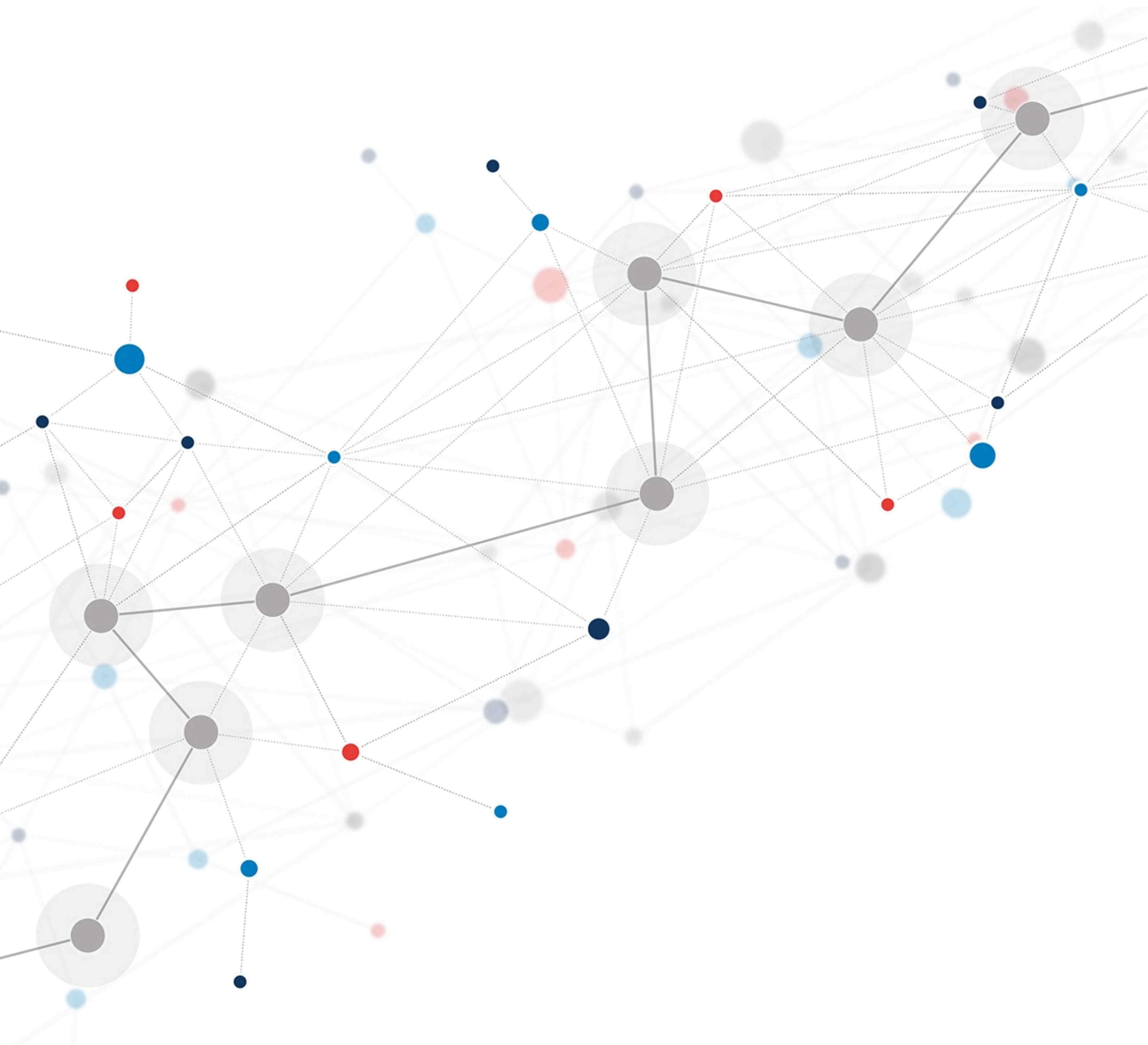
THE IMPACT OF BIDDING ZONE CHANGES ON LIQUIDITY & TRANSACTION COSTS

A STUDY FOR ENTSO-E

July 2024

Non-Confidential

Final for Public Consultation



CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

BZ	Bidding Zone
BZR	Bidding Zone Review
DA	Day-ahead market
DE-LU-AT	German-Luxembourg-Austrian bidding zone
DE-LU	German-Luxembourg bidding zone
EPAD	Electricity Price Area Differential
FTR	Financial Transmission Rights
HHI	Herfindahl-Hirschman Index
ID	Intraday market
NRA	National Regulatory Authority
OTC	Over-the-counter
PSI	Pivotal Supplier Index
RSI	Residual Supply Index
SDAC	Single Day-Ahead Coupling
SIDC	Single Intraday Coupling
TSO	Transmission System Operator

1 INTRODUCTION AND OVERVIEW

Context: the bidding zone review process

The European electricity wholesale market is a zonal market. It is organised by bidding zones (hereafter BZs) and cross-zonal capacities (interconnections) between zones. BZs are defined in Regulation (EU) 2019/943 as the largest geographical area within which market participants are able to exchange energy without capacity allocation (European Commission, 2019). A uniform electricity price in wholesale markets can thus be determined for the whole BZs. Trade between BZs is possible as long as cross-zonal capacities are available. As a result, the configuration of BZs greatly impacts market functioning and cross-border exchange of electricity.

According to Regulation Article 34 of Regulation (EU) 2015/1222, the BZ configuration of European electricity markets must be reviewed regularly (ibid.). Article 14 of Regulation (EU) 2019/943 states that the configuration of BZs should "*maximise economic efficiency*" and "*cross-zonal trading opportunities*" all while "*maintaining security of supply*". To achieve this, BZ borders should be defined based on long-term structural congestions and BZs should not contain structural congestions affecting neighbouring zones. The European Network of Transmission System Operators for Electricity (ENTSO-E) should report on structural congestions every three years. A BZ review (BZR) should analyse different alternative BZ configurations and assess them in comparison with the current configurations. ACER determined the BZR methodology in its decision 29/2020 from 24.11.2020 (ACER, 2020a) (hereafter the BZR methodology). The BZR methodology specifies 22 criteria that should be assessed, one of these criteria is the *Market liquidity and transaction costs*.

Objectives of the report

The objective of the report is to assess the market liquidity and transaction cost criterion for various alternative BZ configurations.

The assignment consists of collecting, processing and analysing various data, determining relevant potential impacts of a BZ reconfiguration, and then transposing those quantitative and qualitative conclusions to the specific changes of BZ configurations, which the TSOs will have to assess in the context of the ongoing BZR. The report aims to inform the market liquidity and transaction cost criterion. It does so by examining the current state of liquidity, and by articulating expected changes to liquidity from BZ reconfigurations. This in turn is done by comparing the characteristics of the existing configurations to alternative BZ configurations, i.e. reconfigurations. Based on the analysis of existing and alternative configurations, the report seeks to assess the impact on market liquidity and transaction costs of individual BZ reconfigurations, compared to the existing BZs.

An important caveat is that the report focuses on each of the BZs individually and thus does not account for potential cross-border effects apart from proxy-hedging to the degree possible. It does not account for potential mitigation measures that may be introduced alongside the BZ reconfiguration. Possible mitigation measures have been discussed in the literature and include for instance the introduction of a trading hub, or standardised transmission rights.[1] For the avoidance of doubt, the investigation of possible mitigation measures, as well as the impact of mitigation measures on possible overall conclusions of the BZR process, are not in the scope of this report. The interim results presented here will be joined with the public consultation organised by the TSOs. This report will then be updated based on the input from the consultation. The results of the analysis and public consultation should ultimately lead to conclude whether an alternative BZ configuration is expected to perform better, worse or equal than the current BZ configuration with regard to liquidity and transaction costs.

Further, in the wake of the difficulties in the EU energy market seen in 2022 with particularly high and volatile prices, the EU Commission presented a proposal on 14 March 2023 to revise the rules for electricity market design. The proposal with amendments has passed the European Parliament on 11 April 2024 and has been formally adopted by the Council of the EU on 21 May 2024. The new EU Directive 2024/1711 and EU Regulation 2024/1747 have been published on 26 June 2024 in the Official Journal of the EU and will enter into force on 16 July 2024. The implementation of the market design reform still remains subject to different timelines and approaches for different market design aspects. . Therefore, the conclusions in this report do not yet take into account these proposedchanges. In particular, as this report does not aim to inform stakeholders on any practical considerations in terms of future market design affecting market participants and other stakeholders, it provides an analysis of the state of liquidity in EU under the current market design and could be complemented by further analysis on the state of liquidity in EU markets once some of the aspects around long term market design will become more concrete.

The analysis of market liquidity and transaction costs focuses on liquidity for the subset of European BZs where alternative configurations have been proposed in ACER decision 11-2022. The proposed alternative BZ configurations concern the BZs of France, Germany-Luxembourg, Italy (BZ Italy “NORD”), the Netherlands and Sweden and are summarised in Table 1.1.

Table 1.1 Summary of proposed and to be evaluated alternative BZ configurations in Central Europe and the Nordics as presented in the Annex I to the ACER decision 11-2022

Alternative BZ configurations	Region	Member State	Number of BZs
2	Central Europe	Germany; Luxembourg	2
5	Central Europe	France	3
6	Central Europe	Italy (Italy “NORD”)	2
7	Central Europe	Netherlands	2

[1] For instance, ENTSO-E published on 3 July 2024 an advocacy note on forward markets, discussing the merit of virtual hubs and other (implicit) mitigation measures. The note can be found here: https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Network%20codes%20documents/NC%20FCA/publications/240703_EE_advocacy_note_forward_markets.pdf

8	Nordic	Sweden	3
9	Nordic	Sweden	3
10	Nordic	Sweden	4
11	Nordic	Sweden	4
12	Central Europe	Germany; Luxembourg	3
13	Central Europe	Germany; Luxembourg	4
14	Central Europe	Germany; Luxembourg	5

Approach and limitations

This report follows the approach set out in the BZR methodology in line with our mandate. The BZR methodology provides that the assessment of market liquidity and transaction costs shall be performed for long- and short-term timeframes:

- **Long-term products** considered in this study are financial derivatives for power to be delivered on a given future date.[2] These derivatives are over-the-counter (hereafter OTC)-traded forwards with or without centralised clearing and exchange-traded futures. As physical products, they typically correspond to the obligation to deliver power in a specified BZ for a specified duration in the future; as financial derivatives they correspond to the financial equivalent of the physical power delivery. The delivery periods are typically either annual, quarterly, or monthly periods. Futures comprise of a standardized master contract while forwards may be customised to the individual needs of the counterparties. The analysis for the long-term timeframe shall include "*a descriptive analysis of liquidity aiming to describe the starting point of market liquidity in the concerned BZs*"; a "*correlation analysis aiming to describe the correlation of average day-ahead prices of the concerned BZ with average day-ahead prices of other BZs*"; a description of "*possible liquidity impacts because of expected changes in competition*"; and "*a holistic analysis […] to conclude whether a BZ reconfiguration is likely to result in increased/reduced hedging opportunities*" (ACER, 2020b).

- **Short-term products** are physical products of electricity to be generated or consumed. They may be traded either OTC or via exchange. Short-term markets are either auctions – as is the case for day-ahead markets (hereafter DA) and also recently for intraday markets – or

[2] Long-term products exist also as physical products. As they are traded less often on the exchanges, they are not in focus for this study.

continuous markets, such as typical intraday markets (hereafter ID) or OTC.[3] Furthermore, market coupling in the form of Single Day-Ahead Coupling (SDAC) and Single Intraday Coupling (SIDC) has been implemented for exchange-traded short-term products. Thereby, trades for these products are, subject to various conditions, cleared across borders. In the study, we only consider exchange-traded short-term products that are traded on intraday and day-ahead markets. OTC-traded short-term products are not considered due to data unavailability. This needs to be taken into account when considering the results shown in this report.[4] For the short-term timeframe, liquidity indicators as well as evolutions from previous BZ reconfigurations, and "*possible effects of intra-company transactions*" shall be analysed "*at least for the day-ahead timeframe*".

In the BZR methodology criteria, liquidity and transaction costs are grouped, and the BZR methodology focuses on liquidity rather than transaction costs. We understand that this is because a) transaction costs are inherently related to liquidity, b) there is no strong reason to assume that fee structures will change due to BZ reconfigurations, and c) the analysis of bid-ask spreads indirectly incorporates the analysis of transaction costs insofar as spreads constitute part of the transaction costs (Glosten & Harris, 1988).[5]

In line with this methodology, the report is structured in three steps:

- First, we conduct a literature review to contextualise the objective at hand in terms of liquidity metrics, their relationship with market characteristics, and past BZ reconfigurations. We leverage some case studies and review in particular the effects of Austria's split from the joint German-Luxembourg-Austrian BZ in October 2018.

- Second, we outline the starting point, i.e. the historic state of liquidity within current BZs through the direct assessment of liquidity metrics as well as through a correlation analysis. We complement this part by analysing the historic relationship between liquidity metrics and selected market characteristics such as market size and market concentration. Considering underlying historic and market design differences among the BZ, we account for these differences by both acknowledging such design specifications in the analysis of the respective market products and, where relevant, country-specific analyses for liquidity and relationships with market metrics as such.[6]

- Third, we analyse the simulated data provided by the BZRR TSOs to assess how BZs' reconfigurations may impact liquidity metrics. More specifically, the BZRR Nordic and Central Europe TSOs simulated market coupling of the status quo BZ configuration and the alternative configurations BZ as set forth in the BZR methodology. On the basis of this modelling work, they have provided us with data relative to load, generation, concentration and prices in the different BZs. Based on these simulation results as well as the identified relationships between

[3] Please note that the existence of auctions or continuous trading is not decisive for DA or ID, but the time until delivery. Further, additional markets in short-term timeframe with further specifications exist as well, such as the balancing market. They are not considered in this study.

[4] Note that the impact of this omission differs between countries as the relative importance of short-term OTC may be high or low.

[5] Bid-ask spreads may give an indication on the fee structure, if the spreads are determined by market makers who have to cover at least their trading fees by arbitrage between the best bid (that they offer) and best ask (that they ask). Other components may be the inventory cost and adverse selection spreads.

[6] As a caveat, we note that the analysis of market liquidity with regards to OTC-trade in the short-term and market concentration in the Netherlands could not be covered due to the unavailability of data.

liquidity metrics and market characteristics, we looked at the evolution of the market size (load and generation volume) and concentration. From this, we assess price correlations between BZs in order to identify whether alternative configurations are likely to improve or to dampen liquidity metrics and hedging possibilities in the different BZs.

The methodological approach and the data we have access to have limitations that call for a careful consideration of the study results:

- In particular, the simulations provide dispatch model results, including marginal BZ prices on an hourly basis, but do not differentiate between the market places through which electricity is traded (e.g. power exchanges, over-the-counter, or intra-company trade), including differences between short-term and long-term products. As a result, the simulation results do not provide the data necessary to compute liquidity metrics; for example, we do not have simulated trading volumes on long-term and short-term markets.

- The analysis of liquidity can therefore only be done indirectly, through (a) the relationships between the key market characteristics and liquidity metrics identified in chapter 2, linking liquidity with the size or the concentration of the market; and (b) price correlations, which inform on the potential increase in market depth from cross-border trade. In this context, it is important to bear in mind that these relationships were established based on historical data and under specific market design conditions. They may not remain valid in the future, for instance if the potential BZ reconfigurations encompass unforeseen changes.

- In addition, the considered scope in terms of geography and products is limited, which prevents us from capturing all potential effects of BZ reconfigurations on liquidity in the provided data. In particular, the study has the following limitations, which may also mark the starting point for further work:

  – As stated above, we focus on each BZ individually and do not account for potential cross border effects, and we do not explore mitigation measures, and their potential impact on the conclusions with regards to an improvement or deterioration of liquidity and transaction costs.

  – We were not able to obtain data in the intraday-OTC market, so we currently cannot make an assessment of how much liquidity that market provides, and how that could be impacted by a BZ split.

  – At the moment, another over-the-counter long-term market is developing dynamically – the market for PPAs. We do not assess the impact of a potential BZ split on the PPA market. The Article 19a (7) Regulation (EU) 2024/1747 states that PPAs need to specify the BZ of delivery and the responsibility for securing cross-zonal transmission rights in case of a change of BZ. Arguably, a BZ split could increase overall costs of PPAs and negatively impact liquidity.

Notwithstanding, the products and geographies analysed are based on a relatively comprehensible dataset and are, hence, in itself not directly affected by these limitations.

Outline of the report

The report is structured as follows:

- Following this introduction, Chapter 2 summarises the literature review on liquidity metrics, its relationship with market characteristics and past BZ reconfigurations. As an extension, this chapter includes the quantitative analysis of the Austrian split from the German-Luxembourg-Austrian BZ in 2018.
- In Chapter 3, we empirically analyse the state of liquidity in selected European countries. To do so, we describe the level of liquidity in terms of a) liquidity metrics, b) relationships between liquidity and market characteristics c) retail risk premia, and d) price correlation between BZs.
- In Chapter 4, we assess if the proposed BZ alternative configurations are expected to see increased, similar, or decreased levels of liquidity compared to the current configurations.
- In Chapter 1, we present a summary of the findings and the conclusions.

2 LITERATURE REVIEW ON THE DEFINITION OF MARKET LIQUIDITY AND THE IMPACT OF BIDDING ZONE RECONFIGURATION ON LIQUIDITY

This chapter reviews a selection of academic articles and industry reports on metrics for market liquidity; on identified and alleged relationships between different market characteristics and liquidity metrics; and on the effects of past BZ reconfigurations. This literature review serves to inform the liquidity study approach by discussing how liquidity may be directly or indirectly assessed through different liquidity metrics as well as their relationship to market characteristics. It also analyses how BZ reconfigurations may impact liquidity.

Note that this chapter does not endeavour to provide an exhaustive list of liquidity metrics, relationships to market characteristics and past reconfigurations. It aims, instead, to provide background for the liquidity analysis.

The section is structured as follows:

- The first subsection reviews the definitions and metrics for liquidity and transaction costs proposed in the literature.
- Secondly, we review how market characteristics and liquidity can be linked according to previous work and papers, looking at the drivers of liquidity.
- Then, we consider how market characteristics consequently affect hedging possibilities.
- Lastly, we review case studies of past reconfigurations, mainly in Sweden and Germany-Luxembourg-Austria, and associated analyses on the effects of such BZ reconfigurations on market liquidity.

2.1 Definition and metrics for liquidity and transaction costs

Liquidity may be generally understood as a "*structure of transactions [providing] a prompt and secure link between the demand and supply of assets, thus delivering low transaction costs*" (Gabrielsen, Marzo, & Zagaglia, 2011, p. 2). In practice, it may be understood as "*the speed and easiness by which assets can be bought or sold without drastically impacting the underlying market price*" (Laur & Küpper, 2020).

To estimate and evaluate the state of liquidity in a market, different metrics have historically been used.[7] Each of them relates to a different aspect of the market and covers parts of the liquidity concept. Table 2.1 summarises these metrics:

[7] In economic literature, various other metrics have been developed. For an overview, see (Gabrielsen, Marzo, & Zagaglia, 2011). For the study at hand, we will resort to historically used metrics in line with the BZR Methodology.

Table 2.1 Metrics for the measurement of market liquidity

Metric	Definition
Turnover	The total traded volume or value generated over a specific timeframe, reflects global trend in market activity.
Open interests	The total number of pending (not yet settled) trades on a forward exchange or for a specific product. Numerous unclosed positions indicate a high willingness to participate.
Churn rates	The total traded volume divided by its targeted physical demand. Although there is no agreement, many stakeholders believe a churn of at least 300% is required for a [power] market to be considered liquid (Economic Consulting Associates, 2015).
Market depth	The ability of the market to absorb orders without them drastically affecting prices.
Bid-ask spread	The difference between the lowest selling price and the highest buying price (both in-the-money, meaning actually selling or buying). It is a direct measure of transaction costs for a specific instrument and should remain low (EFET, 2016).[8]
Time to maturity	Time to maturity in a forward market defines the time between the execution of the forward trade and the target delivery period. Longer maturities (3+ years) indicate liquid products and better price discovery.
Risk premiums	The difference between the forward price and the spot price of the underlying period (DNV GL, 2020). A positive risk premium may indicate a scarce market or a high risk-aversion from buyers. Meanwhile, negative premiums (discounts) can point to a high risk-aversion from producers or an oversupplied market.

Source: EU ASSET study (2021) by Tractebel Impact.

Another report on the assessment of the Nordic forward market[9] proposes measuring liquidity by considering open interest (i.e. the total number of pending forward or future contracts), open interest in relation to physical consumption, trading horizons, bid-ask spreads, traded volumes, churn rates, ex-post risk premiums, correlation, and the Amihud Illiquidity Ratio.[10]

Depending on the specific market, these indicators differ in relevance and applicability. For instance, the time to maturity is only relevant for markets with continuous trading. Changes to the churn rate in day-ahead auctions may lack explanatory power if participation in such auctions is mandatory for all generation and demand because it is therefore automatically "*equal to one*" (ACER, 2021, S. 38).

[8] EFET. (2016). ENTSO-E survey on market efficiency with regard to bidding zone.

[9] NordREG (2020): Methodology for assessment of the Nordic forward market.

[10] In the power market context, this is defined as an average of ratios between daily absolute return of a power derivative and its daily traded volume in Euro, over a certain time period. The Amihud ratio has originally been developed for the analysis of the (il)liquidity of stocks. This illiquidity ratio aims to show the price impact of each traded euro and is a commonly used measure of liquidity. In an illiquid market a large buyer will drive up the market price while a large seller will lower it. The premium the buyer and seller have to pay is called the price-impact cost, and this is what this ratio tries to capture.

In its methodology to estimate the impact of a BZ reconfiguration on market liquidity and transaction costs, DNV GL states that liquidity and transaction costs may be measured by a) number of bids, b) price correlation between adjacent BZs, and c) bid-ask spreads.

Transaction costs are "*intrinsically related*" to liquidity (ACER, 2020b). Low liquidity implies additional transaction costs primarily in the form of higher bid-ask spreads (DNV GL, 2020). Liquidity increases with decreasing spreads, because a low spread indirectly indicates multiple offers close to the market price. These spreads are transaction costs, because they constitute the additional cost a trader incurs for executing the trade.[11] Therefore, the bid-ask-spreads are analysed in the report at hand as an indicator of liquidity but also as a proxy for transaction costs.

2.2 Relationships between market characteristics and liquidity

In addition to the measurement of metrics that are characterising different aspects of liquidity, an assessment of liquidity may also be indirectly derived from some market characteristics that typically go hand-in-hand with liquidity metrics.

In academic literature and industry reports, the market characteristics most considered as drivers of liquidity are BZ size, market concentration, changes in cross-border network capacity, the share of variable generation assets, and the existence of hedging opportunities. We provide below a more thorough description of the way in which these different market characteristics affect liquidity.

2.2.1 Bidding zone number and size

First and foremost, a BZ reconfiguration may have an impact on the BZ size[12]. On the one hand, literature tends to confirm a positive relationship between BZ size and liquidity for long-term products. The size may positively correlate with liquidity due to the increased number of market participants: "*Liquidity of hedging instruments in smaller zones is usually poor*" (ACER, 2013, S. 7) and "*smaller bidding zones might make it harder to construct the perfect hedge*" (Schittekatte & Pototschnig, 2020). Some reports argue that "*merging bidding zones […] may prove beneficial due to efficiency gains of more liquid forward markets*" (THEMA Consulting Group, 2013) and that a "*major consequence of market splitting is the reduction of the market liquidity*" (Hary, 2018). However, it has also been pointed out that smaller zones are not detrimental to liquidity and limit trade opportunities, because existing "*unplanned transit flows would instead become market-controlled flows*" (ČEPS, MAVIR, PSE Operator and SEPS, 2012). In the last BZR in 2018, stakeholders expected that, in general, liquidity would decrease when the BZs in discussion would be split (ENTSO-E, 2018). In the EU Asset Study, Laur & Küpper conclude that "*more zones would translate into more fragmented, possibly less liquid forward products*" (Laur & Küpper, 2020, p. 39). Consentec and Frontier Economics empirically assessed in 2013 that "*smaller markets tend to have greater bid/offer spreads and hence are less liquid*" (Ofgem, 2014, p. 6).

On the other hand, some literature questions this relationship, in particular for short-term products. (ACER, 2014) states that "*the experience from different markets in Europe does not show a clear link between the size of the zones*". Liquidity is influenced more by the market structure, its design and concentration (ibid.). This is also corroborated by Laur & Küpper who, while acknowledging observations for "*absolute liquidity drops […] where smaller BZs were implemented*", explain small

[11] For instance, if the spread is 0.1 EUR, as the highest bidder, you would need to incur an additional cost of 0.1 to execute the trade. If the bidder is not the highest bidder but executes a market order, thereby buying the best bid (or best ask), to sell (buy) it again, he/she would need to be willing to accept a price change amounting to the bid-ask spread to meet the next best limit order (unless new bids (asks) become available).

[12] The definition of "BZ size" is not fully conclusive but it may be generally understood as maximum power demand or supply in a determined bidding zone. In this study, we approximate it by demand which arguably falls short of covering the whole spectrum of the market size.

BZs "*are not necessarily a fundamental driver of lower liquidity*" (Laur & Küpper, 2020, p. 6). Along these lines, ACER highlights that the BZ configuration "*determines how the underlying physical limitations of the network are imposed on market participants*" such that larger zones require treatment of internal congestion and push congestion to the borders (ACER, 2014). Pototschnig (2020) elaborates on the case of physical limitations and argues smaller BZs do not necessarily imply a reduction of liquidity. DNV GL notes 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 BZs. The same goes for SIDC*" (DNV GL, 2020).

Moreover, BZ reconfigurations may have an impact on intra-company transactions. Indeed, for instance, upstream and downstream activities of vertically integrated companies may be affected differently by a BZ split, forcing them to go through the exchange to trade across zones (ibid.). This could have a positive effect on volumes trading on the exchange but also increases the transaction costs for those companies.[13]

The literature and reports discussed suggest that there is a positive relationship between BZ size and liquidity for long-term products but a limited relationship, if at all, for short-term products. Concerning the latter, it has been pointed out that market design and structure can play a stronger role for liquidity than the BZ size itself.

2.2.2 Market concentration

Liquidity and competition in the market go hand-in-hand as market liquidity is key to a competitive market, and competition also drives liquidity up. Thus, according to DNV GL Energy, "*weak competition and high potential to use market power increase uncertainty about short-term as well as forward prices and may cause low liquidity in all timeframes [which may] […] deter new entrants and frighten some incumbents to terminate or constrain their activities*" (DNV GL, 2020, S. 4). The European Commission states that market power "*contributes to a loss of liquidity*" (European Comission, 2017, p. 29). Similarly, Pototschnig concludes that competition "*may impact liquidity more than the dimension of bidding zones*" (Pototschnig, 2020). We analyse empirically this relationship in the next chapter.

Pototschnig further highlights that larger BZs might only appear to enable more competition, but if the zonal configuration does not reflect grid restrictions, market power will still emerge but shift to short-term markets (ibid.).

Furthermore, there are reports that disagree with some stakeholders view that smaller BZs may lead to increased market power (ČEPS, MAVIR, PSE Operator and SEPS, 2012).

Beyond market concentration within a BZ, Laur and Küpper (2020) stress the need to consider competition at the borders. Splitting an internally congested BZ may actually increase – at least relatively to the BZ size – cross-border capacities so that competition may in fact increase because more cross-border parties may participate in the smaller BZs.[14]

In practice, the impact of smaller BZs on competition would depend on various aspects, including:

[13] An alternative for companies with assets in both bidding zones that do not want to go through the (implicitly) coupled market, would be cross-border transmission rights if they exist.

[14] A smaller zone that better reflects (previous) internal congestion may allow for more competition across market participants from other zones, because (relatively) more XB-capacity is available. At the same time, fewer market participants within the zone exist which might decrease competition. Further, virtual cross-border capacity may also affect any changes to competition.

- whether market shares and assets are homogeneously spread between market participants within split BZs,
- whether structural and physical constraints on the transmission network create the possibility to exercise market power independently of the BZ definition, and
- whether the BZ split may affect the competition and contestability of more dominant players through imports and exports.

While literature has alluded to the relevance of market concentration, it is therefore difficult to conclude in general that a BZ split would necessarily lead to a less competitive environment, detrimental to market liquidity, as this depends on many factors, as explained above.

Literature suggests a positive relationship between long-term wholesale and retail market liquidity, stating that "*as long as derivative markets are not sufficiently liquid, retailers will strive to vertically integrate to better hedge their risk exposure. This, on the other hand implies a vicious cycle. The more retailers are vertically integrated the less likely is the development of a liquid contract market, thus forcing non-integrated retailers to leave the market or to move towards physical integration*" (Homayoun Boroumand & Zachmann, 2012).

Because we were not able to get suitable data, we have not been able to explore this relationship further empirically.[15]

2.2.3 Network capacity

A third potential relationship pertains to network capacity, in particular cross-border capacity. According to DNV GL, the "*liquidity benefit of a larger BZ is lost if intra-zonal congestions make some bids unavailable*" and re-dispatch has to be used in its stead (DNV GL, 2020). Such congestions have also occasionally led to restrictions of cross-border intraday trade. "*A more efficient BZ configuration gives liquidity benefits in intraday and balancing timeframes if it eliminates the need to […] close cross-border intraday trade and enables full use of the common merit order list*" (ibid. p.11). More specifically, in case of BZ mergers unsubstantiated by the necessary available network capacity, "*the bottlenecks remain and the lack of competition, and the related costs, is simply "moved" to the less developed, less integrated and less transparent markets for re-dispatching and countertrading*" (THEMA Consulting Group, 2013, S. 9).[16]

However, if a BZ reconfiguration improves the accurate representation of network constraints, it highlights the physical reality of transmission capacity. In this case liquidity is allegedly improved in larger BZs as more suppliers and consumers participate in the market without deteriorating cross-border participation (see discussion on BZ size for long-term products).

This effect is negligible when there is sufficient cross-border capacity for short-term products, because implicit auctions and market coupling in SDAC and SIDC pool intra-zonal and cross-zonal bids and asks in centralised auctions (DNV GL, 2020).

[15] We have tried to get useful data that would allow us to further empirically test the relationship between retail competition and wholesale market liquidity in two ways. First, we asked survey participants taking part in the transition cost survey how they would adopt their electricity purchasing strategy in case of a market zone split and in case they are vertically integrated. Unfortunately, we have not received responses. Second, we collected data on European electricity retail prices from Eurostat. Because those Eurostat data did also contain taxes and network fees, we were not able to isolate a reliable retail margin from those data.

[16] Note that redispatch is not market-based in all jurisdictions. Hence, the applicability of the stated argument concerns different jurisdictions to different degrees.

In forward markets, larger BZs may be relevant for improving liquidity and facilitating hedging (DNV GL, 2020). This is because the limited cross-zonal capacity and the absence of long-term cross-zonal capacity allocation in timeframes consistent with hedging needs (no market coupling of forward markets) prevent market participants from hedging fully across borders. Indeed, cross-zonal capacity is allocated at best on a yearly basis with maturities matching power forward contracts (Eurelectric, 2023).

The lack of liquidity and hedging possibilities has been one of the focus points of attention of the recent debate and market design reform at the EU level (Eurelectric, 2023) and was also discussed by NERA for Ofgem (2019). Their assessment of the relatively low churn ratio in Great Britain compared to other European countries suggests that limited ability to trade across borders has a negative impact on the liquidity of long-term product markets and hedging opportunities. The ability to hedge across borders depends on the possibility to hedge the risk of price divergence in the short term. In the absence of timely cross-zonal capacity allocation, forward markets may offer price differential hedging products, but their liquidity may also be limited (see next chapter, on the electricity price area differentials (hereafter EPADs) on the Nordic market).

By default, market participants may resort to proxy hedges, i.e. hedges through derivatives for other, highly correlated and more liquid, BZs. These may be preferred over hedges in the delivery BZ if the delivery BZ is considered illiquid (ibid. see also (Pototschnig, 2020), despite the price differential risk. DNV GL (2020) also noted the importance of proxy hedges by use of closely correlated BZs.

Against this background, it seems that various matters play directly and indirectly into the influence of BZ reconfigurations and market liquidity. To put it in Ofgem's words: "*While there is no absolute consensus in the literature, and no clarity on the magnitude of impact on market liquidity that a change in the delineation of bidding zones would have, it is nevertheless a critical factor that is likely to be influenced by the configuration of bidding zones*" (Ofgem, 2014).

Text box: Overview of relationships between market characteristics and liquidity

The sources in the literature reviewed in this section point to various aspects of the relationship between market characteristics and liquidity metrics. This text box provides a more systematic summary highlighting the relevance of the time frame considered. Indeed, primarily due to the different state of implementation of market coupling in short (i.e. day ahead or intraday) or longer term markets (i.e. forward), it seems to be accepted in the literature that the effect of a BZ-split on liquidity could be different for long-term and short-term products.

Long-term markets

In cases where there is a geographical area **without structural network constraints**, the liquidity of long-term products would tend (everything else equal) to benefit from a single BZ within this area. Since there is no structural network constraint, prices would in general reflect the physical reality of the underlying network (except in case of an unplanned event leading to the emergence of an occasional constraint). If multiple BZs existed in this unconstrained area, forward trades would be limited by the need to refer to one of those BZs. In other words, forward markets would be split, and since there is no system like implicit market coupling (yet) in place for forward markets, the single submarkets would be smaller with potentially fewer market participants than the merged BZ. Everything else being equal, a split of a BZ would tend to reduce liquidity within the BZ.

In cases where there is a geographical area **with structural network constraints**, liquidity would still benefit from a single BZ within this area. However, assuming that the structural constraint would remain in the long-term, price formation would not reflect the physical reality of the network.

Prices of long-term products would indeed not reflect the network congestion, and could not help in steering investments in electricity production to the area that "should" have higher prices (and investments in demand, to areas that "should" have lower prices). In this case, multiple BZs in this constrained area – assuming the BZ delineation corresponds to the constraints – would still negatively affect liquidity within the formerly single BZ, but this would reflect the physical reality of network constraints and provide more correct price signals in forward markets.

Depending on potential cross-border trade with BZs outside the area, overall liquidity may increase as cross-border trade may flow more easily. So there are actually two countervailing effects, and which effect dominates is an empirical question.

Short-term markets

For the same two cases (of an area with or without structural network constraints), but considering now short-term markets, the analysis in the literature is different due to the impact of market coupling that allows to implicitly factor in network constraints in the determination of the price.

In cases where there is a geographical area **without structural network constraints**, liquidity would likely not be substantially affected whether it is a single or there are multiple BZs, because the market coupling mechanism joins order books across (unconstrained) BZs. The prices in both cases would reflect the physical reality of the network. It could be that market participants with positions in both BZs that now have to trade through the market, would face higher transaction costs than before.

If the geographical area shows **structural constraints**, and day-ahead and intraday markets would be organised in one large BZ, liquidity would likely be higher than in the case of split BZs. But the prices would not reflect the physical realities of the network, and redispatch would have to be used. Indeed, multiple BZs could negatively affect liquidity because market coupling is undertaken only until the constraint emerges. A countervailing effect to this is that some market participants that have positions in both BZs and now have to trade through the market, would increase liquidity with their trades. However, price formation would reflect better the physical reality of the area – if the BZ delineation corresponds to the constraints. That means that a dispatch-solution that respects the limits of the network would already be achieved as a result of the day-ahead and intraday trading.[17]

2.3 Case studies: Effects of recent changes in bidding zone configurations on market liquidity

Apart from conceptual and theoretical discussions on liquidity measurement, the effect of BZ reconfigurations on market liquidity has been assessed from past reconfigurations. In the following section, we focus on two main examples, looking at academic papers and industry reports, as well through our analysis based on historical data for the first one:

- as the split between Austria and Germany-Luxembourg in 2018; and
- the Nordic BZ reconfiguration in 2011, splitting Sweden into 4 BZs, emanating from court proceedings.

[17] The discussion of the relative advantages and inefficiencies associated with market coupling and the need for redispatch is outside of the scope of this report.

Split of Austria and Germany-Luxembourg in 2018

The split of the Austrian-German-Luxembourg BZ was initiated by ACER by Decision 07/2016 after redispatch costs continued to rise within the joint BZ and loop flows via adjacent countries posed challenges to affected TSOs (Laur & Küpper, 2020). It was confirmed in May 2017 by the national regulatory authorities (Bundesnetzagentur, 2017). The split was realised in October 2018 and a cross-border capacity between Germany and Austria was determined at 4900 MW (Bundesnetzagentur, 2018).

Literature suggests that the split had different effects on short-term and long-term products for Austria and the German-Luxembourg BZ. In terms of short-term products, DNV GL noted an increase in liquidity of 13% of the EPEX day-ahead volume and an increase of 20% of day-ahead volumes on EXAA for the 12 months between prior to and after the split (DNV GL, 2020). When considering the split, ACER argues in the Market Monitoring Report 2019 that the increase can be attributed to the reconfiguration. Arguably "*[b]efore the split, market participants with assets or trading activity in both markets were able to net their positions in a common BZ. However, after the split, market participants need to close their positions in the market, independently for both bidding zones*" (ACER, 2020b, p. 40).[18]

The issue appears to be more complex in the long-term market because existing future contracts needed to be adjusted. Adaptation for exchange-traded contracts was a weighted split of 9 to 1 for DE-LU-AT futures to DE-LU and AT futures, leading to a decrease in contract correlation with Austrian prices (Laur & Küpper, 2020). EFET (2019, S. 7) finds that market liquidity in Austria was very poor, leading to "*significant bid-ask spreads – when bids are actually present at all*". In line with this, Schittekatte and Pototschnig (2020) noted that the split "*initially led to a reduction in the volumes in forward contracts*". As time progressed, volumes increased again in Germany-Luxembourg, but not so in Austria (ibid.). According to Laur and Küpper (2020), financial transmission rights (hereafter FTR) were introduced at the border to ease the issue. ACER quantified the development after the split, identifying a 25% annual churn rate increase for Austria between 2018 and 2019 and reductions in the bid-ask spreads by 63% in Austria and 16% in Germany/Luxembourg comparing 2019 and 2021 baseload products (ACER, 2020b, S. 41). It is acknowledged, however, that bid-ask spreads in Austria remained above the pre-split level.

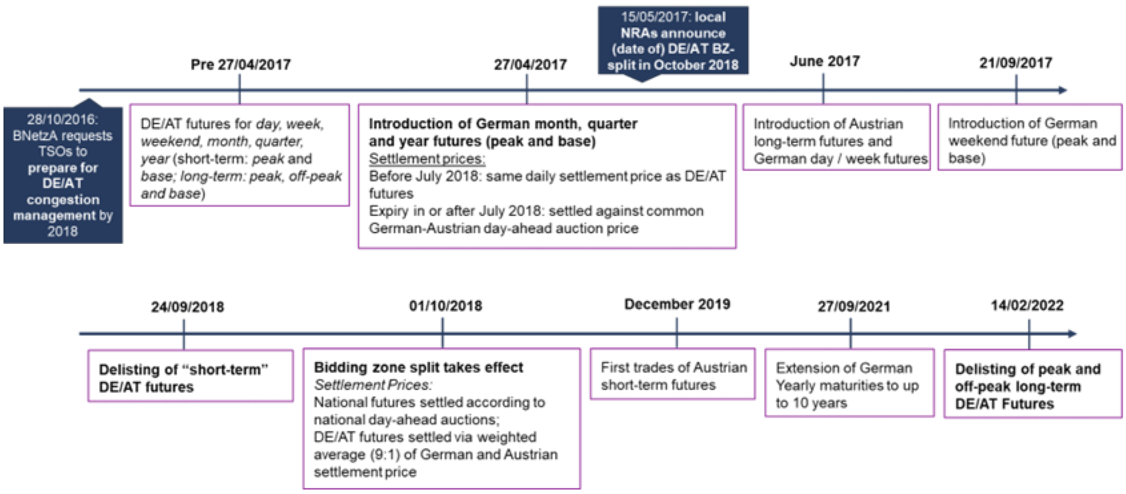
ACER concluded in its market monitoring assessment, that BZ size "*is a relevant factor explaining forward markets liquidity. However [size] is unlikely the only factor explaining forward markets liquidity*" (ACER, 2021, S. 42). Schittekatte and Eike referred to the possibility for Austrian market participants to proxy hedge on the German market due to high price correlation between the countries (Eicke & Schittekatte, 2022).

[18] Please note that this statement specifies the effect on liquidity. The effect on transaction costs may be negative for some parties, if they need to close positions in the market rather than netting them in a common bidding zone.

Text box: German-Austrian BZ split

The reconfiguration of the DE-LU-AT BZ by splitting Austria in October 2018 was a fundamental change for the market, in particular for the Austrian market. Consumers and generators were able to buy and sell electricity in the joint market area, but after the reconfiguration they faced transmission constraints and diverging prices between Germany and Austria. Existing contracts were amended and new contracts were designed. Considering products offered on the exchange, EEX notified contract holders and traders about multiple changes as the reconfiguration date approached. Figure 2.1 shows a high-level summary of product amendments, cessation, and additions in the run-up and aftermath to the split.

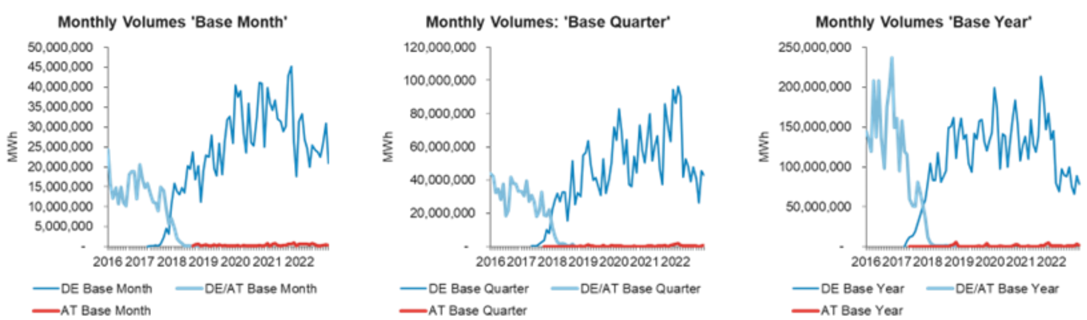
Figure 2.1 Product adaptions before and after the German-Austrian BZ split



Source: Compass Lexecon analysis based on EEX announcements, Bundesnetzagentur announcements and EEX data

The reconfiguration led to liquidity changes in regard to traded volume and bid-ask spreads. Figure 2.2 shows the development of traded volume on EEX German-Austrian, German, and Austrian products.

Figure 2.2 Traded volume of EEX-traded products before and after the German-Austrian BZ split (in MWh)



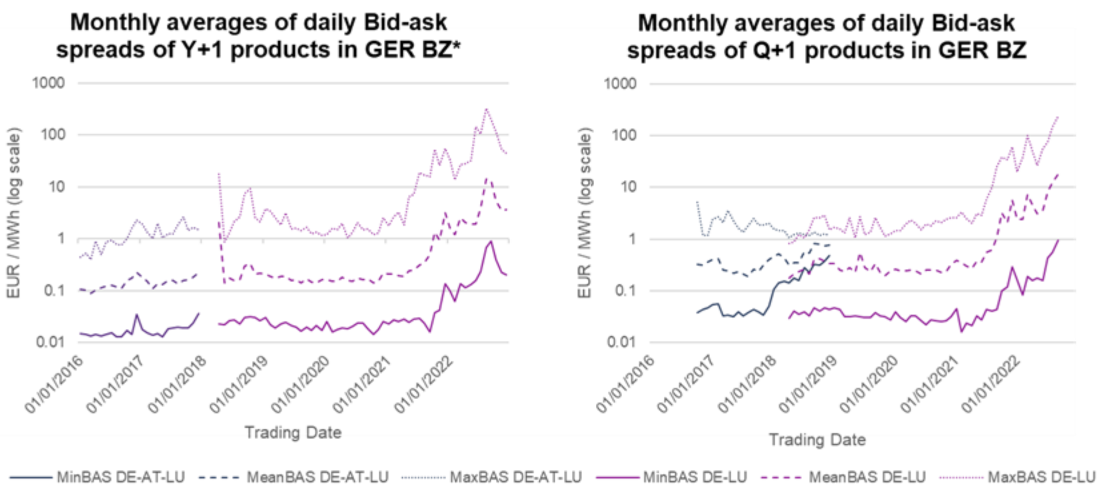
Source: Compass Lexecon analysis of EEX data

It shows that turnover gradually decreased for the joint BZ and picked up again for German-Luxembourg products. The average turnover surpassed the turnover prior to the split for monthly and quarterly products. Annual base products did not reach the maximum turnover from before the split, but it is unknown if and to what extent these observations for the different products may be attributed to the reconfiguration. The turnover of Austrian products remained rather low, and, through mutual reinforcement, Austrian market participants may be inclined to trade, i.e. for proxy-hedging, on the German-Luxembourg market and account for the risk of deviating spot market prices between Germany and Austria.

The consideration of bid-ask-spreads supports the indication that the reconfiguration itself had a limited effect on liquidity on the German-Luxembourg market, if at all.

For the year-ahead base product, the bid-ask spreads increased slightly after the split, but dropped again in 2019 towards 2020, resulting in a slightly higher level than before the reconfiguration. At the same time, the spreads for quarterly products remained largely unchanged or slightly reduced until end of 2020.

Figure 2.3 Monthly averages of daily Bid-ask spreads in German BZ (in EUR/MWh)



Source: Compass Lexecon analysis of bid-ask spread data as provided by ICE
Note: * Data is missing for 01/01/2018-31/03/2018

Considering the significant increase of bid-ask spreads in 2021 and 2022 that coincides with an increase in average future prices due to higher overall electricity prices, the variation in bid-ask spreads seems not to be coming from the BZ reconfiguration (see further below text box: Historic price levels for average price development). As shown in Figure 2.3, the identified variation from before to after the split cannot be observed.

Hence, it may be concluded that any impact on market liquidity for the larger German market has less significance, if at all, than impacts associated with price changes. This can, for instance, be derived when observing the significant increases across spreads as the power and derivative prices increased in 2021 and 2022.

For the Austrian market participants, the case is different as their traded volume decreased substantially, with very limited trading happening on the Austrian market, which also led to high bid-ask spreads. As a result, Austrian market participants may be mostly hedging on the German market, taking on the spread risk.

BZ split of Sweden in 2011

Sweden was initially operating as a single national BZ. In addition to the individual BZs, the Nordic region of which Sweden is a part of used EPADs and a system price. EPADs are future contracts on price differences between the BZ and the system price; the system price is a hypothetical price, calculated with the assumption that no network constraints existed in the Nordics (Eicke & Schittekatte, 2022). In November 2011, the Swedish TSO took the decision to divide the Swedish electricity market into four BZs, following European Commission Case 39351 – Swedish Interconnectors under competition law that challenged Svenska Kraftnät's actions in curtailing transmission capacity to neighbouring countries.

This BZ reconfiguration appears to have caused an increase in short-term product liquidity (DNV GL, 2020). According to Nord Pool, day-ahead volumes increased from 2011 to 2012 in Sweden by 10%.

The long-term market, in contrast, experienced a loss in liquidity which continued for several years with a 20% reduction of cleared futures volume on NASDAQ over the course of four years and a 30% reduction in the volume of EPADs on NASDAQ over the same time (Laur & Küpper, 2020). Notably, liquidity on forward power markets increased in other European markets over the same time period (EFET E. , 2019).

However, literature suggests that this decrease is not necessarily attributable to the split itself, but that other factors such as a) low demand for hedging through EPADs due to high price correlation between zones, b) increased use of bilateral PPAs, and c) increased fees on the exchange (Eicke & Schittekatte, 2022) (Schittekatte & Pototschnig, 2020) (Laur & Küpper, 2020) (Thema, 2021).

Summary of case studies

The Austrian/German BZ-split had a significant effect on long-term markets liquidity. While Germany-Luxembourg remains a very liquid market, and the lead-market in central Europe, the Austrian long-term market became relatively illiquid. There seems to be no negative effect on the liquidity of short-term markets in Germany. Literature does not provide a view as to how liquidity on the Austrian short-term market developed in the years after the split.

For Sweden, the BZ reconfiguration appears to have increased liquidity in the short-term market, while the effect on the long-term market is unclear as a range of other factors likely played a role in the evolution of liquidity.

3 ANALYSIS OF THE STATE OF LIQUIDITY IN RELEVANT EUROPEAN MARKETS

The analysis of the state of liquidity depicts the starting point for the review of BZ changes and resulting impacts on liquidity and transaction costs. The analysis considers liquidity of products in short-term and long-term markets. It aims to support the evaluation of the potential reconfigurations by providing context, as well as a counterfactual to compare the results.

This section is structured as follows:

- We start with the analysis of liquidity metrics in the current BZs in order to establish the current state of liquidity for the different products in the different BZs.
- Then, we assess the relationship between these metrics and market characteristics to understand how liquidity could evolve in case of a BZ reconfiguration, through the changing market characteristics.
- Last, we consider price correlations to understand the existing possibilities to proxy hedge and the price convergence between zones.

3.1 Analysis of the current liquidity of short- and long-term products

In this subchapter, we assess the liquidity of different products traded in the current BZs. We cover exchange-traded DA and ID products as well as annual, quarterly, and monthly exchange- and OTC-traded derivatives. In our analysis, we intend to account for product and geographical specificities both qualitatively and quantitatively. For instance:

- Sweden is part of the Nordic area in which the traded long-term products usually relate to system price and zonal price differences which are accounted for through EPADs, i.e. derivatives to settle price differentials between the system price and the price in the respective BZ. It should be noted that the system price could play a role as part of possible mitigation measures, and so it could impact market liquidity metrics and their relationship to market characteristics of the individual BZs both in short- and long-term markets.
- In France, part of the generated volume bypasses the organised market due to the ARENH regulation.[19]
- Italy uses the Prezzo Unico Nationale (PUN) to clear demand with a uniform price across BZs. Similarly to the system price for the Nordics, the existence of the PUN in Italy could play a role

[19] ARENH stands for ‘Accès Régulé à l’Electricité Nucléaire Historique’ and is a regulatory mechanism through which suppliers other than EDF may acquire nuclear electricity on a yearly basis at a regulated price. The mechanism covers about 20-25% of total consumption in France.

as part of possible mitigation measures and hence impact market liquidity metrics and their relationship to market characteristics of the individual BZs both in short- and long-term markets.

Considering the metrics for liquidity measurement identified in chapter 2.1 and in line with the BZR methodology, we focus our analysis on traded volumes, churn rates and bid-ask spreads but complement the analysis with additional metrics where needed and where data is available. In particular, the traded volumes and the churn rate are the preferred indicators over the number of players, given that competition metrics are made explicit in this study through market characteristics. The churn rate is particularly of interest for continuous markets, as re-selling is possible. Bid-ask spreads is only relevant for continuously trading markets. Risk premiums may be taken into account for long-term products.

3.1.1 Data and methodology

To analyse the historic liquidity of the markets, we use data from the years 2016 to 2022 where available. Traded volumes were provided by the NEMOs and the ACER market monitoring team for the DA and ID market respectively. Notably, OTC trade in the short-term is not included as we could not obtain any relevant data. The exchanges EEX and NASDAQ provided daily traded volumes per specific long-term contract. The London Energy Broker Association (LEBA) provided long-term OTC data based on their member's input on submitted differentiated between cleared and non-cleared contracts and aggregated by country and month.

Churn rates are calculated based on the traded volumes as well as load data provided by the TSOs participating in the study. An overview of data sources used is provided in the Appendix.

Bid-ask spreads are calculated as minimum, average, and maximum spreads on a single trading day across selected annual, quarterly and monthly products from the data provider ICE who sourced the data from EEX, ICE Endex, and NASDAQ commodities. The spreads are aggregated by considering the average minimum, average, and maximum spreads across a month.

We then aggregate and compare the respective data points from the different products across the BZs and over time, explaining elements of context to understand trends and seasonal variations. Where applicable, the analysis of the state of liquidity is enriched through liquidity evaluations from existing publications.

3.1.2 Short-term products

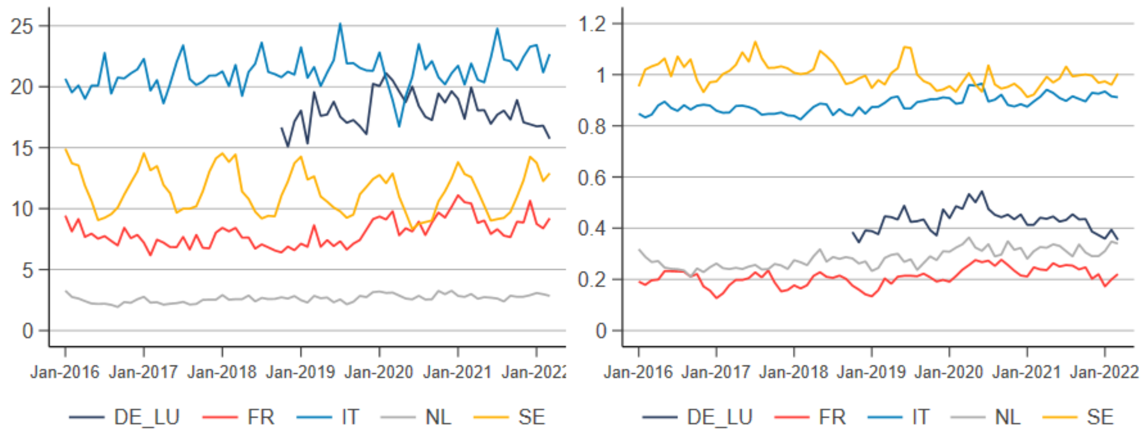
The liquidity of short-term products strongly differs between BZs and the DA versus ID-market. *Prima facie*, the DA market is on average at least about ten times the size of the ID market in terms of traded volume.

Day-ahead market

Figure 3.1 shows that the exchange-traded DA market with the greatest liquidity is the Italian market with traded volumes of up to 25 TWh per month. In contrast, the Netherlands shows the least liquidity out of the analysed sample. However, when looking at the churn rate, i.e. looking at traded volumes levelized by total load, the most liquid market is Sweden.[20] Germany ranks second in terms of traded volumes and has the third highest churn rate with about 0.4.

[20] Note that its monthly churn ratio is at times above 1 – this observation can be attributed to months in which Sweden is net-exporter such that total load (the metric for the market size) is lower than generated electricity.

Figure 3.1 Monthly DA traded volume (left, in TWh) and churn rate (right) by country



Source: Compass Lexecon analysis of traded volume data as provided by the exchanges EEX and NASDAQ and load data from ENTSO-E transparency platform

Amongst analysed countries, churn rates show different levels. Sweden and Italy have churn rates close to 1, however Germany, the Netherlands and France have much lower churn rates (between 0.2 and 0.5). This difference can be explained by the incentives (or even obligations) faced by market participants to settle their physical positions in the DA organised markets (more explanation below), which pools liquidity on the exchange. Market participants in other countries may rely more on OTC trading or intra-group trading, especially in larger BZs.

Italy and Sweden, in particular, are split into several BZs and cross-zonal capacities are allocated in the DA market through the market coupling. Therefore, market participants in these countries need to go to the exchange to trade across BZs in the short term.

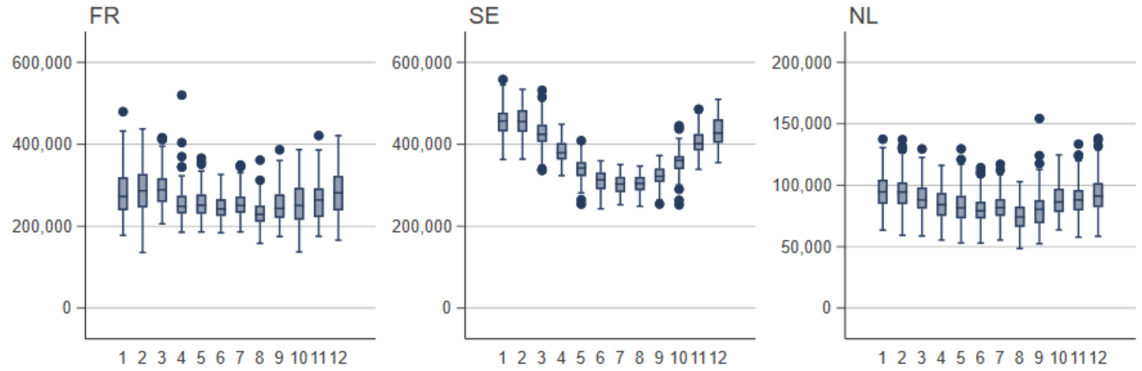
On the other hand, when participation in the DA market is not mandatory and BZs are relatively large, vertically integrated companies, especially incumbents, can net their positions within the company across the whole BZ without the need to settle short-term on the market. One reason to do so is to lower transaction cost. This may be particularly significant in countries with higher market concentration.

The evolution of liquidity over time does not appear very pronounced in DA markets and may display significant volatility. Liquidity in France, Italy and the Netherlands show a slightly increasing trend while traded volumes and churn ratios for Sweden seem to have slowly decreased since 2016. For the reduced timeframe of the German DA market, no clear time trend can be observed. In general, the time trend on the DA market is not very strong with changes in monthly traded volume of up to 21% over 5 years in the case of France.

Seasonal patterns, as evidenced in Figure 3.2, may also be observed in some countries. They are most pronounced in Sweden where traded volumes fluctuate between a minimum traded volume of on average 300 GWh in July and 500 GWh monthly traded volume in January. France and the Netherlands exhibit a similar seasonal pattern with higher traded volumes in colder months of the year. By contrast, Germany-Luxembourg and Italy do not show this type of seasonal pattern. This pattern is strongly correlated with temperature, suggesting that additional demand for electrified heating and cooling implies increased traded volume.[21]

[21] The relationship between market size as approximated by total load and liquidity is assessed in chapter 3.2. There, we identify the suggested relationship.

Figure 3.2 Daily DA traded volumes by month (in MWh)

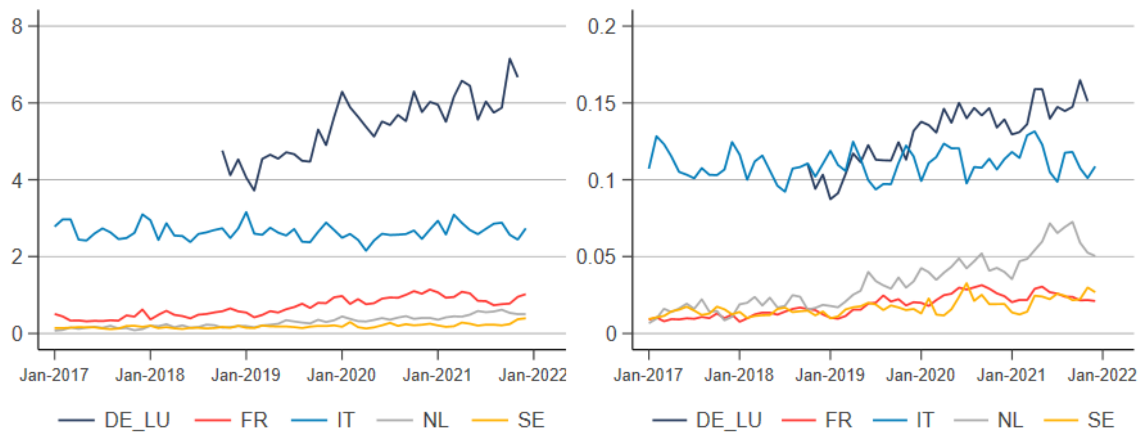


Source: Compass Lexecon analysis based on traded volume data as provided by the exchanges EEX and NASDAQ.
Note: The boxplots visualise the spread of traded volumes in each month. The boxes capture the inner 50% of observations, ordered by size, and the line splitting the boxes is the respective median. Any dots beyond the whiskers indicate outliers.

Intraday market

The ID market is significantly different to the DA market as it is comparatively young and has been relying mostly on continuous trading[22] instead of an auction until recently. As illustrated in the Figure 3.3Figure 3.3 below, comparing the different BZs, Germany shows the highest liquidity and a strong increase over the past years. The Italian ID market ranks second, although the traded volume has remained stable over the past 6 years, within a bandwidth of 2-3 TWh of monthly traded volume. France, Sweden and the Netherlands show comparatively less liquid markets with traded volumes below 1 TWh for the majority of the past five years. However, these latter markets show increases over time with, e.g. the Netherland's churn rate increasing by more than seven times between 2017 and 2022. In contrast to the DA markets, seasonality patterns do not seem to play a role.

Figure 3.3 Monthly ID traded volume (left, in TWh) and churn ratio (right) by country



Source: Compass Lexecon analysis of traded volume data as provided by ACER and load data from ENTSO-E transparency platform

[22] Intraday auctions are in place in some countries as well, for example in the Netherlands, Belgium and Germany, but volumes are comparatively low. Most recently, on the 13th of June 2024, three separate intraday auctions for the single European electricity market have been launched, involving most European countries apart from Switzerland, the UK, Ireland, Serbia, Bosnia-Herzogovina, Macedonia, Albania, Serbia and Montenegro. Pricing the intraday capacities is part of the Single Intraday Coupling (SIDC). A new technical set up and new market coupling communication processes are used amongst Nominated Electricity Market Operators (NEMOs) and Transmission System Operators (TSOs), complementing the current SIDX XBID platform used for continuous trading.

3.1.3 Long-term products

The market for long-term products is substantially different from the DA- and ID-markets because its products are typically financial derivatives. As such, market coupling does not exist, and products are not bound to specific technical delivery obligations. Any cross-border trading rights are, if at all, tendered on specific dates and thus their market is not aligned to long term energy products. Notwithstanding, the different long-term products are implicitly linked to one another by way of the underlying physical product and the existence of spread products for price deviations between BZs.

Three main distinctions among long-term products are in order:

- Bilateral forward contracts (bilateral OTC) are contracts for physical or financial settlements in a specific location at a future delivery date with bilaterally agreed upon contract specifications. Here, neither the trade nor the clearing takes place on a centralised platform.

- Cleared forward contracts (cleared OTC) are contracts for physical or financial settlements in a specific location at a future delivery date for which the trade is centrally cleared. This implies some standardisation in terms of risk allocation, i.e. through standardised margin requirements.[23]

- Exchange-traded futures are forward contracts with an underlying master contract for physical or financial settlements in a specific location at a future delivery date. Due to the standardised master contract, futures can be (re-)traded irrespective of the specific counterparty such that risk allocation and contract design is significantly different to OTC traded forward contracts.

In addition to these main types of long-term derivatives, various other derivatives exist as well. For instance, EPADs (both exchange- and OTC traded) are of specific interest for the liquidity study as they play a relevant role in the Nordic area and hence for Sweden.Despite this differentiation, some substitutability exists between these different types of products, as market participants have visibility across the different types through software solutions which list both exchange-traded and brokered products, i.e. most forward contracts.

In what follows, we look at traded volumes, churn rates and bid-ask spreads for long-term products in turns.

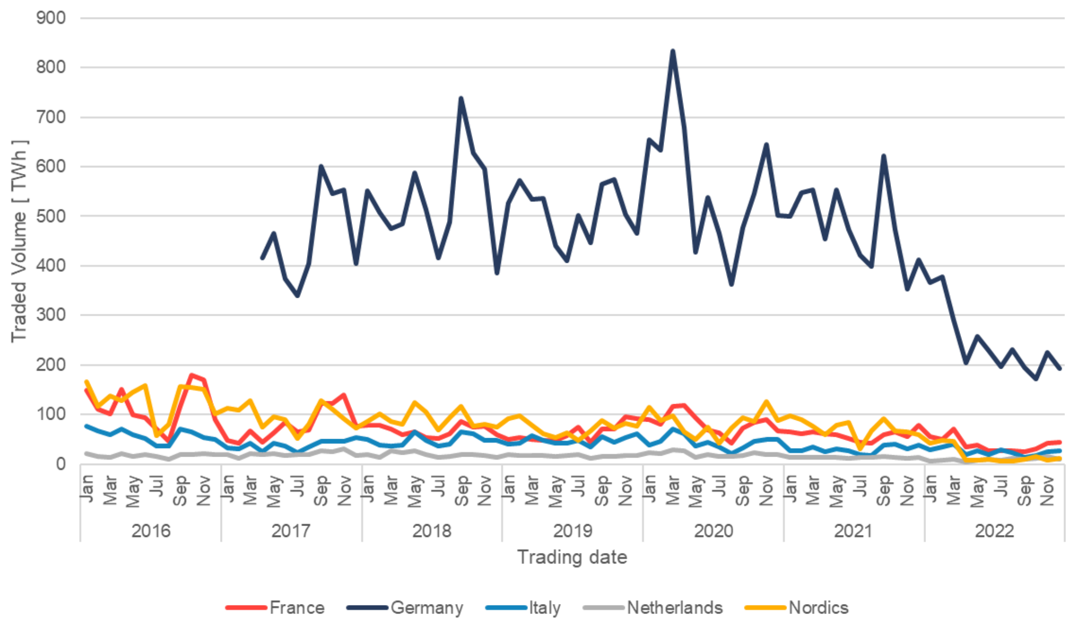
Traded volume

The Figure 3.4Figure 3.4 below shows that the market for German-Luxembourg futures and forwards is by far the most liquid market with monthly traded volumes between 400 and 900 GWh[24] per month over the years 2018 to 2022, traded volumes also seem to be affected by the energy crisis in end of 2021 and 2022. Derivatives for the Nordic system price rank second, closely followed by French and then Italian derivatives. The Dutch long-term product market is comparatively small in terms of traded volumes on EEX of up to 15 TWh per year.

[23] A margin requirement is the requirement to deposit a certain amount of funds or securities for the open interest.

[24] On EEX, NASDAQ and via LEBA associated brokers.

Figure 3.4 Traded volume of long-term products (in TWh)

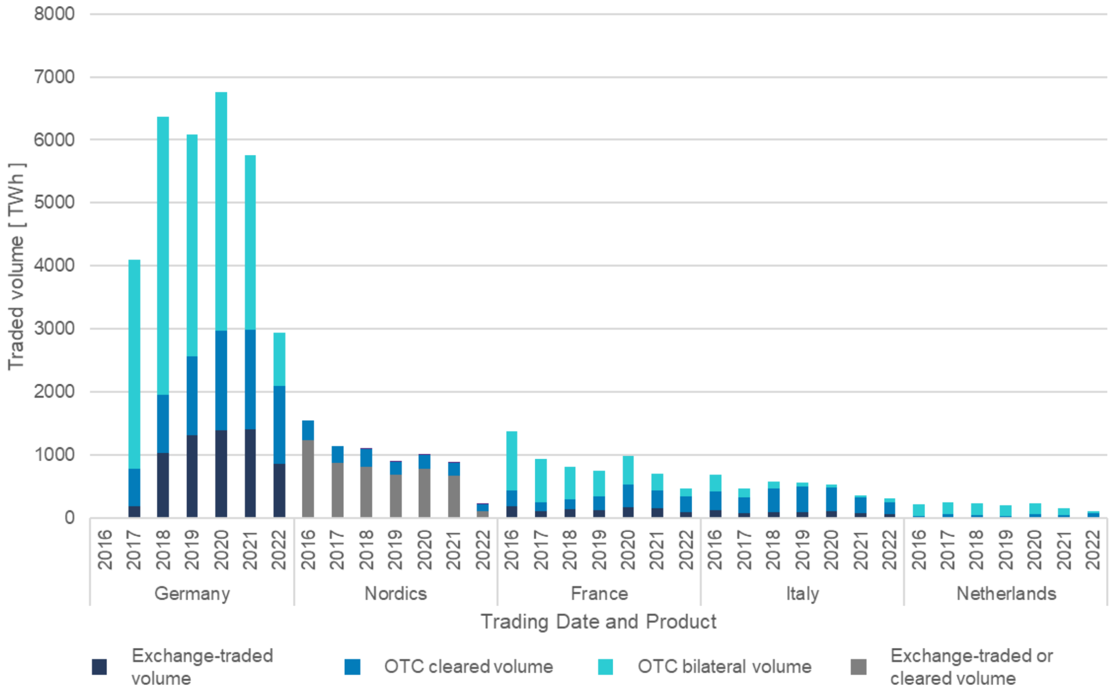


Source: Compass Lexecon analysis of traded volume data as provided by the exchanges EEX and NASDAQ, as well as by LEBA
Note: The traded volume for Germany in 2017 and 2018 is based on LEBA data that specifies "German power" as well as German-Luxembourg futures traded on EEX and NADSAQ. LEBA data may include volume contracted for the Austrian area. Exchange-traded volumes do not include futures for the German-Luxembourg-Austrian BZ.

Beyond the impact of the energy prices, which has affected traded volumes since the end of 2021, liquidity seems to follow a downward trend in most of the analysed countries, except Germany.

The differences of liquidity between countries on the exchange may be explained by the use of OTC trades, clearing and exchanges significantly differing between countries. For instance, the bulk of published and available Dutch trades occurred as bilateral OTC, while Italian contracts have been mostly cleared OTC trades, and Nordic derivatives are typically executed via an exchange. Furthermore, in some countries such as the Netherlands, other exchanges apart from EEX and NASDAQ are frequently used. The liquidity differences could also be explained by the fact that the most liquid markets such as Germany may be used by market participants to hedge their positions including in neighbouring markets (proxy-hedging), concentrating liquidity even further in these markets.

Figure 3.5 Traded volume of long-term products by trading date and type of product (in TWh)

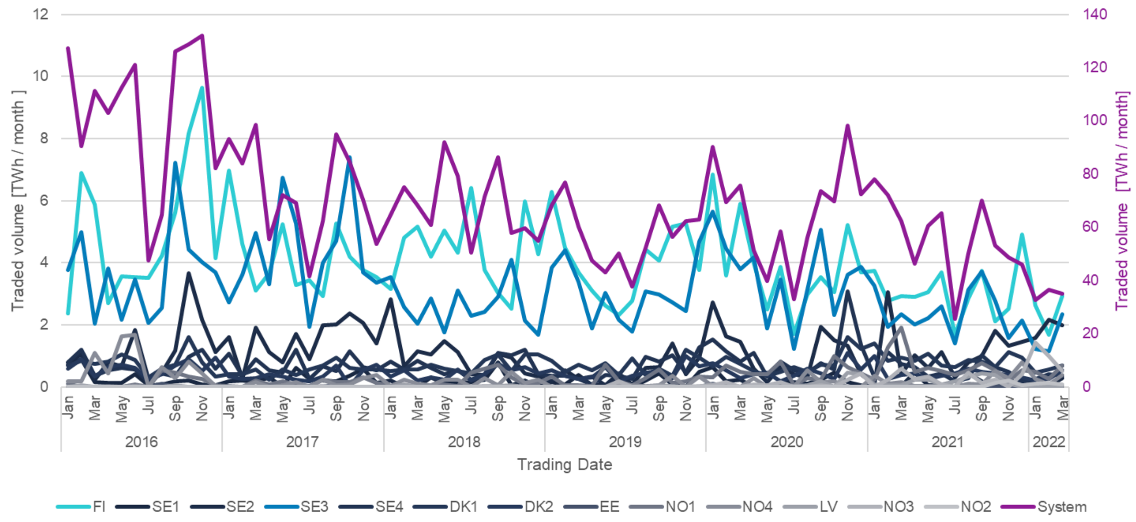


Source: Compass Lexecon analysis of traded volume data as provided by the exchanges EEX and NASDAQ as well as by LEBA
Note: The traded volume for Germany in 2017 and 2018 is based on LEBA data that specifies "German power" as well as German-Luxembourg futures traded on EEX and NADSAQ. LEBA data may include volume contracted for the Austrian area. Exchange-traded volumes do not include futures for the German-Luxembourg-Austrian BZ.

Aside from the products highlighted in Figure 3.5Figure 3.5, significant volumes for hedging are traded as EPADs on the Nordic market. Over the period from 2016 to 2022, between 8% and 31% of monthly Nordic system price future turnover is additionally traded as EPADs. Liquidity of EPADs is highly dependent on the specific BZ.

Figure 3.6Figure 3.6 shows that the bulk of EPADs are traded for the Finish (HEL) and Sweden 3 (STO) BZ. The underlying reason for this is probably that the likelihood of constraints on the cross-zonal capacity with these areas drives price differentials' risks up and therefore the need to hedge these risks against the system price. Figure 3.6Figure 3.6 further shows that the turnover for the Nordics did not only decrease for system price futures, but for EPADs as well.

Figure 3.6 Traded volume by trading date for Nordic and Baltic individual BZs (in TWh)

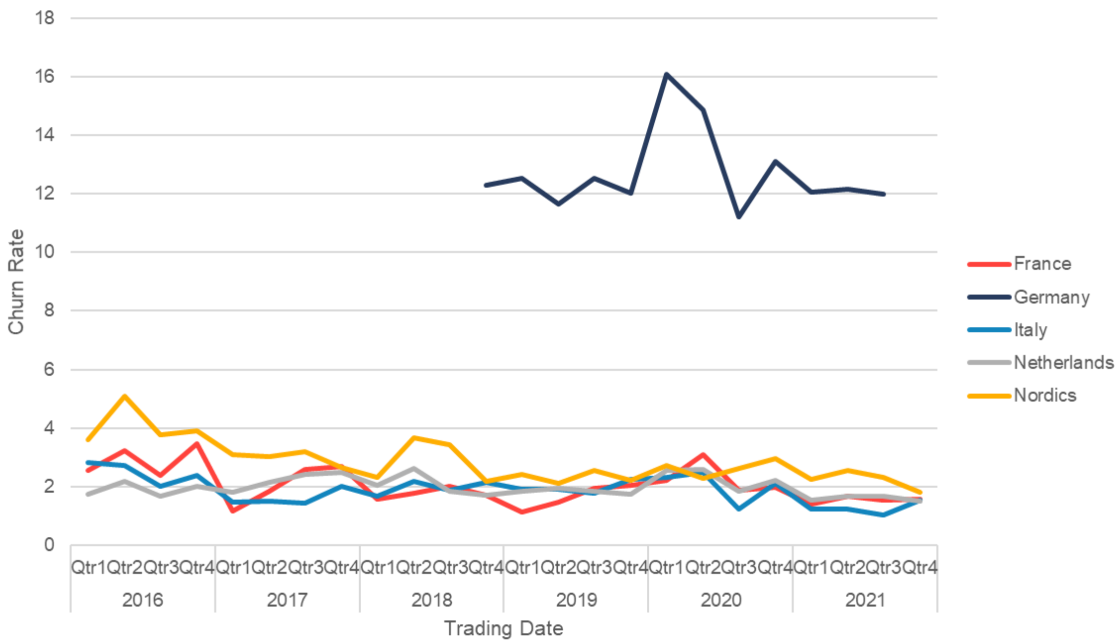


Source: Compass Lexecon analysis of traded volume data as provided by NASDAQ

Churn rate

The churn rate is measured as the ratio between traded volumes and total load. As illustrated in the Figure 3.7Figure 3.7 below, for Germany, it was above 10 for most months between 2019 and 2022. In contrast, the ratios for France, Italy and the Netherlands fluctuated between 1 and 3.5 over the period 2016-2022. The churn rate for the Nordics, has gradually decreased to below 2 in Q4 2021, compared to a maximum of 5 in Q2 2016.

Figure 3.7 Churn rate of long-term products by trading date



Source: Compass Lexecon analysis of traded volume data as provided by the exchanges EEX and NASDAQ, as well as by LEBA and load data from ENTSO-E transparency platform
Note: The churn rate for the German-Luxembourg BZ, here "Germany", is calculated for Q4 2018 onwards as it included Austria beforehand.

Consequently, in the status quo of liquidity in terms of turnover of long-term products, Germany-Luxembourg constitutes a lead market with the churn ratio about 5 times higher than its neighbouring zones.

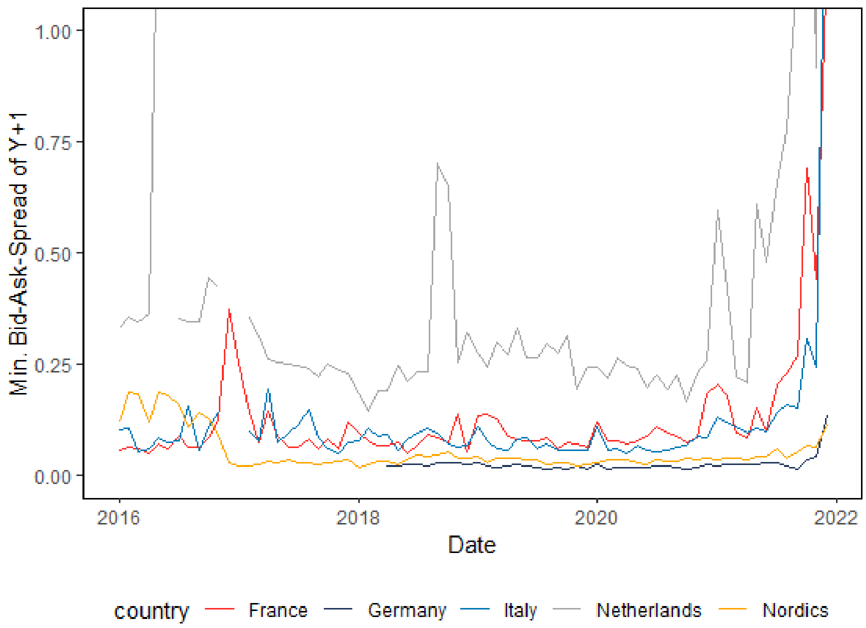
On France, ESMA noted in its opinion on position limits on EEX French Power Base contracts in 2019 that the "*wholesale market […] has low liquidity with the majority of trading taking place OTC*" (ESMA, 2019). From this statement and the industry claim that the churn rate should be 3 or higher, market liquidity in Italy, the Netherlands, and – lately – also the Nordics may be considered low (Economic Consulting Associates, 2015).

Bid-ask spreads

The bid-ask spread is the spread between the highest bid and lowest ask. It is a direct measure of transaction costs for a specific instrument and should remain low in liquid markets.

Its analysis shows a similar but more nuanced pattern compared to the traded volumes and churn rate. As shown in the Figure 3.8 below, which considers the average of minimum bid-ask-spreads for year-ahead products on ICE, EEX and NASDAQ between 2016 and 2022, German futures have the lowest minimum bid-ask spreads of ca. 2.5 EURcent / MWh, followed by the Nordics[25] with average minimum spreads of ca. 5 EURcent / MWh. French and Italian spreads are just above 10 EURcent / MWh while Dutch spreads show a large range with spreads between 20 EURcent / MWh and 120 EURcent / MWh.[26]

Figure 3.8 Minimum Bid-Ask-Spread of Y+1 (in EUR/MWh)



Source: Compass Lexecon analysis of data as provided by ICE

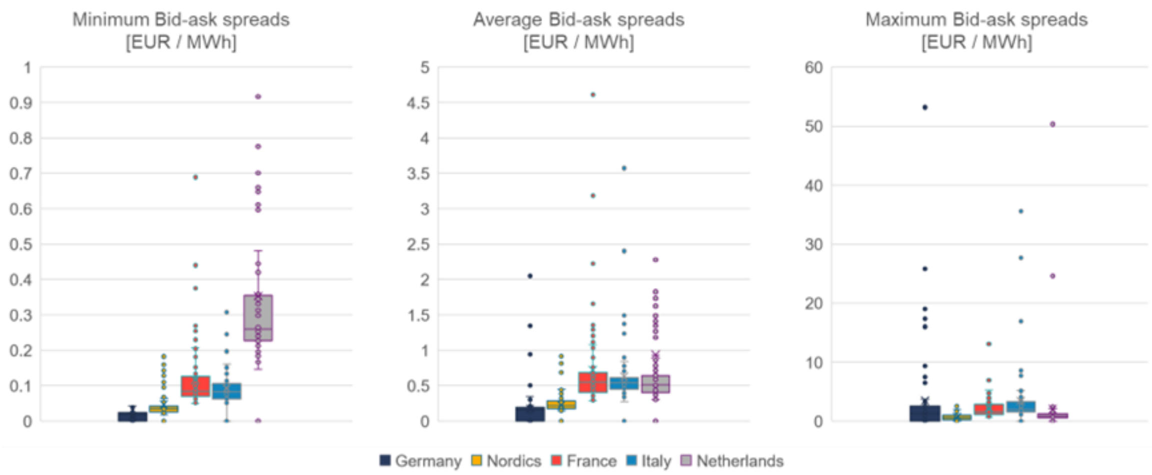
[25] The Nordic system price products have been considered as "Nordics" for the Bid-Ask Spread analysis.

[26] The Bid-Ask Spread units are price differences per product. The overall impact of the Bid-Ask Spread for the sum of MWh delivered differs between Y+1 and Q+1 products. The spreads in percentage of average product prices show a similar ranking. The range of average percentages for minimum bid-ask spreads has been in Germany (after its BZ split from with Austria) with 0.05% and 0.71% for Dutch futures.

The volatility of minimum spreads was lowest for Germany and the Nordics, higher for Italy and France and highest for the Dutch EEX futures. As of Q3 2021, bid-ask spreads increased significantly. This trend can be attributed to the increase in power future prices.

The ranking of market liquidity in terms of minimum bid-ask spreads is largely consistent with the ranking from average and maximum daily spreads.[27] Figure 3.9 shows the three different spreads for each region.

Figure 3.9 Minimum, Average and Maximum Bid-ask spreads of Y+1 and Q+1 products between 2016 and 2022 (in EUR/MWh)



Source: Compass Lexecon analysis of data as provided by ICE

Significant variation in the ranking can be seen for Dutch products as they have the highest minimum bid-ask spread but the second lowest maximum spread. A potential explanation for this is the limitation of available products in the Dutch market. Since fewer products are traded in general, the average and maximum spreads are less impacted by products that are rarely traded. In general, the difference in maximum spreads compared to minimum and average spreads may be attributed to the existence of rarely traded products, but also on information asymmetries that seem to be particularly prevalent at opening hours.

A second take-away from Figure 3.9 is the comparison of the difference between the average minimum and medium spread per BZ. In liquid zones, the medium spread should be closer to the minimum spread as intraday price variation impacts the spread less than in illiquid markets, where a relatively low (minimum) spread may occur at only few instances during the day. By view of this difference, it can be also perceived that the German market is the most liquid, closely followed by the Nordic. For both product types, the difference between the minimum and the average spread is just above 0.2 EUR / MWh on average between 2016 and 2021. In contrast, the Dutch, French, and Italian market show similar spread patterns with a difference between the minimum and the average of just above 0.6 EUR / MWh in the same timeframe.

3.1.4 Conclusions on state of liquidity

In summary, liquidity metrics for short-term products show the following characteristics:

[27] The depiction of these larger spreads is important as they, by design, contain a variance in perceived value that cannot be only due to transaction fees. In addition to this element, bid-ask spreads may follow from inventory holding cost (i.e. overnight), adverse selection, and liquidity considerations such as the existence and behaviour of market makers, the number of active market participants, traded volume, etc. (Menyah & Paudyal, 1996).

- Literature points out that Liquidity on the DA market is generally less of an issue, as supply and demand are concentrated in the auction.
- The DA market has significantly higher liquidity metrics than the ID market, especially France, Sweden and the Netherlands who show very limited traded volumes in ID.
- Liquidity metrics have generally been increasing over time in the past years, with only the Swedish DA market showing a slight downward trend.
- Seasonality appears to play a role on the DA market but not the ID market. The effect can be primarily attributed to changes in demand.

The status quo of market liquidity in the BZs shows the following developments for long-term products:

- The German-Luxembourg BZ constitutes the lead market for forward and future products. Its traded volume is substantially higher than all other BZs and its churn rate has been above 10 over the past years. The Nordic market has seen a decrease in liquidity metrics both for system price futures and EPADs over the past years with churn rates for EPADs dropping from 5 to 2. France, Italy, and the Netherlands also show churn rates of about 2, such that, in line with their ranking of total load, the traded volumes among the three is highest for France, followed by Italy and the Netherlands.
- The type of product and applied trading system (exchange, OTC bilateral or OTC cleared) significantly varies between BZs. While Germany sees substantial traded volumes for all three systems, the other BZs typically see a dominant type with the other two types, if at all, complementing the market.
- In terms of bid-ask spreads, Germany shows the lowest minimum spreads at 2.5 EURcent / MWh, followed by 5 EURcent / MWh for the Nordics, 10 EURcent / MWh for France and Italy, and 20 EURcent / MWh for Dutch futures. Variation in spreads exists both intraday and across products.
- The difference in liquidity could also be explained by the fact that the most liquid markets, Germany in this case, may be used by market participants to hedge their positions including in neighbouring markets (proxy-hedging), concentrating liquidity even further in these markets.

3.2 Relationships between liquidity and other market metrics

3.2.1 Methodological approach

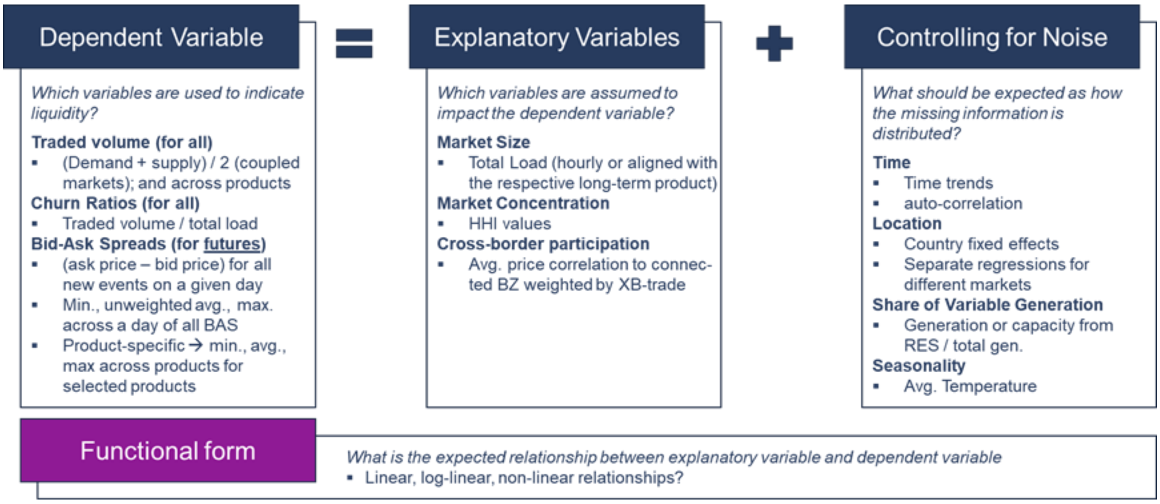
After studying liquidity and relevant market metrics in the short- and long-term markets, we investigate existing relationships among these variables to draw conclusions about historical relationships between liquidity metrics and market characteristics. The identified relationships may then indirectly inform the status of liquidity for the simulated BZs. For this purpose, we conduct a regression analysis using historic data for the countries that may be subject to a BZ reconfiguration. The regression analysis consists of three building blocks:

- First, we identify the variable of interest, liquidity, which is parametrized by traded volumes or churn rate in the case of short-term products, or bid-ask-spread in the case of long-term products.

- The second building block is a set of explanatory variables that are assumed to impact the variable of interest. Here, we include total load to proxy the market size, the flow-weighted price correlations to analyse the effect of cross-border participation, the price spreads to Germany for the ability to proxy-hedge on the lead market, and the HHI[28] to study the impact of market concentration.

- Third, we include controlling variables to filter the effect of the explanatory variables more precisely and to minimise the impact of unobserved variables in our results. One of the controlling variables is temperature as climate conditions may affect both the dependent variable and the explanatory variable. Furthermore, we include the share of renewables, which is defined as the sum of solar, offshore wind and onshore wind generation as a share of total generation[29], to account for uncertainties in a country's generation mix, as well as time trends and country fixed effects to account for individual country characteristics, such as historic trade patterns or fees, that are not explicitly included.

Figure 3.10 Conceptual approach of regression analysis and model determination



Source: Compass Lexecon analysis

We build the regression models for traded volume and churn rate separately since the relationships with the described explanatory variables may differ among the liquidity variables. In order to check our results for the interaction of liquidity with market size, cross-border participation and market concentration, we study several regression models, each with a different selection of explanatory and controlling variables. We analyse the relationship between the liquidity variables and explanatory variables for countries individually and also across countries using a panel data set.

[28] The HHI (Herfindahl Hirschman Index) is based on HHI data as published by the European Commission. According to the European Commission, the HHI is computed as the sum of squared market shares of the three largest electricity generation companies measured in percentages of the total installed capacity, with 10,000 corresponding to a monopoly. European Commission HHI data is used for the years 2016 and 2017, and extrapolated for the subsequent years. See https://energy.ec.europa.eu/data-and-analysis/energy-union-indicators-webtool/data-charts_en.

[29] The computed share of renewables is based on generation forecast data as published on the ENTSO-E transparency platform.

Figure 3.10 shows the conceptual approach to the model determination. We apply different levels of granularity for short- and long-term products. For short-term products, we consider daily data while we consider monthly data for long-term products. Daily data incorporates information that may be disregarded for long-term product estimates but may be relevant for short-term products.

The objective of this approach is to identify market characteristics that show a significant relationship with the liquidity metric. These market metrics may then indirectly inform the status of liquidity for the simulated BZs. In addition, the direction and extent of the explanatory variable's coefficients (the market characteristics) may be used to derive expectations to the extent of the liquidity change of one alternative BZ configuration in comparison to the status quo configuration. Notably, for this conclusion, a set of assumptions would need to be accepted.

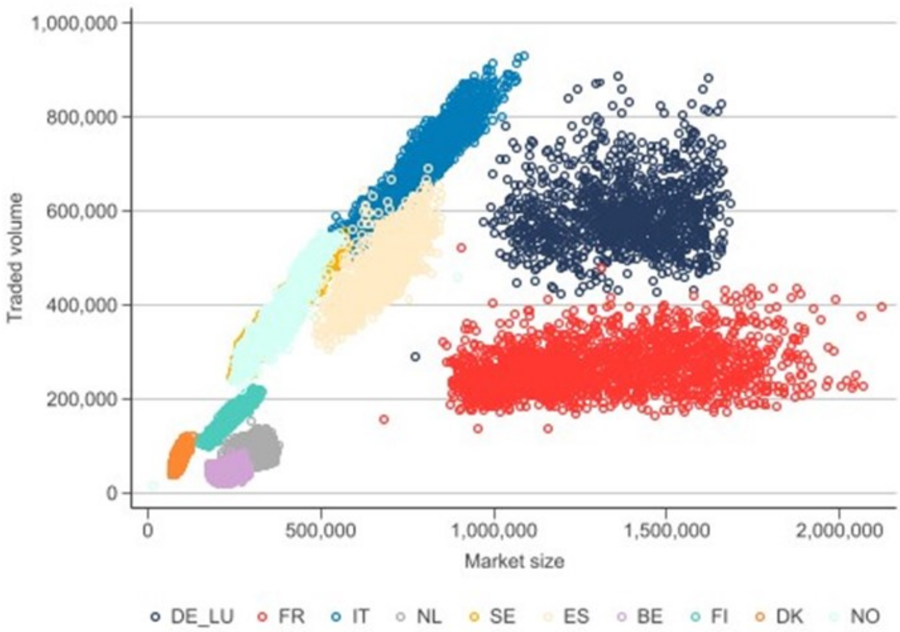
3.2.2 Short-term products

Market size

The Figure 3.11 below presents the traded volumes in the DA market of different countries against the market size, expressed as the daily load, and highlights a significant and positive correlation between these variables.

In particular, it shows a one-to-one relationship between traded volumes and load for countries with high churn rates, suggesting that trades in these markets happen mostly on exchanges. As explained before, in these markets, there are strong incentives, or even obligations, for market participants to settle their physical positions in the DA market (e.g. in Italy, Spain or in the Nordic countries). Conversely, the relationship is less pronounced for countries with lower churn rates, where OTC trading and intra-group trading are more developed and do not have to be settled through the exchange.

Figure 3.11 Market size (daily load) and DA daily traded volume by country (in MWh)

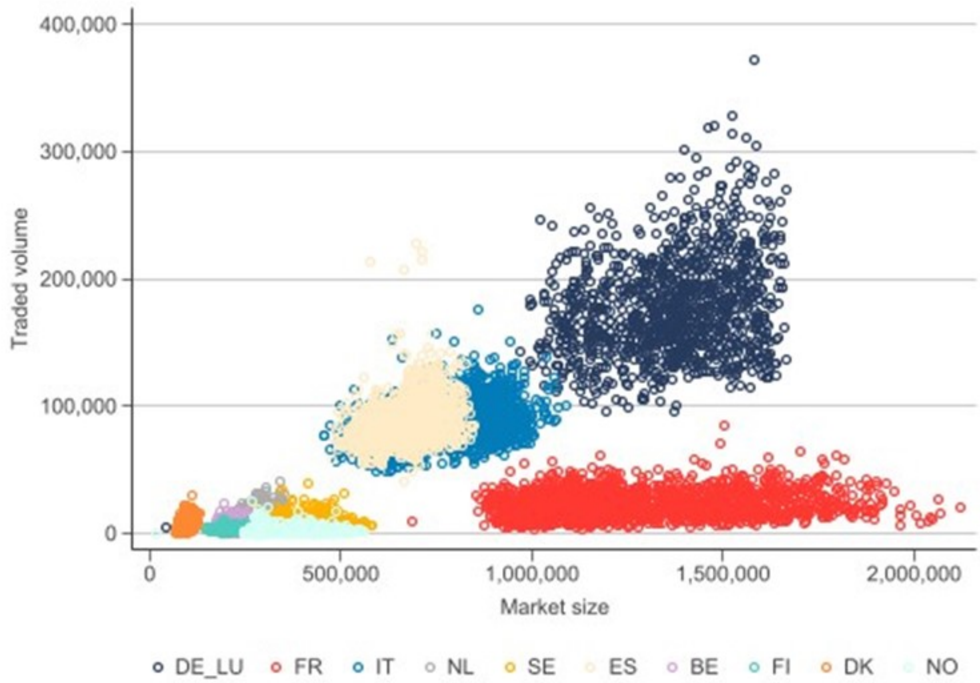


Source: Compass Lexecon analysis of traded volume data as provided by ACER and load data from ENTSO-E transparency platform

The regression analysis including data for Germany-Luxembourg, France, Italy, Sweden and the Netherlands supports the observed positive relationship between traded volumes and market size. The panel data regression results do not point to the same finding for churn rates. Here, for DA, the effect of market size on the churn rate is in some cases even negative and rather small which would mean that larger BZs tend to have lower churn rates (see regression results in the Appendix).

As regards the ID market, illustrated in the Figure 3.12 below, the identified relationships and statistical effects for traded volumes are in line with those in the DA market, although they are generally less pronounced. The positive link between traded volume and market size is most noticeable for Italy and Germany-Luxembourg (see regression results in the Appendix). For ID churn ratios, the relationship is not as clear as for the DA market.

Figure 3.12 Market size (daily load) and ID daily traded volume by country (in MWh)



Source: Compass Lexecon analysis of traded volume data as provided by ACER and load data from ENTSO-E transparency platform

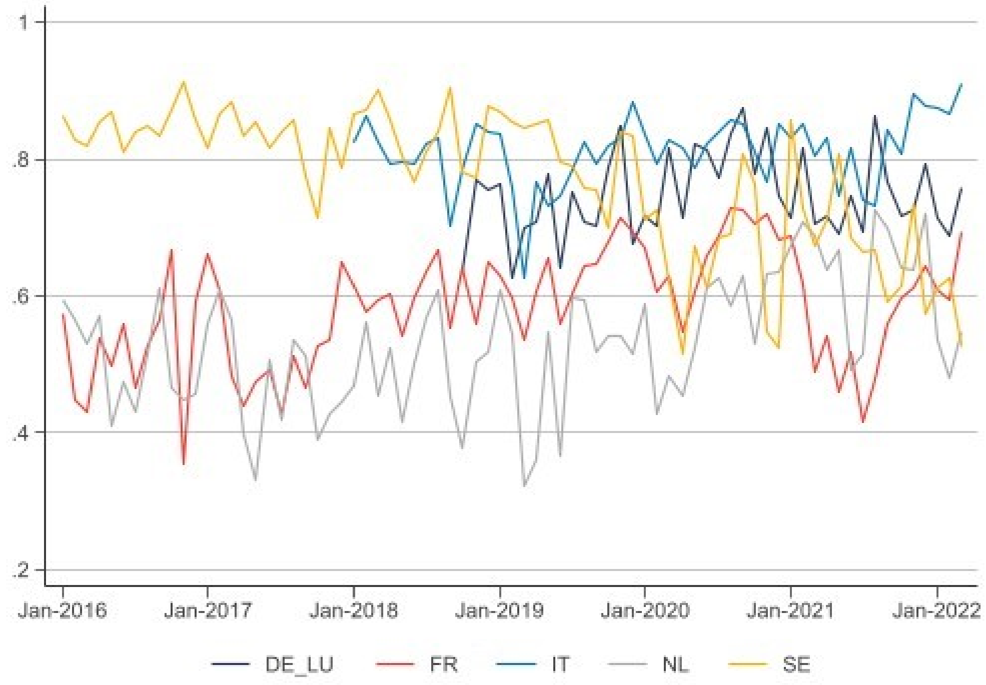
Cross-border participation and correlation of DA prices

In addition to the individual market size of a respective BZ, cross-border trading may impact the market liquidity of a considered zone. To assess this, we calculate a variable for flow-weighted price correlations between BZs. The idea is to create a variable that – in one number – expresses the connectedness of a bidding-zone with its neighbouring zones both in terms of electricity flows and prices. The variable is computed based on hourly DA prices and hourly total in- and outflows between two considered BZs. For each BZ of interest and each of its neighbouring zones, we compute the share of flows in total flows the BZ of interest has with all neighbouring zones. This share serves as a weight for the price correlation of two considered zones. By summing up all weighted correlations per BZ pairs, we obtain the flow-weighted price correlation between the BZ of interest and its neighbouring BZs. The higher the value of the weighted correlation is, the more correlated is the individual BZ to its most relevant neighbours in terms of cross-zonal trade volume.

Figure 3.13 below presents the monthly flow-weighted price correlation by country. Across all countries in scope, weighted price correlations range from about 0.4 to above 0.8. Germany-Luxembourg and Italy exhibit the highest levels of weighted correlations, from about 0.65 to above

0.8. The lowest values are observed for the Netherlands, followed by France with weighted correlations up to 0.7. While the Netherlands and France partially experience an upward trend, correlations of Sweden are decreasing over time from above 0.8 to below 0.6.

Figure 3.13 Monthly flow-weighted price correlation with neighbours by country



Source: Compass Lexecon analysis of day-ahead price data and cross-border flow data from ENTSO-E transparency platform

The regression analysis including historical data on all countries suggests that countries with higher cross-border participation, i.e. a higher weighted price correlation, are, conditional on other factors, more liquid. This holds both in the DA and ID market for traded volume and churn rates, even though robustness appears to be limited for traded volumes in the ID market. The underlying rationale for this finding would be that highly correlated BZs often face price convergence such that the market depth is effectively higher, since market participants may be or are cleared across zones with little constraint.

Market concentration

The third explanatory variable in focus is the HHI to capture the effect of market concentration on liquidity in the DA and ID market.

The regression results suggest that market concentration appears to be negatively correlated with liquidity. This finding holds for liquidity in terms of traded volume and churn ratio, as well as for both the DA and ID market.

However, it should be noted that statistical significance of the negative effect varies across regression models, and is limited as the available data for the HHI is only at an annual level, while the regression models included daily data for the liquidity variables.

Further characteristics

Temperature

Since liquidity variables as well as the explanatory variables for market size, cross-border participation and market concentration may be subject to seasonal patterns driven by temperature, we include temperature as a controlling variable.

The bivariate relationship between traded volumes in the DA market and temperature varies across countries. For France, the Netherlands and Sweden, lower volumes tend to be traded on warmer days, especially in Sweden. For Italy, the relationship appears to be non-linear, with traded volumes decreasing with increasing temperatures until about 12°C, and increasing thereafter. The increasing traded volume with rising temperatures may hint towards additional cooling needs.

Compared to the DA market, the link between ID traded volumes and temperature levels is less pronounced.

In the regression analysis, we included temperature as well as the square of temperature for Italy to take into consideration the country-specific non-linear relationship. The regression analysis suggests a mixed picture for the effect of temperature on DA traded volumes as well as churn ratios. This may be the case as temperature may also impact one or more of the included explanatory variables, e.g. total load, thereby blurring the effect of temperature on the variable of interest. The same holds for squared temperature included for Italy. Here, the results support a positive effect on traded volumes as of a certain temperature level, however, the effect is not robust across regression models. The equivalent analysis for the ID market points to a positive, however not robust, effect of temperature on traded volumes and churn ratios. The country-specific effect for Italy is now negative but, as for the DA market, not robust.

Renewable share

The analysis also takes into consideration uncertainty stemming from the share of renewables in a country's generation mix which may impact trading in the short-term markets. The analysis suggests a conclusive picture for both liquidity variables and the DA, as well as ID market. Though at a small scale, increasing shares of renewables tend to coincide with increasing traded volumes and churn ratios.

Time trend

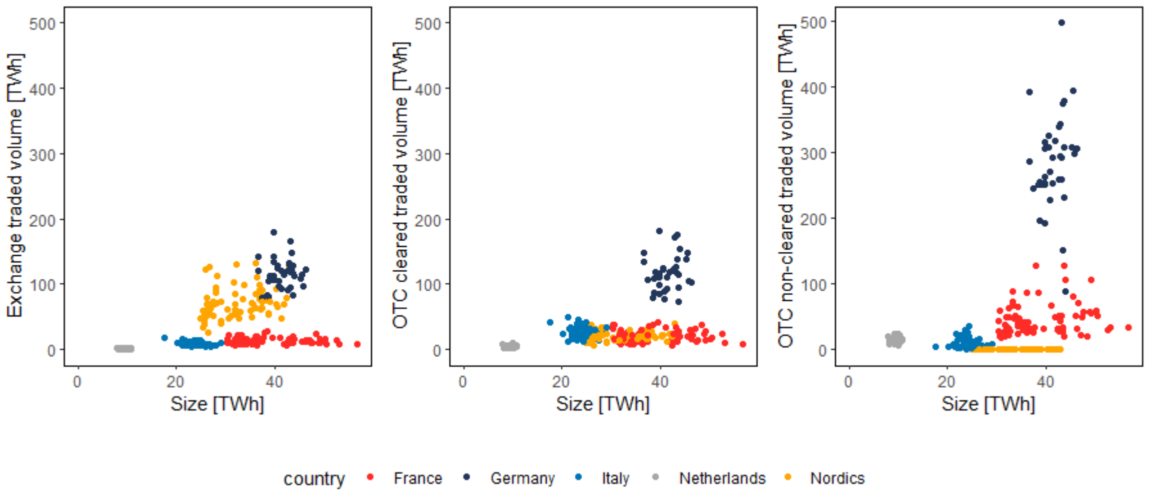
Finally, our analysis supports the existence of an underlying time trend in the data, pointing to increasing liquidity in the countries of interest in the timeframe 2016 to Q1 2022. This positive development could be attributed to the ongoing efforts by policymakers and TSOs to improve market integration.

3.2.3 Long-term products

Market size

Figure 3.14 below presents the traded volumes of exchange-traded, OTC cleared and OTC non-cleared long-term products in different countries against the market size, expressed as the monthly load. The relationship between market size and market liquidity for long-term products appears to be significant and positive across BZs. This means that historically larger markets coincide with higher liquidity. This holds across the liquidity metrics: turnover for various products, churn rates and bid-ask spreads (see regression results in the Appendix).

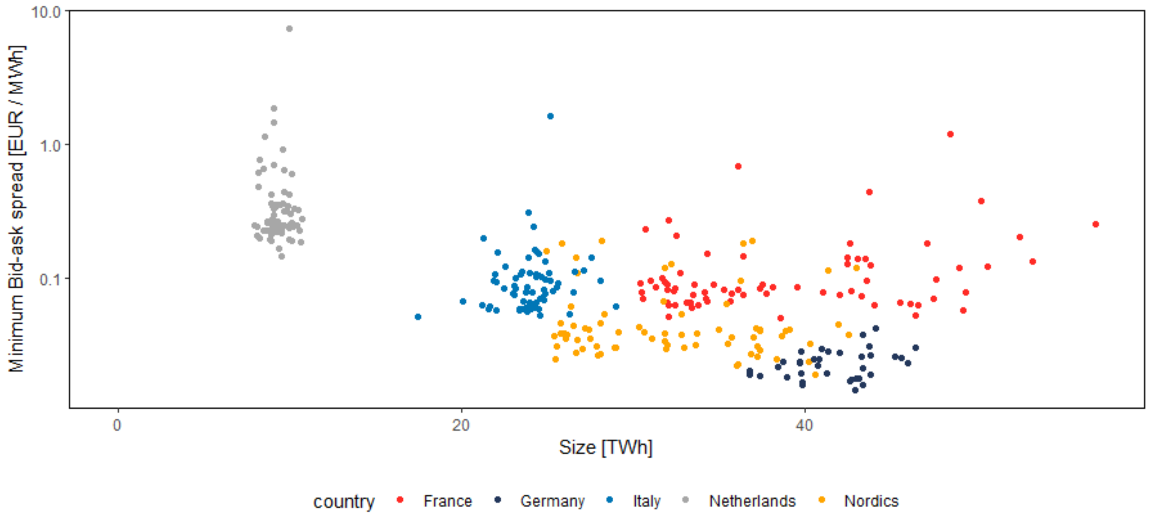
Figure 3.14 Traded volumes of exchange-traded, OTC cleared and OTC non-cleared long-term products by market size (in TWh)



Source: Compass Lexecon analysis of forward traded volumes as provided by EEX, NASDAQ and LEBA

Interestingly, the relationship between bid-ask spreads and market size seems to be nonlinear (the figure below is drawn on a logarithmic scale). This means that small markets have disproportionally high bid-ask spreads, which initially decrease quickly with increasing market size. At some point however, further increases in market size seem to have a smaller effect on bid-ask spreads. The reason for this may be that the spreads approach the transaction costs, i.e. fees, asymptotically: at low market size levels, an incremental increase of size may substantially decrease the spread because the additional demand allows various forms of market entry. In contrast, at high market sizes and already low spreads, the market is already large and liquid, and making it larger still cannot equally contribute to a decrease of the spread. This is because the spread manifests transaction and other costs, if the spread is determined by a market maker.

Figure 3.15 Minimum bid-ask spread (in EUR/MWh) (logarithmic scale) by market size (in TWh)



Source: Compass Lexecon analysis of bid-ask spread data as provided by ICE

Proxy-hedging

Cross-border participation and proxy-hedging is closely related to the relationship between BZ sizes and liquidity, because market participants in small zones that are illiquid may be inclined to proxy-hedge on another market. However, this complicates the differentiation between the relationship of cross-border participation and market size with liquidity.

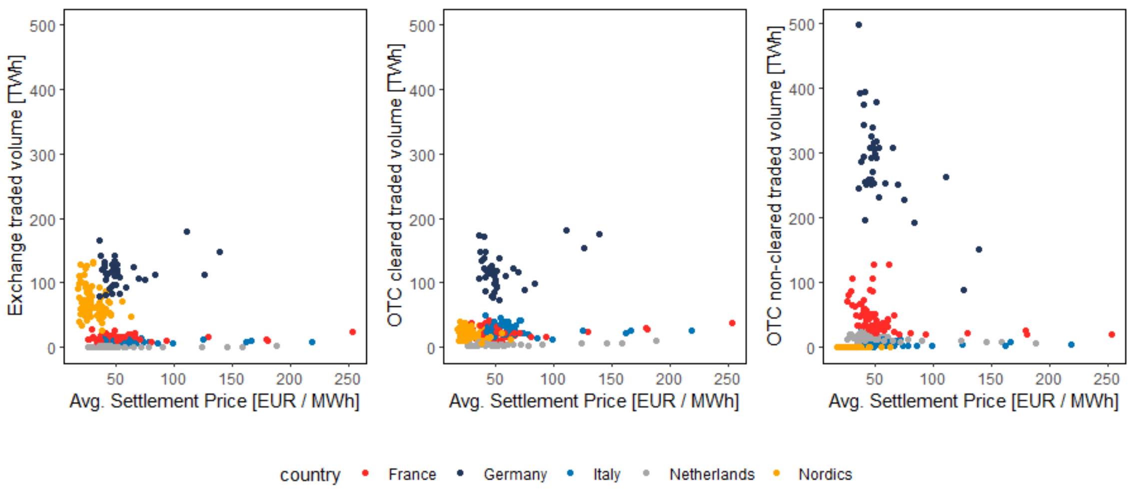
To approximate the relationship, proxy-hedging was parametrised through the explanatory variables “price difference to German futures” and “correlation with German spot market prices”. Germany was assumed as reference point because of the market liquidity. The rationale for these variables is that proxy-hedging may be economical in a more liquid market, with lower bid-ask spreads in particular, if the expected price difference between the proxy and the targeted market is small. This may be indicated either by a high correlation or a low price spread between the German product and the target market product. In these cases, high correlation and low spreads would coincide with low liquidity on the target market, because trade is shifted to the proxy market.

The regression results are inconclusive about the relevance of proxy-hedging for liquidity overall. Although the correlation variable is significant in one case – namely in the model without accounting for country specificities and looking at the minimum bid-ask spread as liquidity metric, meaning that a positive correlation with Germany may decrease the overall liquidity of a market (see regression results in the Appendix). The price spread variable is inconclusive, because its coefficient sign is sometimes positive and sometimes negative, depending on the liquidity metric (see regression results in the Appendix). Notably, this result also follows from the complication of identifying a robust proxy for the ability and need to proxy-hedge. Hence, it does not in itself run counter to the prevalence of proxy-hedging.

Settlement price

Figure 3.16 shows a relatively clear relationship between the settlement price and the traded volumes. Across most markets and liquidity metrics, the settlement price appears to be significantly negatively correlated to liquidity (see regression results in the Appendix). On a BZ-individual basis, this relationship holds for all models except for German exchange traded volumes. This outlier may be explained by the shift from non-cleared OTC trades to exchange trades when increasing prices lead to higher counterparty risk. In the same fashion, the increase of settlement prices implies the decrease of liquidity also in the models irrespective of BZs and with country-fixed effects.

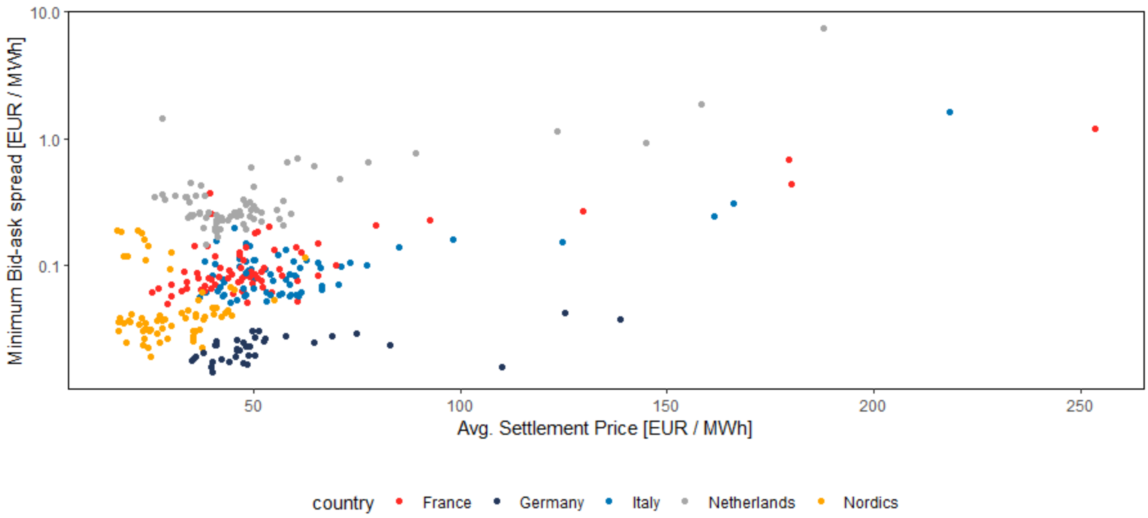
Figure 3.16 Traded volume of exchange-traded products (in TWh) by average settlement price (in EUR/MWh)



Source: Compass Lexecon analysis of exchange-traded data as provided by ICE, EEX, and NASDAQ

As shown in Figure 3.17 the relationship between bid-ask spreads and settlement prices is similar to its relationship to market sizes, as it appears to be log-linear. The rationale for this relationship may lie in the different components of the bid-ask spread: While some components such as trading fees are fixed unit charges, other components are relative to the observed prices.

Figure 3.17 Minimum bid-ask spread (in EUR/MWh) (logarithmic scale) by average settlement price (in EUR/MWh)



Source: Compass Lexecon analysis of bid-ask spread data as provided by ICE

Market concentration

The relationship to market concentration can only be assessed through incomplete means as the data availability for market concentration indicators is limited. Despite this, the regression results support the conceptual argument that higher market concentration implies lower liquidity. In most models, an increase in HHI coincides with a decrease in turnover and the churn rate, and an increase in the minimum or average bid-ask spread (see regression results in the Appendix). This finding does not hold for relationships within a BZ. However, this limitation may also be attributed to the fact that HHI values are only available on an annual basis such that intra-BZ variation is too limited to shed insights in the models at hand.

Further characteristics

We include the share of intermittent renewable energy sources and a time trend as additional variables to control for potential confounding relationships and trends over time respectively. We disregard temperature for long-term products, because long-term products are more likely to be informed by expected future climate years rather than the temperature during the trading period.

The time trend is in most models significant and the sign varies depending on the liquidity indicator. Some indicators suggest an increase in liquidity over time while others seem to decrease (see regression results in the Appendix). These opposing trends indicate that market liquidity for long-term products has seen no consistent trend between 2016 and 2022 but that some elements and products saw an increase while others were subjected to a decrease.

The second variable, the share of renewable energy sources, is insignificant in most models. The models on variation within the Nordics has shown a weakly positive relationship between the share of renewable energy sources and liquidity in terms of exchange and cleared OTC traded turnover as well as the churn ratio. Despite uncertainty for the underlying reason for this relationship, it nonetheless supports the rationale to include the variable as control variable in the models.

3.2.4 Conclusion on historic relationships between liquidity metrics and market characteristics

In conclusion, the presented econometric analysis for short-term markets including historical data for Germany-Luxembourg, France, Italy, the Netherlands and Sweden supports the following relationships between liquidity metrics and market characteristics:

- Larger markets tend to be more liquid in terms of traded volume. The relationship is more pronounced in the DA than in the ID market.
- DA markets with more cross-border participation tend to be more liquid in terms of traded volume and churn ratios. Traded volumes in ID markets exhibit this positive link to a lesser extent.
- Market concentration measured by the HHI negatively affects liquidity in the DA and ID markets. It should be noted that HHI data granularity is limited compared to the other variables included in the regression model.

For the countries in focus, the econometric analysis for long-term markets across countries suggests the following findings:

- Larger long-term markets tend to be more liquid in terms of turnover, bid-ask spreads and churn rate than smaller markets. For bid-ask spreads, the positive effect of market size appears to be non-linear with larger liquidity gains for smaller markets compared to larger markets.
- The regression results on the role of proxy-hedging are inconclusive. While some models suggest that the ability to proxy-hedge goes hand-in-hand with lower liquidity, other models do not attest this relationship or even identify adverse ones. It seems proxy-hedging is not uniform across countries and may be subject to factors not observable on a monthly aggregate.
- Higher settlement prices tend to dampen market liquidity metrics, this finding holds for all analysed long-term markets.
- Market liquidity metrics tend to be lower for higher levels of market concentration. This finding, however, is subject to HHI data limitations in short-term markets.

3.3 Correlation analysis

3.3.1 Rationale and approach to the correlation analysis in the DA market

Under efficient price formation, the same good should have the same value in different locations apart from the associated costs of transporting the good between the locations. It follows that market prices should highly correlate as long as transmission capacity is not constrained. This mechanism has been automatised with the introduction of market coupling for short-term products on organised markets. Hence, metrics that quantify price relationships across BZs are relevant for market liquidity, as market participants may procure power on a different market without significant transaction costs.

In cases where the market liquidity of a respective BZ is limited, market participants may trade contracts in other, more liquid BZs. By holding a contract in a liquid market, agents can hedge their risk of operating in an illiquid market, if the underlying product of the contract is similar, to the targeted product in the illiquid market. By trading the proxy hedge, the market participants must bear the risk of price spreads between the proxy's underlying product and the targeted product. If this risk is lower than the risks and costs associated with hedging on the illiquid market, proxy hedges may be the preferred option. As long-term products are used to hedge against short-term prices variations, the analysis of short-term prices can inform on the risk of price spreads considered when defining one's hedging strategy.

Given the proposed alternative BZ configurations, a special focus lies again on Germany-Luxembourg, France, the Netherlands, Sweden and Italy. Using historical data, our findings are based on the analysis of:

- price spreads indicating the degree of price convergence between BZs. We further compute an indicator for the share of hours where prices are equal in two considered BZs;
- linear relationships measured by the correlation coefficient of two considered BZs. Here, we investigate whether price correlations vary depending on the BZ size, peak versus off-peak hours, as well as for neighbouring versus non-neighbouring BZs.

More detailed descriptions of the studied metrics follow in the dedicated subsections. The analysis allows us to indicate the potential for market participants to proxy-hedge in the BZs of interest.

The main findings from our historical analysis are as follows and are detailed in the next subsections:

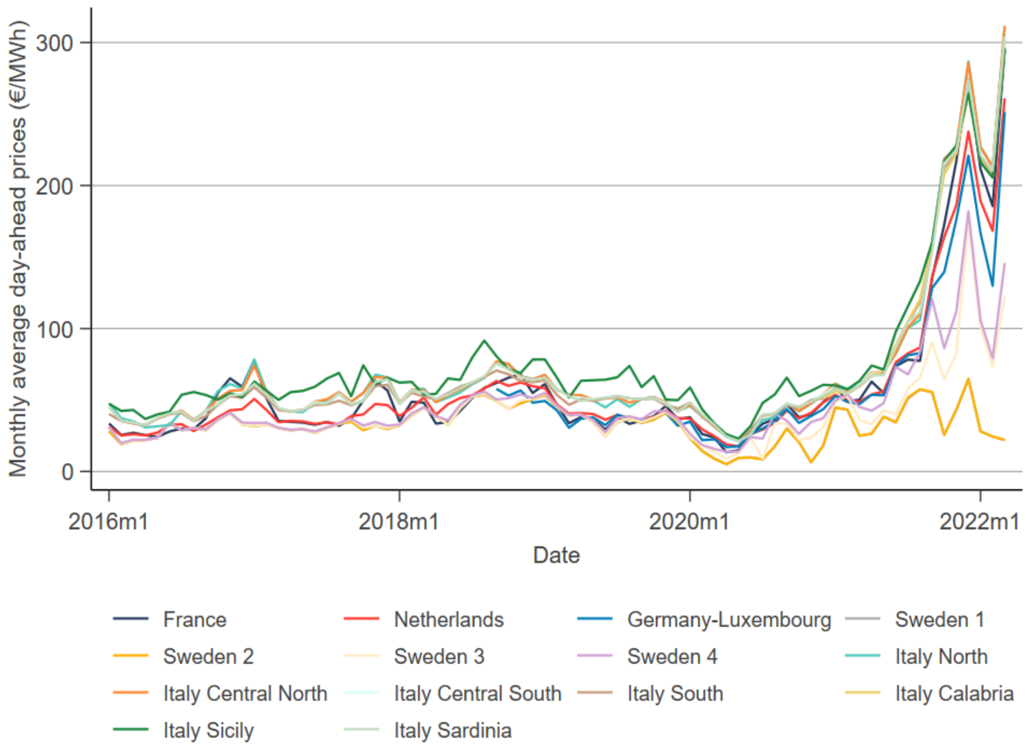
- Firstly, for Italy and Sweden, price convergence between neighbouring zones within the same country is on average higher than between neighbouring zones of different countries.
- Secondly, in all countries in focus, prices tend to be more highly correlated in neighbouring than in non-neighbouring BZs.
- Thirdly, in all countries in focus, price correlations tend to be higher during non-peak than during peak hours.

Text box: Historic price levels

Between 2016 and 2020, the monthly average of hourly day-ahead prices across all BZs varied between 18.19 Euro and 60.85 Euro with a mean of 40.34 Euro per MWh. In June 2021, the average day-ahead price climbed beyond 70 Euro per MWh and reached 214.5 Euro per MWh in December. In March 2022, the average price was at 224.36 Euro per MWh. Apart from increased price levels, markets also observed heightened price volatility, captured in increased standard deviations of hourly prices. In the years 2016 to 2020, the standard deviation of hourly prices was between 9.9 and 12.27, but jumped to 60.24 in 2021. Given the impact of the energy crisis on DA prices, we analyse correlations across the entire time horizon as well as before and after 2021 separately.

Figure 3.18 shows the development of monthly average day-ahead prices of BZs potentially being reconfigured. Prices in BZs Sweden 1 and 2 (towards the northern part of the country) have risen the least while the largest increase is observed in the Central North zone in Italy. Recent price movements from peaks to troughs coincide across the considered BZs.

Figure 3.18 Monthly average of hourly day-ahead prices in BZs considered for reconfiguration (in EUR/MWh)



Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform

3.3.2 Price convergence of bidding zones

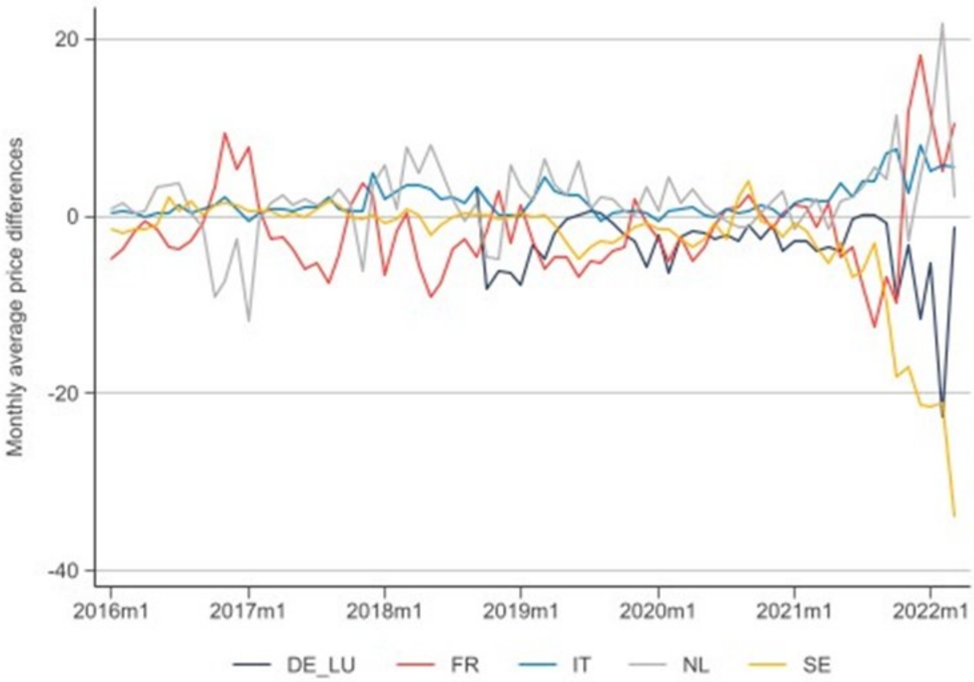
As a result of the day-ahead market coupling, the day-ahead prices in neighbouring BZs tend to be correlated in a non-linear fashion. Prices converge when the cross-zonal capacity between two considered BZs is not constrained. In contrast, prices may diverge in case the interconnection capacity is limiting cross-zonal exchanges.

For each considered pair of neighbouring BZs, we compute the price difference by subtracting the price of the neighbouring BZ from the price of the BZ in focus. In the cases of Italy and Sweden, we also compute the price spreads on the BZ-level, i.e. for each zone in the country and the respectively neighbouring zones separately. As most of the neighbouring zones lie within the same country in the cases of Italy and Sweden, spreads also account price differences to other zones in the same country. For Italy and Sweden, the country-level price spread is an average across all individually computed price spreads on the BZ-level. Equivalently, for the other countries consisting of only one zone, the country-level price spread is an average across all neighbours. We further compute an indicator for price convergence that is equal to one for all hours where prices in two considered BZs are equal, and zero if prices differ. The monthly average of the indicator then gives the share of hours where prices converge, suggesting an increased market depth which indirectly implies extended levels of liquidity. As for price spreads, the share of price convergence is computed for each zone and the respective neighbours individually, and then averaged across all neighbours.

Analysis of price spreads

Figure 3.19 displays the price spreads of the countries in focus averaged across the respective neighbouring zones. Historically, spikes in price differences tend to occur simultaneously across countries. Towards the second half of 2021, price differences increased in all countries, though to a lesser extent in Italy. Considering the entire time horizon, the Netherlands tend to have the largest positive average price gap (1.75 EUR/MWh), i.e. the Netherlands tends to have higher day-ahead prices than its neighbours. Germany-Luxembourg has an average price gap of -3.57 EUR/MWh from 2016-2022, meaning that prices in the neighbouring BZs tend to be higher.

Figure 3.19 Monthly average price spreads for each country in focus across respective neighbouring zones (in EUR/MWh)



Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform
Note: For a given BZ with several neighbouring BZs, we compute the average price spread across all neighbours.

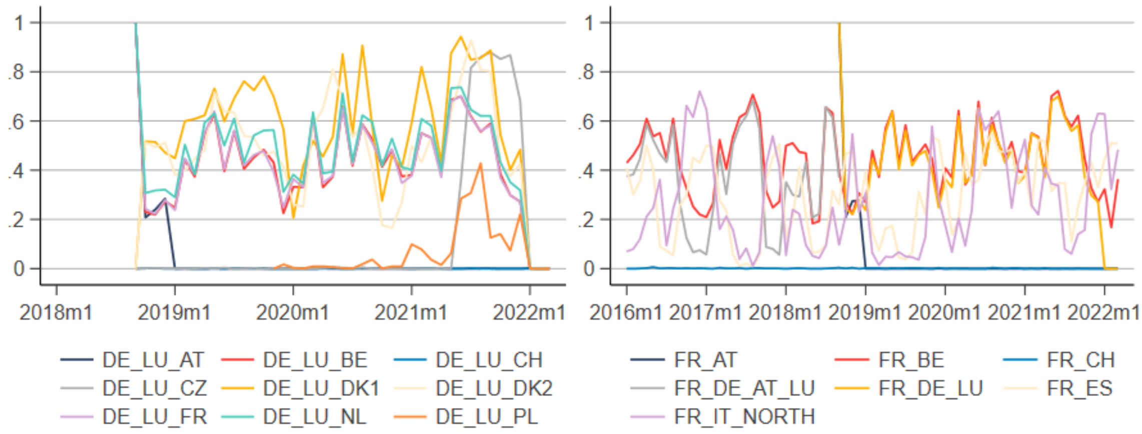
Analysis of price convergence

As shown in Figure 3.20, price convergence of Germany-Luxembourg with its neighbours varies significantly throughout the time horizon, but tends to be the highest for the Western Danish zone with about 57% of overall hours. Germany-Luxembourg also exhibits high levels of price equality (share above 40%) with Eastern Denmark, Belgium, France, and the Netherlands. Price convergence plummeted towards the end of 2021, and in the first quarter of 2022 there were only few hours with equal prices, leading to a monthly average close to zero. After initially full price convergence with Austria following the split of the German-Austrian-Luxembourg BZ, prices diverged and remain detached. Moreover, it is worth noting that since Switzerland is not coupled with the rest of Europe, its price convergence with neighbouring countries is close to zero.

For France, the largest degree of price convergence is observed with the zones in Belgium and Germany-Luxembourg (above 40%). Since 2019, price differences with the Spanish and Northern Italian BZ tend to move inversely with differences with the Belgian and German-Luxemburgish zones. The monthly share of hours with price equality in the Southern European BZs averages to 30% (Spain) and 27% (Northern Italy) across all years.

For the Netherlands, the average share of hours with matching prices is 45% for Belgium and 46% for Germany-Luxembourg (42% for Germany-Austria-Luxembourg).

Figure 3.20 Monthly share of hours with converging prices for Germany-Luxembourg (left) and France (right) with respectively neighbouring BZs

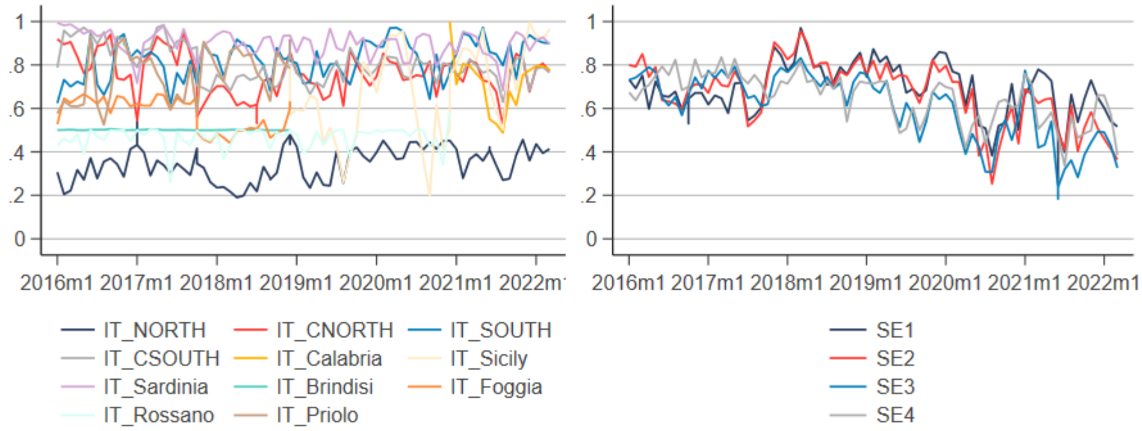


Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform

As shown in Figure 3.21, the Northern Italian BZ exhibits a significantly different pattern than the rest of existing and prior BZs as neighbouring BZs lie outside of Italy. On average, price convergence with Austria, Switzerland, France and Croatia arises in 17% of all hours (23% excluding Switzerland), while prices in the Northern and Central Northern zones are equal in 88% of hours. The same finding holds for the zones Central North, Central South and Calabria. Without distinguishing between zones within or outside of Italy, the share of hours with price equality ranges from 47% to 89% for the zones other than Italy North.

All Swedish BZs exhibit similar trending behaviour with a downward trend initiating in 2019. On average, Swedish prices converged with those of their neighbours in 72% to 75% of hours before 2019, decreasing to 51% to 67% after 2019. The Swedish zones exhibit the same pattern as the Italian ones regarding the difference in price convergence depending on whether a neighbouring zone lies within or outside of Sweden. Price convergence with other Swedish zones ranges from 80% to 99%, depending on the considered zone. By contrast, on average, prices with zones outside of Sweden converge only in 54% to 61% of the cases.

Figure 3.21 Monthly share of hours with converging prices for Italy (left) and Sweden (right) averaged across respectively neighbouring BZs



Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform

As a result, price convergence between BZs of the same countries (Italy and Sweden) is higher than price convergence between BZs of different countries. This likely means simply that interconnection capacity is higher between BTs of the same country.

3.3.3 Price correlations of neighbouring and non-neighbouring bidding zones

To analyse whether price correlations differ for neighbouring versus non-neighbouring countries, we compute average DA price correlations for neighbouring and non-neighbouring zones separately.[30]

An analysis of all European zones shows a clear pattern with monthly average price correlations of 0.81 for adjacent zones, and 0.52 for non-neighbouring ones. The same holds when we consider correlations before and after 2020 separately (see Table 3.1). This observation indicates that the ongoing energy crisis has not altered the underlying relationship between BZs in terms of price co-movements. The crisis may have even intensified co-movements: For both neighbouring and non-neighbouring BZs price correlations are slightly higher from 2021 to 2022 compared to 2016 to 2020. There are several effects at work here at the same time, which cannot be fully disentangled – there also exists a general trend toward more market integration, driven in particular by the efforts of TSOs towards more market integration as well as regulatory pushes like the 70% rule in the Clean Energy Package.[31] There is also an increased level of variation of price correlations for non-neighbouring zones compared to neighbours, as well as for both groups since 2020. Smaller variations in price correlations for neighbouring BZs indicate that more reliable hedging opportunities may be better to find in neighbouring BZs than in non-neighbouring ones.

[30] In the analysis, geographically adjacent countries rather than interconnected countries are considered as neighbouring countries.

[31] Regulation (EU) 2019/943 Art. 16(8)

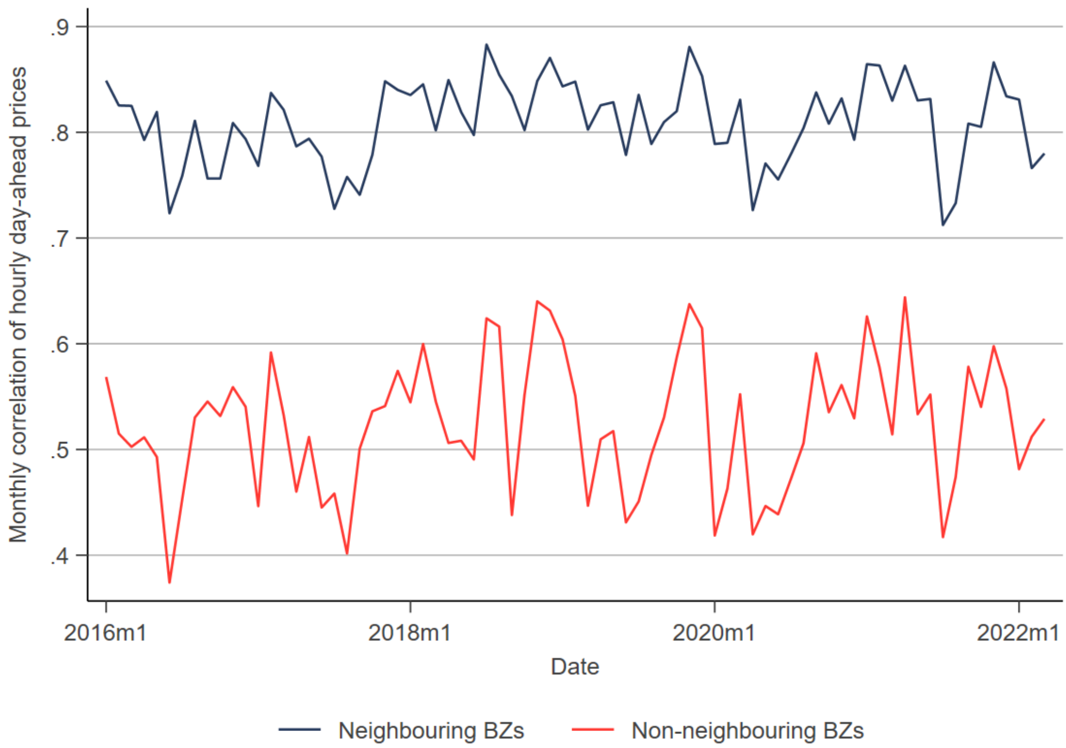
Table 3.1 Average correlation of neighbouring and non-neighbouring BZs

	Neighbouring BZs		Non-neighbouring BZs	
	Mean	Standard deviation	Mean	Standard deviation
January 2016 to March 2022	0.81	0.18	0.52	0.22
January 2016 to December 2020	0.81	0.18	0.52	0.21
January 2021 to March 2022	0.81	0.19	0.54	0.24

Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform

When assessing the development over time, neighbouring and non-neighbouring BZs tend to exhibit peaks and troughs of correlations in the same or following months. Overall, the price correlation is higher between neighbouring BZs than between non-neighbouring ones in all months. The higher correlation arising with geographic proximity of BZs indicates that hedging opportunities may be more effective for neighbours.

Figure 3.22 Monthly correlation of day-ahead prices in neighbouring and non-neighbouring BZs



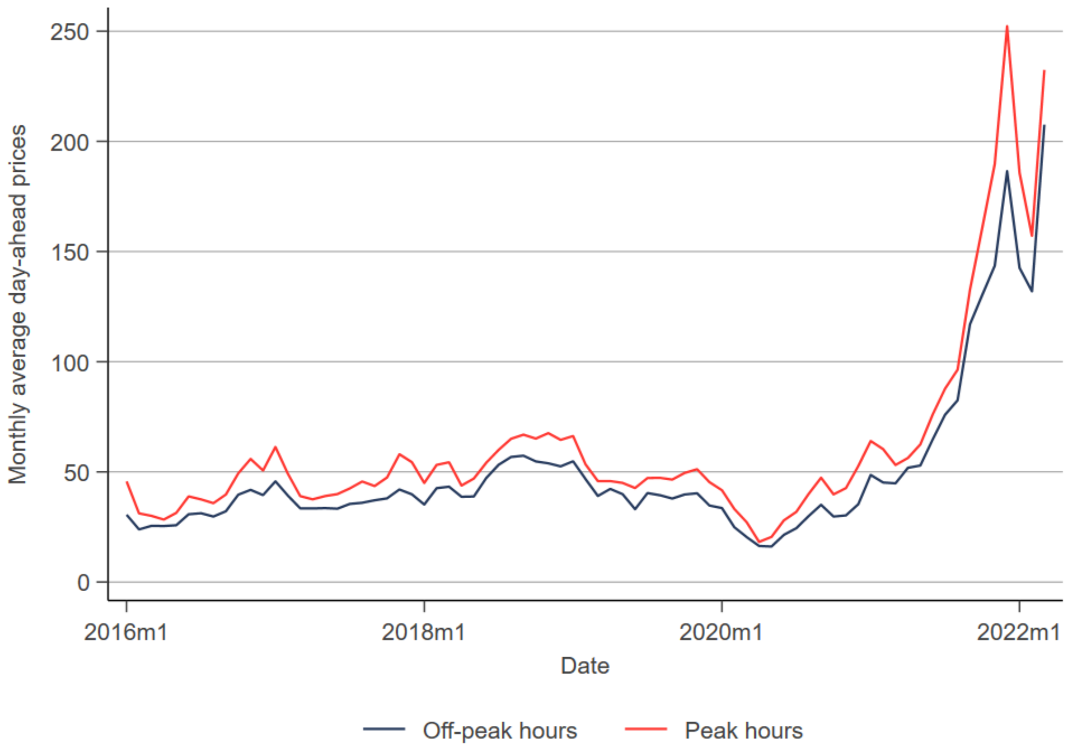
Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform

The same findings hold for the BZs in focus. Except for a few months in the Netherlands, monthly correlations of hourly day-ahead prices with neighbouring BZs are strictly greater than with non-neighbouring zones. This is interesting, as it shows the importance of physical interconnection. At the same time, it also shows that there are similar underlying drivers of electricity prices, that are at work at the same time in all European markets.

3.3.4 Price correlations during peak and off-peak hours

Differences in price correlations may be driven by varying intensities of electricity demand throughout the course of a day or a year. Figure 3.23 indicates that DA prices tend to be higher during the daytime on weekdays (peak hours, as of 8 am until 8 pm on weekdays) where the need for electricity is higher compared to night-time and weekends (off-peak hours, as of 8 pm until 8 am and weekends). For this purpose, we analyse price correlations for peak and off-peak hours separately. Further, we break down average price correlations to quartiles to check for seasonal patterns.

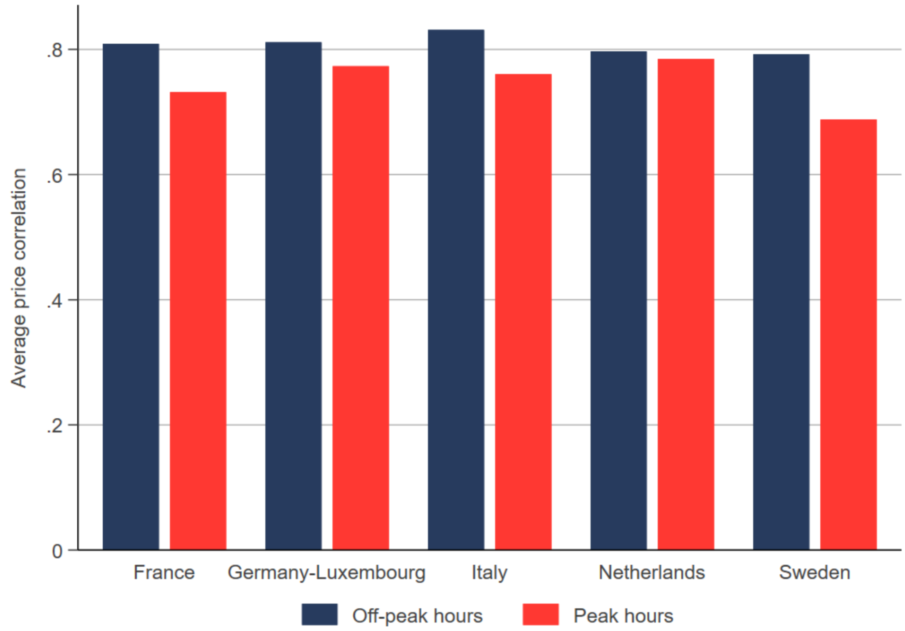
Figure 3.23 Monthly average day-ahead price during peak and off-peak hours (countries in focus and neighbouring BZs, EUR/MWh))



Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform

As can be seen in Figure 3.24, all countries in focus exhibit the same pattern: correlations of DA prices between these countries and their neighbours are higher during off-peak hours compared to peak hours. For Germany-Luxembourg and the Netherlands, the difference between correlations during day- and night-time is less pronounced than for France, Italy and Sweden.

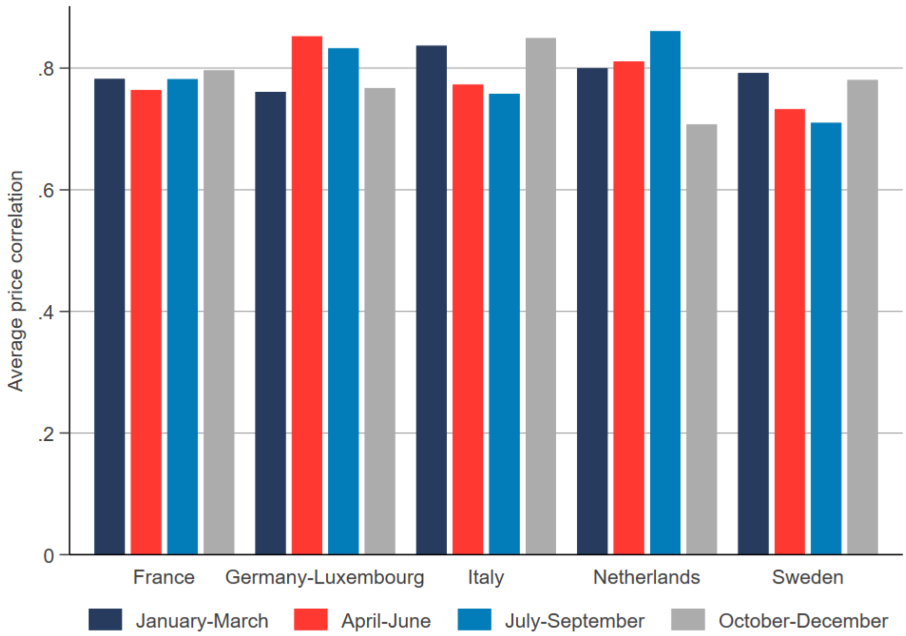
Figure 3.24 Average price correlation during peak and off-peak hours (countries in focus and neighbouring BZs)



Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform

Regarding seasonal differences in price correlations, Figure 3.25 shows that price correlations with adjacent zones tend to be higher during colder months for France, Italy and Sweden. Here, price correlations are the highest in the months from October to March. Germany and the Netherlands exhibit a reverse pattern with the highest correlations between April and September. Across all seasons, higher price correlations are observed during off-peak compared to peak hours.

Figure 3.25 Average price correlation by quarter (countries in focus and neighbouring BZs)



Source: Compass Lexecon analysis of day-ahead price data from ENTSO-E transparency platform

Text box: Granger causality and price developments

We investigated whether price movements in one zone are driven by price developments in another one. For this purpose, we applied a Granger causality test which studies the predictive power that one variable may have on another one (Granger, 1969). It should be highlighted that Granger causality analyses predictive power of temporary relationships in the data, rather than testing for causality in its mere sense. In the present case, we applied the Granger causality test to the price time series of two considered BZs to analyse whether the price in one zone "Granger-causes" that of the other one. The test was applied in both directions, meaning that we check for an impact of prices in zone A on B, and the other way round. If the test results suggest Granger causality in both directions, the conclusion is that none of the zones has a clear predictive power for the price development in the other zone.

The test was based on the comparison of a restricted and unrestricted model. First, we regressed the price data of zone A on lagged prices of only zone A (restricted model). In the second model, we included the variable with potentially predictive power, i.e. we additionally included lagged prices of zone B (unrestricted model). As the test requires stationary time series, we checked for unit roots in the time series by applying an augmented Dickey-Fuller test and eliminated the identified unit roots by taking first differences (Dickey & Fuller, 1979). We applied the Granger causality test for each BZ pair separately.

In most of the cases, the test results suggest Granger causality in both directions, i.e. from zone A to zone B and vice versa. This is the case for Germany-Luxembourg, France, the Netherlands, all Swedish BZs as well as most of the Italian BZs, and the respectively neighbouring BZs. The test statistics suggest Granger causality in just one direction only for the case of Sicily and Calabria. Here, prices in Calabria appear to impact those in Sicily, but not the other way round. Hence, given the Granger causality appears in both directions, the historic price data does not exhibit any clear evidence that prices in one zone influence the price development in another neighbouring zone.

4 EXPECTED LIQUIDITY METRIC DEVELOPMENT FROM BIDDING ZONE RECONFIGURATIONS

After analysing the state of liquidity in the current European BZ configuration, we turn to the liquidity assessment in the proposed alternative configurations. For this purpose, market characteristics that have historically correlated with liquidity metrics are analysed for the proposed alternative configurations of the BZs in Germany-Luxembourg, France, Italy, the Netherlands, and Sweden. The analysis aims at evaluating whether market liquidity metrics are expected to be impaired or enhanced, or potentially remain unaffected by the proposed reconfigurations.

This section is organised as follows:

- First, we provide an overview of the methodological approach and metrics analysed.
- Second, we present the results of the Alternative BZ configurations for Sweden, Germany-Luxembourg, France, Italy, and the Netherlands individually. For each reconfigured BZ:
  - We first outline the possible alternative configuration as well as the data used for the liquidity analysis.
  - We then explain the results of the analysed parameters, respectively regarding market size, market concentration and price correlation.
  - On the basis of these simulated market parameters, we draw conclusions on the expected impact of the proposed bidding zone changes on BZ liquidity metrics.

4.1 Methodological approach for the liquidity analysis of simulated data

We approach the assessment in two steps. First, we analyse the simulated data provided to us by the TSOs.[32] Then, we assess the identified implications for the alternative configurations in light of the likely relationship between liquidity metrics and the parameters as provided by the TSOs. Thereby, we derive, where possible, expectations on changes to liquidity metrics from the proposed alternative configurations.

The data for the proposed alternative configurations as analysed in the first step is limited to the simulation results of a dispatch model. The model does not capture the trading dynamics between long-term and short-term markets and does not differentiate trades executed on organised markets or OTC. It follows that we cannot perform the same analysis of short- and long-term liquidity that

[32] We base this analysis on data provided to us by the TSOs between May and June 2024 (see Appendix 1).

we present in the above chapters based on historical data, i.e. conclusions on market liquidity cannot be directly inferred from the simulated market data we have available.

Analysis of simulated data

The analysis of the state of liquidity in the proposed alternative BZ configurations is based on simulated market parameters that have shown a correlation to liquidity metrics in historical data (as described in Chapter 2 and 3).[33]

These parameters are:

- **Market size** is approximated by the parameters generation and load volume as provided by the TSOs[34]. Based on the results of the historical analysis, we consider increases in market size as, *ceteris paribus*, increases of liquidity metrics both for the short- and long-term markets.[35] In addition to analysing generation and load individually, we check for potential demand-supply asymmetry. For this purpose, we consider the production as a share of load for each zone and alternative configuration and assess changes compared to the status quo.

- **Market concentration** is portrayed by HHI values for the Nordics and RSI and PSI values for Central Europe. An increase in the HHI and a decrease in RSI or PSI indicates an increase in market concentration, which tends to imply a decreased level of liquidity metrics both for short- and long-term markets. The RSI and PSI values are provided in three instances to account for uncertainty of available import capacity.[36] These instances each assume different correction factors (assuming 25%, 50%, or 75% of the flow based minimum net position) for the assumed available import capacity. The higher the correction factor, the higher the assumed available import capacity.

- **Price correlations** of simulated wholesale prices are used as a third indicator for short-term market liquidity. [37] The parameter applied is calculated as the market size-weighted average of price correlation across directly connected BZ to the BZ in question and can take values between -1 and 1.[38] Based on the results of the historical analysis, we consider increases in

[33] As acknowledged in Chapter 3.1, the PUN in Italy and systems price in the Nordics may contribute to changes in market liquidity metrics, both in the short- and long-term markets.

[34] As the reconfiguration of bidding zones may cause a more uneven distribution of power generation than in the current configuration, it is reasonable to also analyse market size approximated by generation volumes.

[35] While we have seen differences in the robustness of this directionality in the historical analysis, i.e. when considering churn rates (see chapter 3.2.2), the general positive relationship as attested by literature (see chapter 2.2.1) remains intact. Further note that additional aspects considered as part of the discussion on the relationship between market size and liquidity, as summarised in chapter 2.2.1, such as cross-border participation, is acknowledged in this analysis through the market characteristic “price correlation”.

[36] The RSI is computed assuming that import potential is independent from ownership by the largest player, i.e. that the volume that could be imported is not controlled by the dominant player in the domestic market. For the provision of this indicator, the TSOs highlighted that the indicators rely on the availability of consistent ownership data across BZs and that significant gaps in the ownership data persist, especially with regard to the ownership of renewable energy sources.

[37] The historical analysis has not identified a robust relationship between cross-border price correlation and liquidity metrics in the long-term market. Therefore, the analysis at hand cannot derive conclusions on expected changes to liquidity metrics for long-term markets on the basis of changes in price correlation. While we understand that an increase in cross-border correlation may imply improved proxy-hedging opportunities irrespective of the individual effect on liquidity in the domestic market zone, changes of or the occurrence of such proxy-hedging patterns cannot be derived from the data and identified relationships at hand.

[38] We consider only correlation to connected BZs, because they have shown structurally higher correlation in the analysis of historical data. We apply a weighting, because high price correlation to larger BZs implies, loosely speaking, unconstraint

price correlation are, ceteris paribus, liquidity enhancements. We have assessed the robustness of the correlations by computing the parameter twice: First, we have only included neighbouring BZ that are also part of the CORE region. Then we have included all neighbouring BZ, i.e. also those that assume a NTC border in the model. Finally, we compared the results in direction and extent and concluded that the model simplification used for NTC borders does not impact the robustness of the parameter. Therefore, we use the price correlation parameter that includes all connected BZs.

The provided simulated data for the proposed reconfigurations entails values for three different climate scenarios based on the climate observed in 1989, 1995 and 2009. For the purpose of the analysis of liquidity metrics, we assume an average climate scenario, i.e. we take means of the hourly values of each parameter across all climate years.

The parameters are computed and analysed both regarding their absolute value and in relative terms, i.e. the change between the status quo configuration (hereafter equivalently called “status quo”) and the alternative configuration. The results show the direction of change and which alternative BZ configurations may lead to critical changes in market size, market concentration and price correlation. In specific, the analysis includes three perspectives:

- We consider the **absolute values of the parameters** to identify any parameters that indicate critical values, e.g. RSI values below 1. We conduct our analysis of market characteristics for each individual BZ in each alternative configuration.

- We compute the **change between the alternative configuration and the status quo** for each parameter. For Sweden, we also analyse the averages of the respective parameter across all zones in a given alternative configuration. We consider average values across zones since a direct comparison of individual zones in the status quo and alternative configurations is not possible given that BZ borders may not be the same after the reconfiguration.

- We identify the **BZ with the minimum and maximum parameter value** based on the annual average of the considered parameter for each alternative configuration and each parameter. To further assess the extremes of the identified most or least liquid BZ over the course of a year, we also analyse the minimum and maximum of monthly values. This approach allows us to study the impact on the least and most liquid individual BZ, i.e. extremes that may arise with a specific reconfiguration.

Forming expectations on liquidity metrics

The identified changes and absolute values of the market characteristics are assessed regarding the corresponding likely implication for liquidity metrics in the alternative configurations. For this purpose, we consider the direction of change of each individual market characteristics, the degree

trading potential with a larger volume of market participants. The weights are applied to the individual BZ pairs, i.e. a neighbouring BZ and the BZ in question. The weights are computed as the average of annual electricity generation and demand of the respective neighbouring BZ over the sum of averages of annual electricity generation and demand of all neighbouring BZs.

Cross-zonal capacity may alternatively be used to approximate the relevance of cross-zonal trade. However, in contrast to cross-zonal capacity, the weighted price correlation does not have computation complexities due to flow-based capacity allocation. It can also account for the actual demand of cross-border participation with less assumption: For instance, spare capacity in itself cannot portray differences in theoretically useful cross-border participation once there is no more spare capacity.

of change, and the level of the resulting parameter. We assess these findings in light of the generalised identified relationship between the market characteristic and liquidity metrics. Due to the differences between historic and simulated data, the generalised identified relationships considered here imply a degree of abstraction from some of the specific findings identified in the historical analysis. Notably, the historical analysis predominately identified relationships based on comparisons within a BZ or across BZs. In contrast, the simulated data considers reconfigured BZs which do not necessarily capture with the same granularity the different nuances identified in the "historic" BZ analysis. Based on this, we derive expectations on changes of liquidity metrics for the individual BZ and the alternative configurations as a whole.

Besides the limitation of data availability, we acknowledge a set of additional limitations to the development of expectations:

- First, the ensuing liquidity levels and metrics after a BZ reconfiguration may be subject to a range of possible mitigation measures. The analysis conducted here assumes no mitigation measures, i.e. liquidity metrics of individual BZs if no changes in product and market design or regulation are made. This also means that any use of long term transmission rights or similar products have not been considered.
- Second, we have identified non-linear relationships between market characteristics and liquidity metrics. We have further identified that some of the conceptual relationships between market characteristics and liquidity metrics can be captured by linear relationships, if at all, only to a limited extent.
- Third, the reconfigurations leading to the alternative configurations assessed here may lead to spill-over effects affecting liquidity in BZs, not directly affected by the reconfiguration. These spill-over effects are not considered in the analysis.
- Fourth, the considered relationships between market characteristics and liquidity metrics are not necessarily exhaustive. The analysis of additional market characteristics may further increase the robustness and portray a more exhaustive picture of the potential effects of the BZ reconfigurations.

Therefore, the approach applied here cannot capture the full – non-linear – effect of BZ reconfigurations on changes in liquidity levels. As a consequence, the concrete manifestation of liquidity may differ from the expectations followed from the analysis conducted here.

Structure of the subsequent sections

The subsequent sections on the proposed BZ reconfiguration in Sweden, Germany-Luxembourg, France, Italy and the Netherlands will each be organised as follows:

- First, we provide an overview of the proposed alternative configurations, highlighting changes in the number and geographic distribution of BZs.
- Second, we present the results for the analysed parameters, i.e. electricity generation and demand for markets size, market concentration and price correlation.

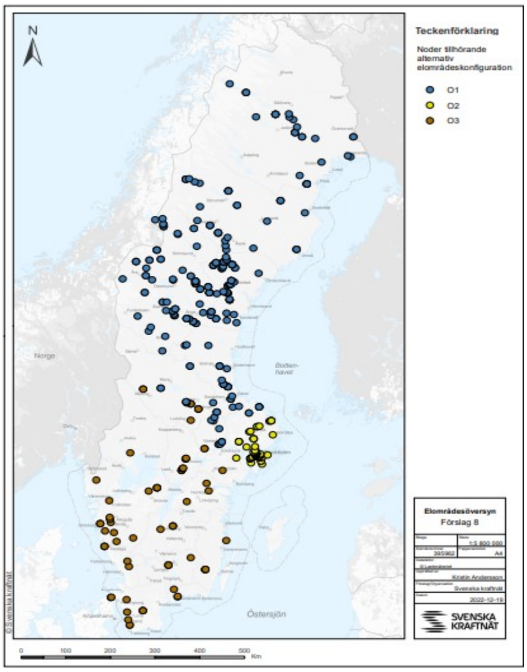
- Third, we summarise the key findings of the analysed parameters and conclude on the implications for market liquidity metrics taking into account changes in the alternative configurations compared to the status quo.

4.2 The Swedish simulated data on proposed bidding zones

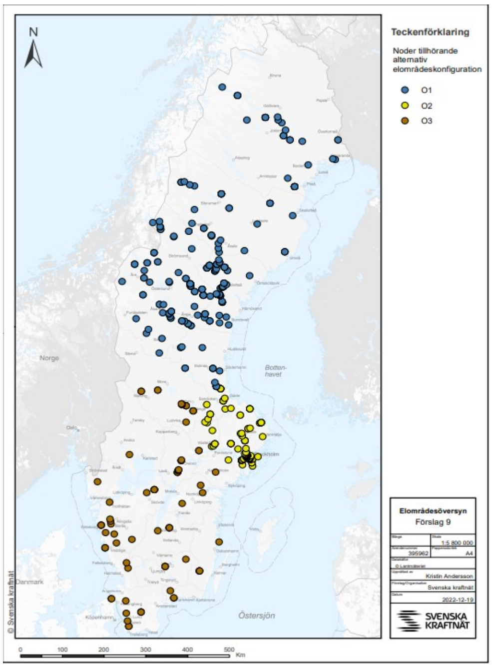
There are four alternative BZ configurations for the Nordic area, two of which are based on recommendations by Svenska kraftnät (alternative configurations 9 and 11). In two of the proposed alternative configurations, Sweden would continue to consist of four BZs (alternative configurations 10 and 11). The other two alternative configurations foresee only three BZs in Sweden, with larger zones in the North and South, and a smaller one in the Mideast of the country (alternative configurations 8 and 9). These simulated zones do not necessarily match with the borders of the currently existing BZs, not even in the cases of four BZs. Given that the data for the simulated alternative configurations was provided by the Nordic TSOs, the reference names for the simulated zones are in line with those proposed by the Nordic TSOs. Figure 4.1 displays the four alternative configurations. The numbering of the simulated zones was assigned from North to South.

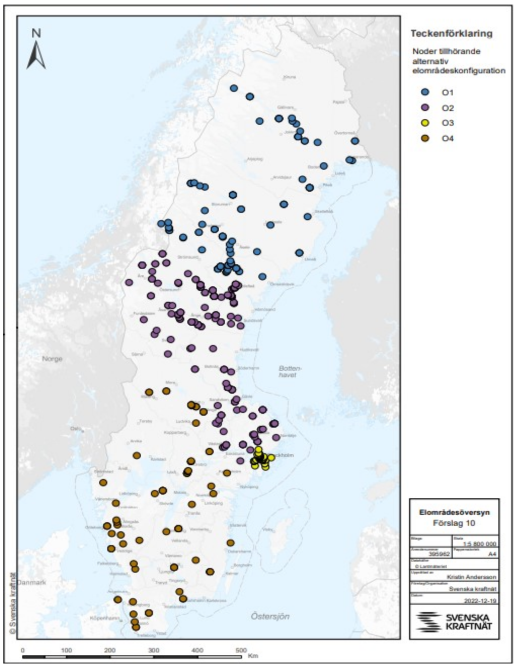
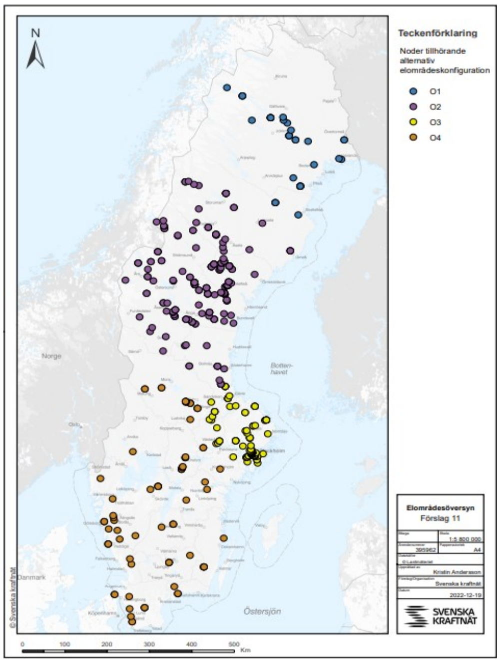
Figure 4.1 Alternative BZ configurations with three or four Swedish BZs

Alternative configuration 8



Alternative configuration 9



<table>
<tr><th>Alternative configuration 10</th><th>Alternative configuration 11</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Source: Svenska Kraftnät
Note: The BZ names are abbreviated with O for optional

For each proposed alternative configuration and in the status quo, i.e. assuming BZs remain the same, the Nordic TSOs simulated hourly dispatch of generation units to meet demand in a Pan-EU model and provided us with hourly values of generation volume, demand, HHI and prices for the year 2025 in each BZ. Further, for each alternative configuration, the simulation was carried out for three different climate scenarios, based on the climate observed in 1989, 1995 and 2009. Apart from the Swedish BZs, the regional scope of the data provided by the Nordic TSOs includes the currently existing BZs in Norway, Finland, Germany-Luxembourg, the Eastern and Western BZ of Denmark, Estonia, Lithuania, the Netherlands, Poland and the United Kingdom.

4.2.1 Market size approximated by generation

The simulated liquidity metrics impact of the alternative configurations in terms of market size approximated by generation volume, is as follows:

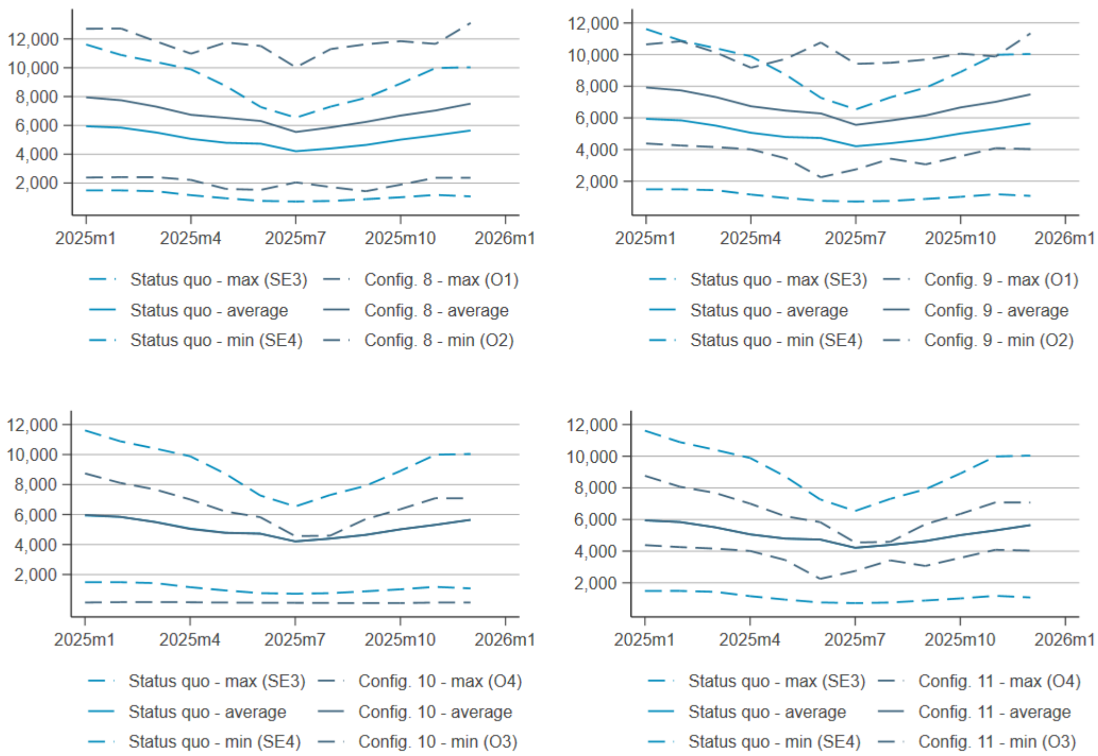
- Average liquidity metrics are expected to increase in alternative configurations 8 and 9 compared to the status quo. The average generation across BZs increases from 5,094 MWh in the status quo configuration to 6,789 MWh in alternative configuration 8 and 6,767 MWh in alternative configuration 9. Alternative configurations 8 and 9 are reconfigurations with three Swedish BZs. Alternative configuration 11 with four BZs also exhibits a slight increase (5,095 MWh).
- The alternative configurations with three zones (8 and 9) and alternative configuration 11 with four zones show a larger size of the smallest zone. In the status quo configuration, the smallest

zone used to be SE4 and is now O2 in alternative configurations 8 and 9, and O3 in alternative configuration 11 (respectively, the central Eastern BZ).

- For both alternative configurations with four zones (10 and 11) and alternative configuration 9 with three zones, we observe reduced maximum generation of the largest zone. In the status quo configurationthe largest zone used to be SE3, but is now O4 in alternative configurations 10 and 11, and O1 in alternative cnonfiguration 9. Alternative configuration 8 shows an increased size of the largest zone O1.

- Maybe more importantly, we see a decrease in minimum generation of the smallest zone in alternative configuration 10 to 98 MWh. Moreover, the difference between supply and demand increases significantly for O3 in configuration 10 compared to observed asymmetries in the status quo. In O3, electricity production suffices to cover only 7% of demand while the lowest value observed in the status quo is at c. 37%. We further see a miniscule decrease in average generation in alternative configuration 10 to 5,092 MWh.

Figure 4.2 Average, minimum and maximum generation in the status quo and alternative configurations (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

Considering generation as a liquidity metric indicator, the effects can be summarised as follows:

- For alternative configurations 8 and 9 (three zones), we see mostly slight improvements in terms of average, maximum and minimum market characteristics and by extension liquidity metrics.

- For alternative configuration 11 (four zones), changes also indicate mostly improvements, though of smaller magnitude than in alternative configurations 8 and 9.

- For alternative configuration 10 (four zones), we see reductions in the maximum generation of the largest zone as well as in average generation.

- A reconfiguration may have a relevant impact in alternative configuration 10 where O3, the Central Eastern BZ, shows substantially lower levels of market size compared to the status quo in extreme situations, implying a further decrease in liquidity metrics. This is supported by the increase in supply-demand asymmetry compared to the status quo.

4.2.2 Market size approximated by demand

As for generation, liquidity metrics approximated by demand appears to improve in alternative configurations 8 and 9 (three BZs) compared to the status quo, given the increased demand levels in both alternative configurations. In both alternative configurations, average demand – which is directly dependent on the number of BZs – increases from 4,250 MWh in the status quo configuration to 5,667 MWh due to having only three BZs in these alternative configurations, compared to four in the status quo. The average demand of alternative configurations 10 and 11 remains unchanged, as these have the same number of BZs as in the status quo.

The impact of the reconfigurations in terms of market size, approximated by demand, may be summarised as follows:

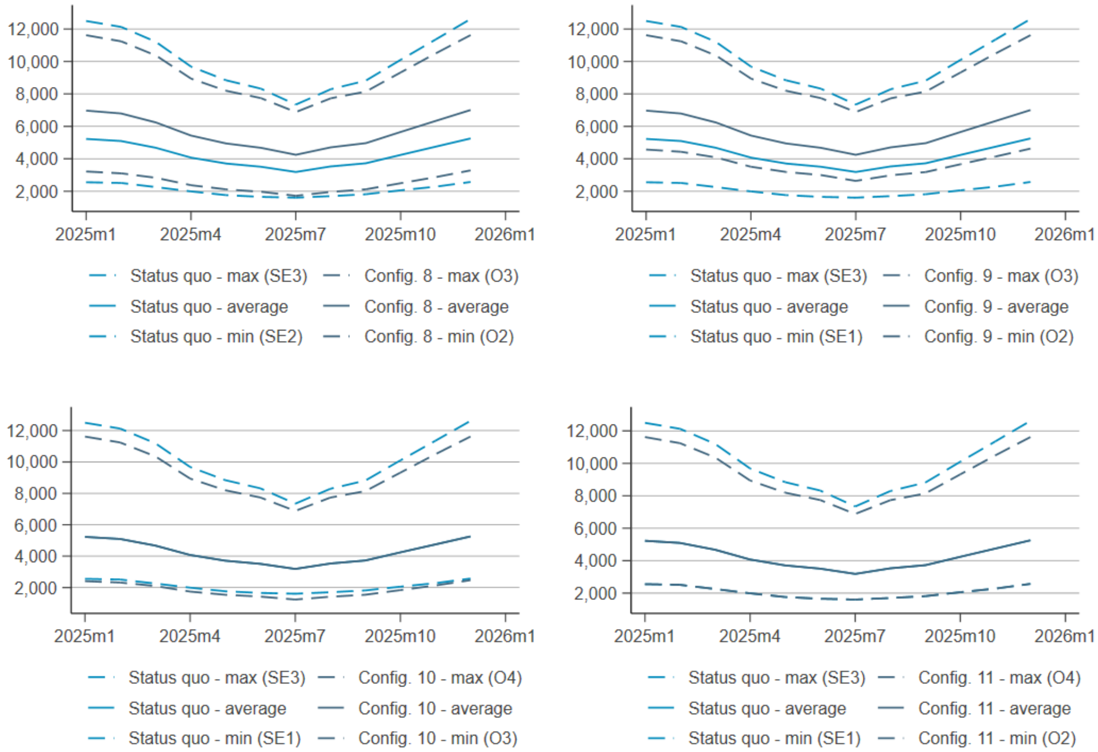
- For alternative configurations 8 and 9, the minimum and maximum demand become less extreme.

- All alternative configurations experience a decrease in the largest demand level observed among BZs. The maximum demand is similar in all alternative configurations, ranging from 11,623 MWh to 11,628 MWh, compared to 12,620 MWh in the status quo configuration. In all alternative configurations, the most Southern zone exhibits the highest observed demand (O3 in alternative configurations 8 and 9, and O4 in alternative configurations 10 and 11).

- Alternative configuration 10 is the only one where the observed minimum demand decreases, from 1,608 MW in the status quo to 1,238 MWh, as illustrated in Figure 4.3 below. Other minima range from 1,608 MWh to 2,641 MWh.

- While the observed maxima decrease in all alternative configurations, the minima become less extreme only in alternative configurations 8 and 9. The smallest demand is observed in alternative configuration 10 in zone O3 with 1,238 MW, which is lower compared to the minimum in the status quo (SE1 with 1,608 MWh). The minimum remains unchanged in alternative configuration 11 compared to the status quo.

Figure 4.3 Average, minimum and maximum demand in the status quo and alternative configurations (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

This indicator, therefore, shows that the proposed alternative configurations are unlikely to aggravate concerns due to liquidity metrics (or could even alleviate them) compared to the status quo, except potentially in alternative configuration 10. In that alternative configuration, over the summer period, the BZ O3 may have a lower market size than the smallest BZ in the status quo, which could lead to a lower realisation of liquidity metrics.

4.2.3 Market concentration

The analysis of the market concentration is based on the HHI[39] values calculated by the Nordic TSOs for each of the alternative BZ configurations in line with the BZR methodology. The results indicate that the evolution of market concentration based on the HHI values is limited.

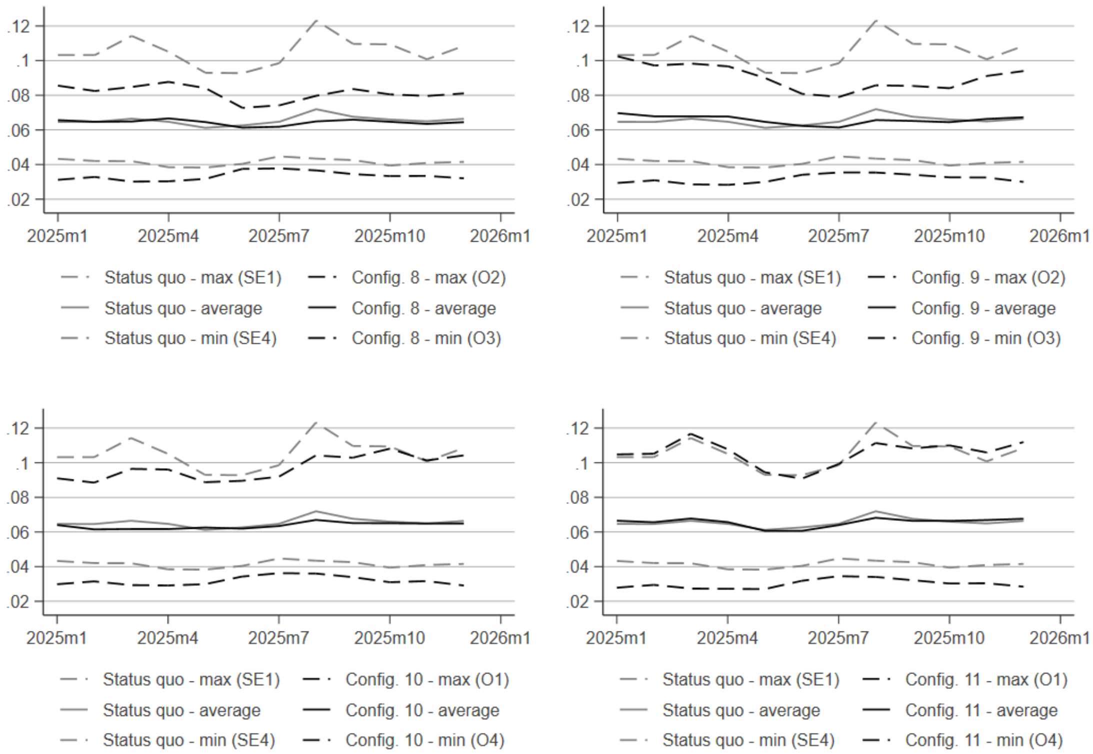
First, the average HHI values across all BZs remain unchanged at 0.07. As shown in Figure 4.4 for alternative configuration 8, average HHI levels also remain fairly stable throughout the simulated year 2025. The same holds for all other alternative configurations.

Second, changes in the extreme values of the HHI compared to the status quo show decreases between 0.01 and 0.03. Across all alternative configurations, the observed minimum decreases from 0.04 to 0.03 and arises in the most southern BZ of the respective alternative configuration. In alternative configuration 8 to 10, the maximum market concentration slightly decreases, which indicates that concentration concerns are likely to be lower for the most concentrated BZs. The HHI

[39] Indicative results in the literature on the relationship between HHI and market liquidity are presented in section 2.2.2.

of the most concentrated BZ in alternative configuration 11 remains the same as the status quo, hence, concentration concerns would remain unchanged.

Figure 4.4 Average, minimum and maximum market concentration given by the HHI in the status quo and alternative configurations



Source: Compass Lexecon analysis of simulated data as provided by TSOs

In alternative configuration 10, the small BZ in the Central Eastern area (O3) is a special case to a certain extent. In this BZ, one producer accounts for 84% of installed capacity in that region. However, as it is standard for HHI calculation in electricity markets, the interconnection capacity of this area was also considered as part of the relevant market. This is why the HHI value for this BZ is uncritical.

To conclude, this indicator shows that the proposed alternative configurations are unlikely to increase market concentration compared to the status quo.

4.2.4 Price correlations

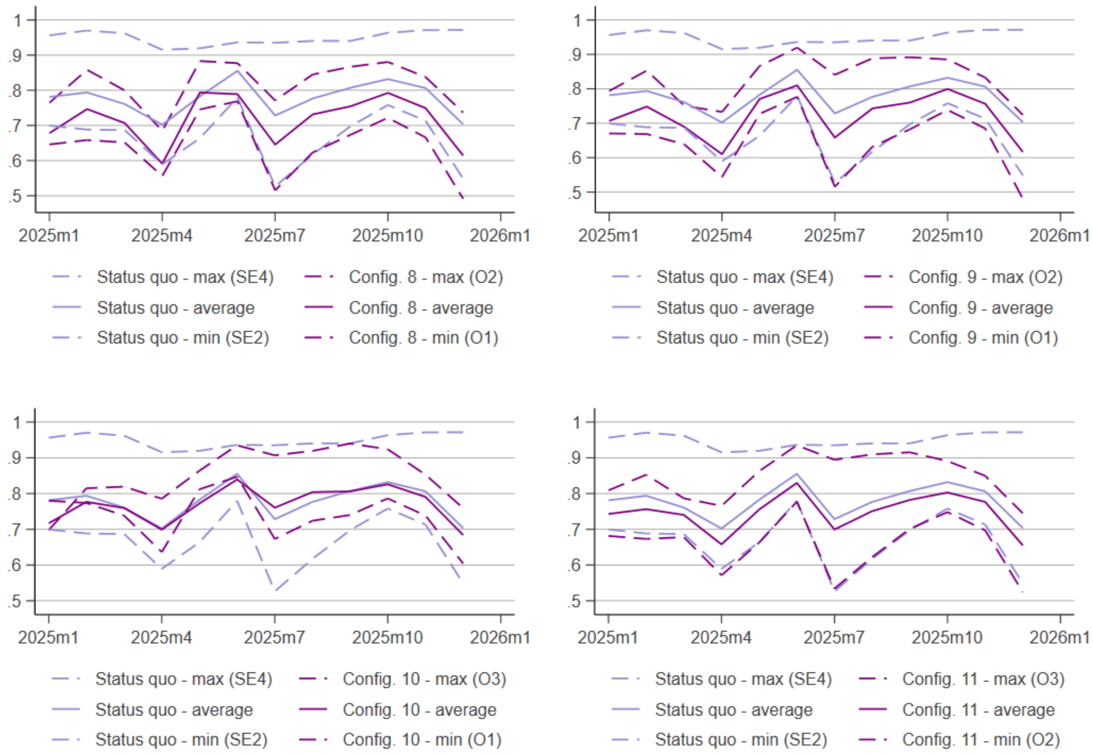
The correlation analysis of the simulated wholesale prices suggests that market liquidity metrics are not affected extensively in any of the alternative configurations in accordance to changes in price correlation in short-term markets.

In alternative configurations 8 and 9, average price correlations decrease by 0.06 from 0.78 in the status quo. In alternative configurations 10 and 11, decreases are slightly smaller, yielding average correlations of 0.77 and 0.75, respectively. In contrast to market concentration, average price correlations are more volatile across months, ranging from about 0.59 in April to 0.79 in June in the case of alternative configuration 8 as illustrated in the Figure 4.4 and Table 4.1.

In all alternative configurations, maximum price correlations decrease compared to the status quo (0.97). However, as for average correlations, changes are rather small, ranging from 0.03 to 0.09.

Similarly, minimum price correlations decrease only to a small extent in alternative configurations 8, 9 and 11. The minimum price correlation slightly increases only in alternative configuration 10, from 0.53 in the status quo up to 0.61. In alternative configurations 8 and 9, the maximum is observed in the most Northern BZ, but in the most Southern BZ in alternative configurations 10 and 11. In alternative configurations 8,9 and 10, the BZ with the minimum correlation level is O1. This may indicate that liquidity concerns may be more present in O1 than in other BZs.

Figure 4.5 Average, minimum and maximum price correlation in the status quo and alternative configurations



Source: Compass Lexecon analysis of simulated data as provided by TSOs

As price correlations of the reconfigured and neighbouring BZs do not change extensively, this indicator tends to show that the proposed alternative configurations are unlikely to aggravate liquidity concerns compared to the status quo.

4.2.5 Conclusions

Table 4.1 below summarises the minimum, average and maximum values observed across BZs for the different liquidity metrics considered in the status quo and in the different proposed alternative configurations in Sweden.

Overall, our analysis suggests potential slight liquidity metric improvements for alternative configurations 8 and 9. These findings are supported by the following observations:

- Average generation volume increases in alternative configurations 8 and 9 compared to the status quo. In addition, the size of the smallest BZ increases in both alternative configurations compared to the status quo.

- As for generation, average demand increases in the alternative configurations 8 and 9 compared to the status quo and also exhibits increased levels of minimum demand compared to the status quo.

- Market concentration in the alternative configurations 8 and 9 remains similar on average and decreases in the most concentrated BZ compared to the status quo. So while competitiveness does not deteriorate in the larger zones, it slightly improves in the smallest zone.

- Even though averages and extremes of price correlations decrease for the alternative configurations 8 and 9 compared to the status quo, the changes are rather small (0.06 for average correlation and 0.04 to 0.09 for the extremes). Given the size of changes, liquidity concerns seem unlikely to aggravate compared to the status quo.

For alternative configurations 10 and 11, even though there are no indications for large deteriorations of relevant metrics, some developments can be noted:

- Alternative configuration 10 shows a substantially smaller minimum market size in terms of generation as well as an increased supply-demand asymmetry in BZ O3 compared to the status quo or the minima of other alternative configurations. This reduces liquidity metrics and may put the BZ at greater dependency on other zones than in other alternative configurations or the status quo.

- In the alternative configuration 10, over the summer period, the BZ O3 may have a lower demand than the smallest BZ in the status quo. This could negatively affect liquidity metrics, although probably only to a limited extent.

- In the alternative configuration 11, the HHI of the most concentrated BZ remains unchanged compared to the status quo, while decreasing in all other alternative configurations. This may indicate a less beneficial realisation of liquidity metrics than in the other alternative configurations.

- As for alternative configurations 8 and 9, averages and extremes of price correlation mostly decrease, but only to a small extent. For alternative configurations 10 and 11, decreases in average and maximum price correlation range from 0.01 to 0.03. While the minimum price correlation decreases by 0.01 in alternative configuration 11, the minimum in alternative configuration 10 increases by 0.08. Even though the magnitude of changes is relatively small, the overall impact on liquidity may be larger in alternative configurations 10 and 11 given the development of the other liquidity metrics.

Table 4.1 Average and extreme values of liquidity metrics in the status quo and alternative configurations for Sweden

Case	Descriptive statistic	Market concentration	Price correlation	Market size	
		HHI		Generation	Demand
Status quo	Max	**SE1:** 0.12	**SE4:** 0.97	**SE3:** 11,614	**SE3:** 12,620
	Average	0.07	0.78	5,094	4,250
	Min	**SE4:** 0.04	**SE2:** 0.53	**SE4:** 722	**SE2:** 1,608
Conf. 8	Max	**O2:** 0.09	**O2:** 0.88	**O1:** 13,110	**O3:** 11,628
	Average	0.07	0.72	6,789	5,667
	Min	**O3:** 0.03	**O1:** 0.49	**O2:** 1,432	**O2:** 1,721
Conf. 9	Max	**O2:** 0.1	**O2:** 0.92	**O1:** 11,344	**O3:** 11,623
	Average	0.07	0.72	6,767	5,667
	Min	**O3:** 0.03	**O1:** 0.48	**O2:** 2,252	**O2:** 2,641
Conf. 10	Max	**O1:** 0.11	**O3:** 0.94	**O4:** 8,741	**O4:** 11,623
	Average	0.07	0.77	5,092	4,250
	Min	**O4:** 0.03	**O1:** 0.61	**O3:** 98	**O3:** 1,238
Conf. 11	Max	**O1:** 0.12	**O3:** 0.94	**O4:** 8,762	**O4:** 11,623
	Average	0.07	0.75	5,095	4,250
	Min	**O4:** 0.03	**O2:** 0.52	**O3:** 2,252	**O2:** 1,608

Source: Compass Lexecon analysis of simulated data as provided by TSOs
Note: Demand and generation in MWh/h on average over the year. Upward arrows indicate increases compared to the status.status quo. Downward arrows indicate a decrease compared to the status quo. Green indicates a liquidity metric-enhancing effect. Red indicates a liquidity metric-dampening effect. The displayed averages are annual averages across all BZs in the considered reconfiguration. The displayed minima and maxima show the highest and lowest observed monthly value of the stated BZ. The stated BZ has been identified based on the average annual value of the considered market characteristic parameter.

Following from the changes in market characteristics for the individual BZ, the following overall conclusion can be derived[40]:

- Alternative configurations 8 and 9 see changes in market characteristics that would coincide with overall increased liquidity metrics for both short- and long-term markets. As the positive changes are limited in extent, the direction of change is not consistent throughout all BZs and price correlation slightly tends to decrease, the positive impact would be expected to be limited.

- The analysis of alternative configuration 10 suggests a noticeable impairment of liquidity metrics for both short- and long-term markets at least for a subset of BZs. The expectation of decreasing market metrics is primarily driven by decreases in market size without strong offsets by other market characteristics such as price correlation. In particular, BZ O3 shows exceptionally small generation volumes and increasing supply-demand asymmetry.

- Alternative configuration 11 shows an inconclusive picture with regard to changes in liquidity metrics as some market characteristics change in opposite directions for different BZs and

[40] Noting the historic relevance of the DA-market and the Nordic system price on market liquidity, the identified expected impact on individual BZs may or may not further affect the overall liquidity of the Nordics. The analysis of these indirect effects are out o the scope of this study.

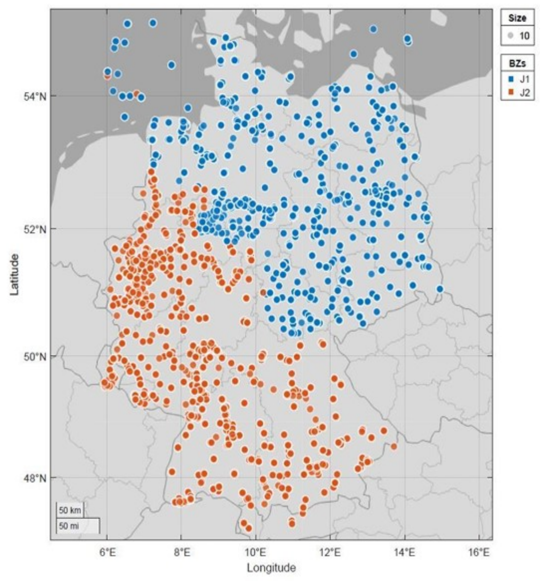
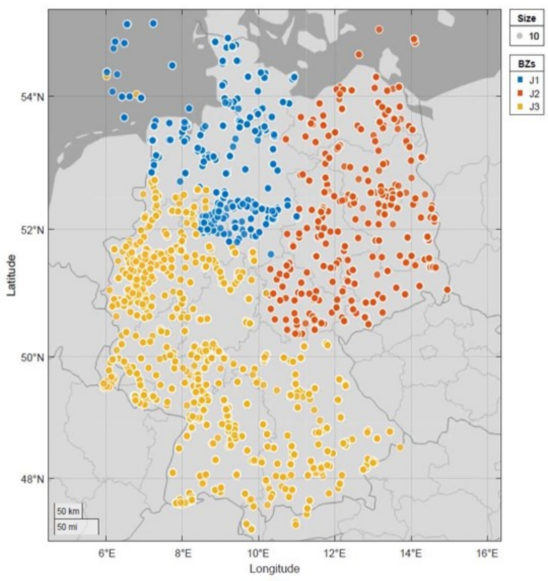
others show very limited changes. Therefore, no tendency for the liquidity metrics for this alternative configuration could be identified for either the short- or long-term market.

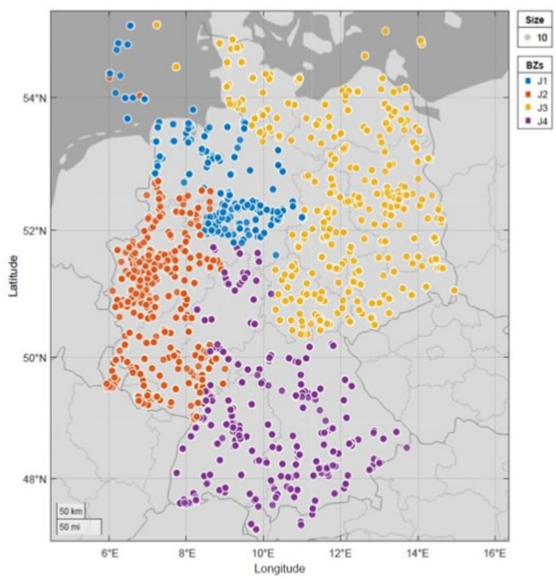
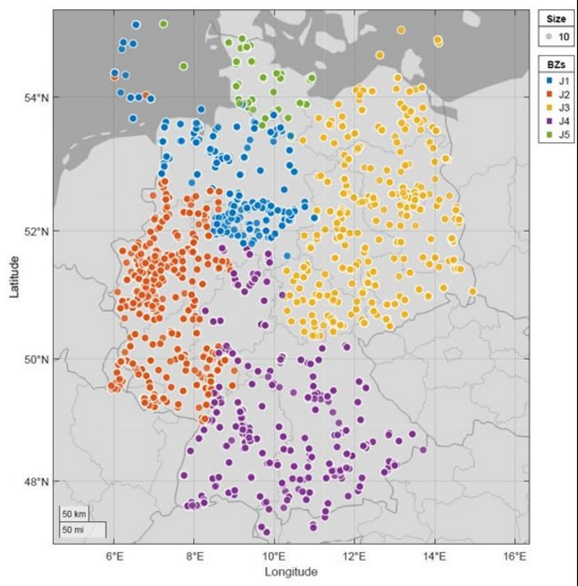
4.3 German-Luxembourg simulated data on proposed bidding zones

There are four alternative BZ configurations for the German-Luxembourg BZs. In accordance with ACER decision 11-2022 on alternative BZ configurations, TSOs have decided to assess the fallback configurations for the German-Luxembourg BZ in the BZR such that the final specifications analysed here are alternative configurations 2, 12, 13, and 14. Each of the four proposals foresees a different number of BZs, ranging from two BZs (alternative configuration 2) to five BZs (alternative configuration 14). In the status quo, only one BZ exists.

All proposals share a common split between the south-west and north-east of the region. This is most clearly seen in alternative configuration 2 with its two zones divided along this border. Additionally, alternative configuration 12 sees a further split into two BZs of the north-east area of the region, resulting in three zones in total. Similarly, in alternative configuration 13 the south-west area of the German-Luxembourg region was divided into two more BZs, forming four BZs in total. Note that the borders of the two zones in the north-east of alternative configuration 12 differ from the border between the two zones in the north-east of alternative configuration 13. Alternative configuration 14 foresees a fifth BZ which splits the far northern part of the North-Eastern zone into two, matching otherwise with all other borders in alternative configuration 13. Figure 4.6 shows the four alternative configurations.

Figure 4.6 Alternative BZ configurations with two to five German-Luxembourg BZs

Alternative configuration 2	**Alternative configuration 12**
 *Note: J1 and J2 are the two newly-defined German-Luxembourgish bidding zones.*	

Alternative configuration 13	Alternative configuration 14
	

Source: ACER

For each proposed alternative configuration and in the status quo, i.e. assuming the BZs remain the same as today, the Central European TSOs simulated hourly dispatch of generation units to meet demand in a Pan-EU model and provided us with hourly values of generation and load volume, RSI and PSI values, and simulated market clearing prices for the year 2025 in each BZ. Further, for each alternative configuration, the simulation was carried out for three different climate scenarios, based on the climate observed in 1989, 1995 and 2009. Apart from the Central European BZs, the regional scope of the data provided by the Central European TSOs includes the currently adjacent BZs to the Central European region.

4.3.1 Market size approximated by generation volume

The analysis of the generation parameter indicates a significant decrease in market size across all alternative configurations. The decrease differs among BZs with the lowest decrease shown for BZ DEJ2 in alternative configuration 2 with a decrease of the hourly average generation in 2025 from 64,000 to ca 34,000 MWh/h and the largest decrease in BZ DEJ5 in alternative configuration 14 with a decrease to around 4,000 MWh/h.

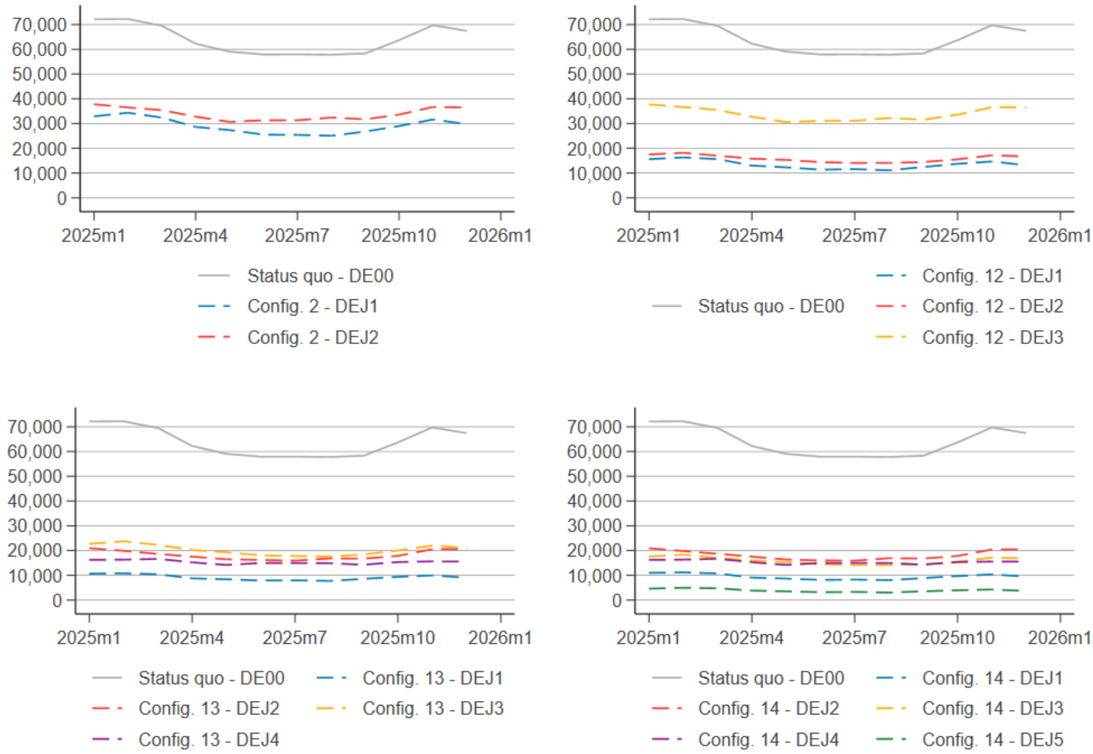
For each alternative configuration, the following changes on liquidity metrics may be derived when solely looking at the market size approximated by the simulated generation volume:

- In **alternative configuration 2**, generation decreases to a similar extent for both zones DEJ1 and DEJ2 in comparison to the status quo. Generation across the two simulated zones decrease from between 60,000 and 70,000 MWh on average per hour in the status quo to around 25,000 to 37,000 MWh/h each. The BZ split implies a near equal split of generation.

- In **alternative configuration 12**, which assumes a split into three zones, generation decreases significantly in both north-eastern zones DEJ1 and DEJ2 by around 50,000 MWh/h per zone compared to the status quo. The simulation results of the south-western zone DEJ3 shows a lower decline in generation compared to DEJ1 or DEJ2 with a simulated decline by only 30,000 MWh/h.

- The **alternative configuration 13 and 14**, for which BZ borders are highly similar, have a similarly low level of generation after the split of the BZ into four and five zones respectively. All simulated zones in those two alternative configurations generate below 22,000 MWh/h compared to the 60,000 to 70,000 MWh/h of the status quo generation . The decrease in zone DEJ1 in alternative configuration 13 with around 10,000 MWh/h of generation and in zone DEJ5 in alternative configuration 14 with around 4,000 MWh/h of generation is particularly significant.

Figure 4.7 Monthly average of hourly generation in the status quo and different reconfigurations (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

In all four alternative configurations, the BZs of the German-Luxembourg region would have a significantly lower market size than the BZ of the status quo. This may imply, under ceteris paribus conditions, the proposed alternative configurations would lead to significantly lower liquidity metrics compared to the status quo.

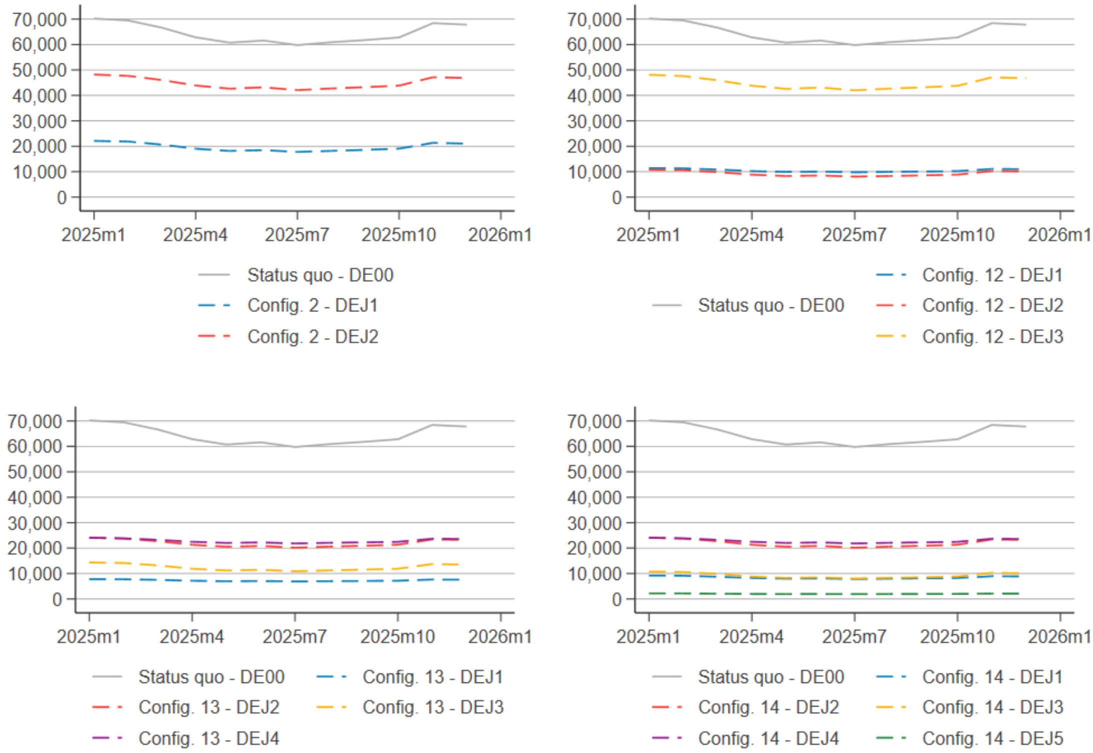
4.3.2 Market size approximated by demand

Market size approximated by load shows a similar pattern as the approximation by generation. Across all BZs, the market size decreases compared to the status quo. However, the load decrease per BZ partially diverges from the decrease in generation, i.e. the decrease in load is sometimes stronger than the decrease in generation volume. Accordingly, liquidity metrics as derived by demand appear to decrease in all four alternative configurations compared to the status quo.

The parameter shows the following changes:

- **For all four alternative configurations** the demand in each zone decreases as the region is diagonally divided between the north-east and the south-west in two or more zones. The total hourly demand of the status quo configuration is simulated to be around 65,000 MWh. All alternative configurations experience a decrease in the demand level observed among BZs. In all alternative configurations, the most Southern zone exhibits the highest observed demand. The smallest hourly demand is observed in alternative configuration 14 in zone DEJ5 with around 1,500 MWh, which is significantly lower compared to the minimum of the status quo(60,000 MWh) and also lower compared to the generation approximation.
- **In alternative configurations 2 and 12**, with two and three zones respectively, the status quo demand decreases from around 65,000 MWh to around 45,000 MWh in the south-western zone and to jointly around 20,000 MWh in the north-eastern zone(s) respectively. Notably, in alternative configuration 12 where the north-eastern zone is geographically split in half again, the demand is also split in half with around 10,000 MWh demand per zone. These decreases in market size differ to the decreases implied by the market size approximation by generation:
  - In alternative configuration 2, load decreases significantly stronger in DEJ1 compared to DEJ2 in contrast to generation.
  - In alternative configuration 12, load decreases significantly in both DEJ1 and DEJ2, while load in DEJ3 decreases by only 20,000 MWh which is less than the decrease of generation. In particular for DEJ2, the size of load reduction compared to the decrease in generation results in an increased difference between electricity generation and demand compared to the status quo.
- The values of demand in **alternative configurations 13 and 14** are similar insofar as these two alternative configurations have the same zonal split in the south-west (into zones DEJ2 and DEJ4 each) with an average hourly load of ca. 21,000 MWh each and in the north into zone DEJ1 with around 10,000 MWh each. The only difference is that alternative configuratio 14 foresees a split of the eastern region into two, which means that the bigger half, zone DEJ3, is simulated to have a demand of around 10,000 MWh and the smaller half, zone J5, of around 5,000 MWh, whereas in alternative configuration 13 the eastern region is one big zone with around 15,000 MWh of demand. For alternative reconfiguration 14, the reduced demand in DEJ3 and DEJ5 results in a significant increase of supply-demand asymmetry compared to the status quo where demand and supply roughly balance.

Figure 4.8 Monthly average of hourly demand in the status quo and alternative configurations (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

This indicator for market size, therefore, tends to show that the proposed alternative configurations are likely to aggravate concerns due to liquidity metrics compared to the status quo. In all four alternative configurations, the BZs of the German-Luxembourg region would have a lower market size than the status quo BZ , which could, ceteris paribus, lead to lower realisations of liquidity metrics.

4.3.3 Market concentration

The analysis of the market concentration for the German-Luxembourg region uses the average hourly RSI[41] values, averaged across climate years as calculated by the Central European TSOs for each of the BZ alternative configurations. We supplement the analysis with the use of PSI values. For both parameters, we consider three instances to account for the uncertainty of import capacity.

Different to the expected liquidity metric changes as derived from the simulated and approximated market size, the results on market concentration do not show a clear trend across the alternative configurations. Notably, for all alternative configurations, there are zones with a higher RSI than the status quo, as well as zones with a lower RSI. In cases of RSI decreases, the changes are mostly limited. No BZ shows monthly average values below the threshold of 1, but DEJ2 (Western region) shows significant increases of the ratio of the PSI values when assuming limited import capacity in alternative configurations13 and 14.

[41] Indicative results in the literature on the relationship between RSI and market liquidity are presented in section 2.2.2.

In the following, we will discuss the market concentration parameters for each alternative configurationindividually.

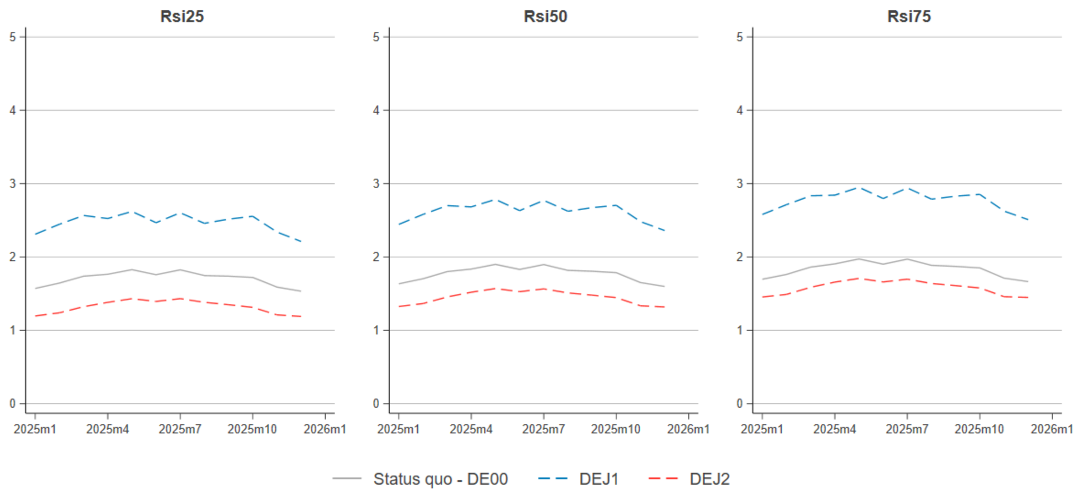
Alternative Configuration 2:

The RSIs of the reconfigured BZs show different changes in direction compared to the status quo. While the RSI of the Northern Zone (DEJ1) increases, the RSI of the Southern zone (DEJ2) decreases compared to the status quo. On a monthly basis, all RSI remain above 1, but when considering the PSI value, the value indicates few instances (3%) of an RSI below 1 for DEJ2. This implies an increase in market concentration in that zone and could, thus, coincide with a decrease in liquidity metrics.

When comparing the RSI values across the different import capacity correction factors (i25, i50, i75), the changes compared to the status quo remain robust across all correction factors. As expected, all RSI values increase gradually with the increase in the correction factor.

Figure 4.9 shows the monthly average hourly RSI values for the different BZs and the status quo for the three instances with different correction factors for import capacity.

Figure 4.9 Monthly average of hourly market concentration given by the RSI in the status quo configuration and alternative configuration 2



Source: Compass Lexecon analysis of simulated data as provided by TSOs

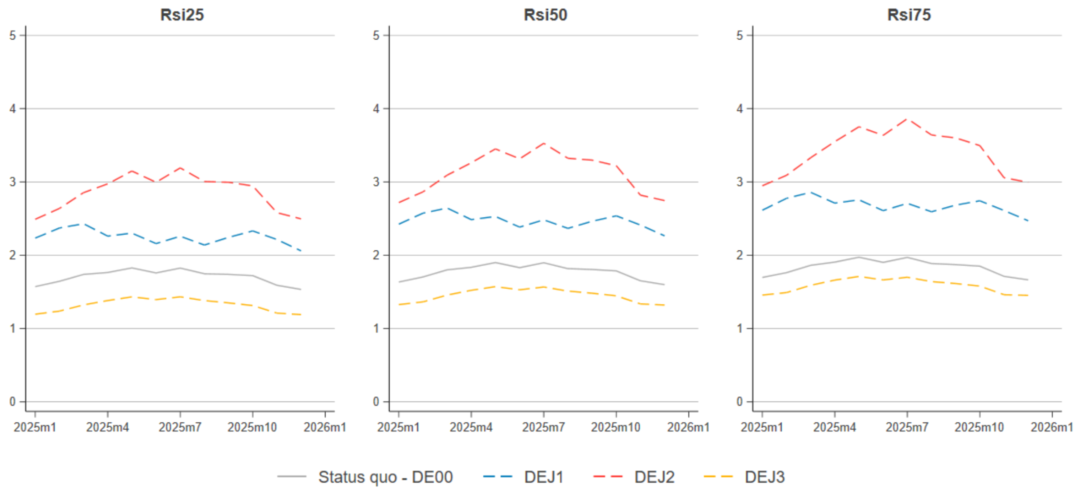
Alternative configuration12:

When the region is split into three zones, the RSIs of the Northern zones (DEJ1 and DEJ2) increase compared to the status quo and the RSI of the Southern zone (DEJ3) decreases for all instances of import capacity correction. Similar to alternative configuration 2, the ratio of the PSI is zero but for the Southern zone that shows a ratio of 3%, indicating an increase in market concentration which could coincide with a decrease in liquidity metrics.

When comparing the RSI values across the different import capacity correction factors, the changes compared to the status quo remain robust across all correction factors. As expected, all RSI values increase gradually with the increase in the correction factor.

Figure 4.10 shows the monthly average hourly RSI values for the different BZs and the status quo for the three instances with different correction factors for import capacity.

Figure 4.10 Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration 12



Source: Compass Lexecon analysis of simulated data as provided by TSOs

<u>Alternative configuration 13:</u>

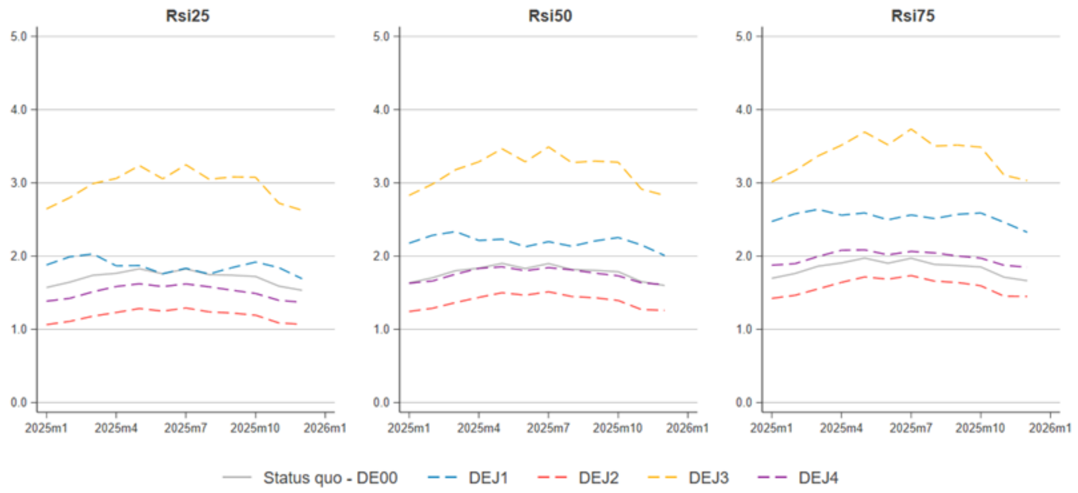
Alternative configuration 13 foresees a fourfold split of the status quo BZ. As in the other alternative configurations, some BZs show an improvement in market concentration compared to the status quo while others show a deterioration.

Notably, when comparing the RSI values across the different import capacity correction factors, the changes compared to the status quo remain robust across all correction factors for all but one BZ. The RSI increases with the increase of the correction factor faster for DEJ4 than for the status quo leading to a change in direction: While DEJ4 shows a lower RSI value than the status quo when assuming little import capacity, it is approximately on par when assuming a 50% correction factor and the DEJ4 RSI exceeds the status quo when assuming comparably high import capacity. In line with the other alternative configurations, all RSI values increase with the increase of the import capacity.

In detail, the RSI of the North-Eastern zone (DEJ3) increases significantly compared to the status quo. DEJ1 values are slightly higher when assuming little import capacity, but the difference increases as import capacity is assumed higher. The market concentration parameters of the Western zone (DEJ2) show increases in market concentration: While monthly RSI values decrease but remain above 1, the ratio of the PSI takes a value of 19% when assuming a 25% correction factor and still 2% with a 50% correction factor. As indicated above, DEJ4 values are below the status quo when assuming a low correction factor and above the status quo when assuming a high correction factor.

Figure 4.11 shows the monthly averages of hourly RSI values for the different BZ and the status quo for the three instances with different correction factors for import capacity.

Figure 4.11 Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration 13



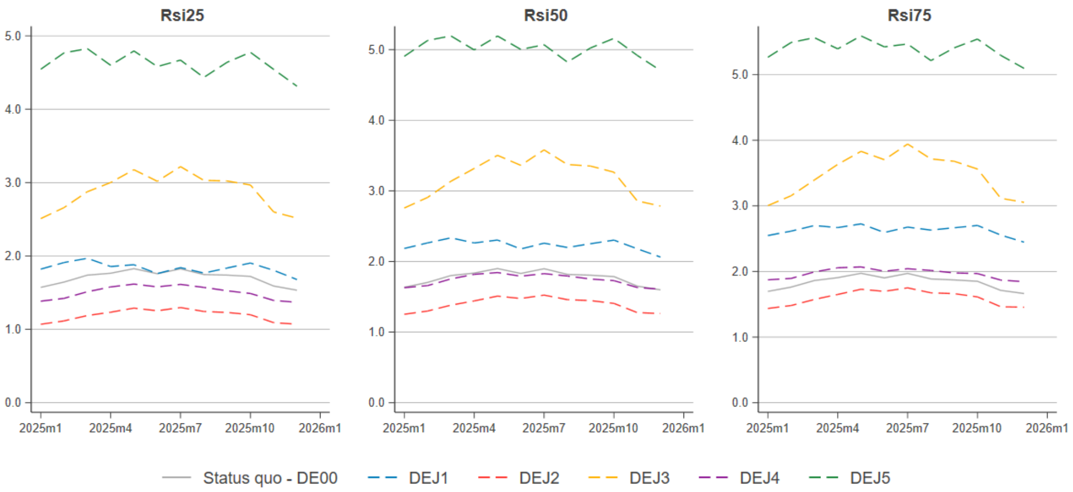
Source: Compass Lexecon analysis of simulated data as provided by TSOs

<u>Alternative configuration 14:</u>

Alternative configuration 14 shows a similar picture as alternative configuration 13 in terms of RSI and PSI values and the impact of the correction factor. Besides the four similar zones, alternative configuration 14 further shows exceptionally high RSI values for DEJ5. This finding may be particularly driven by the reduced dataset used to compute the RSI values, as this dataset contains only very limited ownership data for renewable energy sources which may be expected to supply a relatively large part of the electricity in this new, Northern BZ.

Figure 4.12 shows the monthly average hourly RSI values for the different BZs and the status quo for the three instances with different correction factors for import capacity.

Figure 4.12 Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration 14



Source: Compass Lexecon analysis of simulated data as provided by TSOs

4.3.4 Price correlations

The simulated weighted average wholesale price correlation to the connected BZs is assessed for each BZ for each alternative configuration and the status quo. The results show a picture with an overall trend of increases in cross-border correlation.

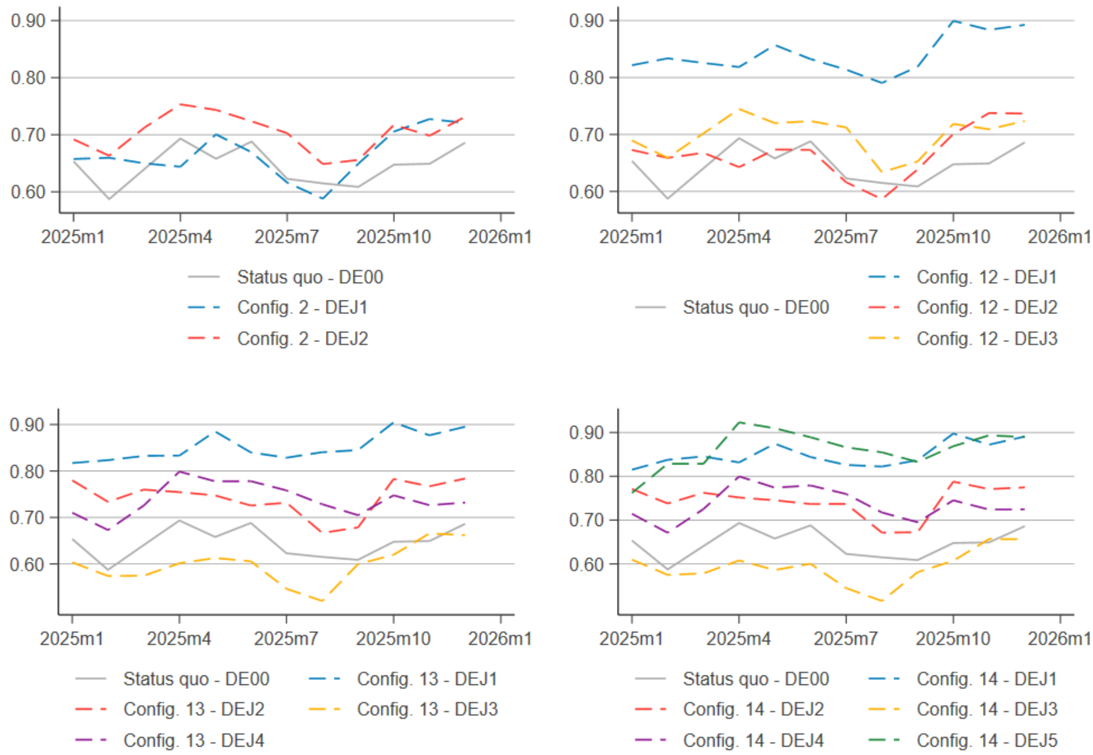
The individual alternative configurations show the following picture:

- **Alternative configuration 2:** When split into only two zones, the price correlation increases for the south-western zone DEJ2 for all months when compared to the status quo. Correlation slightly decreases for DEJ1 for some of the months.
- **Alternative configuration 12:** When split into three zones, the price correlation compared to the status quo increases for south-western zones DEJ1 and DEJ3 but decreases for the eastern zone DEJ2 for some periods.
- **Alternative configuration 13:** The price correlation increases for all reconfigured zones in all periods, with the exception of most of the periods in the eastern BZ (DEJ3).
- **Alternative configuration 14:** DEJ3, the eastern BZ, has a lower correlation than the status quo for most periods. The other four new zones consistently have a higher correlation than the status quo for all periods.

The results indicate that all four alternative configurations show a higher price correlation in the southern and western part of Germany-Luxembourg and slightly lower price correlations in the north-eastern zone. The decrease in correlation in the Eastern BZ may be explained by the comparably low correlation to the Polish and Czech BZ. Alternative configuration 12 is the configuration that shows overall higher price correlations in all the new zones, suggesting better cross-border hedging opportunities which may positively affect liquidity metrics.

Figure 4.13 shows the monthly average weighted price correlations for the different BZs and the status quo.

Figure 4.13 Monthly average of hourly price correlations in the status quo and alternative configurations



Source: Compass Lexecon analysis of simulated data as provided by TSOs

This parameter therefore, as a stand-alone indicator, suggests an overall increase in liquidity metrics for short-term markets in comparison to the status quo with the exception of a tendency towards slightly lower liquidity metrics for the North-East.

4.3.5 Conclusions

Table 4.2 below summarises the simulated market characteristics parameters observed across BZs for the status quo and in the alternative configurations in Germany.

Overall, our analysis shows a differentiated picture. While we see on average an improvement in the parameters market concentration and price correlation, market size decreases substantially. Noting the nonlinear relationship identified between bid-ask spreads and market size for long-term markets (see chapter 3.2.3), the ultimate relevance of market size as an indicator for liquidity metrics may be decisive for the overall picture at least for the long-term markets[42]:

- If it was assumed that market size remains a significant indicator in the future, liquidity metrics for short- and long-term markets are bound to decrease.
- In contrast, if the liquidity metric increases (that is implied by the increase of price correlation and decrease of market concentration) it counters the effect identified through the market size

[42] Noting the historic relevance of Germany as lead market for long-term products, the final effect on liquidty metrics may additionally be impacted by changes in the perception of this lead market. Due to the inconclusive results of the analysis of proxy-hedging as well as the potential impact from mitigation measures, an expectation on the effect from changes in the perception of the lead market cannot be made here.

decrease, e.g. by concentrating liquidity in one zone through increased levels of cross-border hedging and extended market coupling, and the decrease in market size may not be decisive and liquidity metrics may increase – at least for a subset of BZs.

- However, in light of the examined decrease in price correlation in the north-east zones, such an increase in liquidity metrics would at least not be expected to take place in the north-east zones.

This overall conclusion can be explained particularly by the following observations:

- Monthly average hourly generation volumes decrease across all four alternative configurations compared to the status quo but to different degrees, indicating smaller market sizes and lower liquidity metrics for both short- and long-term markets. Generation within each BZ is much lower compared to the status quo when there are three or more BZs.

- Generation volume and load equally indicate a smaller market size for all four alternative configurations. However, the generation volume declines in line with the geographical split in half in alternative configuration 2, while demand is not proportionally split in alternative configuration 2 and 12, with the south-west showing more than twice the demand than the north-east. For alternative configuration 12, this results in an increase in supply-demand asymmetry compared to the status quo where electricity generation roughly matches demand. Especially in DEJ2 in alternative configuration 12, generation significantly exceeds supply. The same holds for alternative configuration 14.

- Price correlation across all four alternative configurations increases in the western zones but not in the eastern BZs compared to the status quo configuration.

- Market concentration across all alternative configurations is likely to increase in the south-west and to decrease in the north-east. There is a particularly strong decrease in market concentration compared to the status quo in alternative configurations 13 and 14 in the far eastern and northern zones. However, it needs to be duly noted that especially in bidding zones with high shares of RES the ownership database for the calculation of the RSI/PSI values is, according to the TSOs, potentially incomplete.

- The simulated north-eastern zones, regardless of the alternative configuration, show less demand (particularly visible in alternative configurations 2 and 12) and lower short-term market integration due to a lower price correlation between neighbours compared to western BZs in all four alternative configurations. However, but market concentration (particularly visible in alternative configurations 13 and 14) is expected to be significantly lower.

Table 4.2 Average and extreme values of liquidity metrics in the status quo and alternative configurations for Germany

Case	Descriptive statistics	Market concentration			Price correlation	Market size	
		Rsi25	Rsi50	Rsi75		Generation	Demand
Status quo		**DE00:** 1.71	**DE00:** 1.77	**DE00:** 1.84	**DE00:** 0.65	**DE00:** 64,018	**DE00:** 64,434
Alt config. 2	Max	↑ **DEJ1:** 2.47	↑ **DEJ1:** 2.62	↑ **DEJ1:** 2.77	↑ **DEJ2:** 0.7	↓ **DEJ2:** 33,919	↓ **DEJ2:** 44,808
	Average	↑ 1.89	↑ 2.04	↑ 2.18	↑ 0.68	↓ 31,504	↓ 32,256
	Min	↓ **DEJ2:** 1.32	↓ **DEJ2:** 1.45	↓ **DEJ2:** 1.58	↑ **DEJ1:** 0.67	↓ **DEJ1:** 29,089	↓ **DEJ1:** 19,704
Alt config. 12	Max	↑ **DEJ2:** 2.86	↑ **DEJ2:** 3.14	↑ **DEJ2:** 3.41	↑ **DEJ1:** 0.84	↓ **DEJ3:** 33,846	↓ **DEJ3:** 44,734
	Average	↑ 2.14	↑ 2.35	↑ 2.56	↑ 0.74	↓ 21,050	↓ 21,498
	Min	↓ **DEJ3:** 1.32	↓ **DEJ3:** 1.45	↓ **DEJ3:** 1.59	↑ **DEJ2:** 0.67	↓ **DEJ1:** 13,429	↓ **DEJ2:** 9,265
Alt config. 13	Max	↑ **DEJ3:** 2.97	↑ **DEJ3:** 3.18	↑ **DEJ3:** 3.39	↑ **DEJ1:** 0.85	↓ **DEJ3:** 20,273	↓ **DEJ4:** 22,830
	Average	↑ 1.88	↑ 2.12	↑ 2.37	↑ 0.73	↓ 15,740	↓ 16,124
	Min	↓ **DEJ2:** 1.19	↓ **DEJ2:** 1.39	↓ **DEJ2:** 1.58	↓ **DEJ3:** 0.6	↓ **DEJ1:** 9,145	↓ **DEJ1:** 7,308
Alt config. 14	Max	↑ **DEJ5:** 4.62	↑ **DEJ5:** 5.01	↑ **DEJ5:** 5.4	↑ **DEJ5:** 0.86	↓ **DEJ2:** 18,153	↓ **DEJ4:** 22,829
	Average	↑ 2.41	↑ 2.71	↑ 3.02	↑ 0.76	↓ 12,562	↓ 12,902
	Min	↓ **DEJ2:** 1.19	↓ **DEJ2:** 1.4	↓ **DEJ2:** 1.6	↓ **DEJ3:** 0.59	↓ **DEJ5:** 3,884	↓ **DEJ5:** 2,038

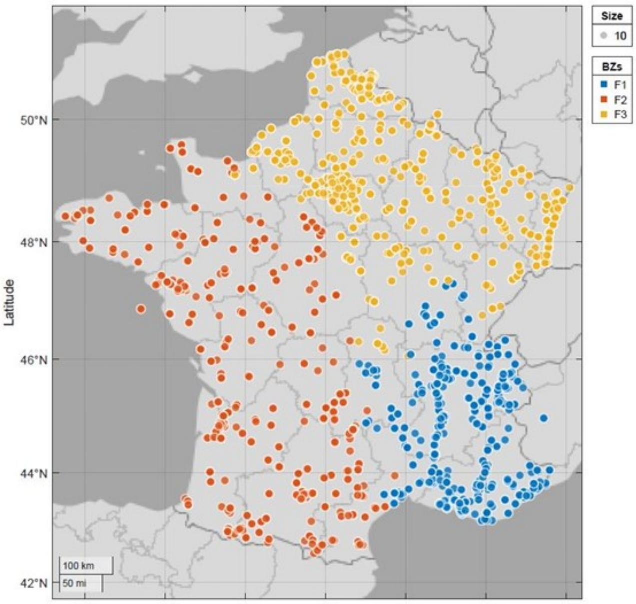
Source: Compass Lexecon analysis of simulated data as provided by TSOs

Note: Demand and generation are presented in MWh/h on average throughout the year. Upward arrows indicate increases compared to the status quo. Downward arrows indicate a decrease compared to the status quo. Green indicates a liquidity metric-enhancing effect. Red indicates a liquidity metric-dampening effect. The displayed averages are annual averages across all BZs in the considered alternative configuration. The displayed minima and maxima show the highest and lowest observed monthly value of the stated BZ. The stated BZ has been identified based on the average annual value of the considered market characteristic parameter.

4.4 France simulated data on proposed bidding zones

There is one alternative configuration for the French BZ. The proposal foresees three different BZs; one large zone in the west and two smaller zones in the east. Figure 4.14 displays the configuration with the three BZs.

Figure 4.14 Alternative BZ configuration with three French BZs



Source: ACER

For the alternative configuration and the status quo configuration, i.e. assuming the BZ remains the same as today, the Central European TSOs simulated hourly dispatch of generation units to meet demand in a Pan-EU model. They provided hourly values of generation volume, demand, RSI and PSI, and wholesale market prices for the year 2025 in each BZ. Further, for each alternative configuration, the simulation was carried out for three different climate scenarios, based on the climate observed in 1989, 1995 and 2009. Apart from the Central European BZs, the regional scope of the data provided by the Central European TSOs includes the currently adjacent BZs to the Central European region, e.g. Spain.

4.4.1 Market size approximated by generation

The generation parameter for the reconfigured zones is significantly lower compared to the status quo. The intra-year pattern showing decreasing generation over summer holds across all BZs.

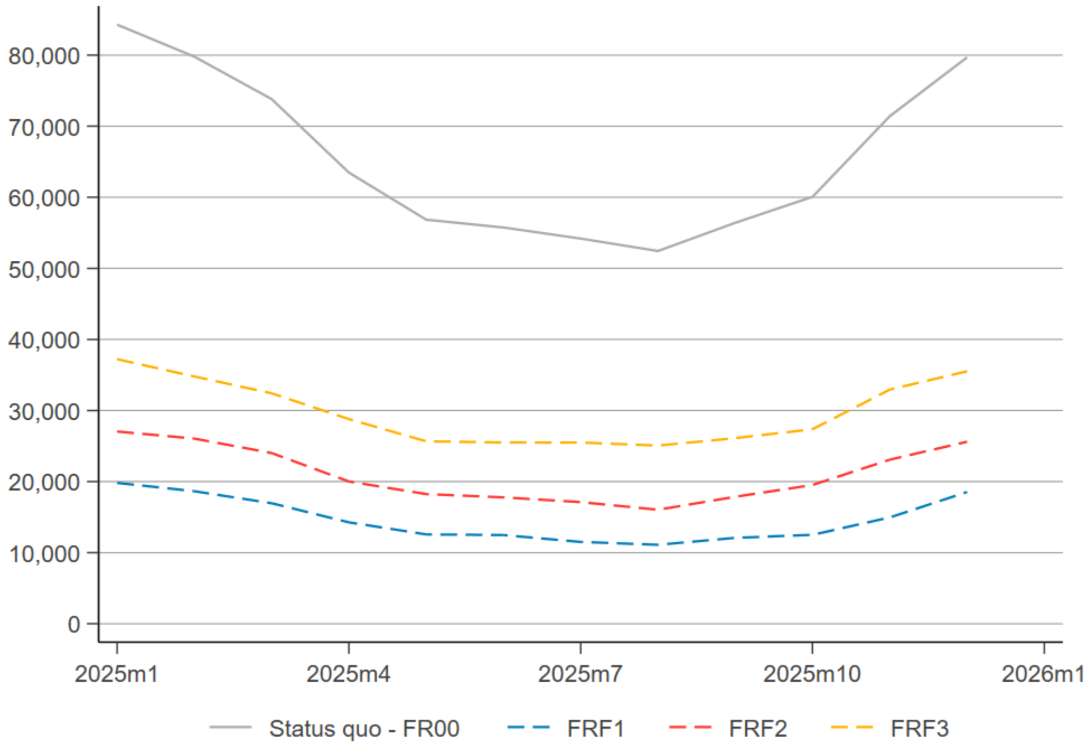
In detail, the observations when comparing the status quo to the alternative configuration may be summarised as follows:

- Generation volume decreases across all three BZs, but the decrease is strongest for the south-eastern zone FRF1. There, hourly generation is on average ca. 16,000 MWh while it is ca. 30,000 MWh in FRF 3 and is 66,000 MWh in the status quo configuration. Generation volume in FRF2 is between FRF1 and FRF3.

- **Hourly average generation per month in the status quo configuration** is simulated to decrease within the first half of the year 2025 from 83,000 MWh to 55,000 MWh, hitting its minimum around August with roughly 53,000 MWh. Status quo generation then increases again from September onwards up to 80,000 MWh in December.

- Similarly, **average generation per month in all three proposed BZs** decreases in the beginning of the year 2025 until the end of summer, after which it increases again towards the end of 2025. Zone FRF3 in the north-east decreases the least compared to the status quo, starting at around 37,000 MWh in January, dipping down to roughly 26,000 MWh at the end of summer and then rising to 35,000 MWh in winter again. In zone FRF1 generation decreases the most compared to the status quo, with 20,000 MWh in winter and coming down to around 10,000 MWh in summer, while generation in the western zone FRF2 lies in the middle of the generation values of the two other zones between 28,000 MWh and 18,000 MWh in winter.

Figure 4.15 Monthly average of hourly generation in the status quo and alternative configuration (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

Considering the identified relationship between liquidity metrics and market size and under ceteris paribus assumptions, liquidity metrics of the new French BZs would decrease as generation in all three zones decreases compared to the status quo.

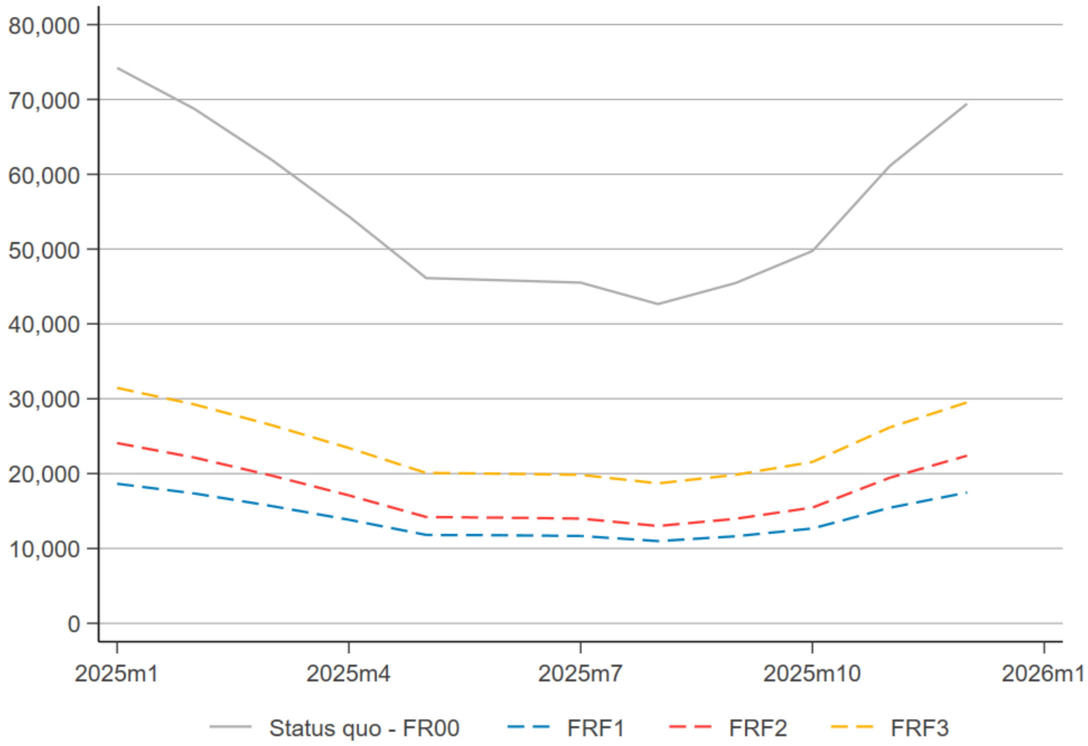
4.4.2 Market size approximated by demand

The market size approximation by demand indicates a similar market size evolution as the approximation by generation. As for generation volume, the market size decreases strongest for FRF1 and the least for FRF3 although all decreases are substantial when compared to the status quo. In detail, we observe the following:

- All BZs experience a similar demand drop over the summer, starting however at different demand levels. For zone FRF3 in the north-east, demand in winter is around 30,000 MWh and plateauing around 20,000 MWh in summer, while we can observe a demand of around 25,000 MWh in the western zone FRF2 in winter and around 15,000 MWh in summer. Demand in the south-east (FRF1) is even lower with around 18,000 MWh in winter and nearly 10,000 MWh in summer.

- Notably, the monthly average hourly demand in the status quo configuration is less than the monthly average hourly generation for France, as status quo demand in winter in the is around 73,000 MWh and in summer drops down to 43,000 MWh compared to a status quo generation of 83,000 MWh and 55,000 MWh. This relationship remains robust across BZs: On average, generation volume is higher than load also in the reconfigured BZs.

Figure 4.16 Monthly average of hourly demand in the status quo and alternative configuration (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

In line with the generation volume parameter, market size approximated by load tends to show that the proposed alternative configurations are, *ceteris paribus*, likely to aggravate concerns from liquidity metrics compared to the status quo. The alternative BZ configuration in France would lead to significantly smaller market sizes in terms of load.

4.4.3 Market concentration

The analysis of the market concentration for the BZs in the French region uses the average hourly RSI[43] values, averaged across climate years as calculated by the Central European TSOs for each of the BZ alternative configurations. We supplement the analysis with the use of PSI values. For both parameters, we consider three instances to account for the uncertainty of import capacity.

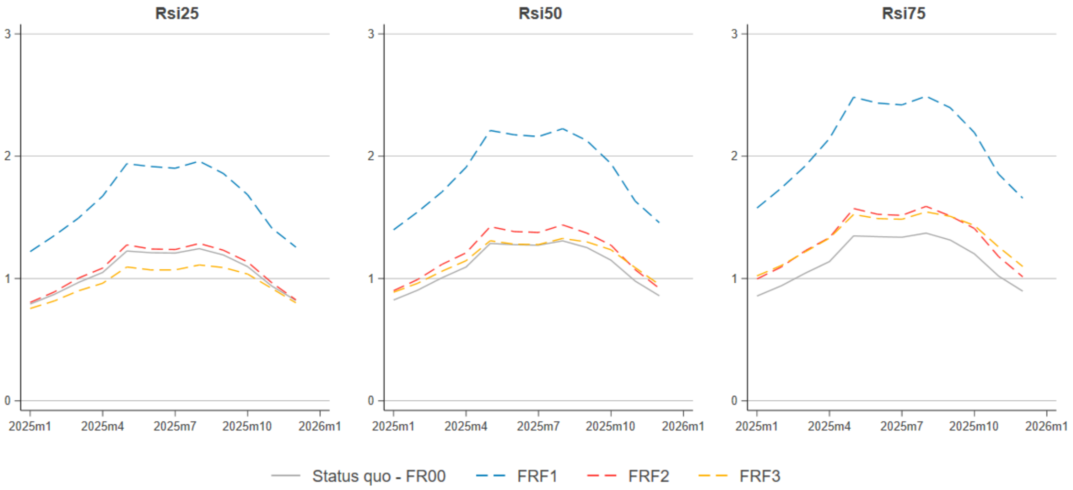
The RSI increases compared to the status quo in all BZ alternative configurations but for FRF3 when assuming a 25% correction factor. In that case, the RSI is also more frequently below 1 as indicated by a ratio of the PSI of 57% compared to a ratio of 39% in the status quo configuration. The increase in RSI shows that the market would overall be less concentrated with the new BZs than in the status quo configuration.

However, the increase in market concentration for FRF3 in case of little import capacity is a noteworthy outlier, as the low RSI indicates substantial market concentration.

Figure 4.17 shows the monthly average hourly RSI values for the different BZs and the status quo for the three instances with different correction factors for import capacity.

[43] Indicative results in the literature on the relationship between RSI and market liquidity are presented in Section 2.2.2.

Figure 4.17 Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration



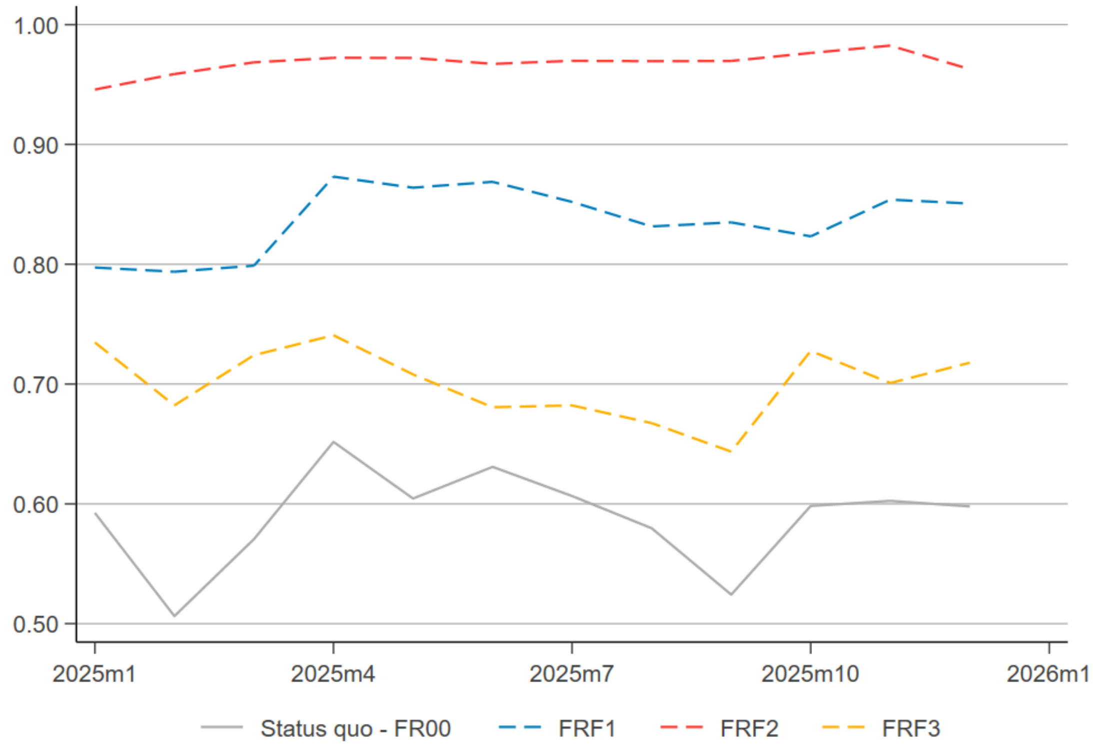
Source: Compass Lexecon analysis of simulated data as provided by TSOs

4.4.4 Price correlations

The price correlation of the French BZs increases substantially in the alternative configurations across all BZscompared to the status quo. While the status quo BZ has a price correlation of ca. 0.59 on average, correlation increases to on average of ca. 0.84 for the reconfigured BZs with a maximum value of 0.97 for FRF2. While this increase is particularly driven by high correlation among the three different French BZs, this effect nonetheless indicates that presumed decrease in liquidity metrics for the short-term markets from the decrease in market size may be (partially) offset by increases in cross-border trade.

Figure **4.18** shows the monthly averages of the price correlation for the different BZs and the status quo.

Figure 4.18 **Monthly average of hourly price correlations in the status quo and alternative configuration**



Source: Compass Lexecon analysis of simulated data as provided by TSOs

4.4.5 Conclusions

Table 4.3 below summarises the observations on the market characteristics parameters across BZs in France in the status quo and the alternative configuration.

Overall, our analysis suggests two opposing effects: While market liquidity metrics for the short- and long-term market would be expected to decrease in line with the substantial decrease of market size per BZ, the decrease of market concentration and increase in price correlation may allow for increased cross-border market participation and therefore heightened liquidity metrics at least for the short-term market. As is the case for Germany, the net effect on liquidity metrics depends on the impact of market size changes and subsequent decisions from market participants. These findings are supported by the following observations:

- Market size as approximated by generation volume and demand decreases across all three zones. Among the reconfigured zones, FRF3 in the north-east is expected to have almost double the size of the western zone (FRF2), despite being geographically half the size. In terms of supply-demand asymmetry, there are no significant changes compared to status quo where electricity generation exceeds demand by about 20%.
- Market concentration as simulated by the RSI is expected to decrease particularly in the south-eastern zone FRF1.
- Price correlation increases in all three zones, but this increase is largely driven by high correlation among the new zones.

Table 4.3 Average and extreme values of liquidity metrics in the status quo and alternative configuration for France

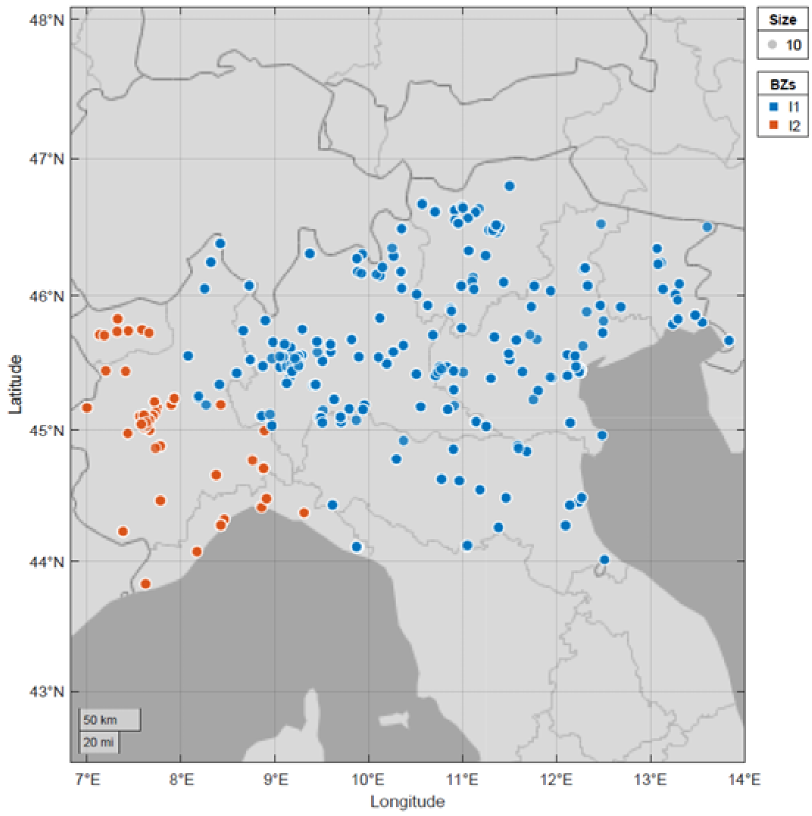
Case	Descriptive statistics	Market concentration			Price correlation	Market Size	
		Rsi25	Rsi50	Rsi75		Generation	Demand
Status quo		**FR00:** 1.05	**FR00:** 1.1	**FR00:** 1.15	**FR00:** 0.59	**FR00:** 65,692	**FR00:** 55,430
Alt config. 5	Max	↑ **FRF1:** 1.64	↑ **FRF1:** 1.87	↑ **FRF1:** 2.11	↑ **FRF2:** 0.97	↓ **FRF3:** 29,748	↓ **FRF3:** 23,863
	Average	↑ 1.23	↑ 1.41	↑ 1.59	↑ 0.84	↓ 21,803	↓ 18,474
	Min	↓ **FRF3:** 0.97	↑ **FRF3:** 1.15	↑ **FRF2:** 1.33	↑ **FRF3:** 0.7	↓ **FRF1:** 14,625	↓ **FRF1:** 14,084

Source: Compass Lexecon analysis of simulated data as provided by TSOs
Note: Demand and generation are presented in MWh/h on average throughout the year. Upward arrows indicate increases compared to the status quo. Downward arrows indicate a decrease compared to the status quo. Green indicates a liquidity metric-enhancing effect. Red indicates a liquidity metric-dampening effect. The displayed averages are annual averages across all BZs in the considered alternative configuration. The displayed minima and maxima show the highest and lowest observed monthly value of the stated BZ. The stated BZ has been identified based on the average annual value of the considered market characteristic parameters.

4.5 Italy simulated data on proposed bidding zones

There is one alternative configuration for the Italian configuration of BZs. The proposal foresees splitting the Northern BZ into two different BZs; one geographically large zone in the east (I1) and one smaller zone in the west (I2). Figure 4.19 displays the reconfiguration.

Figure 4.19 Alternative BZ configuration with two Italian BZs



Note: I1 and I2 are the two newly-defined Italian BZs.
Source: ACER

For the alternative configuration and the status quo configuration, i.e. assuming BZs remain the same, the Central European TSOs simulated hourly dispatch of generation units to meet demand in a Pan-EU model and provided us with simulated hourly values of generation and load volume, RSI and PSI, and wholesale prices for the year 2025 in each BZ. Further, for each alternative configuration, the simulation was carried out for three different climate scenarios, based on the climate observed in 1989, 1995 and 2009. Apart from the Central European BZs, the regional scope of the data provided by the Central European TSOs includes the currently adjacent BZs to the Central European region, e.g. Southern Italy.

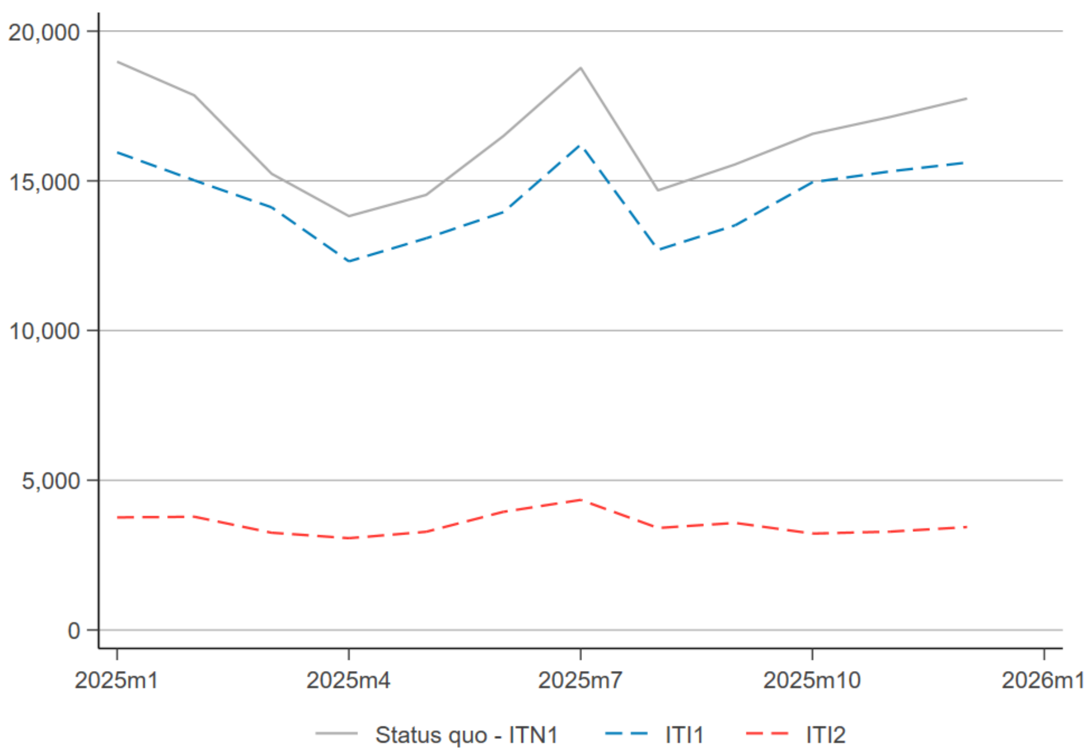
4.5.1 Market size approximated by generation

The generation volume in the western reconfigured zone (ITI2) is significantly lower compared to the status quo while the volume in the eastern zone (ITI1) only decreases slightly.

In detail, the observations when comparing the status quo to the alternative configuration may be summarised as follows:

- The simulated generation volume in the eastern zone ITI1 decreases slightly in comparison to the status quo while the volume in ITI2 decreases by nearly 80%.
- The pattern of monthly average hourly generation remains largely robust across the status quo configuration and the reconfigured zones. Generation volume first decreases from January to April. It then increases again until a peak in Summer, just to drop back and increase gradually until the end of year. This pattern is less pronounced in ITI2. There, the summer peak is stronger while the increase for winter is nearly muted.

Figure 4.20 Monthly average of hourly generation in the status quo and alternative configuration (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

The market size as approximated by generation volume implies a significant decrease for the zones ITI2 while ITI1 only decreases to a limited extend in comparison to the status quo suggesting that, ceteris paribus, also liquidity metrics would be strongly affected by the reconfiguration in ITI2 and only marginally in ITI1.

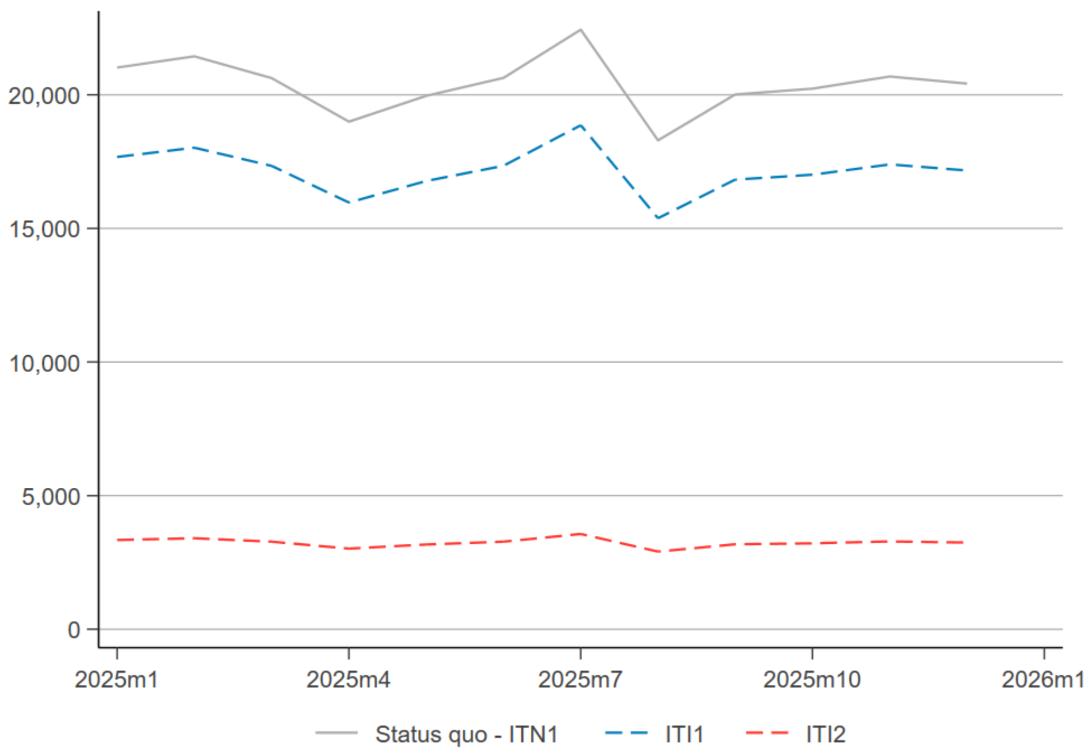
4.5.2 Market size approximated by demand

The market size approximation by demand indicates a similar market size evolution as the approximation by generation. As for generation volume, the market size decreases significantly for ITI2 and to only a limited extent for ITI1 when compared to the status quo. In detail, we observe the following:

- The two reconfigured BZs experience a different demand drop compared to the status quo. Zone ITI1 matches the pattern of demand throughout the year as that of the status quo, starting however around an average Demand of 17,000 MWh per hour in January in comparison to 21,000 MWh of the status quo.

- The simulation results of the smaller, western zone ITI2 show a relatively constant demand between around 3,000 MWh and 4,000 MWh throughout the year 2025. The peak in summer is less pronounced as it is for generation volume.

Figure 4.21 Monthly average of hourly demand in the status quo and alternative configuration (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

It follows that both indicators for market size tend to show that the proposed reconfiguration is likely to decrease liquidity metrics compared to the status quo in the respective zones, assuming no other changes.

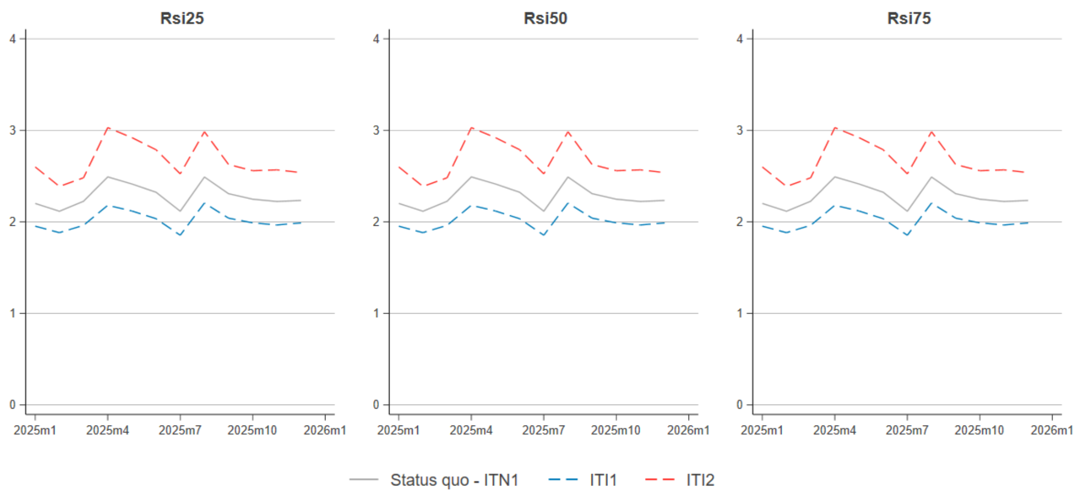
4.5.3 Market concentration

The analysis of the market concentration for the Northern Italian region uses the average hourly RSI[44] values, averaged across climate years as calculated by the Central European TSOs for each of the BZ alternative configurations. We supplement the analysis with the use of PSI values. For both parameters, we consider three instances to account for the uncertainty of import capacity.

The RSI increases compared to the status quo for zone ITI2 and decreases for ITI1 irrespective of the assumed import capacity correction factor. The RSI remains for all BZs significantly above 1 and the PSI is 0 in all instances and for all BZs.

The limited changes in RSI and retention of RSI values well above 1 show that market concentration does not change significantly. This suggests that changes in market concentration are not expected to influence the liquidity metrics significantly. If at all, liquidity metrics would, *ceteris paribus*, slightly increase in ITI2 and decrease in ITI1. Figure 4.22 shows the monthly average hourly RSI values for the different BZs and the status quo configuration for the three instances with different correction factors for import capacity.

Figure 4.22 Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration



Source: Compass Lexecon analysis of simulated data as provided by TSOs

4.5.4 Price correlations

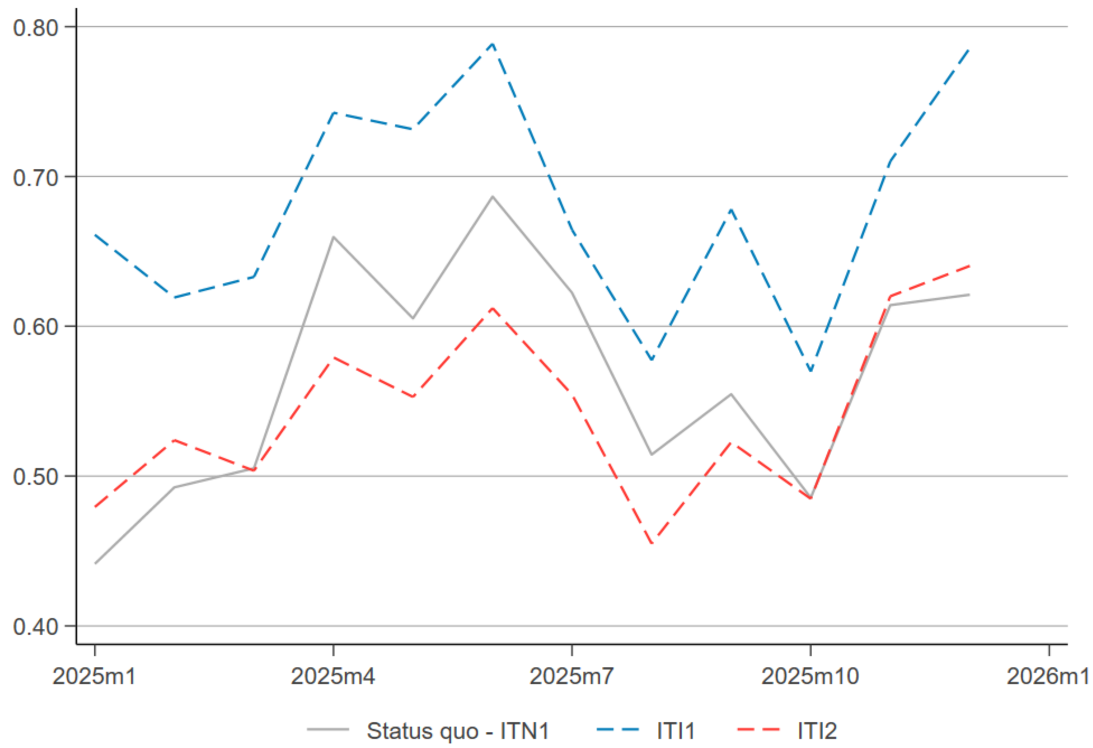
The price correlation of the new northeastern Italian BZ, ITI1, increases compared to the status quo. While the BZ in the status quo has a price correlation of approximately 0.57 on average, correlation increases to 0.68 for the reconfigured BZ ITI1.

Conversely, the price correlation of the new northwestern Italian BZ, ITI2, decreases slightly for most of the periods compared to the status quo, falling on average to 0.55.

[44] Indicative results in the literature on the relationship between RSI and market liquidity are presented in Section 2.2.2.

Figure 4.23 shows the monthly averages of the price correlation for the different BZs and the status quo.

Figure 4.23 Monthly average of hourly price correlations in the status quo and alternative configuration



Source: Compass Lexecon analysis of simulated data as provided by TSOs

4.5.5 Conclusions

Table 4.4 below summarises the observations on the market characteristics parameters across the status quo BZs and in the alternative BZ configurations in Italy .

Overall, our analysis suggests a limited negative effect in market liquidity metrics in both BZs in Northern Italy for both the short- and long-term markets. [45] In particular, the market size of ITI2 implies a decrease in liquidity metrics that is unlikely to be offset by the slight decrease of market concentration, from an already non-critical level. These findings are supported by the following observations:

- Generation and demand in both BZs decrease as a consequence of the reconfiguration in Italy indicating a smaller market size. Notably ITI2, the far smaller BZ, shows significantly lower generation and demand volumes compared to the status quo configuration. Given the changes in both generation and demand, there are no aggravations of supply-demand asymmetries compared to the status quo.

[45] Noting the historic relevance of the DA-market and the PUN mechanism on market liquidity, the identified expected impact on individual BZs may or may not affect the overall liquidity of Italy. The analysis of these indirect effects are out o the scope of this study.

- Market concentration in the smaller zone is decreasing while it is increasing in the bigger BZ.
- Price correlation for the bigger BZ ITI2 remains almost unchanged compared to the status quo while the price correlation slightly increases between the northeastern zone and its neighbours.

Table 4.4 Average and extreme values of liquidity metrics in the status quo and alternative configuration for Italy

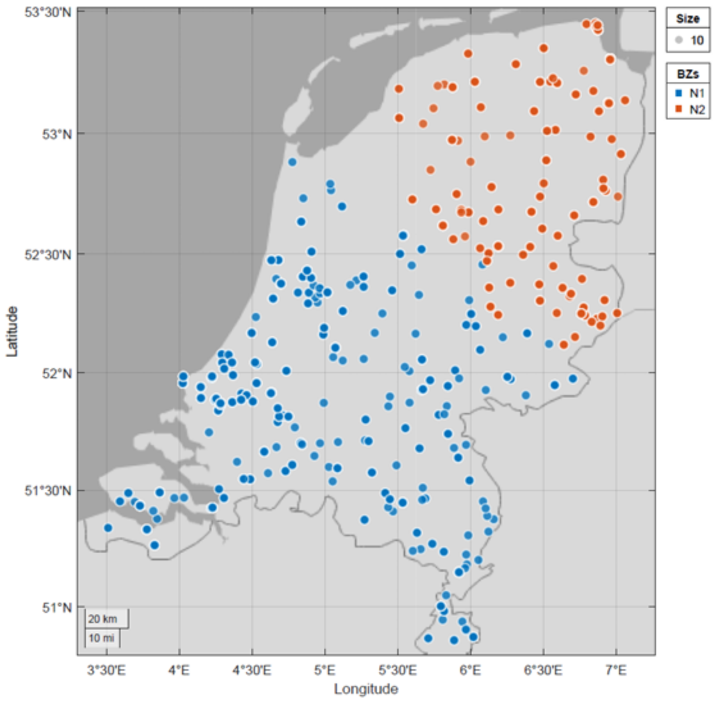
Case	Descriptive statistics	Market concentration			Price correlation	Market size	
		Rsi25	Rsi50	Rsi75		Generation	Demand
Status quo		**ITN1:** 2.28	**ITN1:** 2.28	**ITN1:** 2.28	**ITN1:** 0.57	**ITN1:** 16,447	**ITN1:** 20,399
Alt config. 6	Max	↑ **ITI2:** 2.67	↑ **ITI2:** 2.67	↑ **ITI2:** 2.67	↑ **ITI1:** 0.68	↓ **ITI1:** 14,394	↓ **ITI1:** 17,150
	Average	↑ 2.34	↑ 2.34	↑ 2.34	↑ 0.61	↓ 8,962	↓ 10,196
	Min	↓ **ITI1:** 2.01	↓ **ITI1:** 2.01	↓ **ITI1:** 2.01	↓ **ITI2:** 0.54	↓ **ITI2:** 3,531	↓ **ITI2:** 3,243

Source: Compass Lexecon analysis of simulated data as provided by TSOs
Note: Demand and generation are presented in MWh/h on average throughout the year. Upward arrows indicate increases compared to the status quo. Downward arrows indicate a decrease compared to the status quo. Green indicates a liquidity metric-enhancing effect. Red indicates a liquidity metric-dampening effect. The displayed averages are annual averages across all BZs in the considered alternative configurations. The displayed minima and maxima show the highest and lowest observed monthly value of the stated BZ. The stated BZ has been identified based on the average annual value of the considered market characteristic parameters.

4.6 The Netherlands simulated data on proposed bidding zones

There is one alternative configuration for the Dutch reconfiguration of BZs. The proposal foresees two different BZs: The region NLN1 (N1 in the figure below) would be geographically slightly larger and in the south west of the Netherlands, NLN2 (N2 in the figure below) would be the region in the north east. Figure 4.24 displays the reconfiguration.

Figure 4.24 Alternative BZ configuration with two Dutch BZs



Note: N1 and N2 are the two newly-defined Dutch BZs.
Source: ACER

For the alternative configuration and status quo, i.e. assuming BZs remain the same, the Central European TSOs simulated hourly dispatch of generation units to meet demand in a Pan-EU model and provided us with hourly values of generation and demand volume, RSI and PSI values, and wholesale prices for the year 2025 in each BZ. Further, for each alternative configuration, the simulation was carried out for three different climate scenarios, based on the climate observed in 1989, 1995 and 2009. Apart from the Central European BZs, the regional scope of the data provided by the Central European TSOs includes the currently adjacent BZs to the Central European region.

4.6.1 Market size approximated by generation

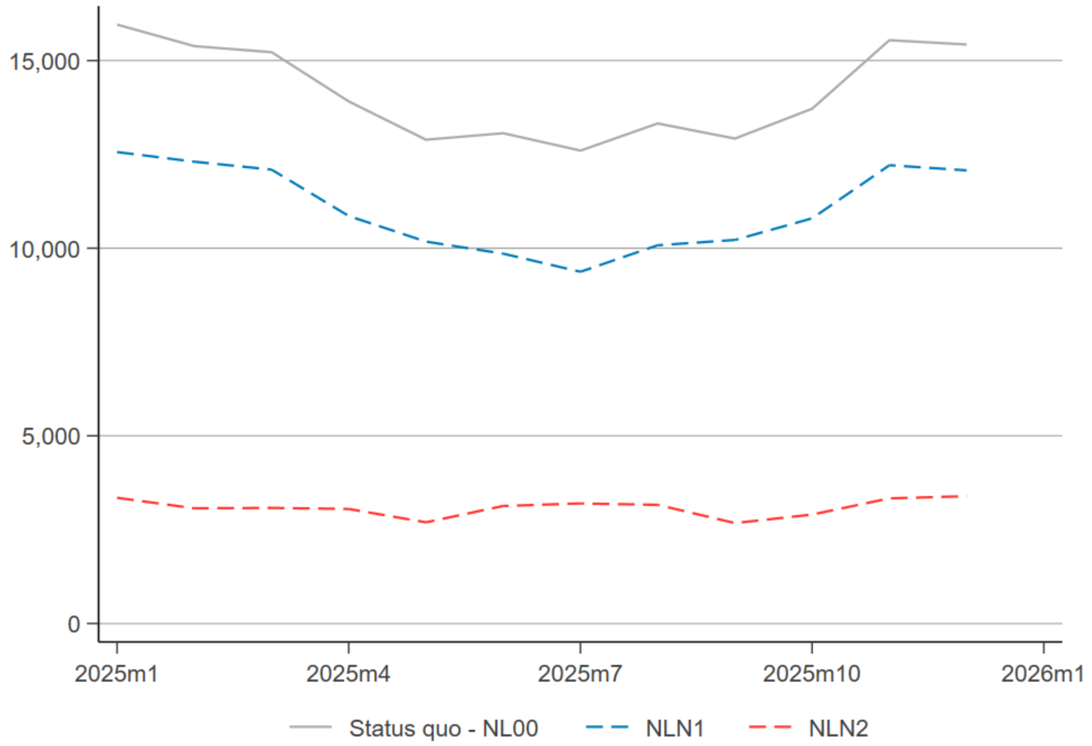
The generation volume in the northern reconfigured zone (NLN2) is significantly lower compared to the status quo while the volume in the southern zone (NLN1) only decreased slightly.

In detail, the observations when comparing the status quo to the alternative configuration may be summarised as follows:

- Generation in the southern zone, NLN1, is simulated to decrease slightly in comparison to the status quo. In contrast, generation volume is expected to be significantly lower in the northern zone NLN2.

- Generation volume in NLN1 follows the generation pattern of the status quo with a decrease in generation towards summer and an increase towards winter, while generation in the northern zone, NLN2, is relatively steady throughout the year. Monthly average hourly generation in the status quo configuration is simulated to decrease within the first half of the year 2025 from on average 16,000 MWh to 13,000 MWh per day and increasing back to around 16,000 MWh in December. Similarly, generation is simulated to be around 13,000 MWh during winter in the southern zone, NLN1, falling to around 9,000 MWh in summer before increasing again to around 13,000 MWh. In contrast, generation in the smaller northern zone, NLN2, is simulated to be rather constant throughout the year between 3,000 MWh and 4,000 MWh.

Figure 4.25 Monthly average of hourly generation in the status quo and alternative configuration (in MWh)



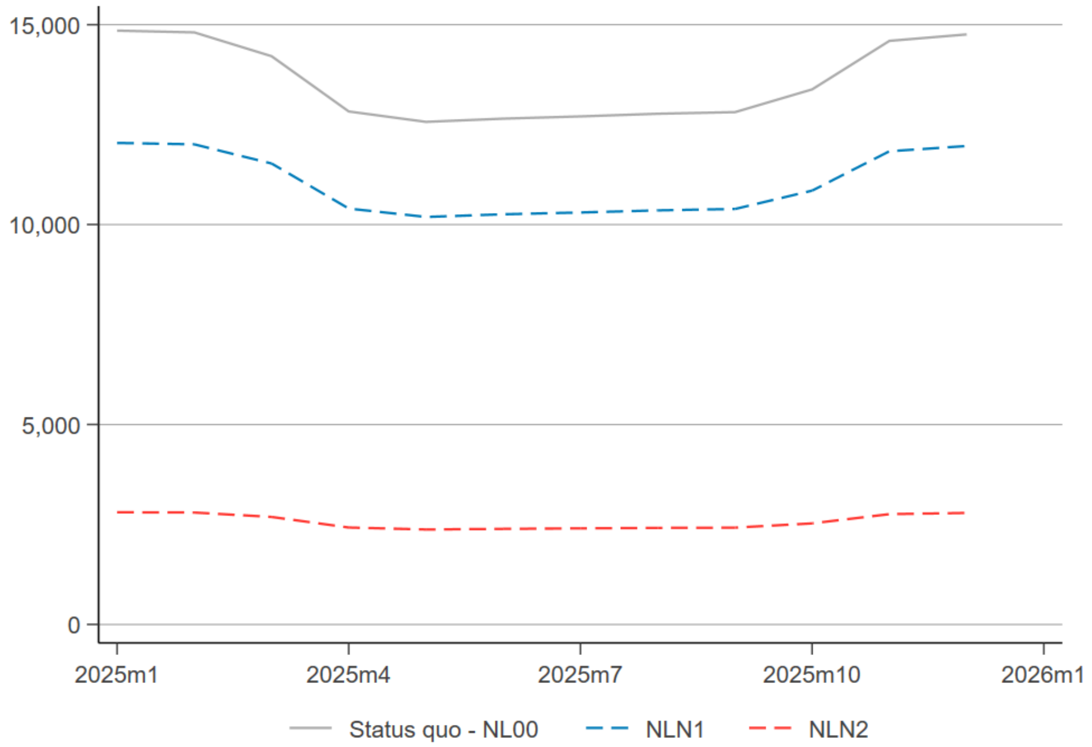
Source: Compass Lexecon analysis of simulated data as provided by TSOs

4.6.2 Market size approximated by demand

The market size approximation by demand indicates a similar market size evolution as the approximation by generation. As for generation volume, the market size decreases significantly for NLN2 and to only a limited extent for NLN1 when compared to the status quo. In detail, we observe the following:

- The parameters indicating market size show a varying decrease across both BZs in comparison to the market size indicators in the status quo.
- The two BZs experience a different demand drop compared to the status quo. Zone NLN1 matches the pattern of demand throughout the year as that of the status quo, starting however around 12,000 MWh of demand in comparison to the almost 15,000 MWh of demand in the status quo.
- The slightly smaller, northern zone NLN2 is simulated to have a relatively constant demand between around 2,500 MWh and 3,000 MWh throughout the year 2025.

Figure 4.26 Monthly average of hourly demand in the status quo and alternative configuration (in MWh)



Source: Compass Lexecon analysis of simulated data as provided by TSOs

It follows that both indicators for market size tend to show that the proposed alternative configuration is likely to decrease liquidity metrics compared to the status quo in the respective zones, assuming no other changes.

4.6.3 Market concentration

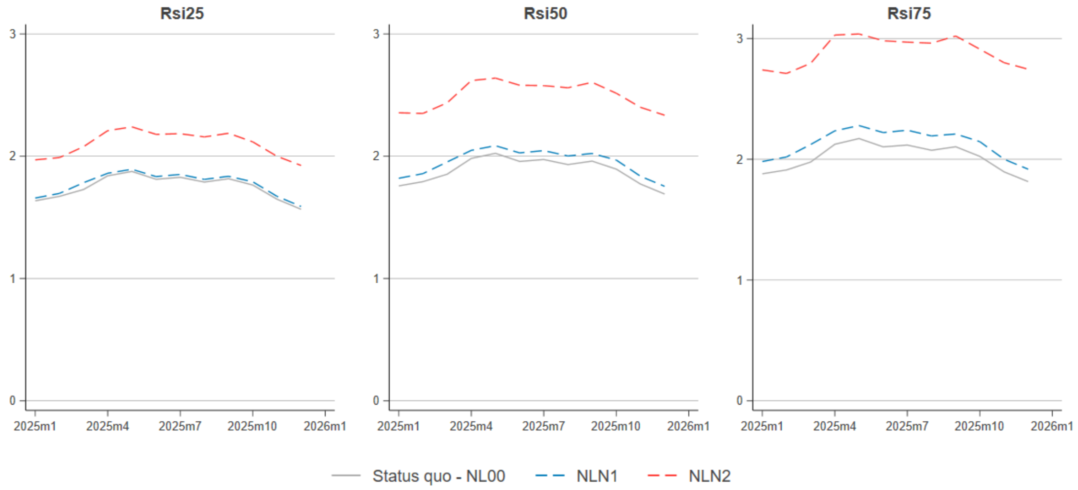
The analysis of the market concentration for the Dutch region uses the average hourly RSI[46] values, averaged across climate years as calculated by the Central European TSOs for each of the BZ alternative configurations. We supplement the analysis with the use of PSI values. For both parameters, we consider three instances to account for the uncertainty of import capacity.

The RSI increases compared to the status quo for both reconfigured BZs. While the RSI only increases marginally for NLN1, the increase in RSI is particularly significant for NLN2 when assuming relatively high import capacity. The RSI remains for all BZs significantly above 1 and the PSI is 0 in all instances and for all BZs.

The limited changes in RSI and retention of RSI values well above 1 show that market concentration does not change significantly in most cases. This suggests that changes in market concentration are not expected to influence the liquidity metrics significantly. If at all, liquidity metrics could benefit from the reconfiguration in NLN2 when high import capacity materialises. Figure 4.27 shows the monthly average hourly RSI values for the different BZs and the status quo for the three instances with different correction factors for import capacity.

[46] Indicative results in the literature on the relationship between RSI and market liquidity are presented in Section 2.2.2.

Figure 4.27 Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration



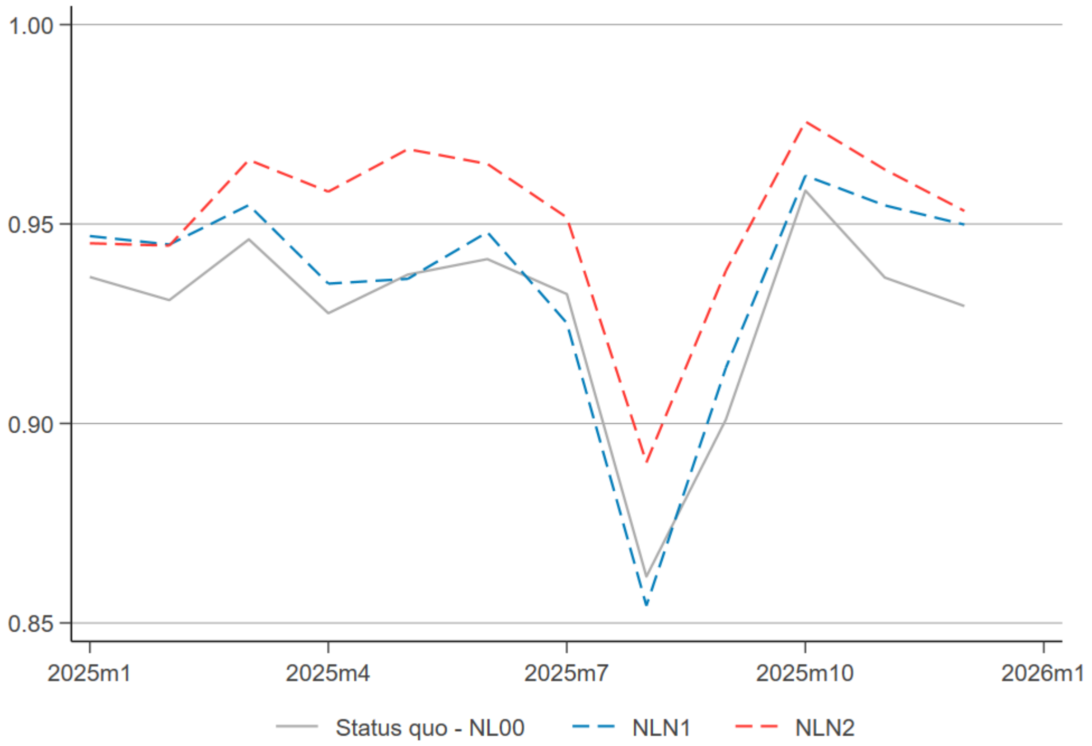
Source: Compass Lexecon analysis of simulated data as provided by TSOs

4.6.4 Price correlations

The price correlation slightly increases for the northern zone NLN1 for all months compared to the status quo and remains largely unchanged in the southern zone NLN2. Considering the already high level of correlation in the status quo and the limited change, the change in price correlation does not provide an indication on expected liquidity metric changes.

Figure 4.28 shows the monthly averages of the price correlation for the different BZs and the status quo.

Figure 4.28 Monthly average of hourly price correlations in the status quo and alternative configuration



Source: Compass Lexecon analysis of simulated data as provided by TSOs

4.6.5 Conclusions

Table 4.5 below summarises the observations on the market characteristics parameters across BZs in the status quo BZ configuration and in the alternative configuration in the Netherlands.

Overall, the analysis suggests a decrease in liquidity metrics for both short- and long-term markets at least in the northern zone of the alternative configuration. Notably, the decrease in market size for the BZs indicates a decrease in liquidity metrics while the limited changes in market concentration and price correlation suggest only limited potential to offset this tendency. This expectation is supported by the following observations:

- Generation and demand, indicating market sizes, decreases in both zones, whereby the northern zone NLN2 declines in market size much more than zone NLN1. Compared to the status quo, there is no significant change in the balance between electricity generation and demand.

- Market concentration decreases in particular in the northern zone NLN2, while the RSI in the South remains largely unchanged. However, pivotality by the PSI is neither expected in the status quo nor alternative configuration.

- Price correlation is slightly improved from an already high level of correlation through the reconfiguration in both BZs.

Table 4.5 Average and extreme values of liquidity metrics in the status quo and alternative configuration for the Netherlands

Case	Descriptive statistics	Market concentration			Price correlation	Market size	
		Rsi25	Rsi50	Rsi75		Generation	Demand
Status quo		**NL00:** 1.75	**NL00:** 1.88	**NL00:** 2.02	**NL00:** 0.93	**NL00:** 14,165	**NL00:** 13,579
Alt config. 7	Max	↑ **NLN2:** 2.1	↑ **NLN2:** 2.5	↑ **NLN2:** 2.89	↑ **NLN2**: 0.95	↓ **NLN1:** 11,051	↓ **NLN1:** 11,011
	Average	↑ 1.94	↑ 2.22	↑ 2.51	↑ 0.94	↓ 7,070	↓ 6,789
	Min	↑ **NLN1:** 1.77	↑ **NLN1:** 1.95	↑ **NLN1:** 2.13	↑ **NLN1:** 0.94	↓ **NLN2:** 3,088	↓ **NLN2:** 2,568

Source: Compass Lexecon analysis of simulated data as provided by TSOs
Note: Demand and generation are presented in MWh/h on average throughout the year. 199 Upward arrows indicate increases compared to the status quo. Downward arrows indicate a decrease compared to the status quo. Green indicates a liquidity metric-enhancing effect. Red indicates a liquidity metric-dampening effect. The displayed averages are annual averages across all BZs in the considered alternative configurations. The displayed minima and maxima show the highest and lowest observed monthly value of the stated BZ. The stated BZ has been identified based on the average annual value of the considered market characteristics parameter.

5 CONCLUSIONS ON LIQUIDITY AND TRANSACTION COSTS

In the context of the BZR of the EU power markets, in application of Article 14 of Regulation (EU) 2019/943, "*a bidding zone review shall be carried out*". As set out in the BZR methodology, one of the criteria to assess is the market liquidity and transaction costs. The objective of the report is to assess the market liquidity and transaction cost criterion for various proposed alternative BZ configurations.

To assess this criterion and following the BZR methodology, we have:

- Reviewed economic literature on liquidity assessment and past BZ reconfigurations, in particular Austria's split from the joint German-Luxembourg-Austrian BZ and the BZR of Sweden.
- Assessed the historic state of liquidity within current BZs through the analysis of liquidity metrics as well as through a correlation analysis.
- Analysed the simulated data provided by the TSOs to assess how BZ reconfigurations may impact liquidity metrics.

5.1 Main findings of the literature review

The literature review suggests that the main relevant metrics to assess liquidity are, amongst others, the traded volumes, the churn rates and the bid-ask spreads. This confirms the indicators suggested in the BZ methodology.

Transaction costs are intrinsically related to liquidity. Low liquidity implies additional transaction costs primarily in the form of higher bid-ask spreads, because they constitute the additional cost a trader incurs for executing the trade. Therefore, the bid-ask-spreads are analysed as an indicator of liquidity but also as a proxy for transaction costs.

Academic literature and industry reports mostly consider that the most important drivers of liquidity are BZ size, market concentration, changes in cross-border network capacity, the share of variable generation assets, and the existence of hedging opportunities, in addition to market design characteristics. More specifically:

- The literature shows a mixed picture regarding the impact of the size of a BZ on liquidity. The size may positively correlate with liquidity due to the increased number of market participants while liquidity of hedging instruments in smaller zones is usually poor. However, other articles and reports conversely conclude on the lack of evidence of a direct relationship between liquidity and the size of the BZ.
- Market concentration has a direct and negative impact on liquidity. It is however difficult to conclude that a BZ split would necessarily lead to a less competitive environment, detrimental

to market liquidity, as this depends on many factors, such as the geographical repartition of assets and demand across the different BZs and the cross-zonal capacities.

- Cross-zonal capacities also play an important role. Firstly, higher cross-zonal capacities stimulate liquidity in the market, e.g. through its positive, i.e. countervailing impact on market concentration. Secondly, it facilitates proxy-hedging, i.e. the ability to hedge in another, more liquid, BZ. Thirdly, available cross-zonal capacity is decisive for liquidity through the use of implicit auctions and market coupling (SDAC and SIDC).

The Austrian/German-Luxembourg BZ-split had a significant effect on long-term market liquidity. While Germany-Luxembourg remains a very liquid market, and the lead-market in central Europe, the Austrian long-term market turned out relatively illiquid. There seems to be no long-lasting negative effect on the liquidity of short-term markets in Germany-Luxembourg. Literature does not provide a view as to how liquidity on the Austrian short-term market has developed in the years after the split.

For Sweden, the BZ reconfiguration appears to have increased liquidity in the short-term market, while the effect on the long-term market is unclear as a range of other factors likely played a role in the evolution of liquidity.

5.2 Main findings as regards the state of liquidity in current EU markets

Liquidity for short-term products has generally been increasing over time in the past years. DA markets concentrate supply and demand in an auction through the market coupling, limiting concerns related to liquidity. Churn rates are higher in markets with various BZs such as Italy and Sweden, as market participants have to go through the exchange to trade across BZ borders. However, liquidity remains low in most intraday markets, although ID liquidity has increased over the past few years in most markets.

As regards long-term products, the German-Luxembourg BZ constitutes the lead market for forward and future products. Its traded volume is substantially higher than in all other BZs and its churn rate has been above 10 over the past years. This is also visible through bid-ask spreads. The difference in liquidity could be explained by the fact that the most liquid markets, Germany-Luxembourg in this case, may be used by market participants to hedge their positions in neighbouring markets (proxy-hedging), concentrating liquidity even further in these markets. The Nordic market has seen a decrease in liquidity both for system price futures and EPADs over the past years with churn rates for EPADs dropping from 5 to 2. Bid-ask spreads, however, remained relatively low for the Nordics throughout the analysed period.

The econometric analysis for short-term markets shows that DA markets with more cross-border participation tend to be more liquid in terms of traded volume and churn ratios, while market concentration measured by the HHI negatively affects liquidity in the DA and ID markets, although the econometric robustness of such relationships is limited by the HHI data granularity. The relationship between BZ size and liquidity is positive in terms of turnover, but – considering the different size of the coefficient per country – subject to other factors such as the market structure.

The econometric analysis for long-term markets shows that larger long-term markets tend to be more liquid in terms of turnover, bid-ask spreads and churn rate than smaller markets. Higher settlement prices or market concentration tend to dampen market liquidity.

Finally, the price correlation analysis shows that price convergence between neighbouring BZs in Italy or Sweden is on average higher than between neighbouring zones of different countries.

5.3 Expected liquidity metric development from BZ reconfigurations

TSOs have modelled the electricity dispatch to meet demand in the current BZ configuration and the alternative BZ configurations as requested in the BZR methodology. This is the input data for this study: simulated data for generation, demand, HHI, RSI and PSI values and wholesale prices in the different BZ reconfigurations.

We have derived parameters from the raw data to approximate market size, market concentration and price correlation for each BZ. Then, we have analysed the parameters in terms of their change between the status quo configuration and the alternative configurations as proposed in ACER decision 11-2022 and in terms of their absolute value. On this basis and noting the relationship between liquidity on the one hand and market size, market concentration and price correlation on the other hand, we have assessed the likely effect on liquidity metrics for the proposed alternative BZ configurations.

The derived assessment comes with several caveats:

- The data for the proposed alternative configurations is limited to the simulation results of a dispatch model. They do not capture the trading dynamics between long-term and short-term markets and do not differentiate trades executed on organised markets or OTC. It follows that we could not perform the same analysis of short- and long-term liquidity that we present in the chapters on historical data. Conclusions on market liquidity were only indirectly inferred from the simulated market data we have available.

- The ensuing liquidity metrics after a BZ reconfiguration may be subject to mitigation measures. The analysis conducted here assumes no mitigation measures, i.e. liquidity metrics of individual BZs if no changes in market design are made. The effect of potential mitigation measures on results and conclusions are out of scope of the current version of this study.

- In the analysis of historical data, we have identified non-linear relationships between market characteristics and liquidity metrics. We have further identified that some of the conceptual relationships between market characteristics and liquidity metrics can, if at all, be captured by linear relationships only to a limited extent. Accordingly, the approach applied here cannot capture the full effect of BZ reconfigurations on changes in liquidity metrics.

- The reconfigurations leading to the alternative configurations assessed here may lead to spill-over effects affecting liquidity in BZs, not directly affected by the reconfiguration. These spill-over effects are not considered in the analysis.

- Finally, the considered relationships between market characteristics and liquidity metrics are not necessarily exhaustive. The analysis of additional market characteristics may further increase the robustness and portray a more exhaustive picture of the potential effects by the BZ reconfigurations.

We have conducted the analysis for the proposed alternative BZ configurations in Germany-Luxembourg, France, Italy, the Netherlands, and Sweden. The analysis aims at evaluating whether market liquidity metrics are expected to be impaired or enhanced, or potentially remains unaffected by the proposed reconfigurations.

The analysis of the market characteristics shows the following:

- **Market size** decreases for most alternative configurations. Only alternative configurations 8 and 9 as well as 11 of the Swedish BZ reconfiguration have either inconclusive effects due to some increases and some decreases for the individual BZs, or are overall increasing due to a smaller number of BZs compared to the status quo in Sweden.

- **Market concentration** as measured by the simulated HHI and RSI is decreasing in most cases or at least remains below critical levels such as RSI values below 1.[47] Notable exceptions are individual BZs in alternative configurations 13 and 14 of Germany and alternative configuration 5 of France. Here, the pivotality of the dominant market player is significantly increasing if import capacity is expected to be largely unavailable.

- **Price correlation** tends to increase for the reconfigured BZs in particular for alternative configurations 5 (France) and 14 (Germany). Apart from this, correlation tends to decrease in those Swedish BZs with the formerly highest correlation.

The changes in market characteristics are used to derive expectations on changes in liquidity metrics for proposed alternative configurations.

The expectations on changes to liquidity metrics, noting the caveats, may be summarised as follows:

- **The Swedish alternative configurations** 8 and 9 see changes in market characteristics that would coincide with overall increased liquidity metrics for both short- and long-term markets. As the positive changes are limited in extent, the direction of change is not consistent throughout all BZs and price correlation slightly tends to decrease, the positive impact would be expected to be limited. The analysis of alternative configuration 10 suggests a noticeable impairment of liquidity metrics for both short- and long-term markets at least for a subset of BZs. The expectation of decreasing market metrics is primarily driven by decreases in market size without strong offsets by other market characteristics such as price correlation. In particular, BZ O3 shows exceptionally small generation volumes and a significant increase in electricity supply-demand asymmetry compared to the status quo configuration. Alternative configuration 11 shows an inconclusive picture with regard to changes in liquidity metrics as some market characteristics change in opposite directions for different BZs and others show very limited changes. Therefore, no tendency for the liquidity metrics for this alternative configuration could be identified for either the short- or long-term market.[48]

- **The German-Luxembourg alternative configurations** are particularly impacted by decreases in BZ market size and related increases in supply-demand asymmetries compared to the status quo configuration. Due to the positive relationship between market size and liquidity metrics,

[47] The results drawn from the analysis of the absolute values should be interpreted with caution as, to our understanding, the ownership data underlying the RSI values is incomplete.

[48] Noting the historic relevance of the DA-market and the Nordic system price on market liquidity, the identified expected impact on individual BZs may or may not further affect the overall liquidity of the Nordics. The analysis of these indirect effects are out o the scope of this study.

this suggests a negative effect on liquidity metrics particurarly for long-term markets.[49] The effect on short-term markets may be partially offset by increases in price correlation and decreases in market concentration. However, it remains inconclusive which change in direction will be decisive for the overall change.

- **The French alternative configuration** shows no clear indication regarding changes in liquidity metrics for the short-term market and a tendency towards impairments of liquidity metrics for long-term markets. On the one hand, market size is decreasing, which would imply decreases in liquidity metrics for both short- and long-term markets. On the other hand, the price correlation parameter increases significantly for all the BZ, which implies increase market integration and therefore increased liquidity metrics for the short-term markets. Besides, France has shown to be a unique case in the analysis of historical data, because the relationship between market size and traded volume in the short-term markets has been relatively inelastic (see chapter 3.2.2).

- **The Northern Italian alternative configuration** suggests a negative effect on liquidity metrics for short- and long-term markets at least in the north-western BZ. This may be derived from the observation of a significant decrease in market size without substantial changes in other parameters that may counter this effect.[50]

- **The Dutch alternative configuration** sees similar changes as the Northern Italian alternative configuration and equally suggests a negative effect on liquidity metrics for short- and long-term markets at least in one BZ. This follows particularly from the market size decreases and the limited increase in price correlation from an already high level.

Notably, these expectations are contingent on the individual decisions of each market participant and the potential introduction of mitigation measures. They are derived from an analysis that has been based on simulated market characteristic parameters and an overall assessment of their directional effect on some key liquidity metrics, acknowledging the possibility of non-linear relationships between market characteristics and liquidity metrics. Thus, the BZ liquidity and its metrics materialising after a BZ reconfiguration may significantly differ from the expectations formed in a “ceteris paribus” analysis based on a necessarily simplified market modelling exercise such as this one.

Table 5.1 shows a detailed summary of these findings.

[49] Noting the historic relevance of Germany as lead market for long-term products, the final effect on liquidty metrics may additionally be significantly impacted by changes in the perception of this lead market. Due to the inconclusive results of the analysis of proxy-hedging as well as the potential impact from mitigation measures, an expectation on the effect from changes in the perception of the lead market cannot be made here.

[50] Noting the historic relevance of the DA-market and the PUN mechanism on market liquidity, the identified expected impact on individual BZs may or may not affect the overall liquidity of Italy. The analysis of these indirect effects are out o the scope of this study.

Table 5.1: Summary of assessed alternative configurations

Countries	ACER identi-fier	Market concen-tration	Price correlation	Market size	Assessment of liquidity metrics of ST markets*	Assessment of liquidity metrics of LT markets*
Sweden	8	Mostly decreasing	Decreasing, but only to a small extent	Mostly increasing	Tendency to **improvement**	Tendency to **improvement**
Sweden	9	Mostly decreasing	Decreasing, but only to a small extent	Mostly increasing	Tendency to **improvement**	Tendency to **improvement**
Sweden	10	Mostly decreasing	Mostly decreasing, but only to small extent	Decreasing	Tendency to **impairment**	Tendency to **impairment**
Sweden	11	Limited change	Decreasing, but only to small extent	Two-sided	**Inconclusive** due to limited changes in market characteristics	**Inconclusive** due to limited changes in market characteristic
Germany; Luxembourg	2	Mostly decreasing	Mostly increasing, but only to a small extent	Decreasing	Tendency to **impairment**	Tendency to **impairment**
Germany; Luxembourg	12	Mostly decreasing	Mostly increasing, but partially to a small extent	Decreasing	Tendency to **impairment,** with potential exceptions for a subset of BZs due to potentially offsetting changes	Tendency to **impairment**
Germany; Luxembourg	13	Mostly decreasing	Mostly increasing	Decreasing	Tendency to **impairment,** with potential exceptions for a subset of BZs due to potentially offsetting changes	Tendency to **impairment**
Germany; Luxembourg	14	Mostly decreasing	Mostly increasing	Decreasing	Tendency to **impairment,** with potential exceptions for a subset of BZs due to potentially offsetting changes	Tendency to **impairment**
France	5	Mostly decreasing	Increasing	Decreasing	**Inconclusive** due to potentially offsetting changes	Tendency to **impairment** in line with

Table 5.1: Summary of assessed alternative configurations

						market size changes
Northern Italy	6	Mostly decreasing	Two-sided	Decreasing	Tendency to **impairment**	Tendency to **impairment**
Netherlands	7	Decreasing	Increasing, but only to a small extent	Decreasing	Tendency to **impairment**	Tendency to **impairment**

Source: Compass Lexecon analysis based on data from the TSOs
Notes: * The conclusions drawn here are solely based on the assessment of the market characteristics and the generalised identified relationships to liquidity metrics as indicated in section 4.1. The BZ liquidity and its metrics materialising after a BZ reconfiguration may significantly differ from the expectations stated here.
Scale for market characteristic assessment:

- "Limited change" – majority of BZs without a change compared to the status quo
- "Increasing" – all BZ changes show an increase
- "Mostly increasing" – most BZ changes show increases, but at least one BZ change shows a decrease
- "two-sided" – same amount of BZ show increases and decreases
- "Mostly decreasing" – most BZ changes show decreases, but at least one BZ change shows an increase
- "Decreasing" – all BZ changes show decreases
- Addition "but only to a small extent" used for upward/downward changes in price correlation that are small (c. 0.01-0.1)

APPENDIX 1: DATA COLLECTION AND DATA USED IN THIS STUDY

The tables below list the historic data used within the study on liquidity and transactions costs as well as the simulated data used for the analysis of expected liquidity metric development from bidding zone reconfigurations detailing the analysis requiring the data and the source providing it. Historic data cover the years 2016 to 2022 if they were attainable.

Historic data

	Analysis	Necessary data	Source
The status quo of liquidity in relevant markets	Traded Volume Churn rates	DA traded volumes by BZ	NEMOs
		Electricity consumption and generation by BZ	ENTSO-E transparency platform
		ID traded volumes by BZ	ACER
State of long-term liquidity in Europe	Traded volume Forward churn ratios	Forward traded volumes by BZ	EEX, NASDSAQ, LEBA
		Electricity consumption and generation by BZ	ENTSO-E transparency platform
	Average of maximum, average, and lowest bid-ask spread per period	First-level tick data for the most frequently traded products	EEX, ICE, and NASDAQ via ICE
Correlation analysis of European markets	Correlation of historical DA prices	DA hourly wholesale prices by BZ	ENTSO-E transparency platform
Relationship between liquidity and competition	Econometric relation of liquidity and competition	HHI for each country/BZ	Eurostat

Simulated data

	Analysis	Necessary data	Source
BZ market size	Future market size per BZ	Load and Generation volume	TSOs

Correlation between BZ	Correlation of future DA prices	Simulated DA wholesale prices by BZ ▪ one future year under three scenarios ▪ BZ pairs with modelled interconnections	TSOs
Relationship between liquidity and competition	Econometric relation of liquidity and competition	HHI and/or RSI/PSI ▪ one future year under three scenarios ▪ for each BZ, in each BZ alternative configuration	TSOs

Compass Lexecon understands that the TSOs made the following methodological assumptions when calculating HHI values: The methodology for calculating the HHI value require TSOs to determine the interconnector capacity between the BZs. This calculation is not straightforward for flow-based capacity calculations since this capacity is given by the RAM values for potentially all CNECs in the capacity calculation region (in this case the Nordics). Nordic TSOs have therefore approximated the corresponding NTC capacity for each of the BZ borders. In addition, the calculation requires TSOs to determine the market price area for each hour. With flow-based capacity calculation, there is never complete price convergence between bidding zones like there can be with NTC. This means that market price areas constituting more than one bidding zone can never be created if all the decimal points in the prices are taken into account. Therefore, when calculating HHI the prices in each BZ have been rounded to the nearest integer. Another assumption (no rounding) would not have affected the results to a greater extent (explanation provided by Nordic TSOs). Compass Lexecon has been provided with HHI values by the TSOs and has not been mandated to do an in-depth methodological review of how to best consider interconnection capacity.

Compass Lexecon understand the PSI as provided by the TSOs uses a binary value that is 1 if the supplier is pivotal, or 0 if the supplier is not pivotal. It measures if one supplier in the market is pivotal, i.e. the demand cannot be fulfilled if the largest supplier withholds its generating capacity from the market. Given that demand changes over time, The RSI uses a continuous scale that measures how much of the demand can still be fulfilled when the largest supplier withholds its generating capacity from the market. An RSI below 1 indicates that the largest supplier is pivotal and has significant market power. The values have been calculated, using a proxy for the import capacity in the CE flow-based region based on the minimum net position. The minimum net position is a common indicator for a flow-based domain, which reflects the theoretical maximum import capacity of a BZ, if the net positions of all zones would be optimized for this. The TSOs have further highlighted when using this proxy however, it should be considered that this theoretical maximum will be an overestimation and should be corrected downwards with a so-called correction factor. The TSOs use three different correction factors (cf), i25, i50 and i75, respectively accounting for 25%, 50% and 75% of the minimum net position of a given BZ in a certain MTU.

In addition, the TSOs provided the following explanation on the source of data: “The calculation of the RSI/PSI and HHI indicators relies on the availability of consistent ownership data across bidding zones. While TSOs gathered the plant ownership data to their best knowledge, it shall be duly noted that significant gaps in the ownership data persist and especially the availability of ownership data for RES is very low. However, one should note that timestamps with high availability of RES usually go along with a high RSI value as the total available generation capacity is particularly high in these timestamps. Next to incomplete ownership data, one needs to acknowledge that for some generation units the owning party is not necessarily the party responsible for the bidding behaviour (especially in case of aggregators for RES). Both aspects, incomplete ownership data as well as lack of information on the party responsible for bidding behavior, set limitations to the study and may result in underestimated market concentration levels for both the status quo and the alternative configurations."

For the Nordics, only HHI values could be provided by the TSOs for technical reasons. For Central Europe, only RSI and Psi values were provided. In general, it would be preferable to also have RSI values available for the Nordics and HHI values for Central Europe.

APPENDIX 2: REGRESSION RESULTS

The following tables summarise the regression results for the analysis of short- and long-term market liquidity. The regression analysis was conducted using data for Germany-Luxembourg, France, Italy, the Netherlands, and Sweden. The considered liquidity metric as well as included explanatory variables are specified in each table.

Day-ahead market: traded volume as liquidity metric

DA traded volume	(1)	(2)	(3)	(4)	(5)	(6)
Total load	0.836***	0.799***	0.794***	0.165***	0.0874***	0.0879***
Share of renewables	225476.9***	158102.1***	147648.9***	63820.1***	9153.4	44135.6***
Flow-weighted price correlation	8253.9	48438.0***			17113.6	5553.4
HHI	-43.95***				-65.03***	-65.85***
Temperature	-146.7	131.7	81.63	-1649.0***	-3889.0***	-3824.0***
IT X Square of temperature	4.919	-4.467	-5.878	97.21***	482.8***	488.1***
DE_LU X Total load	-0.727***	-0.716***	-0.715***			
FR X Total load	-0.767***	-0.735***	-0.728***			
DE_LU	235524.6***	374372.0***	377514.8***	43056.2***		
FR	252130.8***	123244.4***	109891.0***	-246298.1***		
IT	-114697.1***	-11278.8***	-11798.0***	240755.6***		
NL		-228078.0***	-239336.8***	-271595.5***		
Time trend	10.13***	3.752***	6.930***	9.727***	20.27***	
Constant	124518.6***	11174.0*	48539.2***	303184.1***	509973.2***	539003.3***
R2 within	0.712	0.643	0.677	0.255	0.196	0.188
R2 between	1	1	1.000	1	0.959	0.958
R2 overall	0.960	0.973	0.975	0.943	0.843	0.839
Observations	6983	9623	10354	10354	6983	6983

Note: Significance code: '***' p<0.001, '**' p<0.01, '*' p<0.05

Day-ahead market: churn ratio as liquidity metric

DA churn ratio	(1)	(2)	(3)	(4)	(5)	(6)
Total load	-0.000000203***	-0.000000231***	-0.000000210***	-0.000000139***	-0.000000587***	-0.000000587***
Share of renewables	0.128***	0.145***	0.131***	0.145***	-0.0596***	-0.0600***

Flow-weighted price correlation	0.0183*	0.0913***			0.178***	0.178***
HHI	-0.0000532***				-0.0000505***	-0.0000505***
Temperature	0.000973***	0.000434***	0.000479***	0.000622***	-0.00769***	-0.00770***
IT X Square of temperature	-0.0000217***	-0.00000349	-0.0000119*	-0.0000218***	0.000409***	0.000409***
DE_LU X Total load	-4.81e-08***	-3.66e-08***	-6.29e-08***			
FR X Total load	0.000000121***	0.000000131***	0.000000116***			
DE_LU	-0.452***	-0.310***	-0.298***	-0.457***		
FR	-0.611***	-0.728***	-0.746***	-0.661***		
IT	-0.134***	-0.0240***	-0.0355***	-0.0641***		
NL		-0.720***	-0.740***	-0.736***		
Time trend	0.00000248**	0.00000288***	0.00000773***	0.00000693***	-0.000000217	
Constant	1.172***	0.994***	1.052***	1.024***	1.244***	1.243***
R2 within	0.416	0.357	0.338	0.300	0.185	0.185
R2 between	1	1	1	1	0.998	0.998
R2 overall	0.986	0.984	0.983	0.982	0.946	0.946
Observations	6983	9623	10354	10354	6983	6983

Note: Significance code: '***' p<0.001, '**' p<0.01, '*' p<0.05

Intraday market: traded volume as liquidity metric

ID traded volume	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Total load	0.0820***	0.0709***	0.0729***	0.0365***	0.0811***	0.0808***
Share of renewables	72226.7***	40015.0***	41126.3***	34156.7***	84316.5***	102718.1***
Flow-weighted price correlation	19310.8***	15502.1***			-12819.9***	-21119.1***
HHI	-11.30***				-24.46***	-24.72***
Temperature	549.5***	411.9***	399.9***	334.3***	1172.4***	1197.4***
IT X Square of temperature	-32.97***	-27.66***	-30.09***	-24.93***	-64.75***	-62.80***
DE_LU X Total load	0.00349	0.00773*	0.00729			
FR X Total load	-0.0609***	-0.0548***	-0.0560***			
DE_LU	38139.6***	78834.3***	77398.7***	124810.7***		
FR	52993.6***	23766.8***	21097.4***	-17426.9***		
IT	21500.7***	50150.9***	52585.8***	67337.0***		
NL		7646.3***	4270.5***	2445.1***		
Time trend	12.19***	9.339***	8.261***	8.464***	13.86***	
Constant	-38554.3***	-51777.8***	-39357.1***	-24694.1***	14191.5***	36794.3***
R2 within	0.296	0.241	0.230	0.169	0.206	0.129
R2 between	1	1	1	1	1.000	1.000

R2 overall	0.940	0.941	0.938	0.933	0.924	0.915
Observations	6258	8084	8450	8450	6258	6258

Note: Significance code: '***' p<0.001, '**' p<0.01, '*' p<0.05

Intraday market: churn ratio as liquidity metric

ID churn ratio	(1)	(2)	(3)	(4)	(5)	(6)
Total load	-3.88e-08***	-4.06e-08***	-4.06e-08***	-1.52e-08***	4.04e-08***	4.01e-08***
Share of renewables	0.0642***	0.0485***	0.0499***	0.0546***	0.0670***	0.0852***
Flow-weighted price correlation	0.0169***	0.0297***			0.00206	-0.00615
HHI	-0.00000492***				-0.0000196***	-0.0000199***
Temperature	0.0000447	0.000126***	0.0000880**	0.000137***	0.00104***	0.00107***
IT X Square of temperature	-0.0000186***	-0.0000208***	-0.0000233***	-0.0000270***	0.00000826***	0.0000102***
DE_LU X Total load	-3.85e-09	-1.92e-09	-5.57e-10			
FR X Total load	3.44e-08***	3.65e-08***	3.78e-08***			
DE_LU	0.131***	0.144***	0.142***	0.115***		
FR	0.0111***	-0.00241	-0.00869***	0.0165***		
IT	0.0990***	0.109***	0.114***	0.103***		
NL		0.0162***	0.00962***	0.0109***		
Time trend	0.0000104***	0.0000130***	0.0000116***	0.0000115***	0.0000137***	
Constant	0.00916*	-0.0142***	0.0103***	0.0000229	0.0282***	0.0506***
R2 within	0.305	0.358	0.307	0.285	0.0668	0.0164
R2 between	1.000	1	1	1.000	0.972	0.970
R2 overall	0.929	0.916	0.909	0.906	0.859	0.845
Observations	6258	8084	8450	8450	6258	6258

Note: Significance code: '***' p<0.001, '**' p<0.01, '*' p<0.05

Long-term products: minimum bid-ask spread as liquidity metric

Minimum BAS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Intercept	1.966**	-2.46	-6.42**	1.323**	-3.51**	-3.66**	-0.13	-5.18**	-1.50**		
Settlement price	0.007**	0.007**	0.003**	0.007**	0.006**	0.006**	0.006**	0.003**	0.006**	0	0.008**
Total load	-0.02**			-0.01**			0		0.004 *		0
Time trend	-0.00**	0	0.000**	-0.00**	0.000**	0.000 *	-7.78**	0.000**			
Correlation with German spot market prices		0.549**				0.01					
Price difference to German futures			0		-0.00 *			0.001**		-0.00**	0
HHI				8.857**	0	0					0
Share of renewables				0.25	-0.08	-0.53		0.06	-0.03		-0.12
Germany							-0.63**		-0.67**		
Italy							-0.02	-0.1	0		

Netherlands							0.665**	0.524**	0.685**		
Nordics							-0.15**	-0.36**	-0.16**		
R2	0.6438	0.6561	0.7063	0.5872	0.7858	0.7912	0.8585	0.9282	0.8511	0.3309	0.7362
Observations	335	168	228	251	135	117	335	216	335	228	135

Note: Significance code: '***' p<0.001, '**' p<0.01, '*' p<0.05

Long-term products: mean bid-ask spreads as liquidity metric

Mean BAS	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
Intercept	-0.4	-3.12**	-4.72**	-0.81**	-3.41**	-3.57**	-1.92**	-4.63**	-0.74**		
Settlement price	0.006**	0.005**	0.003**	0.007**	0.006**	0.006**	0.005**	0.003**	0.006**	0.003**	0.007**
Total load	-0.00**			-0.01**			0		0		-0.01
Time trend	0	0.000**	0.000**	0	0.000**	0.000**	6.898**	0.000**			
Correlation with German spot market prices		0.07				-0.03					
Price difference to German futures			0.000**		0			0.001**		0	0
HHI				9.461**	0	0					3.501*
Share of renewables				0.686**	-0.06	-0.28		-0.08	0.373*		-0.14
Germany							-0.50**		-0.55**		
Italy							0.01	-0.04	-0.07		
Netherlands							0.159*	0	0.12		
Nordics							-0.17**	-0.25**	-0.20**		
R2	0.6502	0.8514	0.8863	0.7556	0.8324	0.8466	0.8005	0.9254	0.7942	0.5653	0.7202
Observations	335	168	228	251	135	117	335	216	335	228	135

Note: Significance code: '***' p<0.001, '**' p<0.01, '*' p<0.05

Long-term products: churn ratio as liquidity metric

Churn ratio	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	(11)
Intercept	-15.8**	4.45	8.120**	-11.4 *	9.124**	4.97	11.59**	9.833**	4.480**		
Settlement price	-0.01 *	-0.00**	-0.00**	-0.01 *	-0.00 *	-0.00**	-0.00**	0	-0.00**	0	-0.01 *
Total load	0.104**			0.304**			-0.05**		-0.04**		-0.02
Time trend	0.000**	0	-0.00 *	0	-0.00 *	0	-0.00**	-0.00**			
Correlation with German spot market prices		0.02				0.04					
Price difference to German futures			0		0			-0.00 *		0	-0.01
HHI				-0.00**	0	0					0
Share of renewables				0.5	2.19	2.57		1.39	-0.25		1.46

Germany							10.51**		10.36**		
Italy							-0.92**	-0.24	-0.79 *		
Netherlands							-1.68**	-0.14	-1.56**		
Nordics							0.29	0.565**	0.24		
R2	0.1785	0.1632	0.1728	0.5947	0.1666	0.1608	0.9092	0.3212	0.9055	0.0558	0.1870
Observations	340	168	192	253	135	117	340	192	340	192	135

Note: Significance code: '***' p<0.001, '**' p<0.01, '*' p<0.05

Long-term products: overall traded volume (exchange- and OTC-traded) as liquidity metric

Overall traded volume	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Intercept	-799.**	80.55	274.6**	-611.**	213.2 *	159.1	277.6**	263.6**	61.65**		
Settlement price	-0.44 *	-0.12 *	-0.04 *	-0.43	-0.15**	-0.14 *	-0.16 *	-0.01	-0.28**	0.1	-0.45**
Total load	6.301**			14.95**			0.67		0.82		1.125 *
Time trend	0.042**	0	-0.01 *	0.02	-0.01	-0.01	-0.01**	-0.01**			
Correlation with German spot market prices		-9.33				-4.26					
Price difference to German futures			-0.04		0.18			-0.21**		0.194 *	-0.34
HHI				-0.05**	0.006**	0.008**					0
Share of renewables				42.55	35.89	58.98		20.22	11.98		48.26
Germany							434.5**		425.6**		
Italy							-21.9 *	-26.7**	-21.43		
Netherlands							-40.3 *	-51.5**	-37.6 *		
Nordics							11.45	11.78**	7.36		
R2	0.2986	0.0655	0.1610	0.6549	0.2808	0.3235	0.9337	0.7343	0.9320	0.0280	0.4275
Observations	340	168	228	253	135	117	340	216	340	228	135

Note: Significance code: '***' p<0.001, '**' p<0.01, '*' p<0.05

APPENDIX 3: PIVOTAL SUPPLY INDEX OF THE SIMULATED BIDDING ZONES

Average Pivotal Supply Index per (re)configuration and import capacity correction factor

Country	Case	BZ	PSI w/ corr. fact. 25%	PSI w/ corr. fact. 50%	PSI w/ corr. fact. 75%
Germany	0	DE00	0%	0%	0%
	2	DEJ1	0%	0%	0%
		DEJ2	3%	0%	0%
	12	DEJ1	0%	0%	0%
		DEJ2	0%	0%	0%
		DEJ3	3%	0%	0%
	13	DEJ1	0%	0%	0%
		DEJ2	19%	2%	0%
		DEJ3	0%	0%	0%
		DEJ4	0%	0%	0%
	14	DEJ1	0%	0%	0%
		DEJ2	19%	2%	0%
		DEJ3	0%	0%	0%
		DEJ4	0%	0%	0%
		DEJ5	0%	0%	0%
France	0	FR00	39%	33%	29%
	5	FRF1	2%	0%	0%
		FRF2	37%	25%	16%
		FRF3	57%	26%	11%
Italy	0	ITN1	0%	0%	0%
	6	ITI1	0%	0%	0%
		ITI2	0%	0%	0%
Netherlands	0	NL00	0%	0%	0%
	7	NLN1	0%	0%	0%
		NLN2	0%	0%	0%

Source: Compass Lexecon analysis based on data from the TSOs

BIBLIOGRAPHY

ACER. (2013, July 31). *The Influence of Existing Bidding Zones on Electricity Markets.* Retrieved from acer.europe.eu: https://acer.europa.eu/Official_documents/Public_consultations/PC_2013_E_04/PC_2013_E_04%20on%20the%20influence%20of%20existing%20bidding%20zones%20on%20electricity%20markets.pdf

ACER. (2014). *Market Report on Bidding Zones 2014.* Retrieved from https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER%20Market%20Report%20on%20Bidding%20Zones%202014.pdf

ACER. (2020a, November 24). *ACER Decision on the methodology and assumptions that are to be used in the bidding zone review process and for the alternative bidding zone configurations to be considered.* Retrieved from entsoe.eu: https://eepublicdownloads.entsoe.eu/clean-documents/cep/ACER_Decision_%2B_Annexes.pdf

ACER. (2020b, October 21). *ACER Market Monitoring Report 2019 – Electricity Wholesale Markets Volume.* Retrieved from ceer.eu: https://www.ceer.eu/documents/104400/7065288/ACER+Market+Monitoring+Report+2019+-+Electricity+Wholesale+Markets+Volume/60bd97a2-7724-369a-8fe9-57f097340124

ACER. (2020b). *Decision on the methodology and assumptions that are to be used in the bidding zone review process and for the alternative bidding zone configurations to be considered.* Retrieved from https://www.acer.europa.eu/Individual%20Decisions/ACER%20Decision%2029-2020%20on%20the%20Methodology%20and%20assumptions%20that%20are%20to%20be%20used%20in%20the%20bidding%20zone%20review%20process%20and%20for%20the%20alternative%20bidding%20zone%20config

ACER. (2021, February 12). *ACER Market Monitoring Report 2019 – Electricity Wholesale Markets Volume (Document Version 1.2).* Retrieved from acer.europe.eu: https://acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER%20Market%20Monitoring%20Report%202019%20-%20Electricity%20Wholesale%20Markets%20Volume.pdf

ACER. (2022). *Decision No 11/2022 of the European Union agency for the cooperation of energy regulations.* Brussels: ACER.

ACER. (2022). *Decision on the alternative bidding zone configurations to, ANNEX1, List of alternative bidding zone configurations to be considered for the bidding zone review.* ACER.

Balardy, C. (2020, May). *AN EMPIRICAL ANALYSIS OF THE BID-ASK SPREAD IN THE CONTINUOUS INTRADAY TRADING OF THE GERMAN POWER MARKET.* Retrieved from CHAIRE EUROPEAN ELECTRICTY MARKETS Fondation Paris-Dauphine: http://www.ceem-dauphine.org/assets/wp/pdf/CEEM_Working_Paper_35_Clara_BALARDY.pdf

Bonaldo, C., Caporin, M., & Fontini, F. (2021, March). *The Relationship between Day-Ahead and Futures Prices in the Electricity Markets: an Emprical Analysis on Italy, France, Germany and Switzerland.* Retrieved from Universita degli Studi di Padova - economia.unipad.it: https://www.economia.unipd.it/sites/economia.unipd.it/files/20210272.pdf

Bundesnetzagentur. (2017, May 15). *Austria and Germany: agreement on common framework for congestion management.* Retrieved from bundesnetzagentur.de: https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2017/15052017_DE_AU.html?nn=404422

Bundesnetzagentur. (2018, 10 1). *Trennung der deutsch-österreichischen Strompreiszone*. Retrieved from https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2018/20181001_E-Control.html

ČEPS, MAVIR, PSE Operator and SEPS. (2012, March). *Bidding Zones Definition.* Retrieved from sepsas.sk: https://www.sepsas.sk/media2/Dokumenty/Aktuality/2012/03/27/120326_CEPS_MAVIR_PSEO_SEPS-Bidding_Zones_Definition.pdf

Consentec. (2015). *Economic efficiency analysis of introducing smaller bidding zones.* Aachen: Consentec GmbH.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for the Autoregressive Time Series With a Unit Root. *Journal of the American Statistical Association, Volume 74, Issue 366*, 427-431.

DNV GL. (2020). *Liquidity and Transaction Costs - Methodology to Estimate the Impact of a Bidding Zone Reconfiguration on Market Liquidity and Transaction Costs.* Retrieved from ACER Europe: https://www.acer.europa.eu/en/Electricity/MARKET-CODES/CAPACITY-ALLOCATION-AND-CONGESTION-MANAGEMENT/Documents/200406%20DNV%20GL%20report_final.pdf

Economic Consulting Associates. (2015). *European Electricity Forward Markets and Hedging Products – State of Play and Elements for Monitoring.* ACER. Retrieved from https://www.acer.europa.eu/en/Electricity/Market%20monitoring/Documents_Public/ECA%20Report%20on%20European%20Electricity%20Forward%20Markets.pdf

EFET. (2016). *ENTSO-E survey on market efficiency with regard to bidding zone configuration.* Amsterdam: EFET.

EFET, E. (2019, September). *Bidding zones delineation in Europe: Lessons from the past & recommendations for the future.* Retrieved from data.efet.org: https://eepublicdownloads.entsoe.eu/clean-documents/Network%20codes%20documents/Implementation/stakeholder_committees/MESC/2019-09-17/5.2_EFET%20position%20paper_%20BZ%20review_16092019.pdf?Web=1

Eicke, A., & Schittekatte, T. (2022). Fighting the wrong battle? A critical assessment of arguments against nodal electricity prices in the European debate. *Energy Policy*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0301421522004396

ENTSO-E. (2018). *First Edition of the Bidding Zone Review.* Brussels: ENTSO-E.

ENTSO-E. (2018, March). *First Edition of the Bidding Zone Review.* Retrieved from eepublicdownloads.entsoe.eu: https://eepublicdownloads.entsoe.eu/clean-documents/news/bz-review/2018-03_First_Edition_of_the_Bidding_Zone_Review.pdf

ENTSO-E. (2018, March). *First Edition of the Bidding Zone Review - Final Report.* Retrieved from EEPublicDownloads: https://eepublicdownloads.entsoe.eu/clean-documents/news/bz-review/2018-03_First_Edition_of_the_Bidding_Zone_Review.pdf

ESMA. (2019). *Opinion on position limits on EEX French Power Base contracts.* Paris: ESMA, European Securities and Markets Authority.

Eurelectric. (2023, March). *Electricity market design: Fit for Net Zero - Policy recommendations*. Retrieved from https://cdn.eurelectric.org/media/6448/market-design-flagship-final-h-0706B927.pdf

European Comission. (2017). *Commission Decision (EU) 2017/1540 of 15 May 2017 concerning measure SA.40454 2015/C (ex 2015/N) by which France plans to assist the CEB consortium.*

European Commission. (2019). *Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity.*

Gabrielsen, A., Marzo, M., & Zagaglia, P. (2011). *Measuring market liquidity: an introductory survey.* arXiv e-prints.

Glosten, L. R., & Harris, L. E. (1988). Estimating the components of the Bid-Ask spread. *Journal of Financial Economics*, 123-142.

Granger, C. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica, Vol. 37, No. 3*, 424-438.

Greece. (2021). *Market Reform Plan for Greece: Preliminary for consultation only - Subject to Revision.* Retrieved from https://energy.ec.europa.eu/document/download/a2396756-15c7-44b7-8379-e8779484294c_en?filename=greece_market_reform_plan.pdf

Hary, N. (2018). *Delimitation of bidding zones for electricity markets in Europe.* Retrieved from Deloitte: https://www2.deloitte.com/content/dam/Deloitte/fr/Documents/financial-advisory/economicadvisory/deloitte_delimitation-zones-marches-electriques-Europe-et-consideration-des-congestions-internes.pdf

Homayoun Boroumand, R., & Zachmann, G. (2012). Retailers' risk management and vertical arrangements in electricity markets. *Energy Policy*, 465-472.

Laur, A., & Küpper, G. (2020, November). *ASSET Study on Smaller bidding zones in European power markets: liquidity considerations.* Retrieved from Advanced System Studies for Energy Transition - European Commision: https://op.europa.eu/en/publication-detail/-/publication/5fd3daca-a17f-11eb-b85c-01aa75ed71a1/language-en/format-PDF/source-201851317

Menyah, K., & Paudyal, K. (1996). The determinants and dynamics of bid-ask spreads on the London Stock Exchange. *The Journal of Financial Research*, 377-394.

NERA Economic Consulting. (2019, December 16). *GB Wholesale Power Market Liquidity Options Assessment.* Retrieved from ofgem.gov.uk : https://www.ofgem.gov.uk/sites/default/files/docs/2020/01/nera_report.pdf

Ofgem. (2014). *Bidding Zones Literature Review.* Retrieved from ofgem.gov.uk: https://www.ofgem.gov.uk/sites/default/files/docs/2014/10/fta_bidding_zone_configuration_literature_review_1.pdf

Ofgem. (2020, January 30). *Update – Liquidity Policy Review: Publication of NERA Economic Consulting Options Assessment Report.* Retrieved from ofgem.gov.uk: https://www.ofgem.gov.uk/publications/update-liquidity-policy-review-publication-nera-economic-consulting-options-assessment-report

Petr Spodniak, N. C. (2014, May 16). *Efficiency of Contracts for Differences (CfDs) in the Nordic Electricity Market.* Retrieved from SSRN: https://dx.doi.org/10.2139/ssrn.2496889

Pototschnig, A. (2020, May). *Policy Brief - The Importance of a Sound Bidding-Zone Review for the Efficient Functioning of the Internal Electricity Market.* Retrieved from cadmus.eui.eu: https://cadmus.eui.eu/bitstream/handle/1814/67051/PB_2020_22_FSR.pdf?sequence=1

Schittekatte, T., & Pototschnig, A. (2020, June 26). *What English gardens, monkeys and the Titanic have to do with bidding zones - Highlights from the FSR Policy Workshop on The Configuration of Bidding Zones, Liquidity and Competition in the Electricity Market*. Retrieved from Florence School of Regulation - fsr.eui.eu: https://fsr.eui.eu/bidding-zones-configuration-liquidity-and-competition-in-the-electricity-market/

Thema. (2021). *Power Price Risk Hedging Opportunities in the Norwegian Market.* Retrieved from https://www.statnett.no/globalassets/for-aktorer-i-kraftsystemet/utvikling-av-kraftsystemet/power-price-risk-hedging-opportunities-in-the-norwegian-market.pdf

THEMA Consulting Group. (2013, October). *Nordic Bidding Zones - Commissioned by the Swedish Ministry of Enterprise, Energy and Communications / The Nordic Council of Ministers.*

Berlin
Kurfürstendamm 217
Berlin, 10719

Brussels
23 Square de Meeûs
Brussels, 1000

Copenhagen
Bredgade 6
Copenhagen, 1260

Düsseldorf
Kö-Bogen
Königsallee 2B
Düsseldorf, 40212

Helsinki
Unioninkatu 30
Helsinki, 00100

London
5 Aldermanbury Square
London, EC2V 7HR

Madrid
Paseo de la Castellana 7
Madrid, 28046

Milan
Via San Raffaele 1
Milan, 20121

Paris
22 Place de la Madeleine
Paris, 75008

Singapore
8 Marina View
Asia Square Tower 1
Singapore, 018960

Tel Aviv
Yigal Alon Street 114
Toha Building
Tel Aviv, 6744320