second-best approach is to analyse ex-post risk premia. While it does not say anything precise about the future, it is a useful approach to better understand the dynamics of existing markets.

An inherent problem, however, with any attempt to estimate or calculate risk premia, is how to interpret the outcome of an analysis. We will not be able to easily explain if an apparently high observed ex-post risk premium is caused by lack of market participants, lack of liquidity, large degrees of risk aversion, relatively high uncertainty, or by a quite unexpected outcome in the day-ahead market.

7.2 Risk premium - explaining the concept

One approach to investigate pricing accuracy of power derivatives contracts is to calculate risk premiums, which are systematic differences between the trading prices of an electricity contract and the contract's expected (ex-ante) spot price when it is delivered. We call this systematic difference forward risk premium (Benth & Meyer-Brandis, 2009; Longstaff & Wang, 2004; Benth, Cartea, & Kiesel, 2008; Marckhoff & Wimschulte, 2009). Forward risk premiums can be understood as mark-ups or compensations in the derivatives contracts charged either by traders, suppliers or consumers for bearing the price risk for the underlying commodity (Longstaff & Wang, 2004, p. 1887).

The underlying question behind risk premiums is whether they denote a natural behaviour of risk-averse market participants willing to pay (accept) a risk premium (discount) for transferring the risk of unfavourable spot price movements (Marckhoff & Wimschulte, 2009), or whether they are a sign of market inefficiency, such as arbitrage (Borenstein, Bushnell, Knittel, & Wolfram, 2008). From the available data and empirical analyses, we cannot disentangle the two directly, but we can study the magnitudes, persistency, direction, and significance of risk premiums, which then shed light on the accuracy of the market to price power derivatives. Put differently, by studying risk premiums we may assess, whether the specific power derivatives contracts are unbiased predictors of the future spot price.

In the forward and futures pricing literature it is a common practice to calculate the ex-ante premium in the forward price as the ex-post differential between the futures prices and the realized delivery date spot prices (Redl, Haas, Huber, & Böhm, 2009). Longstaff and Wang (2004) suggested this ex-post approach to risk premiums in electricity forward prices. Marckhoff and Wimschulte (2009) applied this proxy to calculate ex-post risk premiums for EPADs. Ex-post risk premiums are easy to calculate with readily available data, while the ex-ante approach relies on unobservable information (the expected prices).

Forward risk premium in a derivatives contract at time t for delivery during period T is equal to the derivatives price $F_{t,T}$ at time t for delivery at period T minus the average expected (if ex-ante) or realized (if ex-post) day-ahead price S_T during the delivery period T. The ex-ante risk premium is expressed by Equation 6 and the ex-post risk premium is expressed by Equation 7:

$$\pi_{t,T} = F_{t,T} - E_t(S_T) \tag{6}$$

$$\pi_{t,T} = F_{t,T} - \frac{1}{n}\sum_{h\in T} S_h \tag{7}$$

The derivatives price $F_{t,T}$ can be for any type of power derivatives contract, such as German futures, system price futures or EPAD. For clarity, the ex-post risk premium calculation for Nordic EPADs is shown in Equation 8, where $EPAD_{t,T}$ represents the EPAD's price at time t for delivery during period T. The risk premium is this price minus the average realized day-ahead difference between the zonal price P_h^{Area} and the system price S_h^{System} during the delivery period T.

$$\pi_{t,T}^{EPAD} = EPAD_{t,T} - \frac{1}{n}\sum_{h\in T}\left(P_h^{Area} - S_h^{System}\right) \tag{8}$$

Ex-post risk premiums can be calculated for individual contracts by taking the difference between this average price of a derivative and the average day-ahead outcome during the underlying delivery period (Equation 7, or for the Nordic region, Equation 8). Risk premiums calculated for individual contracts can then be presented in yearly averages over individual trading horizons (yearly, quarterly or monthly) and bidding zones.

In summary, we recommend calculating average ex-post risk premiums for individual contracts e. Comparative insights on risk premium magnitudes and directions will be gained which would expose possible systematic biases of derivatives.

7.3 Risk premium matrix

Risk premiums are likely to vary over time, due to continuously changing market conditions. To ease the interpretation of risk premiums, we proceed with a discussion on determinants and dynamics of risk premiums.

It can be proposed that the interaction between *structural market shares* (Kristiansen, 2004) with *risk aversion* has the potential to explain both the negative term-structure and positive term-structure of risk premiums. By structural market share we mean the share of demand (consumers) and supply (producers) in the hedging position. Figure 7-2 depicts the proposed relationship in a simple xy chart with four highlighted sectors, where the vertical axis represents the risk aversion dimension and horizontal axis the market share dimension. The figure explains the sign and magnitude of risk premiums in the electricity futures contracts by focusing on four sectors in the chart.

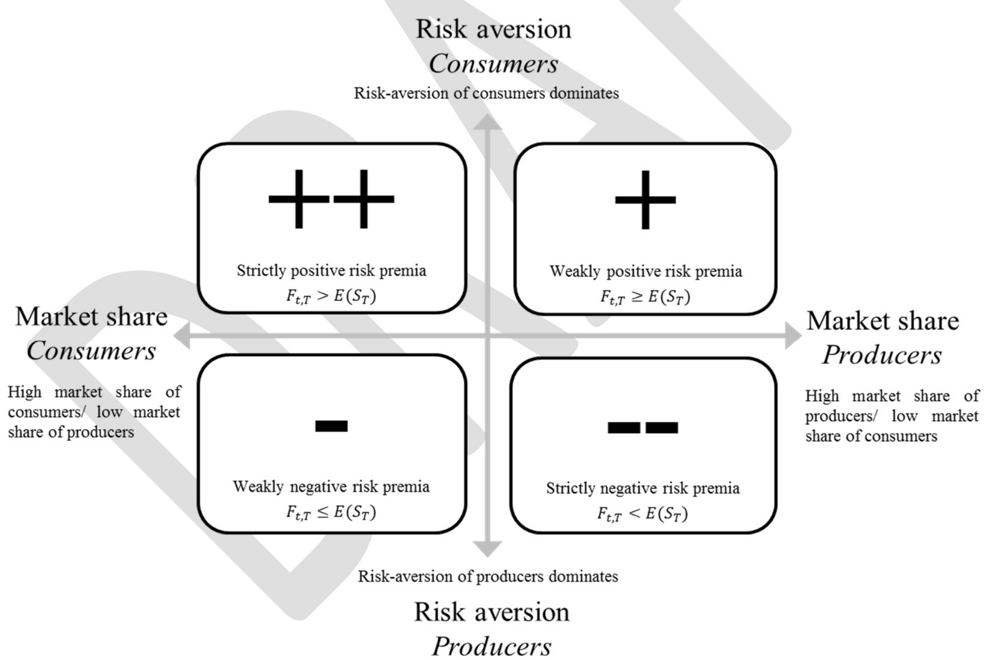

Figure 7-2 Explanation of sign and magnitude of forward risk premiums according to risk aversion and market share dimensions (Source: Spodniak, P. (2017))

Current thinking generally predicts moving from the bottom-right to the top-left corner or more generally from the bottom-half to the upper-half of the diagram during the decreasing time to maturity. This is explained by smaller number of consumers hedging longer-term positions combined with high risk aversion of producers eager to hedge their long-term profits (bottom-right sector). This is also called market power of consumers who push the futures prices below their expected delivery price (strictly negative risk premium). When coming closer to the contract delivery more consumers enter hedging positions because of increasing desire to hedge against short-term risks (top-left sector). This situation is called market power of producers who can charge a premium on the futures contract compared to the expected delivery date price (strictly positive risk premium).

Risk aversion and market shares are both influenced by many fundamental factors, such as exceptionally cold or warm weather, peak/off peak periods, high/low hydro reservoir inflows, CO_2 prices, etc. (Redl, Haas, Huber, & Böhm, 2009; Redl & Bunn, 2013). As the decarbonisation of Europe accelerates, new such factors are coming in, such as wind patterns and new behaviour of electricity demand. However, most of the past theoretical and empirical studies have worked with the "traditional" electricity system dominated by dispatchable generation and inelastic demand. This is hardly the case anymore. Due to changing *elasticity or flexibility* of electricity supply and demand we can expect changing dynamics (direction and magnitude) of the forward risk premium. Thus, we cannot take it for granted that forward risk premiums follow the term structure above, and hence systematically positive and negative term structures can be observed.

7.4 Practical risk premium calculations

The starting point for the calculations is obviously collecting the required data. As this is an ex-post calculation, no simulation results are required. Instead, two types of data are required:

- Average day-ahead prices for all potentially relevant bidding zones
- Average prices for forward contracts

These data are in general publicly available from marketplaces, although some relevant marketplaces have a practice of charging for access to long time series. Our experience is, however, that for analytical purposes, all relevant marketplaces are willingly sharing necessary information and helping with interpretation of observations.

The first question about the time dimension is time resolution. This is about the *T* in Equation 6, 7 and 8 above. It is useful to think of *T* as a delivery period, and to recall that we will study multiple delivery periods, reflecting that different types of market participants typically have different hedging horizons, from month(s) to quarter(s) to year(s). Consequently, we should collect prices for both monthly, quarterly and yearly contracts backwards in time.

The next question is how far back in time we should look. There is no precise answer to this question. As the calculations are quite simple and fast, we suggest going back quite some time. In the example provided below, we have included prices back to 2007 regarding the delivery year 2008. It is a different question if information from the early period is equally relevant for a coming period.

For forward contracts, we recommend focusing on closing or settlement prices. Marketplaces for forward contracts will normally need to determine a daily settlement price for all listed contracts. The settlement price could be the last recorded trade for that particular trading day, an average of the x last trades, the mid-price between the best bids and asks, or something similar. The settlement prices are used to determine daily profit and loss for the contract owners and is normally regarded as the 'official' market value at the trading day for a delivery in the future.

When the data are collected, the calculation is essentially following the equations above:

1. Calculate the monthly, quarterly and yearly averages of the day-ahead prices for each bidding zone.
2. For each delivery period (see above), calculate the average forward price as the average of all forward prices for that specific delivery period in the preceding delivery period(s). Thus, for the delivery period 2019, we need to calculate the average of the settlement prices for a forward contract for 2019 for all trading days in 2018.
3. Subtract the day-ahead price average from the forward price average. The result is the ex-post risk premium for a buyer. The risk premium for a producer has the opposite sign.

For illustration we have calculated ex-post risk premiums for year-ahead forward contracts in four CWE countries Germany, Belgium, the Netherlands and France. The average year-ahead prices are from the CREG monitoring report 2018. Day-ahead prices are from EPEX Spot. The risk premium for a delivery year Y is calculated as the average price during Y-1 for a forward contract regarding Y minus the average day-ahead price during Y.

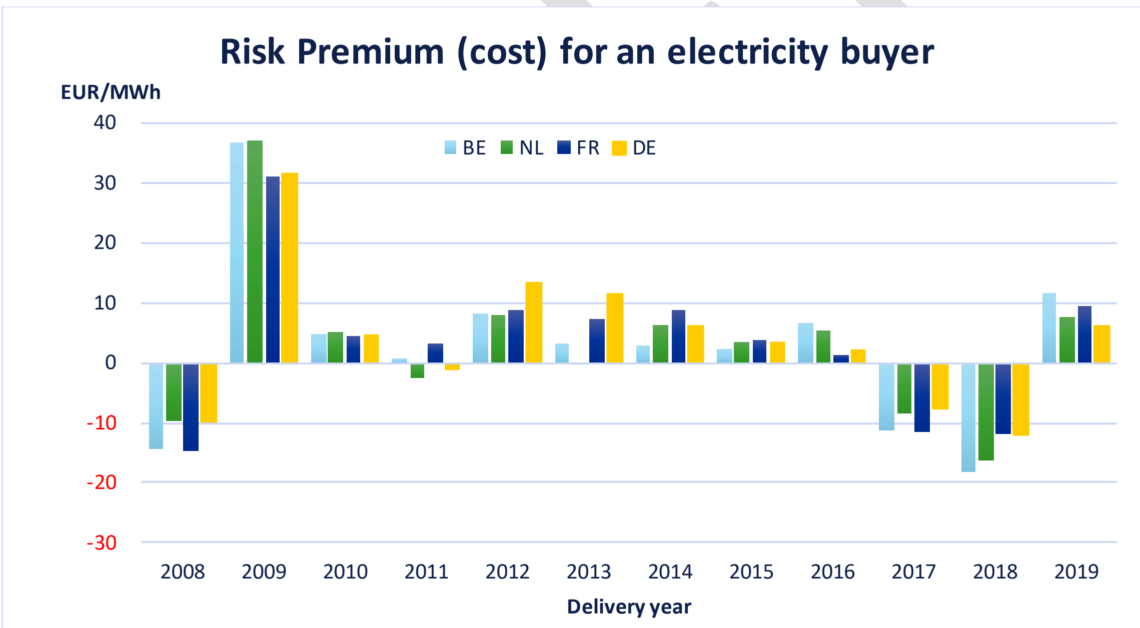

Figure 7-3 Ex-post risk premium in four CWE countries for year-ahead forward contracts (Data sources: CREG, EPEX Spot)

It is interesting to note that the risk premium is quite volatile. One factor causing this volatility is due to the uncertainty itself. A forward price has some similarities with the expected outcome of a probability distribution while the day-ahead price can be interpreted as an outcome of the same probability distribution. It is only natural that the difference between the two varies, just as the difference between a throw of dice and its expected value will vary.

Another important factor is that unexpected events occur and can strongly affect realized day-ahead prices such as the fuel price collapse after the Leman collapse October 2008 or nuclear problems 2017 and 2018 in France and Belgium.

It is also interesting to note that there is no sign of a systematic trend towards lower risk premiums in larger markets (in terms of annual consumption or turnover in forward markets). On the contrary, the average risk premium for year-ahead contracts for delivery years 2008-2019 follows an opposite trend. The calculated average risk premium is 2,8 EUR/MWh in Belgium, 3,0 EUR/MWh in the Netherlands, 3,3 EUR/MWh in France and 4,0 EUR/MWh in Germany. However, we do not interpret these figures as an indicator of an opposite trend. Instead, we interpret the figures as an indicator that risk premium is dependent on many factors and not as dependent on the size of a bidding zone as sometimes have been argued.

7.5 Other transaction costs

There are also other transaction costs as explicit costs and implicit costs as bid-ask spreads.

In the forward markets, explicit transaction costs as exchange fees, clearing fees and brokerage commissions vary more due to the total volume from a firm than to the number of bidding zones traded. An extra bidding zone will normally not change explicit costs significantly.

Potentially more important in a BZR is if bid-ask spreads increase. The bid-ask spread can be seen as a starting point for a process to find the real market value of a forward contract. The bid-ask spread is often very low in the most liquid contracts and buyers and sellers can normally conclude a trade on the screen by adjusting their bids.

The exchange bid-ask spread on the screen is for less liquid contracts often the maximum allowed market maker spread. OTC spreads are often lower, and brokers are most often used to assist in closing the bid-ask spread. Brokers have therefore normally a high market share in less liquid contracts. Closing a bid-ask spread can take some time and brokers are not starting their work until they have a request.

Momentary bid-ask spreads are important for traders if they have to perform a fast stop-loss. The open positions of a trader must be within the risk limits. A fast stop-loss may have to be performed if a price change means that the risk limit is met. High liquidity in the market enables fast stop-loss for a trader without changing the price. Turnover, market depth and bid-ask spreads are therefore important indicators when deciding trading limits for a trader.

Hedging is on the contrary normally not done on an hourly or daily basis. Time is normally available for hedgers to give brokers time to reduce bid-ask spreads and reveal the 'real' price. The average of exchange bid-ask spreads is therefore not a relevant measure. The average of the best bid-ask spread per week (exchange and OTC) is a more relevant measure when assessing the efficiency of different hedging instruments.

8 LIQUIDITY IMPACTS BECAUSE OF CHANGED COMPETITION

Facilitation of effective competition is one of the criteria prescribed in CACM for reviewing bidding zone configurations.[7] We will in this chapter discuss possible liquidity impacts in forward markets because of changed competition in the day-ahead market.

Dominant generator(s) or retailer(s) in a new bidding zone can cause poor competition in the day-ahead market and a potential to use market power. A dominant integrated company makes the competition even more complicated. An integrated company is less dependent on the day-ahead market. In addition, it is less dependent on the forward market for hedging since it has a natural hedge in its portfolio.

However, poor competition is not anything which is created by a BZR. The alternative to turn a blind eye on a structural congestion means that the congestion has to be managed in another way than in the day-ahead market. Problems because of poor competition will then emerge in intraday, balancing or redispatch. These problems will also affect the bidding and the price formation in the day-ahead market.

A local forward market may be undermined or prevented if trust in the day-ahead market is undermined by the potential to exert market power. Dominant market player(s) in a bidding zone may increase the risk for unexpected reverses for a new entrant. Poor competition and high potential to use market power can thus deter new entrants and frighten some incumbents to terminate or constrain their activities.

Extensive interconnections between a zone with poor competition and neighbouring bidding zones can essentially reduce the potential to use market power for dominant generator(s) or retailer(s). In addition, extensive interconnections improve the correlation between the bidding zone and neighbouring zones. If there is sufficient correlation, proxy contracts can be used for hedging purposes.

Special attention is therefore needed if a BZR includes a bidding zone with weak competition, small interconnection capacities with neighbouring bidding zones and insufficient correlation for use of proxy contracts.

The potential for a supplier to use market power and set a price above prices in adjacent zones can be measured by the Residual Supply Index (RSI). The index is calculated for each hour as the capacity of all other suppliers within the bidding zone plus available import capacities to the bidding zone divided by the demand in the bidding zone. If the index for an hour is under 1, the analysed supplier is classified as a pivotal supplier. Such a supplier is necessary in order to achieve market clearing and has high potential to use market power in order to impact prices. If the index for an hour is slightly over 1, the analysed supplier is not necessary for market clearing but has still a potential to use market power in order to impact prices, although the potential is less than for a pivotal supplier.

An advantage with RSI calculations is that they identify hours with higher potential for use of market power (the hours with lowest RSI). Such hours are typically hours with high demand, low import capacities or low weather-dependent production.

The market concentration in the areas with common price to which a new bidding zone will belong during a year can be measured by the Hirschman-Herfindahl Index (HHI). HHI is

[7] Article 33 of Regulation (EU) 2015/1222

calculated as the sum of the squares of the market shares of all generators in the relevant market. The higher the index, the more is the market concentrated. The maximum HHI is 10 000 and corresponds to a monopolistic market with only one generator having a market share of 100 %.

The issue regarding how to determine market shares is not trivial. HHI calculations can be based on market shares in energy produced (TWh) or market shares in production capacity (GW). We recommend that market shares in production capacity are calculated since use of market power implies decisions regarding how capacity shall be bid. Actual capacity from wind and photovoltaic varies dependent on the weather. It is informative to include one HHI calculation based on high available wind and photovoltaic capacity and one calculation based on low available wind and photovoltaic capacity. Normally, competition concerns are more related to weather situations with low production of renewable electricity.

Calculations are normally performed based on ownership but calculations on the balance responsible party (BRP) level can be even more relevant. A company which is BRP for another company has full information regarding their bids and their bidding strategy. We recommend also that capacities as much as possible are attributed to 'mother companies'. This means that partnerships are divided among the owners and that consolidated companies are attributed to the parent company.

Simulations can for a year show for each hour if a new bidding zone is an isolated price area or included in different clusters of bidding zones with common price. The number of hours the bidding zone is included in each identified outcome is thereafter calculated. A time weighted HHI for the bidding zone can then be calculated in the following way:

1) Calculate HHI for each of the identified outcomes (each of the identified different clusters of bidding zones with common price).
2) Multiply the HHI for each cluster of bidding zones with the hours the bidding zone has common price with the other bidding zones within the cluster.
3) Sum these products and divide by 8760 hours.

9 SOCIOECONOMIC EFFICIENCY

One of the objectives of this study is to analyse whether the impact on market liquidity and transaction costs can be considered as i) a (social) welfare gain (or loss), ii) welfare redistribution or iii) none of them.

The aim of a bidding zone reconfiguration is given in Article 14(1) of the recast Electricity Regulation. It states that the configuration of bidding zones shall be designed in such a way as to maximise economic efficiency and to maximise cross-zonal trading opportunities while maintaining security of supply. A bidding zone reconfiguration shall thus aim to increase the economic efficiency.

A bidding zone reconfiguration addressing structural congestions will result in more efficient congestion management and more efficient cross-border flows. This will give a more efficient market clearing and result in increased resource efficiency and welfare gains. Such a bidding zone reconfiguration will also result in changed prices and will thus give welfare redistribution among different categories of market participants. These effects will be assessed according to other methodologies for a bidding zone review.

The issue for our study is whether market liquidity and transaction costs will be impacted in such a way that welfare changes or redistribution arise.

In chapter 4 regarding impacts in day-ahead and intraday markets, we found no reasons to expect that transaction fees will be affected by a changed bidding zone configuration. SDAC and SIDC auctions are themselves consolidations of liquidity. A bidding zone reconfiguration will not affect the functioning of SDAC and SIDC markets unless changed competition affects the willingness to participate in the market.

In the forward markets, explicit costs as exchange fees, clearing fees and brokerage commissions vary more due to the total volume from a firm than to the number of bidding zones traded. An extra bidding zone will normally not change explicit costs significantly. Some transitional costs will occur if a market participant will have to use an extra platform or acquire a new system for trading or for contract and position management.

A bidding zone reconfiguration will cause more severe impacts for a market participant if the forward market will cease to provide sufficient hedging opportunities. The two key issues in this respect are sufficient correlation and extra transaction costs because of changed risk premium and changed bid-ask spread. These key issues were analysed in chapters 6 and 7.

Hedging means normally that a premium is paid in order to reduce a risk. Market participants are not seeking perfect hedges that eliminate all risks. The ‘insurance premium’ would be too high if all risks were to be eliminated. The challenge for a market participant is therefore to find an acceptable level of risk at acceptable costs.

Inefficient hedging instruments for a new bidding zone will normally give extra transaction costs. These costs can be avoided or reduced if there are other efficient hedging instruments with sufficient correlation. Such hedging instruments may not be found if a new bidding zone will often be an isolated price area because of weak interconnections and a different production structure compared to adjacent bidding zones.

As discussed in chapter 7, there are multiple factors determining uncertainty and the risk premium in a forward market. An increase in the risk premium may be due to e.g. asymmetric demand for hedging, inefficient competition or increased level of uncertainty. In this respect, the immediate short-term effects of increased risk premia tend to be redistribution between participants in the market for hedging rather than changes in resource efficiency.

However, in the medium to long-term, resource efficiency may be affected if market participants (and in particular electricity producers, retailers or consumers) start to find hedging too costly, are unable to find alternative proxies for hedging and/or do not tolerate the increased risk, leading to a reduction of their activities in the concerned bidding zones or not to enter the market at all.

Finding alternative proxies for hedging, deciding to tolerate part of the risks or the development of retail products that transfer part of the risks to consumer (if they are willing to do it at all) may also reduce the possibility of reduced overall efficiency effects.

10 METHODOLOGY – TECHNICAL SUMMARY

In the previous chapters, we have analysed important building blocks of the impact of a bidding zone reconfiguration on liquidity and transaction costs. In this chapter, we sum up the analyses we suggest, including some that does not require as comprehensive explanations as the building blocks already explained.

We suggest three sets of analyses and metrics; some descriptive indicators, a set of analyses and indicators of hedging opportunities and costs, and finally, analyses aimed at understanding the future competitive pressure in the new or modified bidding zones.

All the descriptive indicators and two of the indicators for hedging costs are considering the past. The objective of all these backward-looking analyses is to get a better understanding of the starting point prior to an eventual bidding zone reconfiguration. However, we recommend not to extrapolate historical trends towards the future. Instead, we recommend concluding based on a consideration of all metrics in a holistic manner.

In the overview below, indicators relying on historical information are outlined in green tables, and those relying on simulated data are outlined in blue tables.

10.1 Descriptive indicators

The descriptive indicators describe the trading horizon, the volume of the trade and the open interest in different timeframes.

The **traded horizon** shows for different listed contracts (derivatives) which maturities that can be traded and cleared and is thus an indicator of hedging possibilities.

Parameter	Object
Name	Traded horizon
Objective	Understand the starting point before an eventual bidding zone reconfiguration
Indicators	Identification of contracts listed at forward market exchanges and/or available for clearing
Granularity	All available forward products
Data sources	Forward market exchanges, OTC brokers, clearing houses, and commercial information vendors
Calculation	No calculations needed; the output is simply a table explaining which forward contracts are supported at the relevant marketplaces, e.g. as this: • Yearly contract, base load: Y+1, Y+2, … , Y+n • Yearly contract, peak load: Y+1, Y+2 • Quarterly contract, base load: Q+1, Q+2 • Quarterly contract, peak load; Q+1 • Etc.

In general, **traded forward volumes**, representing number of MWh traded for a given contract during a specified period, provide information on liquidity and demand for a particular hedging instrument. Contracts in high demand are traded more and can be easily sold or bought whereas contracts with low traded volumes can be difficult to sell or buy without assistance from brokers.

Parameter	Object
Name	Traded forward volumes
Objective	Understand the starting point before an eventual bidding zone reconfiguration
Indicators	Number of MWh traded
Granularity	Sum of all trades per period (e.g. month) per bidding zone and per contract type (months, quarters, years)
Data sources	Forward market exchanges, OTC brokers, clearing houses, and commercial information vendors
Calculation	Sum of MWh traded during each period, where the MWh is calculated as the contract size (MW) multiplied with the duration (h) for the contract

Traded day-ahead and intraday volumes provide information of the role of these markets in the market participants physical portfolio management.

Object	Comment
Name	Traded day-ahead and intraday volumes
Objective	Understand the starting point before an eventual bidding zone reconfiguration
Indicators	Number of GWh sold and bought in the bidding zone divided by 2
Granularity	Per bidding zone and per month or year over some years
Data sources	NEMOs, PXs, and commercial information vendors The traded volumes are part of the results from the market coupling arrangements
Calculation	Collect information on day-ahead and intraday market volumes, per bidding zone for the status quo configuration. For the intraday market, include volumes from both the continuous trade and the auctions

Open interest refers to all open positions with a clearing house at a given point in time. It corresponds to the total amount of energy in forward contracts that have not yet been closed out by an offsetting trade, fulfilled by means of the physical delivery of the underlying asset or executed via cash settlement. An important metric to understand financial markets is the development of open interest over time. When a contract is bought or sold for hedging purposes, the intention is to keep the new position until the contract goes to delivery. If the contract is bought (sold) for trading purposes, the idea is most often to sell (buy) a similar contract for a higher (lower) price at a later point in time. The first of the trader's transaction will increase open interest, while the second will reduce open interest. Hence, the size of the open interest in a contract in relation to the traded volumes in the contract shows to what extent the contract is used primarily for hedging purposes or for short-term speculative trading.

Parameter	Object
Name	Open interest
Objective	Understand the starting point before an eventual bidding zone reconfiguration
Indicators	Number of MWh in open positions
Granularity	Observation per contract duration categories (monthly, quarterly and yearly contracts) per bidding zone, e.g. by the end of each month
Data sources	Clearing houses for forward contracts, and commercial information vendors
Calculation	Collect information on open interest, e.g. at the last trading day of each month, for each contract duration (months, quarters, years)

10.2 Indicators of correlation and transaction costs

The basis for the correlation analyses and the risk premium analysis is described in detail in chapters 6 and 7. The tables below summarise the scope for the analyses without repeating the calculation details.

Object	Comment
Name	Correlation analysis
Objective	Understand the correlation of average prices of the concerned bidding zone with average prices of other bidding zones or bidding zone combinations that potentially could offer proxy hedges
Indicators	Correlation coefficients
Granularity	Per bidding zone and per month, quarter and year
Data sources	TSOs' simulation of future bidding zone market equilibrium
Calculation	As described in chapter 6 Determine if the correlation coefficients are relatively high, low or medium

Parameter	Object
Name	Risk premium analysis
Objective	Understand the starting point before an eventual bidding zone reconfiguration
Indicators	Ex-post risk premium
Granularity	Per bidding zone and per front month, front quarter and front year over some years (Note that the 'front' contract is the first full period, such that in 2020, the front year is 2021, etc.)
Data sources	Forward market exchanges, OTC brokers, and commercial information vendors
Calculation	As described in chapter 7 Compare with other bidding zones, and determine if the risk premium is relatively high, low or medium, and consider the stability over time

Parameter	Object
Name	Bid-ask spread
Objective	Understand the starting point before an eventual bidding zone reconfiguration
Indicators	The spread between the best bid and the best ask within a week
Granularity	Weekly figures, per forward contract duration (front month, front quarter and front year), per bidding zone over the past five years
Data sources	Forward market exchanges, OTC brokers, and commercial information vendors
Calculation	a. From forward market exchanges and brokers, collect information on bids and asks for each business day for each contract duration and each bidding zone for the status quo configuration b. For each contract duration, find the best bid and the best ask within each week, and calculate the difference

10.3 Indicators of competitive pressure

The basis for the calculation of competition indexes is described in chapter 8. The tables below summarise the scope for the analyses without repeating the calculation details. In addition, we suggest a descriptive analysis of retail competition.

Object	Comment
Name	Changes in wholesale competition – RSI analysis
Objective	Explore to which extent a bidding zone reconfiguration opens new opportunities for use of dominant positions
Indicators	RSI
Granularity	Per (new) bidding zone and per year
Data sources	Overview of power station capacity and ownership. BRP identity may be used as a substitute for ownership Rough estimates of transmission capacity between adjacent bidding zones (NTC-based, not flow-based)
Calculation	As explained in chapter 8 The RSI shall be calculated per bidding zone and consider the forecasted import capacity (regardless the prices) Compare with other bidding zones and determine if the indexes have relatively high, low or medium values

Object	Comment
Name	Changes in wholesale competition – HHI analysis
Objective	Explore to which extent a bidding zone reconfiguration opens new opportunities for use of dominant positions
Indicators	HHI
Granularity	Per (new) bidding zone and per year
Data sources	Overview of power station capacity and ownership. BRP identity may be used as a substitute for ownership Simulation of market equilibrium in a future bidding zone configuration to determine for how long periods adjacent bidding zones represent a common price area
Calculation	As explained in chapter 8 The HHI shall be calculated per bidding zone and include data for adjacent bidding zones for periods in which they have common prices (thus resulting into a calculation per price area) Compare with other bidding zones and determine if the indexes have relatively high, low or medium values

The **number of retailers** is an easily available metric that provides insight on the organisation of the retail market.

Parameter	Object
Name	Retail competition
Objective	Understand the starting point before an eventual bidding zone reconfiguration
Indicators	Number of retailers
Granularity	Number of retailers active in each (current) bidding zone over the past five years
Data sources	TSOs and NRAs Where retailers need a license to operate, the relevant NRA will normally maintain an overview of licensees. Otherwise, the TSOs will normally be able to identify the number of BRPs active on the buy side of the wholesale market per bidding zone
Calculation	The indicator is the sum of existing retailers

10.4 A holistic evaluation

Above, we have listed several quantitative analyses that should be part of an assessment of the impact of a bidding zone reconfiguration on liquidity and transaction costs. The ultimate question is whether the impact is expected to be negative, neutral or positive, and if the impact is expected to be significant.

In total, we have suggested ten numerical analysis. While some are very easy to do – like establishing the number of retailers active in an area – others require a significant effort. As a minimum, we recommend performing a thorough correlation analysis and calculation of ex-post risk premium. However, to interpret these and anticipate possible liquidity trends, one should have some basic knowledge about the state of the forward markets and on the expected level of competitive pressure (which to some extent can be simulated). The best way to ensure this basic knowledge would be to find the relevant indicators for both the concerned bidding zone(s) and adjacent or otherwise relevant bidding zones.

If the analyses indicate that a bidding zone reconfiguration is likely to result in reduced hedging opportunities, mitigating measures should be considered. Long lead-time before implementation eases the challenge for market participants to prepare and adjust. Another measure can be to establish an index that according to correlation tests could offer sufficient hedges against price risks.

As noted, we do not recommend any knock-out criteria or threshold levels. An unsatisfactory score for one of the indicators might not represent a challenge if the score is good for one or several others. One way to make an overall assessment of the impacts of changed hedging opportunities in a bidding zone is to perform analysis of liquidity and transaction costs in another bidding zone with comparable hedging opportunities.

11 REFERENCES

Alexander, C. (2008). *Market Risk Analysis III: Pricing, Hedging and Trading Financial Instruments.* New York, NY: John Wiley and Sons.

Benth, F. E., & Meyer-Brandis, T. (2009). The infromation premium for non-storable commodities. *The Journal of Energy Markets, 2*(3), 111-140.

Benth, F. E., Cartea, Á., & Kiesel, R. (2008). Pricing Forward Contracts in Power Markets by the Certainty Equivalence Principle: Explaining the Sign of the Market Risk Premium. *Journal of Banking & Finance, 32*, 2006-2021.

Bloomberg New Energy Finance. (2018). *What Drives Europe's Top Three Corporate PPA Markets?*

Borenstein, S., Bushnell, J., Knittel, C. R., & Wolfram, C. (2008). Inefficiencies and Market Power in Financial Arbitrage: A Study of California's Electricity Markets. *The Journal of Industrial Economics, 55*(2), 347-378.

Ehrenmann, A., Henneaux, P., Küpper, G., Bruce, J., Klasman, B., & Schumacher, L. (2019). *The future electricity intraday market design.* Brussels: European Commission, Directorate-General for Energy, Directorate B — Internal Energy Market, Unit B2 — Wholesale markets; electricity & gas.

Finnerty, J., & Grant, D. (2003). Testing hedge effectiveness under SFAS 133. *The CPA Journal, 73*(4).

Hailer, A., & Rump, S. (2005). Evaluation of Hedge Effectiveness Tests. *Journal of Derivatives Accounting, 2*(1), ss. 31-52.

Kristiansen, T. (2004). Pricing of Contracts for Difference in the Nordic Market. *Energy Policy*, 1075-1085. doi:10.1016/S0301-4215(03)00065-X

Longstaff, F. A., & Wang, A. W. (2004). Electricity Forward Prices: A High-Frequency Empirical Analysis. *The Journal of Finance, 59*(4), 1877-1900.

Marckhoff, J., & Wimschulte, J. (2009). Locational Price Spreads and the Pricing of Contracts for Difference: Evidence from the Nordic Market. *Energy Economics*, 257-268.

Povh, M. (2009). *Stochastic modelling of long-term electricity forward prices.* Ljubljana: University of Ljubljana, Faculty of electricial engineering.

Redl, C., & Bunn, D. (2013). Determinants of the Premium in Forward Contracts. *Journal of Regulatory Economics, 43*, 90-111.

Redl, C., Haas, R., Huber, C., & Böhm, B. (2009). Price Formation in Electricity Forward Markets and the Relevance of Systematic Forecast Errors. *Energy Economics, 31*, ss. 356-364.

Spodniak, P. (2017). *Long-term Transmission Rights in the Nordic Electricity Markets: An Empirical Appraisal of Transmission Risk Management and Hedging.* Lappeenranta: Acta Universitatis Lappeenrantaensis.

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