ENTSO-E Report

Bidding Zone Review of the 2025 Target Year

April 2025

ANNEX IV

The Impact of Bidding Zone Changes on Liquidity & Transaction Costs

COMPASS LEXECON

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1 Introduction and Overview

Context: Bidding zone review process

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

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

Study objectives

This study aims to assess the market liquidity and transaction cost criterion for various alternative BZ configurations.[1]

The assignment instructed by ENTSO-E and the TSOs for Compass Lexecon comprises 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 transmission system operators (TSOs) will have to assess in the context of the ongoing BZR. The study aims to inform the market liquidity and transaction cost criterion by examining the current state of liquidity and articulating expected changes to liquidity from BZ reconfigurations. This is achieved 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 study seeks to assess the impact of individual BZ reconfigurations on market liquidity and transaction costs compared to the existing BZs.

An important caveat is that the study focuses on market liquidity in each of the BZs individually to the strongest degree possible, and thus does not account for potential cross-border effects on liquidity apart from proxy hedging. In particular, it does not account for potential mitigation measures that might be introduced alongside the BZ reconfiguration. Possible mitigation measures have been discussed in the literature, including introducing trading hubs or allocating standardised transmission rights.[2] Investigating possible mitigation measures and their impact on possible overall conclusions of the BZR process lies beyond the scope of this study. Mitigation measures have been considered by the TSOs in the final BZR report when concluding the assessment of the liquidity and transaction costs criteria. The results presented here incorporate feedback from the public consultation organised by the TSOs regarding the degree of feedback within the study's scope. Some elements such as the potential role of mitigation measures are excluded from this study. Therefore, the results of this analysis can be used in combination with the results of the public consultation to assess whether an alternative BZ configuration is expected to perform better or worse than or

1 This annex has been prepared by a group of experts comprising of Compass Lexecon, ENTSO-E and TSO professionals. The views expressed in this annex are those of this group of experts and do not necessarily represent the views of Compass Lexecon, its management, its subsidiaries, its affiliates, its employees or clients.
The annex is based on information made available to the group of experts at the time of writing and as explained in the annex, it was not part of the scope to audit/verify the underlying data and information. We accept no responsibility for updating the annex or informing any recipient of the annex of any new information.

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

equal to the current BZ configuration regarding 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 was passed by the European Parliament on 11 April 2024 and formally adopted by the Council of the EU on 21 Might 2024. The new EU Directive 2024/1711 and EU Regulation 2024/1747 were published on 26 June 2024 in the Official Journal of the EU and entered into force on 16 July 2024. Given that the implementation of the market design reform remains subject to different timelines and approaches for different market design aspects, the conclusions in this study do not consider these proposed changes. Indeed, this study provides an analysis of the state of liquidity in the EU under the current market design and could be complemented by further analysis of the state of liquidity in EU markets once some of the aspects around long-term market design become more concrete.

Moreover, this study elaborates on practical considerations as required by the BZR Methodology. More specifically, practical aspects are discussed throughout the market liquidity analysis rather than in a separate chapter. These findings are primarily based on interviews conducted with market participants, particularly discussions on practical drivers of trading behaviour. Indeed, following insights from the interviews, the analytical approach was refined to include further relevant market metrics for trading activities (e.g. price volatility, supply-demand imbalance; see chapters 3.1 and 4.1). In addition, questions on practical considerations were asked during the public consultation. As the responses addressed a wide range of topics, they were incorporated into the summary of responses (see Appendix B). As stated in the BZR Methodology, different lead times for implementing alternative BZ configurations were considered throughout the analysis and the study.

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.

Alternative BZ configurations	Region	Member state	Number of BZs	Name of the alternative configuration in the main body of the BZR report
2	Central Europe	Germany – Luxembourg	2	DE2
5	Central Europe	France	3	FR3
6	Central Europe	Italy (Italy "NORD")	2	IT2
7	Central Europe	Netherlands	2	NL2
8	Nordic	Sweden	3	configuration 8
9	Nordic	Sweden	3	configuration 9
10	Nordic	Sweden	4	configuration 10
11	Nordic	Sweden	4	configuration 11
12	Central Europe	Germany – Luxembourg	3	DE3
13	Central Europe	Germany – Luxembourg	4	DE4
14	Central Europe	Germany – Luxembourg	5	DE5
21	Central Europe	Germany; Luxembourg; Netherlands	2 + 2	DE2 + NL2
22	Central Europe	Germany; Luxembourg; Netherlands	5 + 2	DE5 + NL2
23	Central Europe	Germany; Luxembourg; Netherlands	4 + 2	DE4 + NL2

Table 1.1: Summary of proposed and to-be-evaluated alternative BZ configurations in central Europe and the Nordics as presented in Annex I to the ACER decision (November 2022)

Approach and limitations

This study 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 beyond a day-ahead (DA) time frame.[3] These derivatives are over-the-counter (OTC)-traded forwards with or without centralised clearing and exchange-traded futures and correspond to the financial equivalent of the physical power delivery.[4] The delivery periods are typically either annual, quarterly, or monthly. Futures comprise a standardised master contract, while forwards can 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*

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

4 Physical long-term products typically correspond to the obligation to deliver power in a specified BZ for a specified duration in the future.

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 due to expected changes in competition*", and "*a holistic analysis […] to conclude whether a BZ reconfiguration is likely to result in increased/reduced hedging opportunities*" (ACER, 2020 c).

› **Short-term products** are physical products of electricity to be generated or consumed. They can be traded either OTC or via exchange. Short-term markets are either auctions – as is the case for DA markets and recently for intraday (ID) markets – or continuous markets, such as typical ID markets or OTC.[5] Furthermore, DA market dispatch has been implemented for exchange-traded short-term products in the form of single day-ahead coupling (SDAC) and single intraday coupling (SIDC). Thereby, trades for these products are – subject to various conditions – cleared across borders. In the study, we only consider exchange-traded short-term products traded on ID and DA markets, while OTC-traded short-term products are not considered due to data unavailability. This needs to be considered when considering the results shown in this study.[6] For the short-term timeframe, liquidity criteria, evolutions from previous BZ reconfigurations, and "*possible effects of intra-company transactions*" shall be analysed "*at least for the day-ahead timeframe*" (ACER, 2020 c).

Liquidity and transaction costs are grouped in the BZR Methodology criteria, which 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).[7] To assess the impact of the BZ configuration on the liquidity of short- and long-term products, we apply the following three-step methodology:

› First, we conduct a literature review and a series of interviews with active power traders in the market to understand liquidity metrics and their relationship with market characteristics, including the BZ configuration itself. We also leverage the previous experience of BZ reconfigurations. In particular, we review the effects of Austria's split from the joint German–Luxembourg–Austrian BZ in October 2018, as well as the split of the Swedish BZs in 2011.

› Second, we outline the starting point, i. e. the historic state of liquidity in short- and long-term markets within current BZs through directly assessing liquidity metrics and a correlation analysis of DA prices across BZs.[8] We complement this part by analysing the historic relationship between liquidity metrics and selected market characteristics such as market size, market concentration, supply-demand imbalances, and price volatility. We account for underlying historic and market design differences among the BZs by acknowledging such design specifications in the analysis of the respective market products and – where relevant – region-specific analyses for liquidity and relationships with market metrics as such.[9]

› Third, we analyse the simulated dispatch model results including the marginal BZ prices provided by the bidding zone review region (BZRR) TSOs to assess how BZs' reconfigurations might influence liquidity metrics. More specifically, the BZRR Nordic and central Europe TSOs simulated the DA market dispatch of the status quo BZ configuration and the alternative configurations BZ as outlined in the BZR Methodology. Based on this modelling work, we have been provided with the hourly data relative to load, generation by technology type, concentration, and spot prices in the different BZs. Based on these simulation results and the relationships identified between liquidity metrics and market characteristics, we assess the evolution of the market size (load and generation volume), the share of wind- and photovoltaic (PV)-based generation, the supply-demand imbalance, and concentration. Further, we assess changes in spot price correlations between BZs and price volatility. Thereby, we identify whether alternative configurations are likely to improve or dampen liquidity metrics and hedging possibilities in the different BZs given these changes in market characteristics and irrespective of mitigation measures and other factors.

In addition, we conducted interviews with key market participants to gather insights and information on practical considerations in the context of BZ reconfigurations and market liquidity. Overall, we conducted thirteen interviews, particularly with traders and suppliers, as well as retailers, consumers, exchanges, and banks. The interviews focused on discussing:

› factors influencing liquidity on short- and long-term markets (including price volatility, price levels, cross-border correlation, degree of vertical integration, transaction costs);

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5 Note that the existence of auctions or continuous trading is not decisive for DA or ID markets, but rather the time until delivery. Further, additional markets in a short-term timeframe with further specifications also exist, such as the balancing market. They are not considered in this study.

6 Note that the impact of this omission differs between regions as the relative importance of short-term OTC might be high or low.

7 Bid-ask spreads can indicate 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 the best ask (that they ask). Other components might be the inventory cost and adverse selection spreads.

8 The correlation analysis explores the current level of cross-zonal price correlation. It also gives clues for which concrete variables to use (for example correlation to all countries or correlation to specific countries) when using correlation as an indicator for cross-border participation in the regression analysis.

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

- the main drivers influencing the decision to participate in the market;
- the decision to trade OTC or via an exchange; and
- revision of hedging strategy, trading activities, and intra-company transactions in case of a BZ reconfiguration.

The methodological approach and data that we have access to have limitations that call for 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 marketplaces through which electricity is traded (e.g. power exchanges, OTC, or intra-company trade), including differences between short- and long-term products. As a result, the simulation results do not provide the necessary data to compute liquidity metrics; for example, we do not have simulated trading volumes on long- and short-term markets.
- Therefore, the analysis of liquidity can only be conducted indirectly through the relationships between the key market characteristics and liquidity metrics identified in chapter 2, linking liquidity with market size, market concentration, price volatility, supply-demand imbalance, and the participant mix, as well as price correlations, which inform the potential increase in market depth from cross-border trade. In this context, it is important to consider that these relationships were established based on historical data and under specific market design conditions. They might 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 data provided. In particular, the study has the following limitations, which might 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. We do not explore mitigation measures and their potential impact on the conclusions regarding an improvement or deterioration of liquidity and transaction costs.
  - Given that we were unable to obtain data on the ID OTC market, we currently cannot assess how much liquidity that market provides and how that could be affected by a BZ split. We have also not obtained ID-exchange data besides daily traded volumes.
  - At present, another OTC long-term market is developing dynamically, namely the market for power purchase agreements (PPAs). We do not assess the impact of a potential BZ split on the PPA market. 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 the overall costs of PPAs and negatively affect liquidity.

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

Study outline

This study is structured as follows:

- Following this **introduction, Chapter 2** summarises the literature review and interview results on liquidity metrics, their 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. For this purpose, we describe the level of liquidity in terms of a) liquidity metrics, b) relationships between liquidity and market characteristics c) retail risk premiums, and d) price correlation between BZs.
- In **Chapter 4**, we assess whether the proposed alternative BZ configurations are expected to see increased, similar, or reduced levels of liquidity compared to the current configurations.
- In **Chapter 5**, we present a summary of the findings and the conclusions.

2 Definitions and Drivers of Liquidity According to Literature and Practitioner Interviews

This chapter reviews a selection of academic articles and industry reports on metrics for market liquidity and presents the findings of a series of interviews with active power traders on identified and alleged relationships between different market characteristics and liquidity metrics and the effects on the liquidity of past BZ reconfigurations. This chapter informs the liquidity study approach by discussing how liquidity can be directly or indirectly assessed through different liquidity metrics, as well as their relationship with market characteristics. It also provides qualitative insights into how BZ reconfigurations can influence liquidity.

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

The section is structured as follows:

- First, we reviews the definitions and metrics for liquidity and transaction costs proposed in the literature.
- Second, we review how market characteristics and liquidity can be linked according to previous work and papers and appraisals from market participants, exploring the drivers of liquidity.
- Third, we consider how market characteristics consequently affect hedging possibilities.
- Finally, 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 of liquidity and transaction costs

Liquidity can 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 can 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).

Different metrics have historically been used to estimate and evaluate the state of liquidity in a market.[10] Each of them relates to a different aspect of the market and covers parts of the liquidity concept. Table 2.1 summarises these metrics:

Metric	Definition
Turnover	The total traded volume or value generated over a specific timeframe, reflecting the 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 that a churn of at least 300 % is required for a [power] market to be considered liquid (Economic Consulting Associates, 2015).
Market depth	A market's ability to absorb orders without them drastically affecting prices.
Bid-ask spread	The difference between the lowest selling price and the highest buying price. It is a direct measure of transaction costs for a specific instrument and should remain low (EFET, 2016).[11]
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 might 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.

Table 2.1: Metrics for measuring market liquidity

A report on the assessment of the Nordic forward electricity market[12] 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.[13]

Depending on the specific market, these criteria differ in relevance and applicability. For instance, the time to maturity is only relevant for markets with continuous trading. The churn rate of the DA auctions might lack explanatory power as a liquidity criterion if participation in such auctions is mandatory for all generation and demand because it is therefore automatically "*equal to one*" (ACER, 2021, p. 38).

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 can be measured by a) the number of bids, b) the price correlation between adjacent BZs, and c) bid-ask spreads.

Transaction costs are "*intrinsically related*" to liquidity (ACER, 2020 a). 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 bids and offers close to the market price. These spreads are transaction costs because they constitute the additional costs that a trader incurs for executing the trade.[14] Therefore, the bid-ask spreads are analysed in this study as a liquidity criteria and a proxy for transaction costs.

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

11 EFET (2016). ENTSO-E survey on market efficiency regarding bidding zone.

12 NordREG (2020): Methodology for assessment of the Nordic forward market.

13 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 was originally developed to analyse the (il)liquidity of stocks. This illiquidity ratio aims to show the price impact of each traded Euro and is a commonly used liquidity measure. In an illiquid market, a large buyer will drive up the market price while a large seller will lower it. The premium that the buyer and seller have to pay is called the price-impact cost, which is what this ratio tries to capture.

14 For instance, if the spread is 0.1 Euros, as the highest bidder, you would need to incur an additional cost of 0.1 Euros 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), 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 to sell (buy) it again(unless new bids (asks) become available).

2.2 Relationships between market characteristics and liquidity

In addition to measuring metrics characterising different liquidity aspects, a liquidity assessment might also be indirectly derived from some market characteristics that typically go hand-in-hand with liquidity metrics.

In academic literature and industry reports, structural market characteristics that are most strongly considered as drivers of liquidity include BZ size, market concentration, and network capacity.

In interviews with industry experts and active traders and through feedback from the consultation, several specifics of supply, demand, and market dynamics were also highlighted as key factors influencing market liquidity, such as the supply-demand balance, participant mix (e.g. the share of variable generation assets), and spot price volatility.

Below, we provide a more thorough description of how these different market characteristics affect liquidity.

2.2.1 Bidding zone size

First and foremost, a BZ reconfiguration might influence the BZ size.[15] On the one hand, literature confirms a positive relationship between BZ size and liquidity for long-term products. The size might 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 studies argue that "*merging bidding zones […] might 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). In the last BZR in 2018, stakeholders expected that in general liquidity would decrease when the BZs in discussion were split (ENTSO-E, 2018). In the EU ASSET study, Laur and Küpper (2020) conclude that "*more zones would translate into more fragmented, possibly less liquid forward products*" (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). However, it has also been highlighted that smaller zones should not be expected to be detrimental to liquidity and limit trade opportunities because they would allow more efficient use of the existing transmission capacity, leading to better price correlation between BZs. In particular, ČEPS, MAVIR, PSE Operator and SEPS (2012) consider that in the case of a BZ split, market liquidity might be improved because "*unplanned transit flows would instead become market-controlled flows*". For the same reason, Schittekatte and Pototschnig (2020) consider that "*the claim that smaller bidding zones would lead to lower market liquidity is not thoroughly substantiated and mainly relies on illustrative or anecdotal evidence that is rather inconclusive*".

On the other hand, some literature questions this relationship, particularly 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 and the liquidity of the day-ahead market*". Liquidity is more strongly influenced by the market structure, design, and concentration (ibid.). This is also corroborated by Laur and Küpper (2020) who – while acknowledging observations for "*absolute liquidity drops […] where smaller BZs were implemented*" – explain that small BZs "*are not necessarily a fundamental driver of lower liquidity*" (p. 6). Along these lines, ACER (2014) 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. Pototschnig (2020) elaborates on the case of physical limitations and argues that smaller BZs do not necessarily imply a reduction of liquidity. DNV GL (2020) 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*".

Moreover, BZ reconfigurations might influence intra-company transactions. Indeed, for instance, upstream and downstream activities of vertically integrated companies might be affected differently by a BZ split, forcing them to go through the exchange to trade across zones (ibid.). This could positively affect volume trading on the exchange but also increase transaction costs for such companies.[16]

15 The definition of "BZ size" is not fully conclusive but it can 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 entire spectrum of the market size.

16 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.

The literature and reports discussed suggest that there might be a positive relationship between BZ size and liquidity for long-term products, although some question this relationship and argue for a limited relationship – if at all – for short-term products. Concerning the latter, it has been highlighted 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 (2020), "*weak competition and high potential to use market power increase uncertainty about short-term as well as forward prices and might cause low liquidity in all timeframes [which might] […] deter new entrants and frighten some incumbents to terminate or constrain their activities*" (p. 4). The European Commission (2017) states that market power "*contributes to a loss of liquidity*" (p. 29). Similarly, Pototschnig (2020) concludes that competition "*might impact liquidity more than the dimension of bidding zones*". We empirically analyse this relationship in the next chapter.

Pototschnig (ibid.) further highlights that larger BZs might only appear to enable more competition, although if the zonal configuration does not reflect grid restrictions, market power will still emerge but shift to short-term markets in which the intra-zonal congestion is resolved, e. g. redispatch markets.

Furthermore, some reports disagree with some stakeholders' view that smaller BZs might lead to increased market power (ČEPS, MAVIR, PSE Operator and SEPS, 2012). In particular, Schittekatte and Pototschnig (2020) suggest that "*smaller bidding zones do not lead to lower levels of competition… Within large bidding zones, market power is pushed to real-time as physics always wins. Market players anticipating real-time will adjust their bidding strategy in preceding markets to profit from the inconsistency between markets and physics. With smaller bidding zones, possibilities to exercise market power will be more transparent and, as such, easier to mitigate*".

Beyond market concentration within a BZ, Laur and Küpper (2020) stress the need to consider competition at the borders. Splitting an internally congested BZ might actually increase cross-border capacities– at least relatively to the BZ size – whereby competition might actually increase due to more cross-border parties participating in the smaller BZs.[17]

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

- 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 might affect the competition and contestability of more dominant players through imports and exports.

While the literature has alluded to the relevance of market concentration, it is difficult to conclude in general that a BZ split would necessarily lead to a less competitive environment that is 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 unable to obtain suitable data, we have not been able to further explore this relationship empirically.[18]

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

18 We tried to obtain 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 did not receive any responses. Second, we collected data on European electricity retail prices from Eurostat, although such data also contain taxes and network fees, we were unable to isolate a reliable retail margin.

2.2.3 Network capacity

A third potential relationship pertains to network capacity, in particular cross-border capacity. According to DNV GL (2020), the "*liquidity benefit of a larger BZ is lost if intra-zonal congestions make some bids unavailable*" and redispatch has to be used in its stead. Such congestions have also occasionally led to restrictions on cross-border ID 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, p. 9).[19]

However, if a BZ reconfiguration improves the accurate representation of network constraints, it can highlight 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 the discussion on BZ size for long-term products).

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

In forward markets, larger BZs might be relevant for improving liquidity and facilitating hedging (DNV GL, 2020) 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 Economic Consulting (2019). Their assessment of the relatively low churn ratio in Great Britain compared to other European countries suggests that a limited ability to trade across borders harms the liquidity of long-term product markets and hedging opportunities. The ability to hedge across borders depends on the possibility of hedging the risk of price divergence in the short term. Without timely cross-zonal capacity allocation, forward markets might offer price differential hedging products, although their liquidity might also be limited (see the next chapter on the electricity price area differentials (EPADs) on the Nordic market).

By default, market participants might resort to proxy hedges instead of acquiring a hedge through long-term products in their delivery BZ, through products in other BZs that are more liquid and whose spot prices are strongly correlated with the spot price of the delivery BZ. These might 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 using closely correlated BZs.

Against this background, it seems that various matters directly and indirectly influence BZ reconfigurations and market liquidity. In Ofgem's (2014) 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*".

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

Overview of relationships between structural market characteristics and liquidity highlighted in the literature on bidding zone configurations

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 timeframe considered. Indeed, primarily due to the different state of implementation of DA market dispatch in short- (i.e. DA or ID) or long-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- and short-term products.

Long-term markets

In cases with a geographical area **without structural network constraints**, the liquidity of long-term products would tend (everything else being equal) to benefit from a single BZ within this area. Since there is no structural network constraint, prices would generally reflect the physical reality of the underlying network (except in the case of an unplanned event leading to 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. Since there is no system like implicit DA market dispatch 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 with 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 they would not help to steer 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, although this would reflect the physical reality of network constraints and provide more correct price signals in forward markets.

Independently of the structural network congestion within the geographical area, a split of a BZ could increase the capacity on the borders of the resulting BZ since some part of the uncontrolled transit flows and loop flows would become controlled by the market. As a result, overall liquidity might increase as cross-border trade might flow more easily.

Therefore, 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 now considering short-term markets, the analysis in the literature is different due to the impact of market coupling that allows implicitly factoring in network constraints in determining the price.

In cases of geographical areas without structural network constraints, liquidity would likely not be substantially affected whether it is a single or 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 the case 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 DA and ID markets are organised in one large BZ, liquidity would likely be higher than in the case of split BZs. However, 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 only undertaken 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 better reflect the physical reality of the area, if the BZ delineation corresponds to the constraints. This means that a dispatch solution respecting the limits of the network would already be achieved due to the DA and ID trading.[20]

20 The discussion of the relative advantages and inefficiencies associated with DA market dispatch and the need for redispatch lies beyond the scope of this study.

2.2.4 Supply-demand balance

Market participants indicated that the balance between supply and demand within a BZ is a key factor influencing market liquidity. An imbalance might affect liquidity for several reasons:

a. **Difficulty finding trade counterparts:** In cases where either supply or demand dominates, potential buyers or sellers might struggle to find a counterpart for transactions. This can force participants to rely on a small number of market players or strongly depend on cross-border capacity. This increases the market power of the relatively scarce market participants and might impede market liquidity.

b. **Wider bid-ask spreads:** A market dominated by either suppliers or buyers might experience wider bid-ask spreads. In the case of low demand, fewer bid orders are present, while fewer asks are available in the case of limited supply. This reduced availability of counterparties diminishes competition and consequently the pressure to narrow the spreads.

c. **Reduced market depth:** In imbalanced markets, liquidity becomes concentrated in one direction, meaning that fewer orders are available to absorb market movements, reducing the depth and robustness of the market.

The southern Swedish BZ SE4 is often used as an example to highlight the negative impact of supply-demand imbalance on market liquidity. In SE4, generation capacity falls significantly short of consumption. In 2021, electricity generation was 7.1 TWh, while consumption reached 23.2 TWh (excluding grid losses; Holmberg & Tangeras, 2023). This imbalance has arguably affected the retailers' ability to hedge and thus the availability of fixed price retail contracts for consumers. In 2022, only 16.4 % of contracts in SE4 were fixed price, compared to 25.7 % in SE2 and SE3, and 40.3 % in SE1 (ibid.).

2.2.5 Market participant mix

In addition to the overall balance of supply and demand, the share of variable generation assets – such as wind and solar power – has been identified as affecting market liquidity, at least via impacts on volatility (Eicke & Schittekatte, 2022). Variable generation assets introduce increased fluctuation and uncertainty into the market due to their reliance on weather conditions, leading to greater output volatility and the expected market price. This dynamic affects liquidity by increasing the need to adjust trading positions, particularly in short-term markets.

More generally, interview partners highlighted that the diversity of market participants influences liquidity. A diverse mix of participants – including utilities, independent power producers, proprietary traders, and industrial consumers – each have different trading needs, capabilities, and strategies. A more varied participant base thus provides a broader range of trading strategies and liquidity, ensuring that more trading opportunities exist and that market participants are more likely to find suitable trade counterparts. This diversity arguably reduces bid-ask spreads and enhances overall market depth, making the market more robust to shocks.

Sufficient liquidity is often considered a minimal requirement for proprietary traders to open positions on a market, reflecting a channel that might lead to self-reinforcing properties of liquidity.

2.2.6 Price volatility

Market participants further explained that price volatility influences market dynamics and trading behaviour. It affects margining requirements, hedging strategies, and how traders manage their positions, thereby influencing market liquidity. Depending on the specific market and market participant mix, increases in volatility might imply either increases or decreases in liquidity. More specifically, price volatility influences liquidity through the following channels:

- **Impact on margining requirements:** The calculation of margin requirements uses historical volatility as one of the parameters. Furthermore, margin calls become more likely with increasing price volatility. Increased volatility therefore implies higher margining requirements and a higher risk of margin calls, which might lead to higher capital requirements for traders. This means that traders reach internal limits on trading earlier, restricting their trading activity.
- **Hedging policies:** Market participants might adjust or revise their hedging policies to account for changes in price volatility to reduce risk exposure. Depending on the change, this might imply more or less hedged – and with it trading – volume.
- **Position adjustments:** Price swings might imply that traders rebalance their portfolios or take on new positions to manage exposure or seize new opportunities.
- **Proprietary trading opportunities:** Volatility might allow proprietary traders to identify profit opportunities from price fluctuations, sometimes leading to an increased engagement of prop traders.

Zooming in on asset-based and proprietary trading

The series of interviews with market participants has provided further insights into the relationship between specificities of supply and demand and market liquidity. In particular, this text box focuses on the primary objective of the trade, whereby a general distinction between proprietary (prop) trading and asset-backed trading can be made:

- Asset-based trading is trading on behalf of asset owners (origination) or due to direct asset ownership. Participants with their own assets tend to use the long-term markets to hedge expected output and demand based on their hedging policy.[21]
- Proprietary trading implies taking positions in long- and short-term electricity markets to profit from the expected price movements and price arbitrages without the objective of hedging the market exposure of a specific physical asset.

It is important to note that these trading strategies are not mutually exclusive, and market participants can engage in multiple forms of trading, with overlapping patterns depending on their strategic goals and portfolio needs.

A recent survey conducted by Svenska Kraftnät (SVK) for the Nordic market revealed that approximately 50 % of participants engage in generation asset-backed trading, while 25 % to 30 % are involved in consumption asset-backed trading (Svenska Kraftnät, 2024). Around 25 % of participants operate without asset backing, focusing on proprietary trading.

Asset-backed trading in long-term markets

Participants with their own assets tend to use the long-term markets to hedge expected output and demand based on their hedging policy.[22] Originators act similarly, but do so for third-party assets.

A hedging policy is designed in light of both internal and external factors:

- **Internal factors** include specific elements of the individual business, such as:
  - **Target risk exposure:** This refers to the company's ability to pass through costs to consumers and willingness to maintain stable cash flows.
  - **Portfolio technology mix:** This refers to the types of assets that they operate, such as "must-run" generators, flexible assets, and variable renewable assets, as well as the geographical location of these assets and their associated load profiles.
- **External factors** stem from conditions beyond the business's control, including:
  - **Market price risk**: Exposure to price levels, price volatility, and basis risk.
  - **Market liquidity risk:** The ability to adjust positions without incurring significant transaction costs.
  - **Counterparty risk:** The likelihood and cost given default of credit default from trading partners.

These factors shape hedging policies, which vary in terms of how much capacity is hedged versus being left open to market conditions (free capacity). For instance, portfolio strategies consider netting supply and demand positions or leveraging cross-border trades to manage risk.

Hedging policies are relevant for market liquidity as they are executed through trades. For instance, adjustments might be made if the underlying assets change or market conditions shift, requiring new positions to be opened or closed. A **BZ reconfiguration** can influence both internal and external factors, requiring firms to revise their hedging strategies accordingly.

21 In this context, "assets" refers to both generation and consumption assets.
22 In this context, "assets" refers to both generation and consumption assets.

Asset-backed trading in short-term markets

Participants with their own assets primarily engage in short-term markets to buy or sell electricity and balance their portfolio schedules, while origination performs similar activities on behalf of third-party assets. Their level of participation varies based on both market and generation expectations:

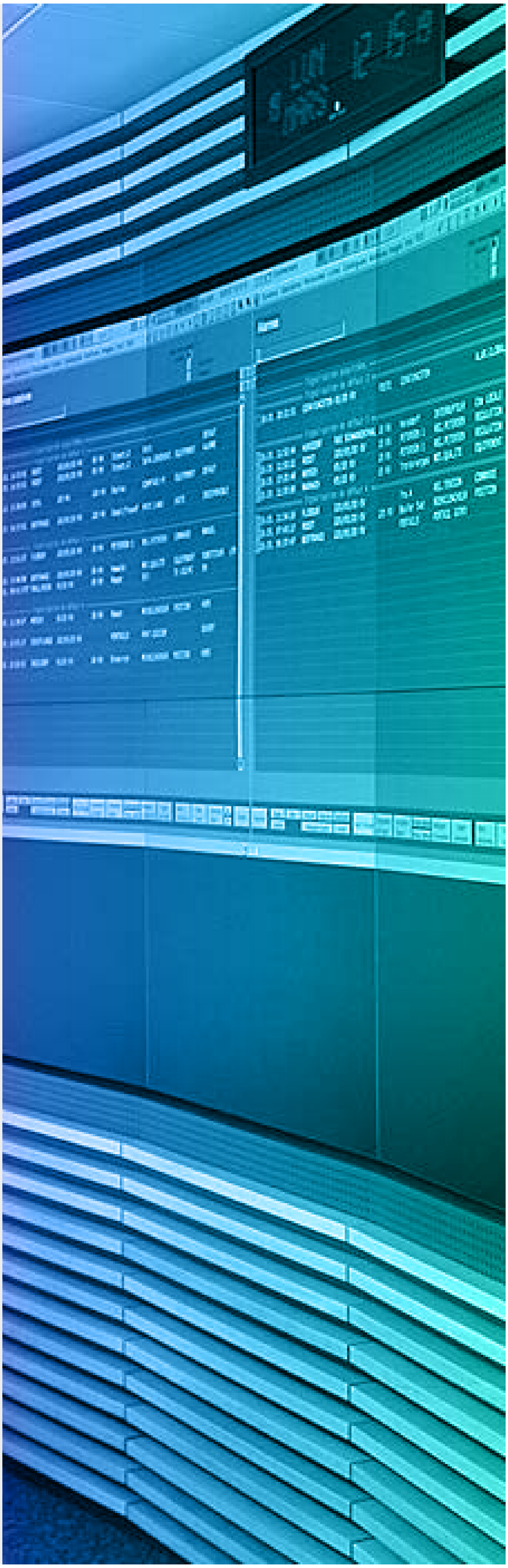
- **OTC trades** might be used to lock in positions ahead of the DA auction. For example, when there is strong uncertainty around the expected DA settlement price, participants might choose to secure a portion of their forecasted output or demand through OTC trades in advance.
- The **DA auction** is often used to clear large volumes, take advantage of market coupling and auction-induced liquidity, or optimise selling power through block orders, namely multiple interdependent bids within a day.
- The **ID market** is primarily used for adjusting positions as needed; for example, if free capacity remains after the DA auction, weather forecasts change generation expectations, or changes in the ID price imply that the moneyness of flexible assets changes.

Participation in these markets depends on the asset portfolio and the market conditions, especially expected price levels. Implicit market coupling makes zone-specific characteristics less important when no cross-zonal capacity constraints exist. However, these characteristics become crucial when cross-zonal constraints exist or during periods without coupling.

A bidding zone reconfiguration would affect cross-zonal capacity and price formation, potentially leading to changes in market participants' behaviour and strategies.

Proprietary trading in long- and short-term markets

Proprietary traders apply sophisticated models to form expectations on future price movements. They typically only enter into trades if the estimated return-risk ratio exceeds a predefined threshold. Market characteristics and metrics – particularly liquidity – are essential for model calibration as liquidity ensures that positions can be exited without significant losses. A BZ reconfiguration could alter market dynamics, influencing price formation and liquidity and thus forcing traders to recalibrate their models and adjust strategies accordingly.



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 as through our analysis based on historical data for the first one:

- The split between Austria and Germany–Luxembourg in 2018.
- The Nordic BZ reconfiguration in 2011, splitting Sweden into four BZs, emanating from court proceedings.

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 4,900 MW (Bundesnetzagentur, 2018).

Literature suggests that the split had different effects on short- and long-term products for Austria and the German–Luxembourg BZ.

In terms of short-term products, DNV GL (2020) noted an increase in liquidity of 13% of the EPEX DA volume and an increase of 20% of DA volumes on EXAA for the twelve months between before and after the split. ACER (2020b) argues in the Market Monitoring Report 2019 that the increase can be attributed to the reconfiguration: "*Before 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*" (p. 40).[23]

The issue appears to be more complex in the long-term market because it was necessary to adjust existing future contracts. Adaptation for exchange-traded contracts was a weighted split of nine to one for German–Luxembourg–Austrian futures to German–Luxembourg and Austrian futures, leading to a decrease in contract correlation with Austrian prices (Laur & Küpper, 2020). EFET (2019) found that market liquidity in Austria was very poor, leading to "*significant bid-ask spreads – when bids are actually present at all*" (p. 7). 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 in Austria (ibid.). According to Laur and Küpper (2020), financial transmission rights (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, p. 41). However, it is acknowledged that bid-ask spreads in Austria remained above the pre-split level.

ACER (2021) 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*" (p. 42). Schittekatte and Eike (2022) referred to the possibility for Austrian market participants to proxy hedge on the German market due to the countries' strong price correlation.

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

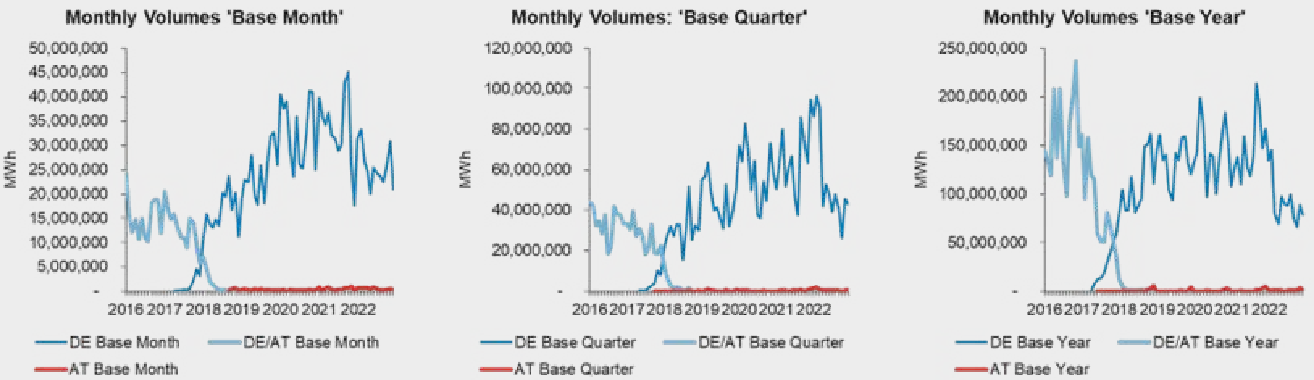
German–Austrian BZ split

The reconfiguration of the German–Luxembourg–Austrian 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, the European Energy Exchange (EEX) notified contract holders and traders about multiple changes as the reconfiguration date approached. Figure 2.1 provides a high-level summary of product amendments, cessation, and additions in the run-up and aftermath to the split.

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

Figure 2.1: Product adaptations before and after the German–Austrian BZ split

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



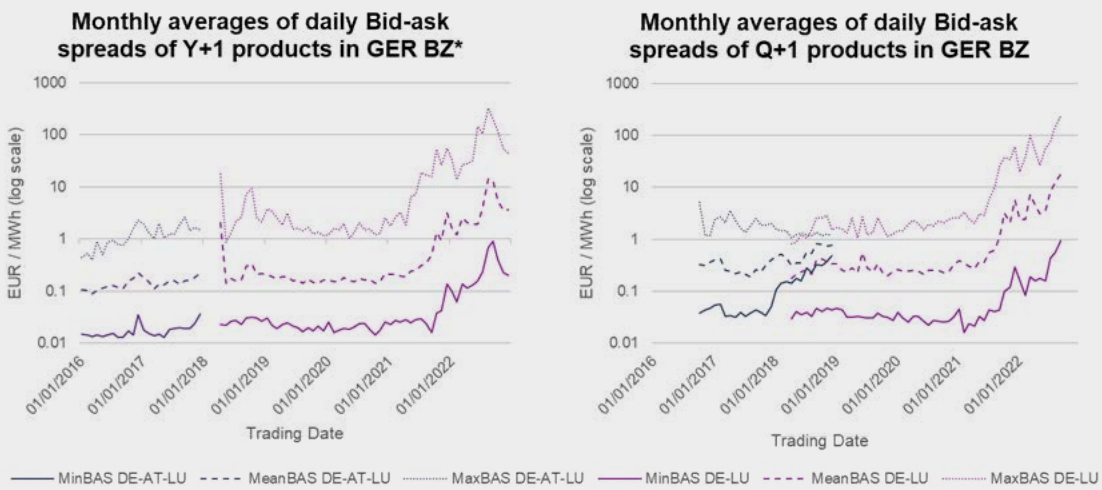
Source: Compass Lexecon analysis of EEX data

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

It can be seen 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, although it is unknown whether and to what extent these observations for the different products can be attributed to the reconfiguration. The turnover of Austrian products remained rather low, and through mutual reinforcement, Austrian market participants might 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 – if any – effect on liquidity on the German–Luxembourg market.

For the year-ahead base product, the bid-ask spreads slightly increased 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 declined until the end of 2020.



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

Figure 2.3: Monthly averages of daily bid-ask spreads in the German BZ (in €/MWh)

Considering the significant increase of bid-ask spreads in 2021 and 2022 coinciding with an increase in average future prices due to higher overall electricity prices, the variation in bid-ask spreads does not seem to stem 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 can 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. For instance, this can be derived when observing the significant increases across spreads as the power and derivative prices increased in 2021 and 2022.

The case differs for the Austrian market participants as their traded volume substantially decreased, with very limited trading on the Austrian market, leading to high bid-ask spreads. As a result, Austrian market participants might 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 – 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 assuming 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, which 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, DA volumes in Sweden increased by 10 % from 2011 to 2012.

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

However, literature suggests that this decrease is not necessarily attributable to the split itself but rather other factors such as a) low demand for hedging through EPADs due to strong correlation between zones, b) the increased use of bilateral PPAs, and c) increased fees on the exchange due to increased regulatory requirements (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 remained a very liquid market and the lead market in central Europe, the newly created Austrian long-term market remained relatively illiquid. There seems to be no adverse effect on the liquidity of short-term markets in Germany. Literature does not show how liquidity in 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 reviewing BZ changes and the resulting impacts on liquidity and transaction costs. The analysis considers the liquidity of products in short- and long-term markets. It aims to support the evaluation of the potential reconfigurations by providing context and a counterfactual to compare the results.

This section is structured as follows:

- We start with the analysis of liquidity metrics in the current BZs to establish the current state of liquidity for the different products in the different BZs.
- We then assess the relationship between these metrics and market characteristics to understand how liquidity could evolve through the changing market characteristics in case of a BZ reconfiguration.
- Finally, we consider spot price correlations to understand the existing possibilities to proxy hedge and the spot 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 and annual, quarterly, and monthly exchange- and OTC-traded derivatives. Our analysis intends to account for product and geographical specificities both qualitatively and quantitatively. For instance:

- Sweden is part of the Nordic area in which the long-term products traded usually relate to system price (namely the price calculated without accounting for the transmission congestion between the Nordic BZs) and differences between the prices of individual BZs and the system price, which are accounted for through EPADs, i.e. derivatives to settle price differentials between the system price and the price in the respective BZ. Given that the system price could play a role in possible mitigation measures, it could influence market liquidity metrics and their relationship with market characteristics of the individual BZs in both short- and long-term markets. Furthermore, the total traded volume of system price products and EPADs offers limited insights into available liquidity for Swedish market participants, as the system price might vary from prices in the Swedish zones and EPADs might not be required by market participants.
- In France, part of the generated volume bypasses the organised market due to the regulated access to incumbent nuclear electricity (ARENH) regulation.[24]
- 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 in possible mitigation measures and hence influence market liquidity metrics and their relationship with market characteristics of the individual BZs in both short- and long-term markets.

24 ARENH stands for 'Accès Régulé à l'Electricité Nucléaire Historique' and is a regulatory mechanism through which suppliers other than EDF can acquire nuclear electricity on a yearly basis at a regulated price. The mechanism covers about 20–25 % of total consumption in France.

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, complementing the analysis with additional metrics where necessary and where data is available. In particular, the traded volumes and 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 holds particular interest for continuous markets as re-selling is possible. Bid-ask spreads are only relevant for continuously trading markets. Risk premiums might be taken into account for long-term products.

3.1.1 Data and methodology

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

Churn rates are calculated based on the traded volume and load data provided by the TSOs participating in the study. The Appendix provides an overview of the data sources used.

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, which sourced the data from EEX, ICE Endex, and NASDAQ commodities. The spreads are aggregated by considering the average minimum, average, and maximum spreads across one 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. We draw conclusions at the country level since the regression analysis in Chapter 3.2 is conducted at this level due to data limitations for some variables. However, for Sweden and Italy, we still highlight key BZ-level observations to account for the countries' liquidity differences.[25] Where applicable, the analysis of the state of liquidity is enriched through liquidity evaluations from existing publications.

3.1.2 Short-term products

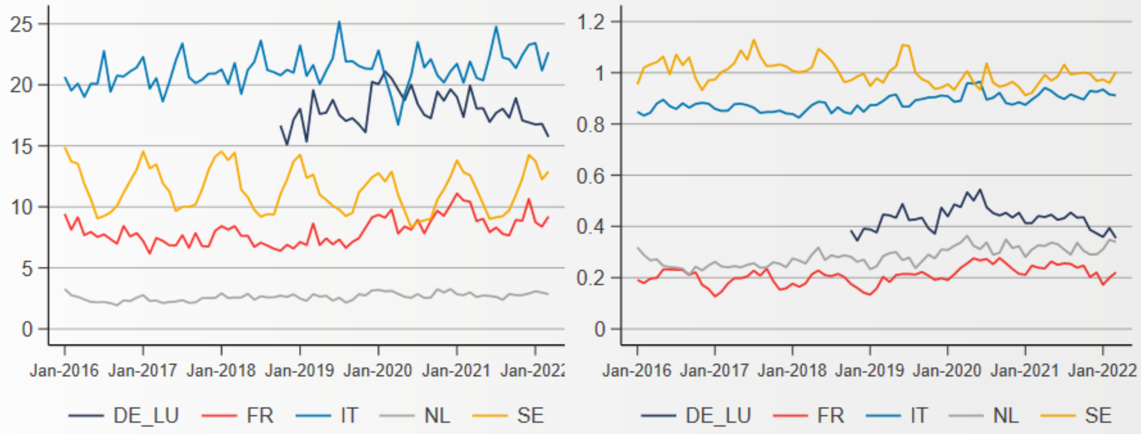
The liquidity of short-term products strongly differs between BZs and the DA versus ID market. *Prima facie*, the DA market is on average at least about ten times the size of the ID market in terms of traded volume.

Day-ahead market

Figure 3.1 shows the monthly DA traded volume on the left and the churn rate calculated as the DA traded volume over load on the right by region. It suggests that the Italian aggregate market is the exchange-traded DA market with the greatest liquidity, with traded volumes of up to 25 TWh per month. By contrast, the Netherlands shows the least liquidity out of the analysed sample. However, when looking at the churn rate, i.e. at traded volumes levelised by total load, Sweden is the most liquid market at a country-aggregated level.[26] Germany ranks second in traded volumes and has the third highest churn rate at about 0.4. It is important to note that the aggregate traded volumes for Sweden and Italy do not imply these liquidity levels for the individual BZs. For instance, with an average traded volume of 6.3 TWh over the timeframe considered, SE3 in Sweden is significantly more liquid than the other BZs (average traded volumes ranging from 1.2 TWh in SE4 to 2.5 TWh in SE2). Similarly, with an average traded volume of 11.9 TWh, traded volumes in the northern BZ substantially exceed those of the other BZs (ranging from 0.8 TWh to 3.3 TWh).

25 A refined analysis of liquidity at the BZ level is presented for the status quo BZ and alternative BZ configurations in Chapter 4.

26 Note that the monthly churn ratio in Sweden and Italy is above 1 at times. This observation can be attributed to months in which the countries are net exporters such that total load (the metric for the market size) is lower than the electricity generated.



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

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

Churn rates show different levels among the regions analysed. Sweden and Italy have churn rates close to 1, whereas Germany, the Netherlands, and France have much lower churn rates (between 0.2 and 0.5). This difference can be explained by the incentives faced by market participants to settle their physical positions in the DA-organised markets (see below for a further explanation), which pools liquidity on the exchange. Market participants in other regions might rely more on OTC 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 DA market dispatch. Therefore, market participants in these regions must go to the exchange to trade across BZs in the short term.

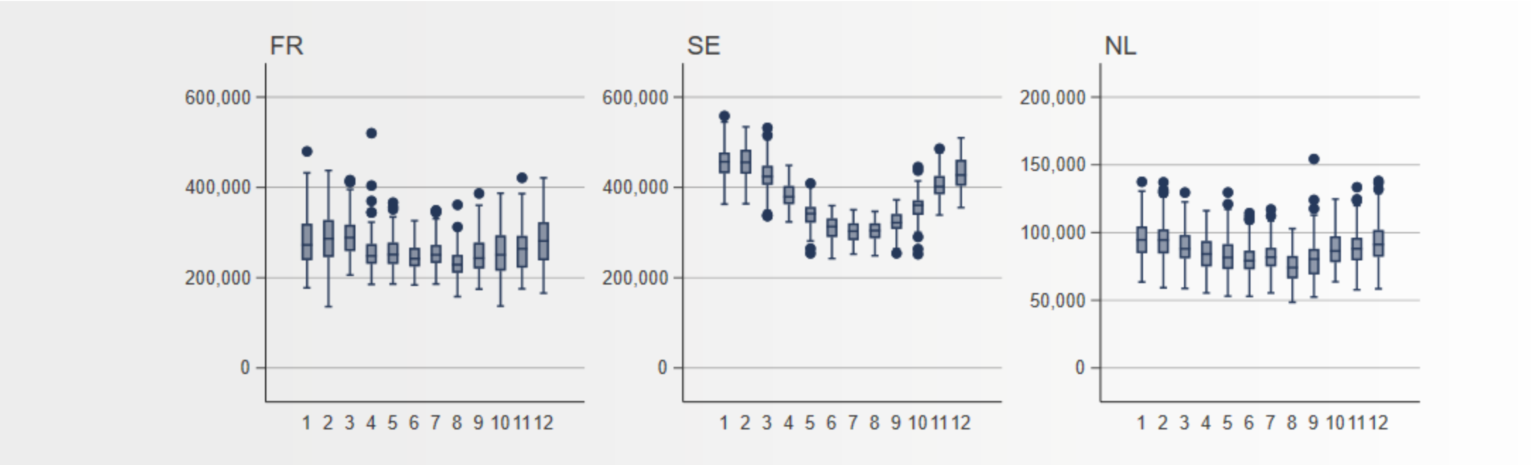
By contrast, when participation in the DA market is not similarly incentivised and BZs are relatively large, vertically integrated companies can net their positions within the company across the whole BZ without settling short term on the market. One reason for this is lower transaction costs. This might be particularly significant in regions with higher market concentration.

The churn rates close to 1 at the country level in Sweden and Italy are also observed for the largest BZs regarding traded volume, i.e. SE3 and the northern Italian BZ (average churn rate of 0.9 over the timeframe considered). However, the most liquid BZs in terms of traded volume are not the most liquid in terms of churn rates. In Sweden, SE2 exhibits the highest average churn rate, while in Italy the highest level is observed in Calabria. Moreover, the traded volume and load data suggest that SE1 and SE2 in Sweden and Calabria, Sardinia, and the southern BZ in Italy have average churn rates above 1. This means that traded volumes exceed the total load in the respective BZ for most of the timeframe considered.

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

Seasonal patterns can also be observed in some regions, with Figure 3.2 showing the distribution of the daily DA traded volume by month from 2016 to 2022 in France, Sweden, and the Netherlands. They are most pronounced in Sweden, where traded volumes fluctuate between a minimum traded volume of 300 GWh on average 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. By contrast, Germany–Luxembourg and Italy do not show this seasonal pattern. This pattern is strongly correlated with temperature, suggesting that additional demand for electrified heating and cooling implies increased traded volume.[27]

27 The relationship between market size as approximated by total load and liquidity is assessed in Chapter 3.2, in which we identify the suggested relationship.

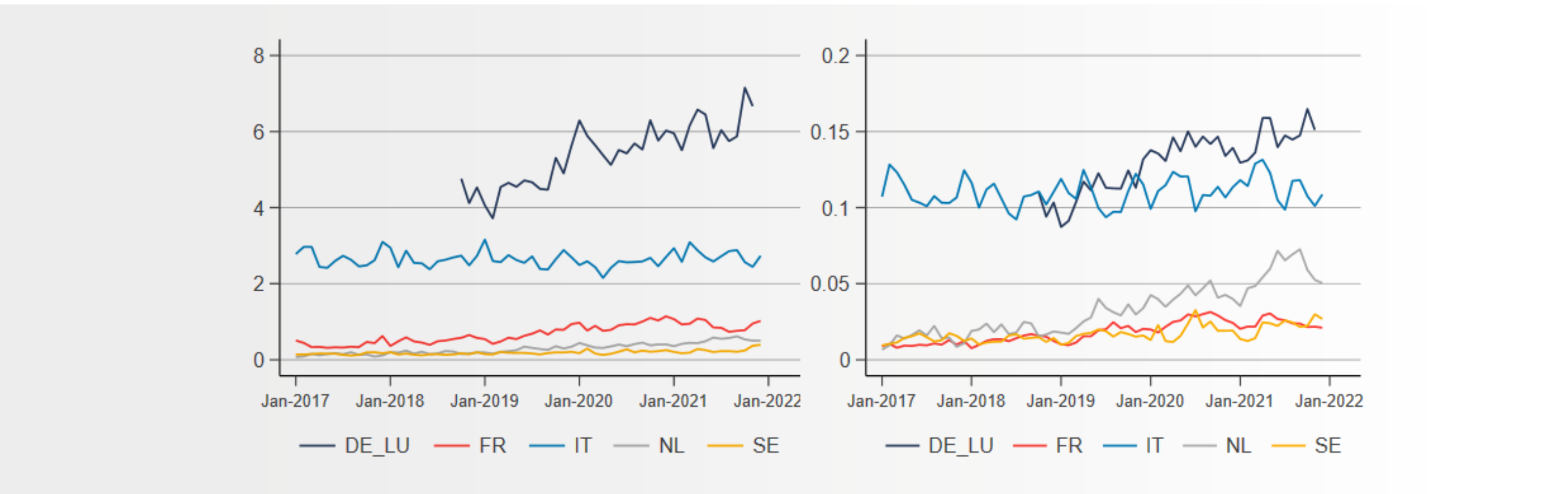


Source: Compass Lexecon analysis based on traded volume data provided by the EEX and NASDAQ exchanges.
Note: The boxplots visualise the spread of traded volumes in each month. The boxes capture the inner 50 % of observations, ordered by size, and the line splitting the boxes is the respective median.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

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

Intraday market

The ID market is significantly different from the DA market as it is comparatively young and has mostly relied on continuous trading[28] instead of an auction until recently. This is illustrated in Figure 3.3, which shows monthly ID traded volume on the left and the churn rate calculated as the monthly ID traded volume over load on the right by region. In particular, Germany shows the highest liquidity and a strong increase over recent years. The Italian ID market ranks second, although the traded volume has remained stable over the past six 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 most of the past five years. However, these latter markets show increases over time; for example, with the Netherlands' 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. As in the DA market, the main contributions to ID liquidity in Sweden and Italy stem from traded volumes in SE3 and the northern Italian BZ, respectively. SE4 in the south of Sweden and Sardinia and Sicily exhibit the lowest levels of traded volume in the two countries.



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

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

28 ID auctions are also in place in some regions – for example, in the Netherlands, Belgium, and Germany – although volumes are comparatively low. Most recently, on 13 June 2024, three separate ID auctions for the single European electricity market were launched, involving most European countries apart from Switzerland, the UK, Ireland, Serbia, Bosnia-Herzegovina, North Macedonia, Albania, Serbia, and Montenegro. Pricing the ID capacities is part of the SIDC. A new technical setup and new DA market dispatch processes are used among NEMOs and 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, DA market dispatch 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 the underlying physical product and the existence of spread products for price deviations between BZs.

Three main distinctions among long-term products are as follows:

- 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 occurs 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 risk allocation, i.e. through standardised margin requirements.[29]
- 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 from OTC-traded forward contracts.

In addition to these main types of long-term derivatives, various other derivatives also exist. For instance, EPADs (both exchange and OTC-traded) hold 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 that list 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

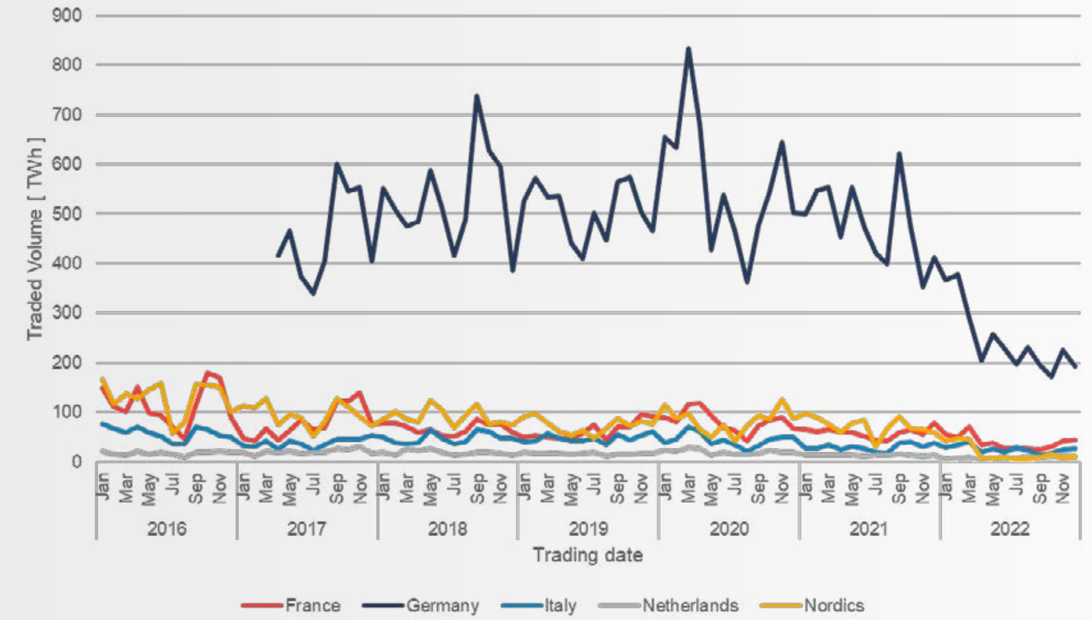
Figure 3.4 shows the monthly aggregated traded volume of long-term products per region from 2016 to 2022. It suggests that the market for German–Luxembourg futures and forwards is by far the most liquid market, with monthly traded volumes between 400 GWh and 900 GWh[30] per month from 2018 to 2022, while traded volumes also seem to be affected by the energy crisis at the 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 regarding traded volumes on EEX of up to 15 TWh per year. Note that liquidity implied in the Nordic system price is only a limited indicator for perceived liquidity levels by Swedish market participants as their potential to use system price products depends on the correlation with the specific underlying BZ market prices. Therefore, liquidity levels might be overstated for the Swedish participants.

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 regions, except Germany.

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

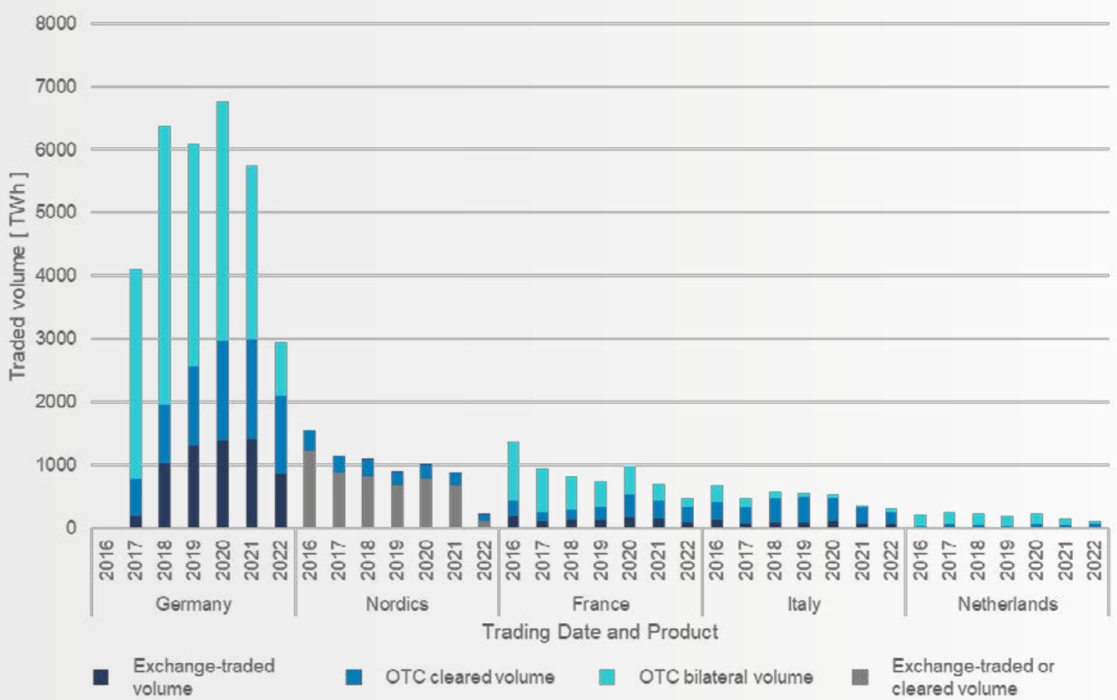
This is illustrated by Figure 3.5, showing the aggregated annual traded volumes per region and type of product from 2016 to 2022.

29 A margin requirement is the requirement to deposit a certain amount of funds or securities for the open interest.
30 On EEX, NASDAQ and via LEBA associated brokers.



Source: Compass Lexecon analysis of traded volume data as provided by the EEX and NASDAQ exchanges and 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 might include volume contracted for the Austrian area. Exchange-traded volumes do not include futures for the German–Luxembourg–Austrian BZ.

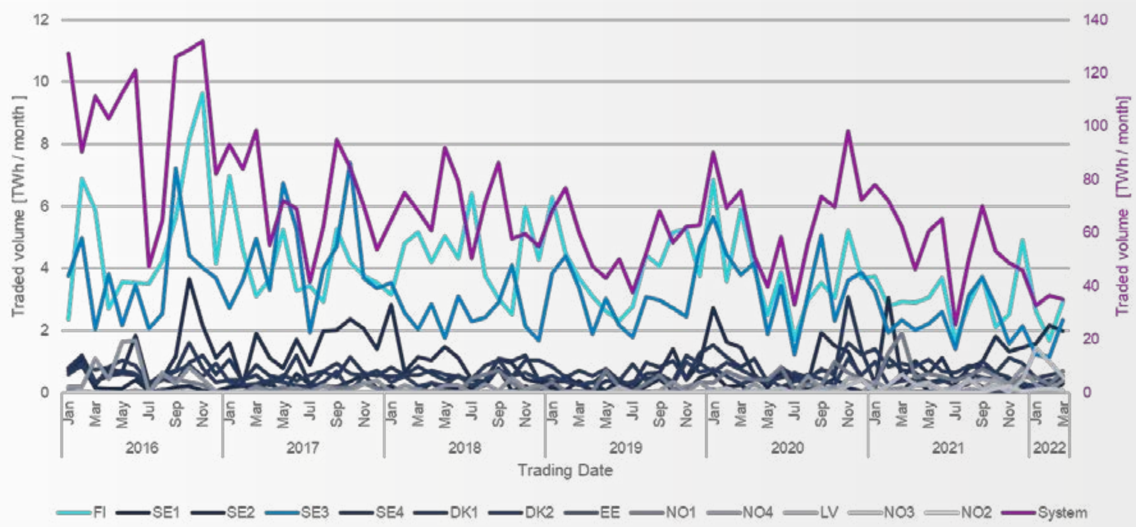
Figure 3.4: Traded volume of long-term products (in TWh)



Source: Compass Lexecon analysis of traded volume data as provided by the EEX and NASDAQ exchanges and LEBA.
Notes: [1] 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 might include volume contracted for the Austrian area. Exchange-traded volumes do not include futures for the German–Luxembourg–Austrian BZ.
[2] According to one stakeholder, bilateral trading via so-called "black pools" is gaining relevance, with one black pool trading between 60 to 80 TWh in 2023.

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

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



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

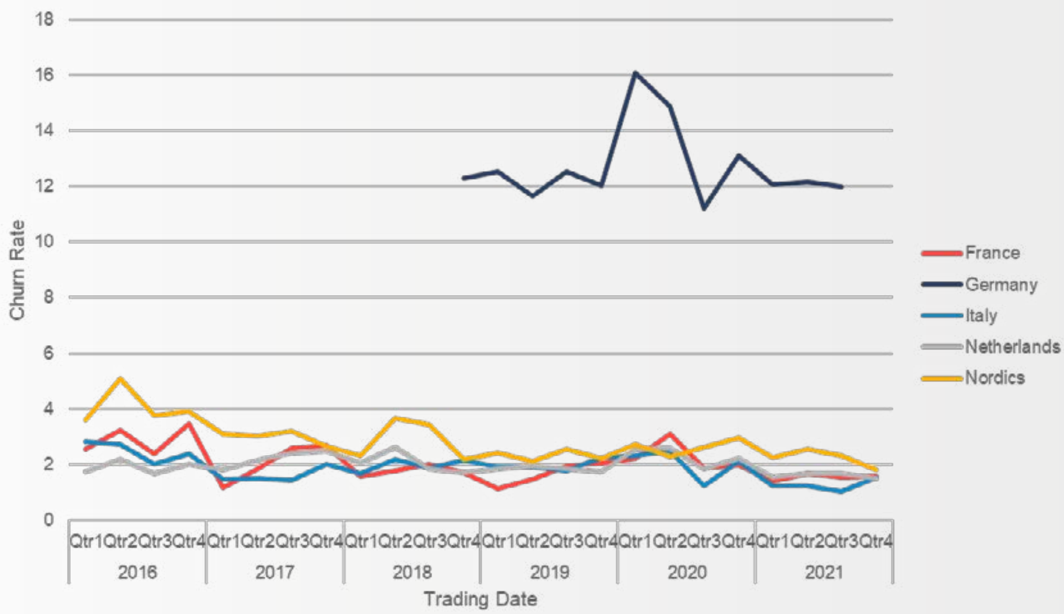
Figure 3.6: Traded volume by trading date for Nordic and Baltic individual BZs (in TWh)

Figure 3.6 shows that most EPADs are traded for the Finnish (HEL) and Sweden 3 (STO) BZs. The probable underlying reason for this that the likelihood of constraints on the cross-zonal capacity with these areas drives up price differentials' risks and therefore the need to hedge these risks against the system price. However, another reason for EPAD liquidity is the existence of supply or demand for EPADs. As supply or demand might be driven by risk, the inexistence of liquid EPADs does not necessarily imply that the market participants consider the system price as a standalone product sufficient or suitable for hedging.

Figure 3.6 further shows the monthly traded volume of EPADs from 2016 to 2022, showing that the turnover for the Nordics not only decreased for system price futures but also EPADs.

Churn rate

The churn rate is measured as the ratio between traded volumes and total load. Figure 3.7 shows the quarterly churn rates for long-term traded products per region from 2016 to 2021. For Germany, the churn rate was above 10 for most quarters between 2019 and 2022. By contrast, the ratios for France, Italy, and the Netherlands fluctuated between 1 and 3.5 from 2016 to 2022. The churn rate for the Nordics gradually decreased to below 2 in Q4 2021 compared to a maximum of 5 in Q2 2016.



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

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

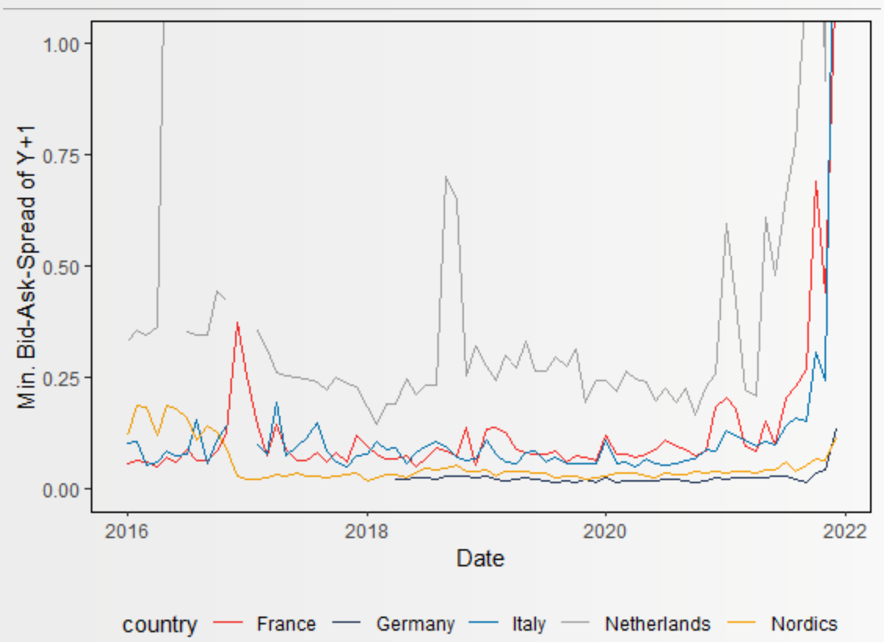
Consequently, in the status quo of liquidity in terms of turnover of long-term products, Germany–Luxembourg constitutes a lead market with the churn ratio about five times higher than its neighbouring zones.

On France, ESMA (2019) 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*". From this statement and the industry claim that the churn rate should be 3 or higher, market liquidity in Italy, the Netherlands, and – more recently – the Nordics might 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. Figure 3.8 shows the average of minimum bid-ask spreads for year-ahead products on ICE, EEX, and NASDAQ between 2016 and 2022. It suggests that German futures have the lowest minimum bid-ask spreads of around 2.5 € cent/MWh, followed by the Nordics[31] with average minimum spreads of around 5 € cent/MWh. French and Italian spreads are just above 10 € cent/MWh, while Dutch spreads show a large range with spreads between 20 € cent/MWh and 120 € cent/MWh.[32]



Source: Compass Lexecon analysis of data as provided by ICE

Figure 3.8: Minimum bid-ask spread of Y+1 (in €/MWh)

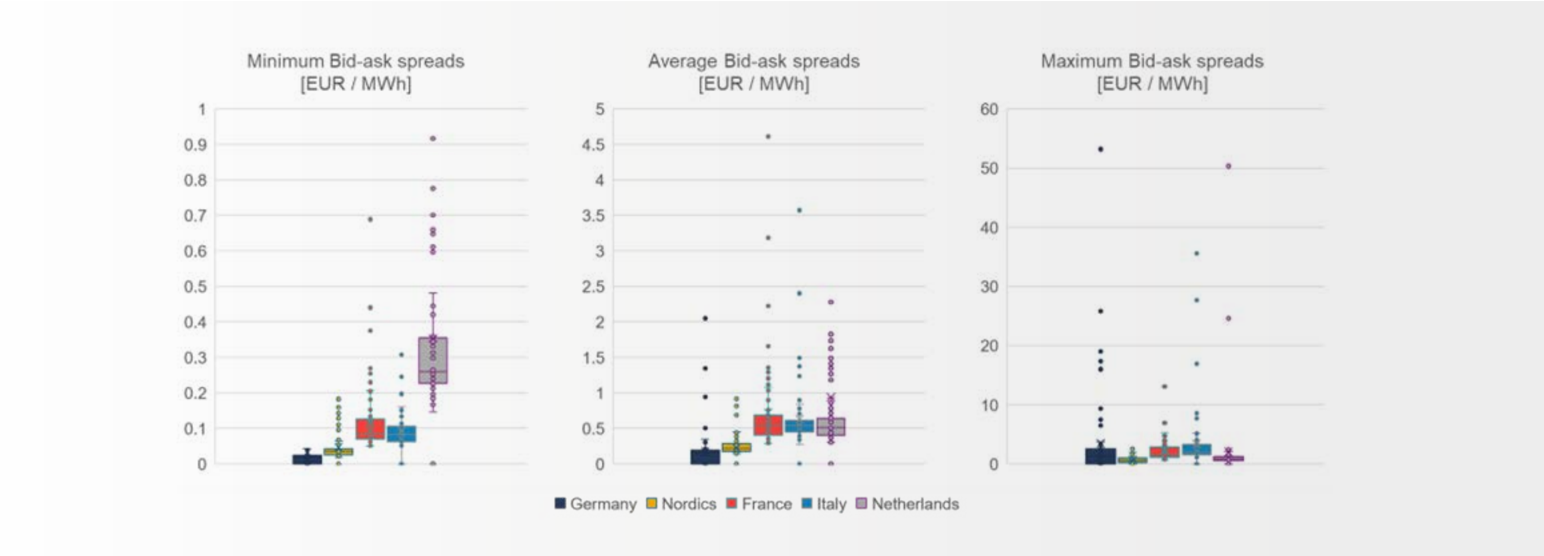
The volatility of minimum spreads was lowest for Germany and the Nordics, higher for Italy and France, and highest for the Dutch EEX futures. As of Q3 2021, bid-ask spreads had significantly increased, which can be attributed to the increase in power future prices.

The ranking of market liquidity in terms of minimum bid-ask spreads is largely consistent with the ranking from average and maximum daily spreads.[33] Figure 3.9 shows the three different spreads for each region.

31 The Nordic system price products are considered as "Nordics" for the bid-ask spread analysis.

32 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 0.05 % in Germany (after its BZ split with Austria) and 0.71 % for Dutch futures.

33 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 might 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).



Source: Compass Lexecon analysis of data as provided by ICE

Figure 3.9: Minimum, average and maximum bid-ask spreads of Y+1 and Q+1 products between 2016 and 2022 (in €/MWh)

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 strongly affected by products that are rarely traded. In general, the difference in maximum spreads compared to minimum and average spreads can be attributed to the existence of rarely traded products, as well as information asymmetries that seem to be particularly prevalent during opening hours.

A second takeaway from Figure 3.9 emerges from comparing 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 ID price variation affects the spread less than in illiquid markets, where a relatively low (minimum) spread might only occur during a few instances during the day. Based on this difference, it can also be perceived that the German market is the most liquid, closely followed by the Nordic one. For both product types, the difference between the minimum and the average spread is just above 0.2 € / MWh on average between 2016 and 2021. By contrast, the Dutch, French, and Italian markets show similar spread patterns with a difference between the minimum and the average of just above 0.6 € / MWh in the same timeframe.

3.1.4 Conclusions on the state of liquidity

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

- Literature highlights that liquidity in 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 in France, Sweden, and the Netherlands, which show very limited traded volumes in ID.
- Liquidity metrics have generally been increasing over time in recent years, with only the Swedish DA market showing a slight downward trend.
- Seasonality appears to play a role in the DA market but not in 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 recent years. The Nordic market has seen a decrease in liquidity metrics for both system price futures and EPADs over recent years, with churn rates for EPADs dropping from 5 to 2. France, Italy, and the Netherlands also show churn rates of about 2, whereby – 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 trading system applied (exchange, OTC bilateral or OTC cleared) significantly varies between BZs. While Germany sees substantial traded volumes for all three systems, the other BZs typically have 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 € cent / MWh, followed by 5 € cent / MWh for the Nordics, 10 € cent / MWh for France and Italy, and 20 € cent / MWh for Dutch futures. Variation in spreads exists in intraday trading and across products.
- The difference in liquidity could also be explained by the fact that market participants might use the most liquid markets – Germany in this case – to hedge their positions including in neighbouring markets (proxy hedging), concentrating liquidity even further in these markets.

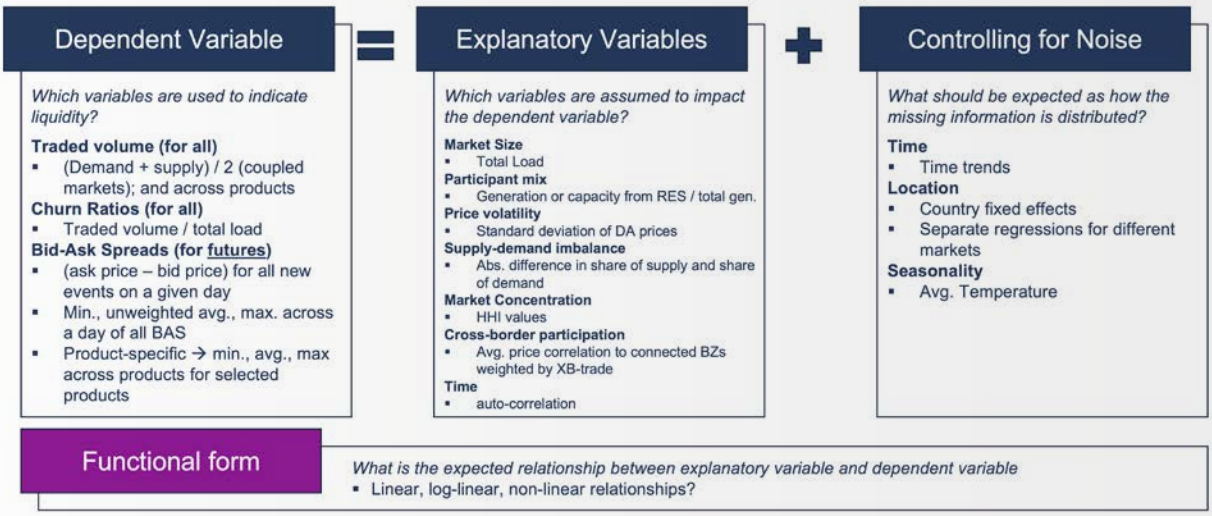
3.2 Relationships between liquidity and other market metrics

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 relationships identified can then indirectly inform the status of liquidity for the simulated BZs. For this purpose, we conduct a regression analysis using historic data for the regions that might be subject to a BZ reconfiguration. The regression analysis comprises three building blocks:

› First, we identify liquidity as the variable of interest, parametrised 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 influence the variable of interest. Here, we include total load to proxy the market size, the participant mix approximated by the share of renewable generation,[34] price volatility as measured by the daily standard deviation, supply-demand imbalance as measured by the difference between the respective shares of demand and supply over the sum of the two, 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 Herfindahl-Hirschman index (HHI)[35] to study the impact of market concentration. In addition, we also consider the previous traded volume in the regression as it might be necessary to account for auto-correlation and serve as an explanatory variable given that liquidity is claimed to attract liquidity.



Source: Compass Lexecon analysis

Figure 3.10: Conceptual approach of regression analysis and model determination

› Third, we include controlling variables to more precisely filter the effect of the explanatory variables and minimise the impact of unobserved variables in our results. One of the controlling variables is temperature as climate conditions might affect both the dependent and explanatory variables. Furthermore, we include time trends and region fixed effects to account for individual region characteristics – such as historic trade patterns or fees – that are not explicitly included.

We build the regression models for traded volume and churn rate separately since the relationships with the described

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

35 The HHI is based on data 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 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.

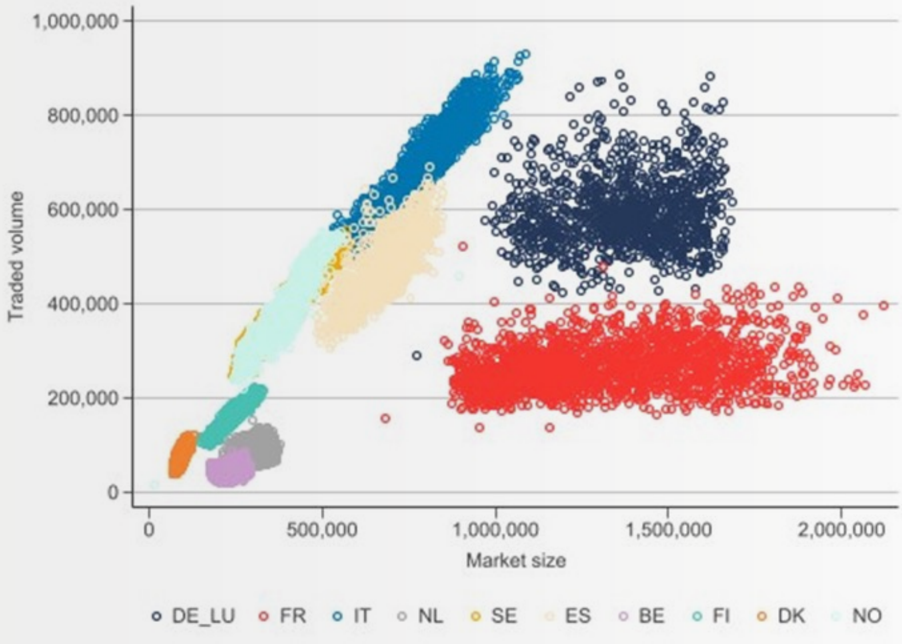
explanatory variables might differ among the liquidity variables. In order to check our results for the interaction of liquidity with market size, participant mix, price volatility, supply-demand imbalance, cross-border participation and market concentration, we study several regression models, each with a different selection of explanatory and controlling variables (see regression results in the Appendix). We analyse the relationship between the liquidity variables and explanatory variables for regions individually and across regions using a panel data set. Figure 3.10 shows the conceptual approach to the model determination. We apply different levels of granularity for short- and long-term products. We consider daily data for short-term products and monthly data for long-term products. Daily data incorporates information that might be disregarded for long-term product estimates but could 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 characteristics might then indirectly inform the expected status of liquidity metrics for the simulated BZs. Specifically, the direction and level of the explanatory variable's coefficients (the market characteristics) can be used to derive expectations on the extent of liquidity changes in one alternative BZ configuration in comparison to the status quo configuration. Notably, it would be necessary to accept a set of assumptions for this conclusion.

3.2.2 Short-term products

Market size

Figure 3.11 presents the relation between the daily traded volumes in the DA market of different regions and market size, expressed as the daily load. It highlights a significant positive correlation between these variables. In particular, it shows a one-to-one relationship between traded volumes and load for regions with high churn rates, suggesting that trades in these markets mostly happen on exchanges. As previously explained, there are strong incentives or even obligations for participants in these markets to settle their physical positions in the DA market (e. g. in Italy, Spain, or the Nordic countries). Conversely, the relationship is less pronounced for regions with lower churn rates, where OTC and intra-group trading are more developed and do not have to be settled through the exchange.

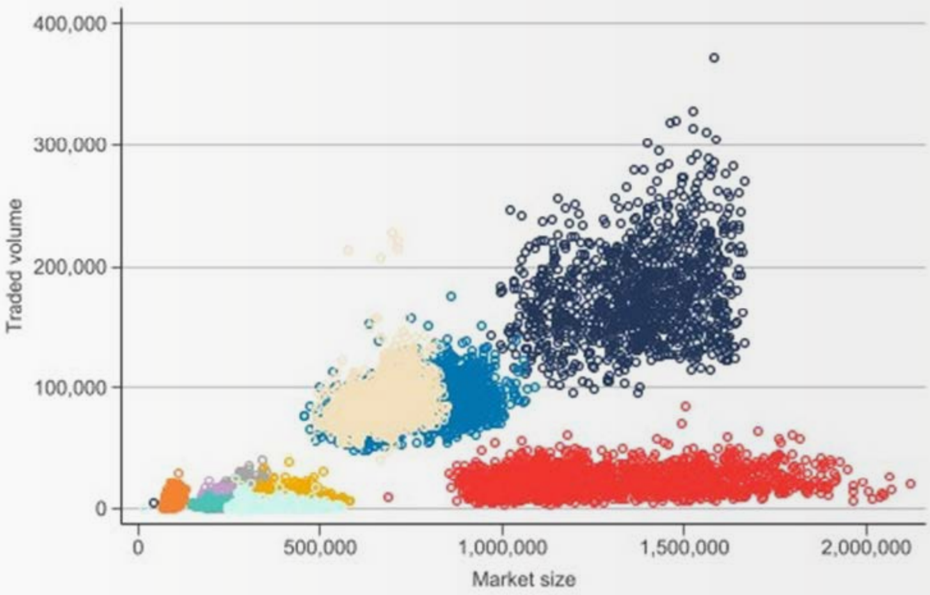


Source: Compass Lexecon analysis of traded volume data as provided by ACER and load data from the ENTSO-E transparency platform

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

The regression analysis including data for Germany–Luxembourg, France, Italy, Sweden, and the Netherlands supports the positive relationship observed 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 even negative and rather small in some cases, which would mean that larger BZs tend to have lower churn rates (see regression results in the Appendix).

Regarding the ID market, Figure 3.12 shows the relationships identified and statistical effects for traded volumes 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.



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

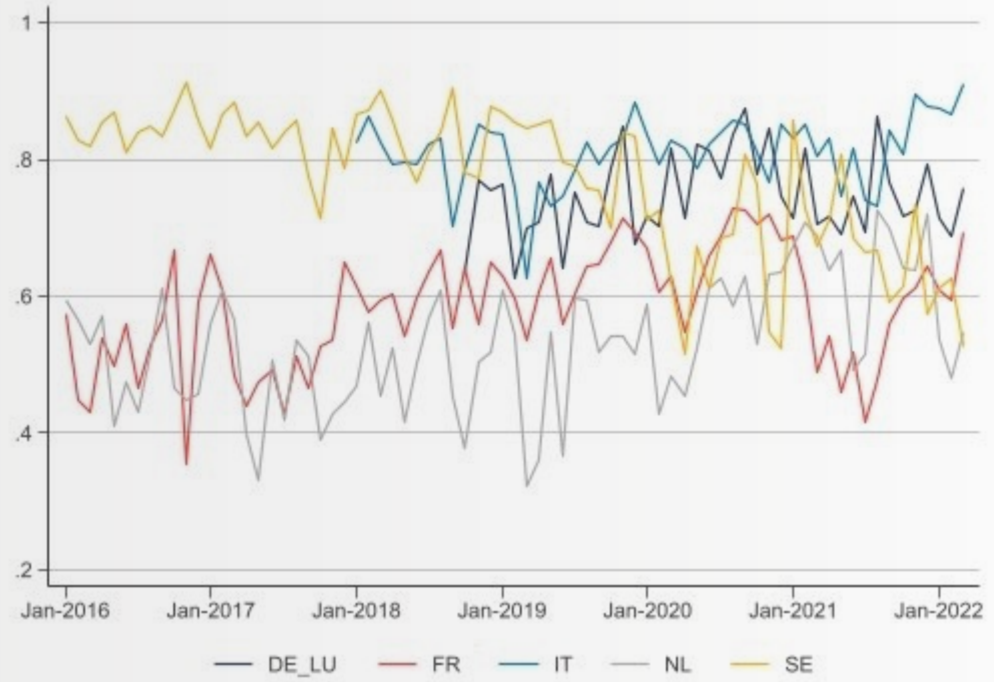
Figure 3.12: Market size (daily load) and ID daily traded volume by region (in MWh)

Cross-border participation and correlation of day-ahead prices

In addition to the individual market size of a respective BZ, cross-border trading might influence the market liquidity of a considered zone. To assess this, we calculate a variable for flow-weighted DA price correlations between BZs. The idea is to create an indicator expressing a BZ's connectedness with its neighbouring zones in terms of prices while accounting for the electricity flows. 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 that the BZ of interest has with all neighbouring zones. This share serves as a weight for the DA price correlation of two considered zones. By summing up all weighted DA price correlations per BZ pair, we obtain the flow-weighted DA price correlation between the BZ of interest and its neighbouring BZs. The higher the value of the weighted correlation, the more strongly correlated that the individual BZ is with its most relevant neighbours in terms of cross-zonal trade volume.

Figure 3.13 presents the monthly flow-weighted DA price correlation by region. Across all regions 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 decrease over time from above 0.8 to below 0.6.

The regression analysis including historical data for all regions suggests that regions with higher cross-border participation – i.e. a higher weighted price correlation – are more liquid, conditional on other factors (see Appendix for the regression results). This holds in both the DA and ID markets 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 strongly correlated BZs often face price convergence such that the market depth is effectively higher, since market participants might be or are cleared across zones with little constraint.



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

Figure 3.13: Monthly flow-weighted DA price correlation with neighbours by region

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 markets.

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 markets. However, it should be noted that the 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.

Supply-demand imbalance

Another explanatory variable considered in the historic liquidity analysis is the supply-demand imbalance. This variable describes the relative gap between electricity generation and demand per BZ, whereby higher values suggest an increasing imbalance in the BZ.

The panel data regressions for Germany–Luxembourg, France, Italy, and the Netherlands suggest that an increasing imbalance between electricity generation and demand negatively affects market liquidity. This finding is robust across all models for traded volume and churn ratios in the ID market, and supported by most models for DA traded volume. The coefficients for DA churn ratios tend to support a positive relationship between market liquidity and supply-demand imbalance, although it should be noted that these results are less robust than for traded volumes and churn ratios in the ID market and traded volumes in the DA market.

Further, we observe that the relative effect of imbalance – i.e. the effect size relative to levels of traded volume in the ID and DA market – is stronger in the ID than in the DA market.

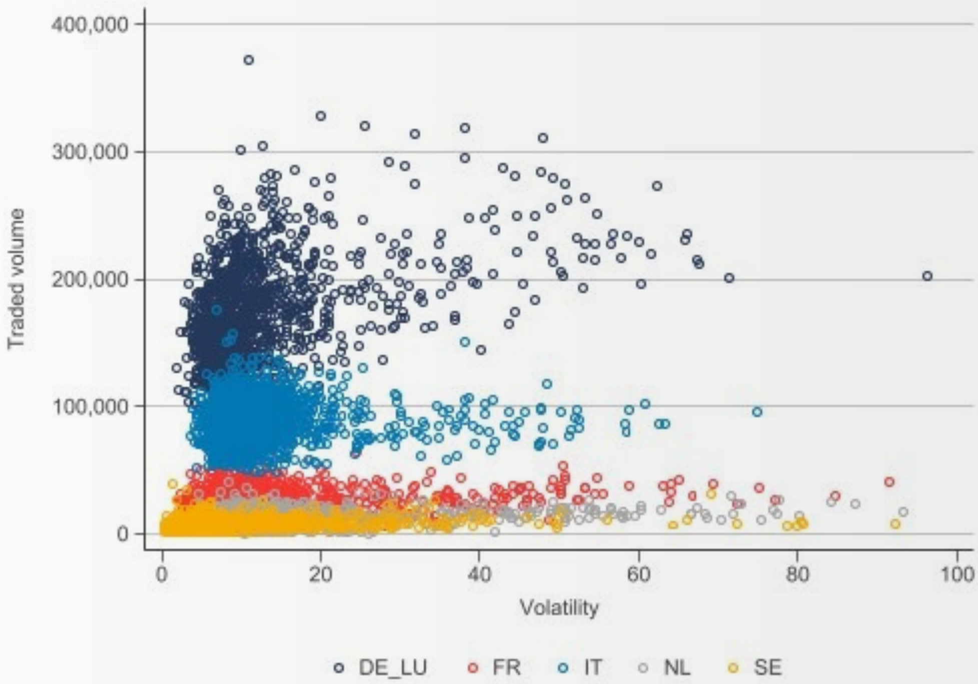
Price volatility

As a further explanatory variable, we analyse the effect of price volatility on liquidity in the DA and ID markets.

The regression results indicate a positive effect of price volatility on liquidity in the ID market, in terms of both traded volumes and churn ratio. This finding is supported by significant coefficients across various models (see regression results in the Appendix). Although significant, it should be noted that the size of the effect varies across regions, as indicated in Figure 3.14 depicting the relationship between ID traded volume and price volatility.

For traded volumes in the DA market, the coefficients of price volatility in the regression analyses suggest a less robust picture. Although most models indicate a significant positive effect, others yield a significant negative coefficient for price volatility. In terms of DA churn ratios, the regressions indicate a negative – albeit not significant – relationship between market liquidity and price volatility (see regression results in the Appendix).

Overall, the regression results for the ID and DA markets indicate that with a decreasing trading timeframe, market liquidity and price volatility tend to be more strongly positively correlated. This finding could support the argument that market participants react more to price volatility when trading in the shorter term. Put differently, when prices are volatile, there might be more of an incentive to trade in the shorter rather than the longer term.



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

Figure 3.14: Daily price volatility (€/MWh) and daily ID traded volumes by region (in MWh)

Participant mix

Finally, we include the RES participant mix as an additional explanatory variable in the panel data regression. This variable is approximated by the share of renewables-based generation to capture renewables penetration in the region's generation mix.

The regression results suggest a slight positive relationship between the RES participant mix and market liquidity. This finding is particularly robust for traded volumes in the DA and ID markets, and can also be observed for churn ratios.

The positive effect of the participant mix on market liquidity could indicate that market participants respond with increased short-term trading to an increased renewables share. This might be the case due to the impact of updates in short-term RES generation profiles on their market position and the potential need for short-term adjustments.

Further characteristics

Temperature

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

The bivariate relationship between traded volumes in the DA market and temperature varies across regions. 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 might 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 and its square for Italy to consider the region-specific non-linear relationship. The regression analysis suggests a mixed picture for the effect of temperature on DA traded volumes and churn ratios. This might be the case as temperature possibly also affects one or more of the explanatory variables included, 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, although the effect is not robust across regression models. The equivalent analysis for the ID market points to a positive – albeit not robust – effect of temperature on traded volumes and churn ratios. The region-specific effect for Italy is now negative but – as for the DA market – not robust.

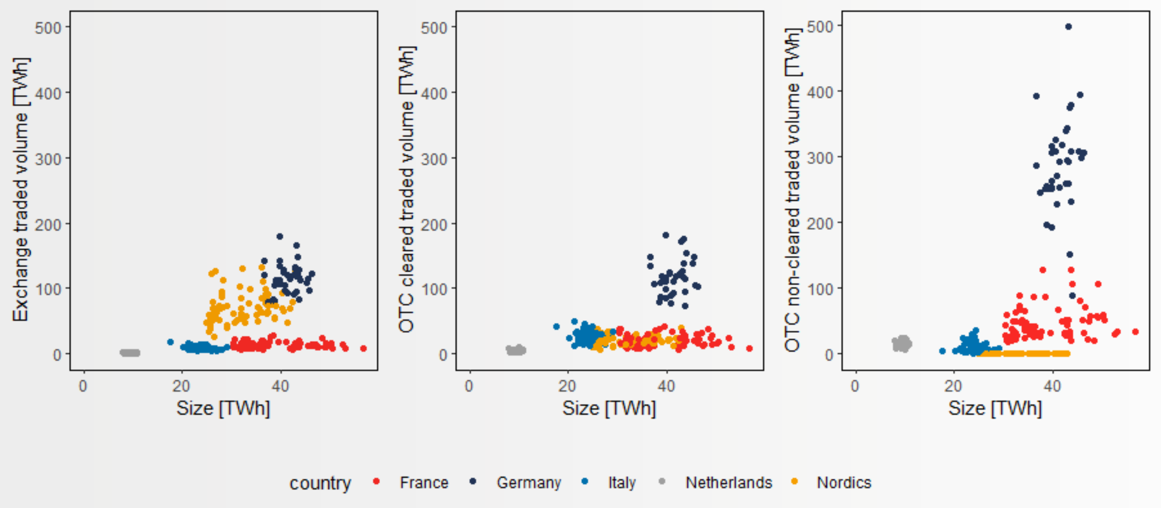
Time trend

Finally, our analysis supports the existence of an underlying time trend in the data, pointing to increasing liquidity in the regions of interest in from 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

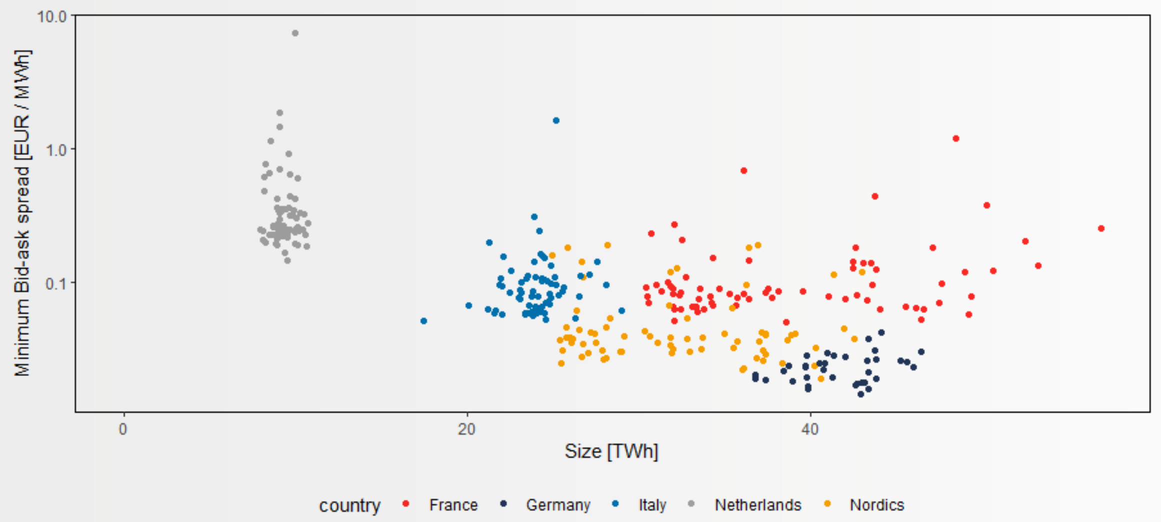
Market size

Figure 3.15 presents the traded volumes of exchange-traded, OTC cleared and OTC non-cleared long-term products in different regions 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, meaning that historically larger markets coincide with higher liquidity. This holds for traded volume and bid-ask spreads as dependent variables. However, the results for churn ratios are not robust (see regression results in the Appendix).



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

Figure 3.15: Traded volumes of exchange-traded, OTC cleared and OTC non-cleared long-term products by market size (in TWh)



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

Figure 3.16: Minimum bid-ask spread (in €/MWh) (logarithmic scale) by market size (in TWh)

Interestingly, the relationship between bid-ask spreads and market size seems to be non-linear (Figure 3.16 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. However, at some point, further increases in market size seem to have a smaller effect on bid-ask spreads. One possible reason for this is that the spreads approach the transaction costs – i.e. fees – asymptotically, whereby at low market size levels, an incremental increase in size might substantially reduce the spread because the additional demand allows various forms of market entry. By 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 the case because the spread manifests transaction and other costs, if the spread is determined by a market maker.

Proxy hedging

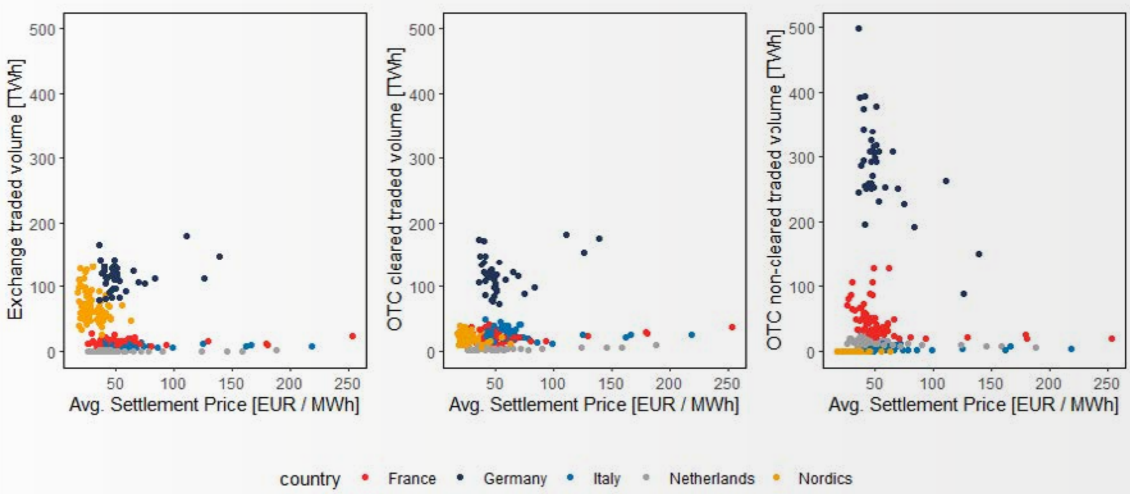
Cross-border participation and proxy hedging is closely related to the relationship between BZ sizes and liquidity because market participants in small zones that are illiquid might be inclined to proxy hedge in another market. However, this complicates the differentiation between the relationship of 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 average weighted correlation with neighbouring zones.[36] Germany was assumed as a reference point due to its high market liquidity.[37] The rationale for these variables is that proxy hedging might 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. In this case, low spreads would coincide with low liquidity on the target market because trade is shifted to the proxy market. In addition, if zones see stronger correlation, the basis risk for foreign asset-backed traders is reduced, thus incentivising trades.

The regression results are weakly supportive of the hypothesis of proxy hedging affecting liquidity. The price spread to Germany has a significant negative relationship with bid-ask spreads and a significant positive relationship with exchange-traded volume, but a negative relationship with cleared and non-cleared volume. This suggests that less proxy hedging potential supports domestic trading for exchange-based products. The average weighed correlation suggests a generally positive relationship between correlation and liquidity. Across all tested liquidity metrics, correlation is significantly and positively associated with increased liquidity metric levels when not controlling for region fixed effects. However, as this relationship does not persist when controlling for fixed effects, it indicates that proxy hedging might require further, more detailed assessment beyond the scope of this study.

Settlement price

Figure 3.17 shows a relatively clear relationship between the settlement price and traded volumes. Across most markets and liquidity metrics, the settlement price appears to be significantly negatively correlated with liquidity.[38]



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

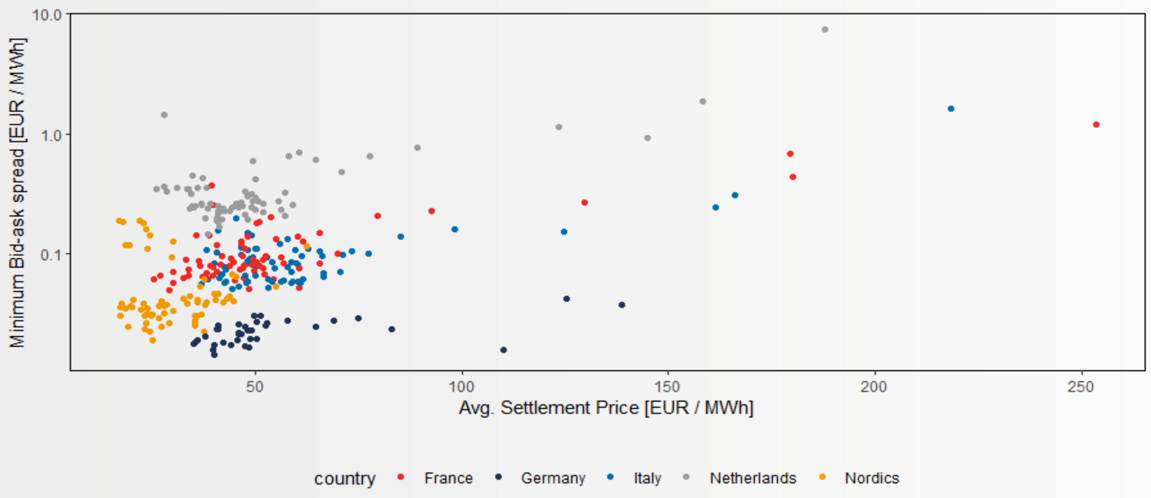
Figure 3.17: Traded volume of exchange-traded products (in TWh) by average settlement price (in €/MWh)

36 The latter uses the same indicator as for the analysis of cross-border participation and correlation of DA prices for short-term products.

37 This assumption was tested and confirmed in stakeholder interviews.

38 The settlement price is not included in the final regression analyses because the parameter is closely related to price volatility and market participants identified volatility as the more important market characteristic in the series of interviews (see Chapter 2.2.6). The inclusion of both settlement price and price volatility would have risked distorted regression results for the parameter coefficients.

As shown in Figure 3.18, the relationship between bid-ask spreads and settlement prices is similar to its relationship with market sizes, as it appears to be log-linear. The rationale for this relationship might 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.



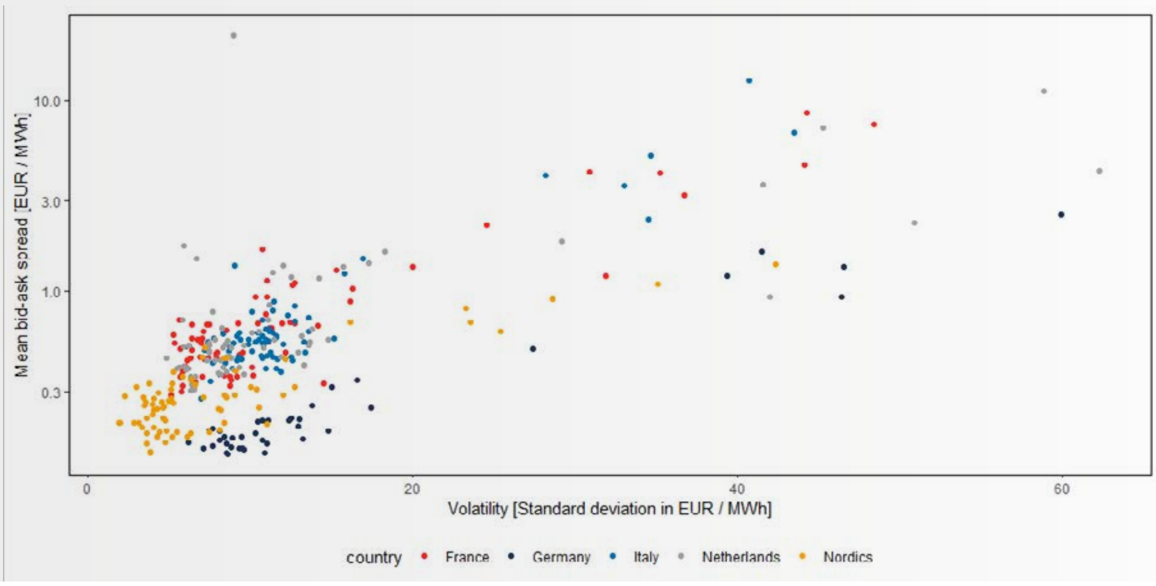
Source: Compass Lexecon analysis of bid-ask spread data as provided by ICE

Figure 3.18: Minimum bid-ask spread (in €/MWh) (logarithmic scale) by average settlement price (in €/MWh)

Price volatility

The regression analysis suggests a negative relationship between market liquidity and spot price volatility.[39] This finding is supported by significant negative coefficients when assessing churn rates and traded volume as the liquidity metric. This finding holds for both within- and across-region analyses. However, a more granular analysis of long-term products shows that this relationship does not hold for all types of long-term products.

Equivalently, the finding of decreasing market liquidity with increasing price volatility is supported by the positive relationship between price volatility and bid-ask spreads, i.e. transaction costs tend to be higher in markets with higher price volatility, as shown in Figure 3.19.



Source: Compass Lexecon analysis of bid-ask spread data as provided by ICE and day-ahead price data from the ENTSO-E transparency platform

Figure 3.19: Mean bid-ask spread (in €/MWh) (logarithmic scale) by volatility (as standard deviation in €/MWh)

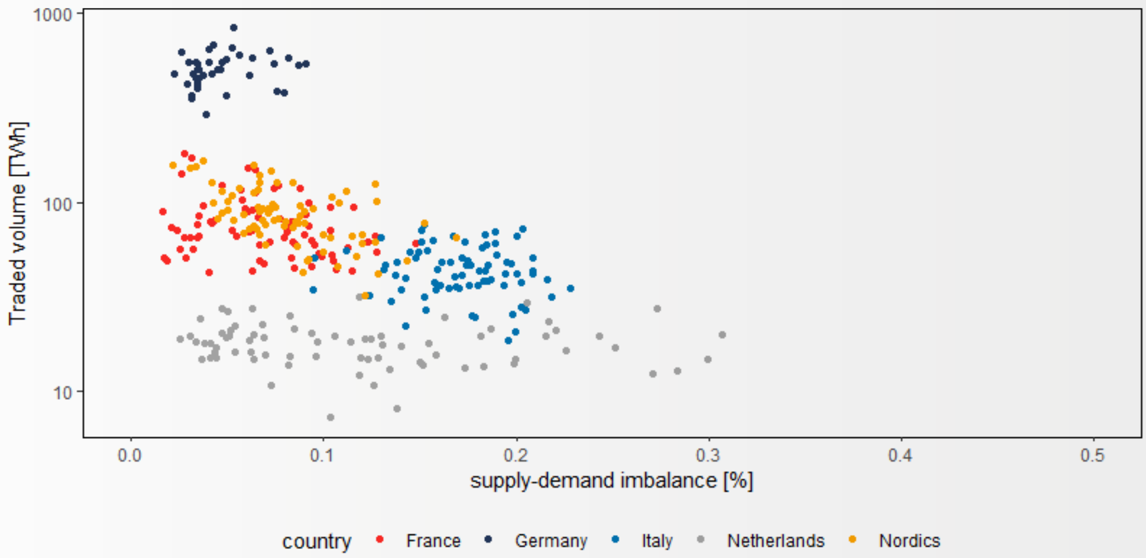
39 We consider the relationship with spot price volatility to ensure the comparability of this indicator with the indicator computed from the model results, obtained for the analysis of bidding zone reconfigurations.

Market concentration

The relationship with market concentration can only be assessed through incomplete means due to the limited data availability for market concentration indicators. 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, although this limitation might also be attributed to the fact that HHI values are only available on an annual basis, whereby intra-BZ variation is insufficient to shed insights in the models at hand.

Supply-demand imbalance

The analysis of the supply-demand imbalance explanatory variable indicates a slightly lower long-term market liquidity in markets with a larger supply-demand imbalance. We observe this relationship across liquidity indicators and in analyses both within and across the regions of interest. Figure 3.20 shows this relationship between supply-demand imbalance, measured as the absolute difference between the share of demand and the share of supply over the sum of demand and supply and traded volume. However, this identified relationship within regions is only significant at a lower significance level and not for all liquidity metrics.



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

Figure 3.20: Traded volume (in TWh) (logarithmic scale) by supply-demand imbalance (in %)

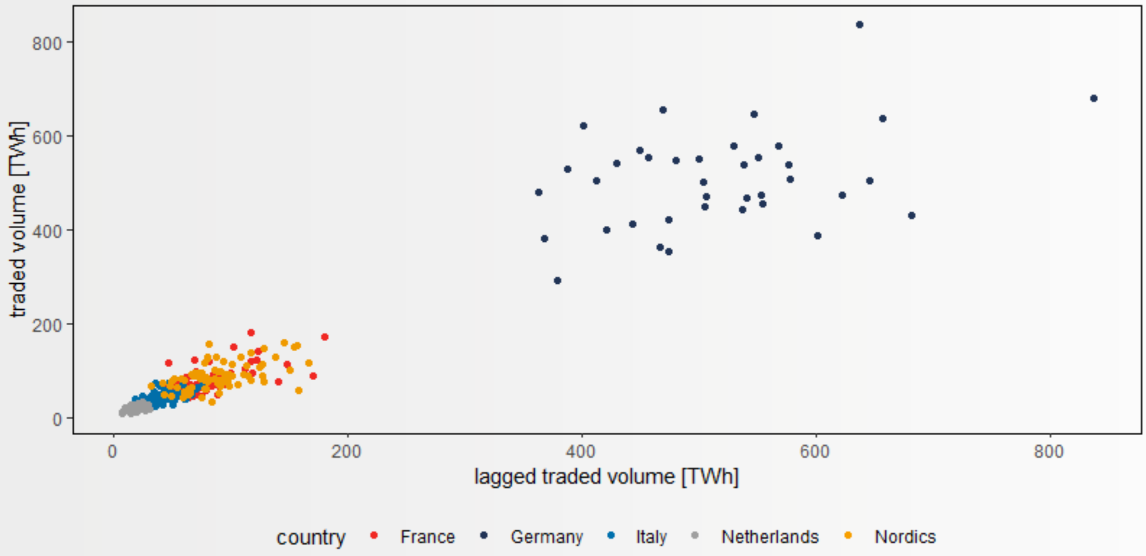
Participant mix/share of renewables

The participant mix is measured as the share of wind and solar PV electricity. The variable is tested in one regression model per liquidity metric because the literature review and series of interviews suggested that the relationship is particularly important for short- rather than long-term markets.

All but one regression results identify a positive and significant relationship with liquidity metrics, whereby the relationship is only negative and significant for non-cleared traded volume. However, noting the limited theoretical foundation for this relationship, the indicator is interpreted with caution for long-term markets.

Lagged traded volume

Traded volume from the previous month is a strong indicator of liquidity levels both within and across regions. Lagged traded volume is significantly positively correlated to traded volume and churn levels across nearly all models (see regression results in the Appendix). One exception is that lagged traded volume is no significant indicator for bid-ask spreads when controlling for region fixed effects. Figure 3.21 shows the relationship between traded volume and lagged traded volume. Besides the linear and positive relationship, heteroscedasticity might be observed.



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

Figure 3.21: Traded volume (in TWh) by lagged traded volume (in TWh)

Further characteristics

We include a time trend as an additional variable to control for trends over time. We disregard temperature for long-term products because such products are more likely to be informed by expected future climate years rather than the temperature during the trading period.

The time trend is significant in around half of the models runs and the sign varies depending on the liquidity indicator. The indicator suggests an increase in liquidity over time (see regression results in the Appendix).

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, whereby this 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.
- Market liquidity tends to increase with price volatility. This finding is more pronounced for the ID than the DA market.
- Increasing supply-demand imbalance negatively affects market liquidity, particularly in the ID market and for market liquidity measured in terms of traded volumes in the DA market.
- The participant mix measured as the share of renewables in a region's generation mix tends to positively affect DA and ID market liquidity, albeit only to a minor extent.

For the regions in focus, the econometric analysis for long-term markets across regions 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 rather than 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 to this relationship or even identify adverse ones. It seems that proxy hedging is not uniform across regions and might be subject to factors that are not observable on a monthly aggregate.
- Market liquidity metrics tend to be lower for higher levels of market concentration. However, this finding is subject to HHI data limitations in short-term markets.

- Higher settlement prices and increased volatility tend to dampen market liquidity metrics, whereby this finding holds for all analysed long-term markets. The relevance of volatility might be observed across all models and both within and across regions.
- Supply-demand imbalance shows a negative relationship with liquidity metrics across regions. However, this relationship is not robust across all models, especially when controlling for region fixed effects.
- The share of renewable energy as an indicator for the participant mix tends to be positively correlated with liquidity metrics across regions.
- Lagged traded volume is a strong and positive indicator for most liquidity metrics both within and across regions. For bid-ask spreads, the indicator is only significant across regions.

3.3 Correlation analysis

3.3.1 Rationale and approach to the DA price correlation analysis

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 stronger 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, such as the DA market. Hence, metrics that quantify DA price relationships across BZs are relevant for short- and long-term market liquidity as market participants might procure power on a different market without significant transaction costs.

In cases where the market liquidity of a respective BZ is limited, market participants might 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 might be the preferred option. As long-term products are used to hedge against short-term price variations, analysing short-term prices can inform about 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, further computing an indicator for the share of hours where prices are equal in two considered BZs; and
- 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, and 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.

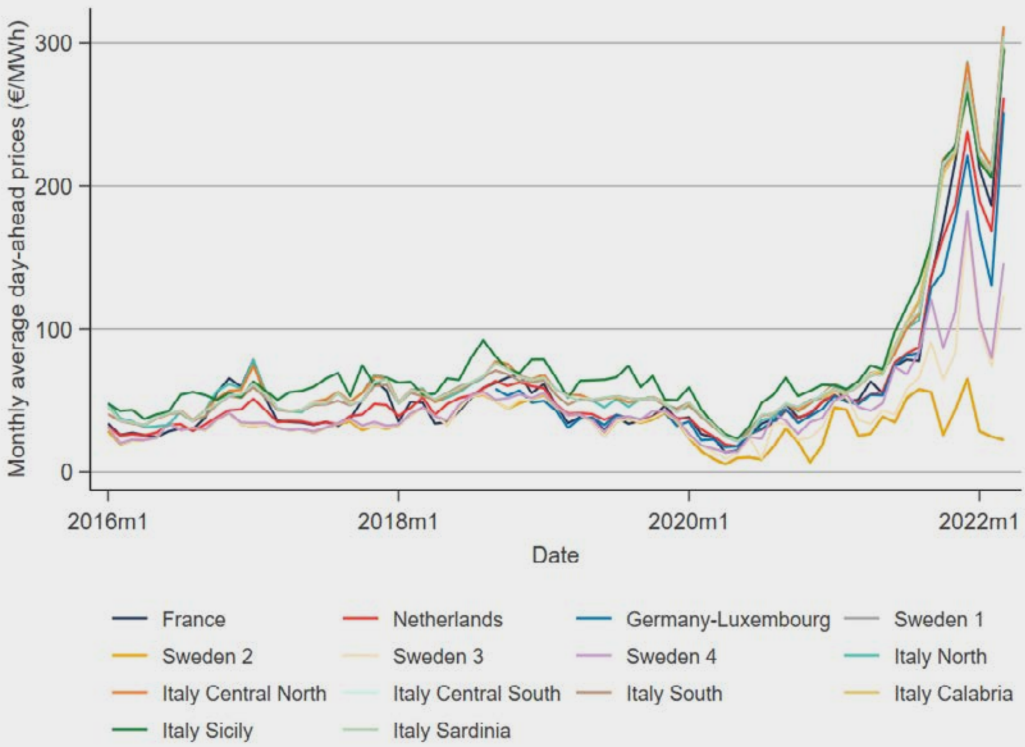
The main findings from our historical analysis are as follows and detailed in the next subsections:

- First, for Italy and Sweden, price convergence between neighbouring zones within the same country is on average higher than between neighbouring zones of different regions.
- Second, in all regions in focus, prices tend to be more strongly correlated in neighbouring rather than non-neighbouring BZs.
- Third, in all regions in focus, price correlations tend to be stronger during non-peak than during peak hours.

Historic price levels

Between 2016 and 2020, the monthly average of hourly DA 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 DA price climbed beyond 70 Euro per MWh and reached 214.5 Euro per MWh in December 2021. In March 2022, the average price was 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 2016 to 2020, the standard deviation of hourly prices was between 9.9 and 12.27, subsequently jumping 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 3.22 shows the development of monthly average DA prices of potentially reconfigured BZs. 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 BZs considered.



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

Figure 3.22: Monthly average of hourly day-ahead prices in BZs considered for reconfiguration (in €/MWh)

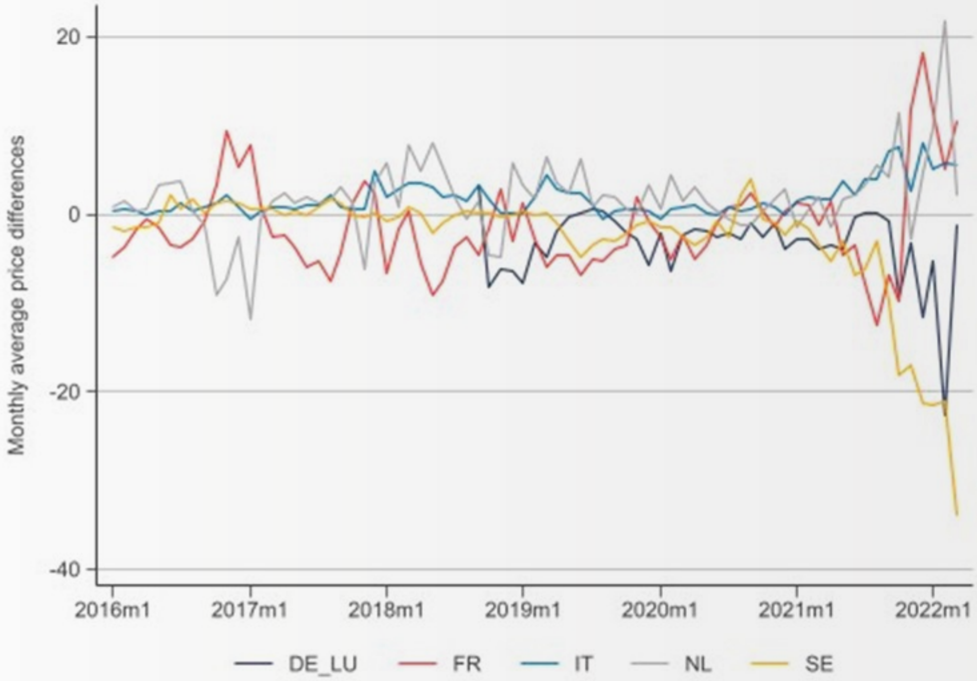
3.3.2 Price convergence of bidding zones

As a result of the market coupling, the DA 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. By contrast, prices might diverge if the interconnection capacity limits cross-zonal exchanges.

For each pair of neighbouring BZs considered, 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 at 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 for price differences with other zones in the same country. For Italy and Sweden, the region-level price spread is an average across all individually computed price spreads at the BZ level. Equivalently, for the other regions comprising only one zone, the region-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 the prices in two considered BZs are equal, and zero if the 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 liquidity levels. 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 3.23 displays the price spreads of the regions in focus averaged across the respective neighbouring zones. Historically, spikes in price differences tend to simultaneously occur across regions. Towards the second half of 2021, price differences increased in all regions, albeit to a lesser extent in Italy. Across the entire time horizon, the Netherlands tends to have the largest positive average price gap (1.75 €/MWh), i.e. higher DA prices than its neighbours. Germany–Luxembourg has an average price gap of –3.57 €/MWh from 2016 to 2022, meaning that prices in the neighbouring BZs tend to be higher.



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

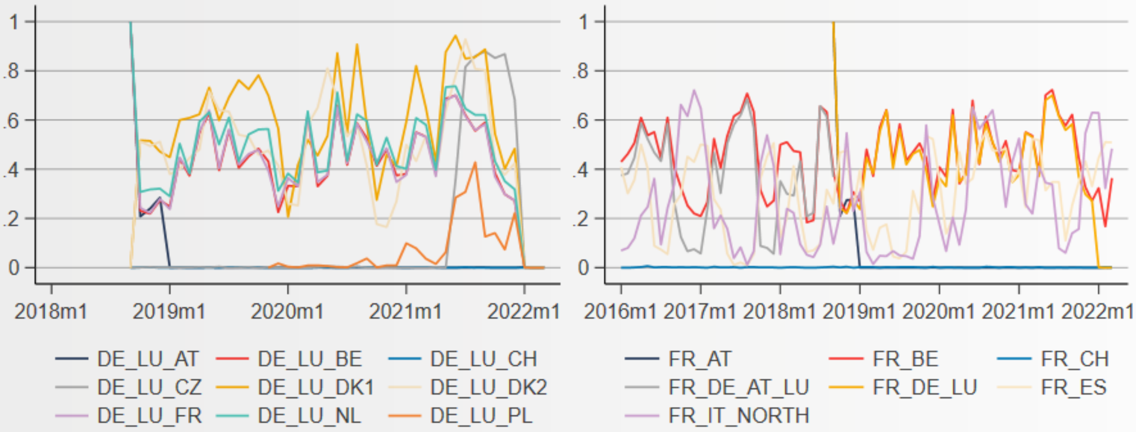
Figure 3.23: Monthly average price spreads for each region in focus across respective neighbouring zones (in €/MWh)

Analysis of price convergence

Figure 3.24 shows the share of hours with converging prices for Germany–Luxembourg and France, i.e. the share of hours per month where prices of the zones in focus are equal to those in neighbouring BZs. As depicted in Figure 3.24, price convergence of Germany–Luxembourg with its neighbours significantly varies 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 a few hours with equal prices, leading to a monthly average close to zero. After an initial 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 regions is close to zero.

For France, the strongest 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 have tended 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 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).

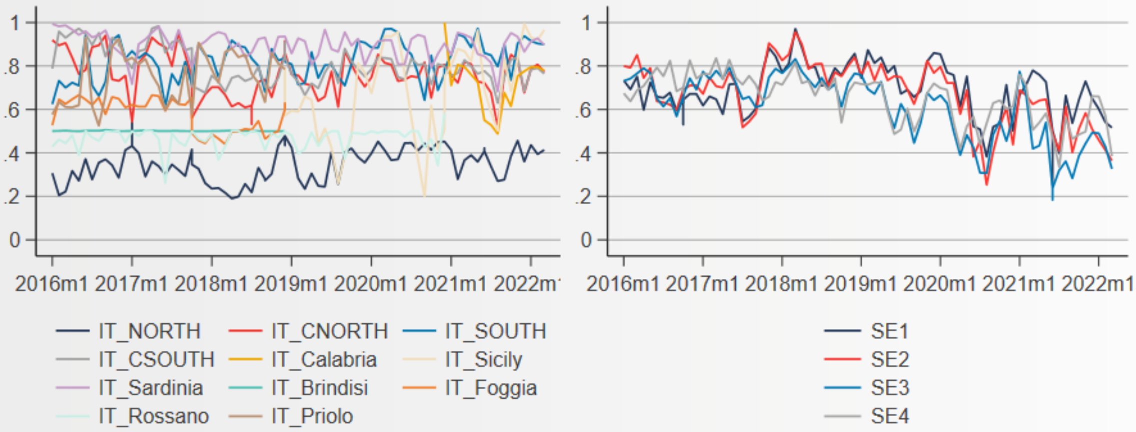


Source: Compass Lexecon analysis of day-ahead price data from the ENTSO-E transparency platform

Figure 3.24: Monthly share of hours with converging prices for Germany–Luxembourg (left) and France (right) with respective neighbouring BZs

Similarly, Figure 3.25 displays the monthly share of hours with converging prices for the Italian and Swedish BZs. As shown on the left-hand side of Figure 3.25, the northern Italian BZ exhibits a significantly different pattern than the rest of the 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 Central North, Central South and Calabria zones. 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 zone considered. By contrast, on average, prices with zones outside of Sweden only converge in 54 % to 61 % of the cases.



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

Figure 3.25: Monthly share of hours with converging prices for Italy (left) and Sweden (right) averaged across respective neighbouring BZs

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

3.3.3 Price correlations between neighbouring and non-neighbouring bidding zones

To analyse whether price correlations differ for neighbouring versus non-neighbouring regions, we compute average DA price correlations for neighbouring and non-neighbouring zones separately.[40]

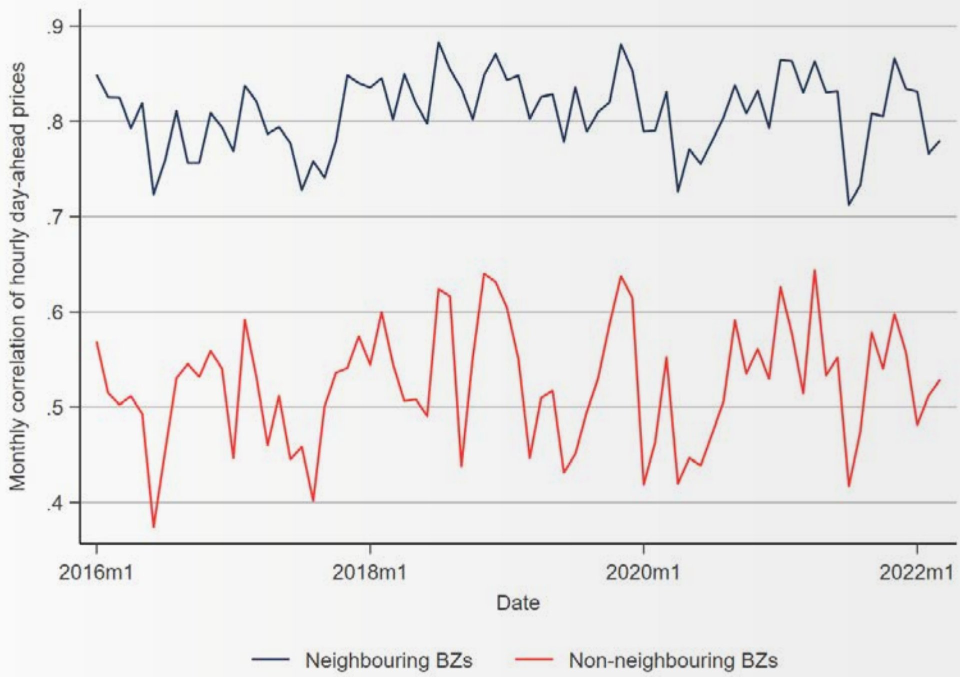
An analysis of all European zones shows a clear pattern, with monthly average price correlations of 0.81 for adjacent zones and 0.52 for non-neighbouring ones. The same holds when we consider correlations before and after 2020 separately (see Table 3.1). This observation indicates that the ongoing energy crisis has not altered the underlying relationship between BZs regarding price co-movements. Indeed, the crisis might have even intensified co-movements as for both neighbouring and non-neighbouring BZs, price correlations are slightly stronger from 2021 to 2022 compared to 2016 to 2020. There are several effects simultaneously at work here that cannot be fully disentangled, including a general trend towards increased market integration, driven in particular by TSOs' efforts towards more market integration as well as regulatory pushes such as the 70% rule in the Clean Energy Package.[41] There is also an increased level of variation in 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 might be better found in neighbouring rather than 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 the ENTSO-E transparency platform

Table 3.1: Average correlation of neighbouring and non-neighbouring BZs

When assessing the development of price correlations over time (see Figure 3.26), neighbouring and non-neighbouring BZs tend to exhibit peaks and troughs of correlations in the same or following months. Overall, the price correlation is stronger between neighbouring than between non-neighbouring BZs in all months. The stronger correlation arising with the geographic proximity of BZs indicates that hedging opportunities might be more effective for neighbours.



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

Figure 3.26: Monthly correlation of day-ahead prices in neighbouring and non-neighbouring BZs

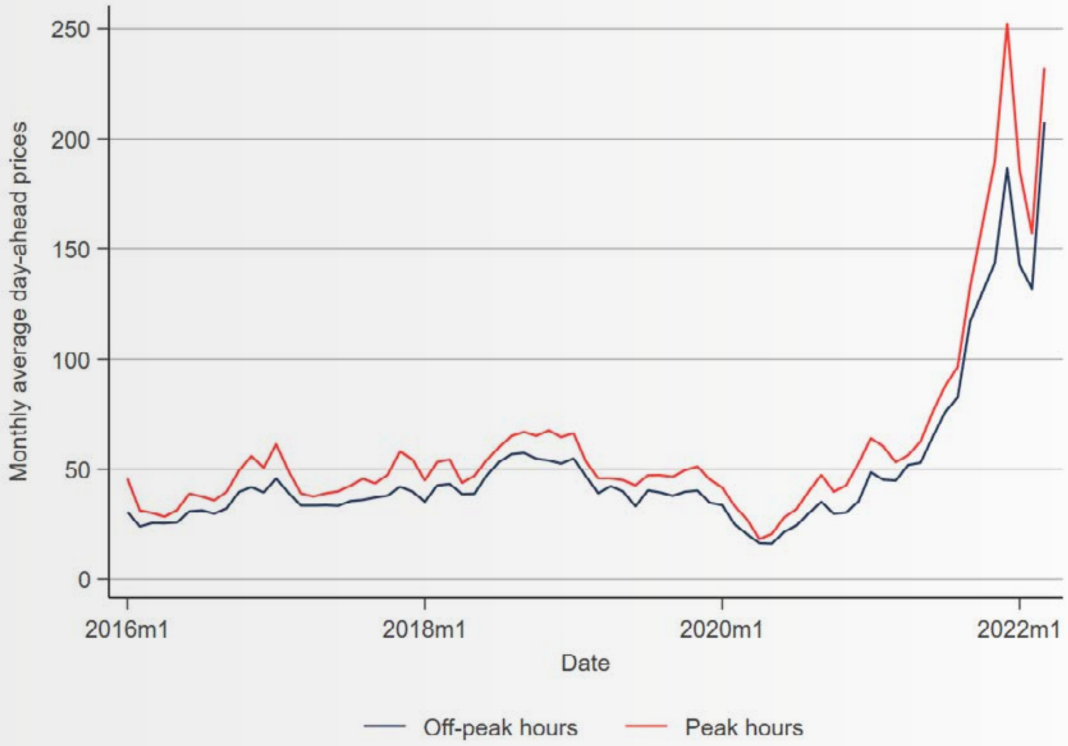
40 In the analysis, geographically adjacent countries rather than interconnected countries are considered as neighbouring countries.

41 Regulation (EU) 2019/943 Art. 16(8)

The same findings hold for the BZs in focus. Aside from a few months in the Netherlands, monthly correlations of hourly DA prices with neighbouring BZs are strictly stronger than with non-neighbouring zones. This is interesting as it highlights the importance of physical interconnection. At the same time, it also shows that there are similar underlying drivers of electricity prices 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 might be driven by varying intensities of electricity demand throughout a day or year. Figure 3.27 shows monthly average DA prices for peak and off-peak hours separately. The figure indicates that DA prices tend to be higher during the daytime on weekdays (peak hours, from 8 am until 8 pm on weekdays), when the need for electricity is higher compared to nighttime and weekends (off-peak hours, from 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 into quartiles to check for seasonal patterns.

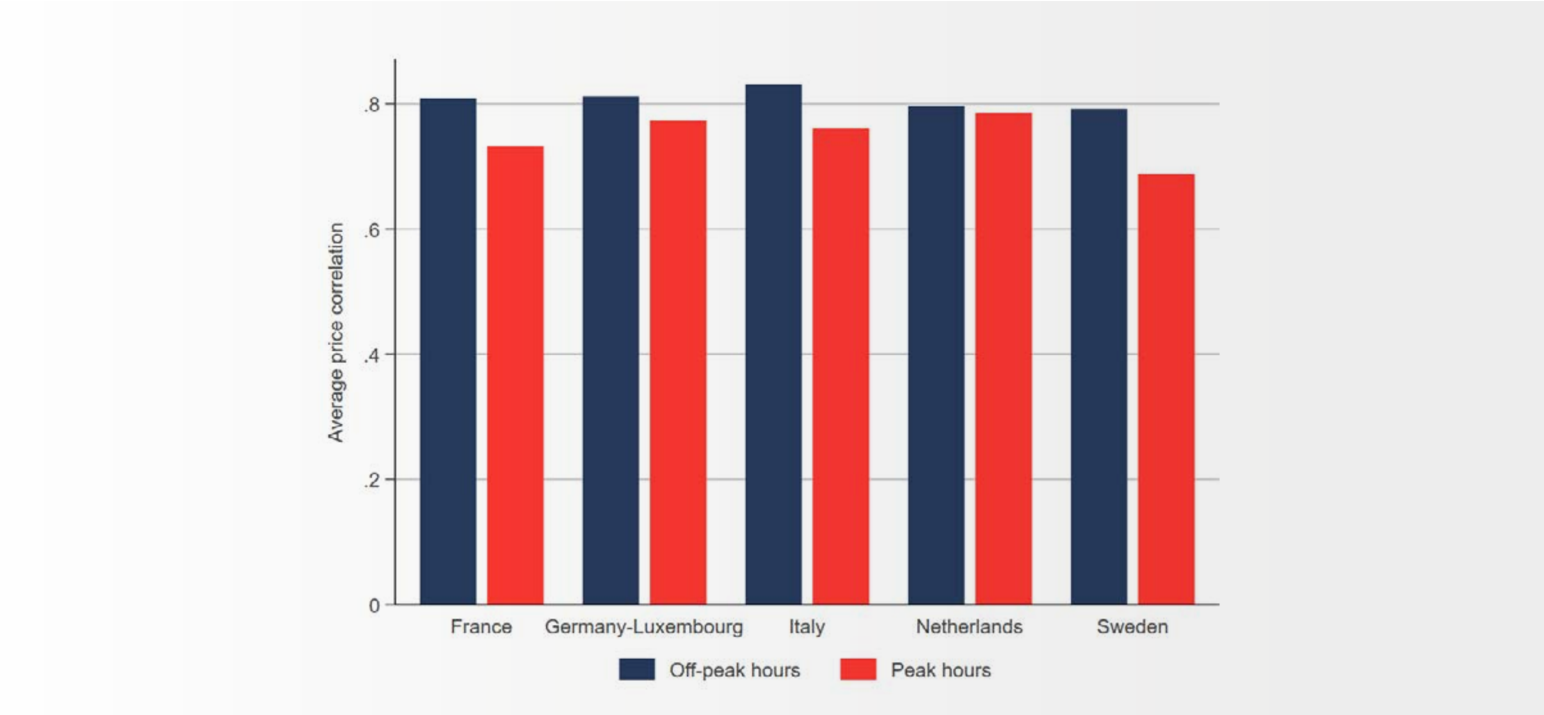


Source: Compass Lexecon analysis of day-ahead price data from the ENTSO-E transparency platform

Figure 3.27: Monthly average day-ahead price during peak and off-peak hours (regions in focus and neighbouring BZs, €/MWh))

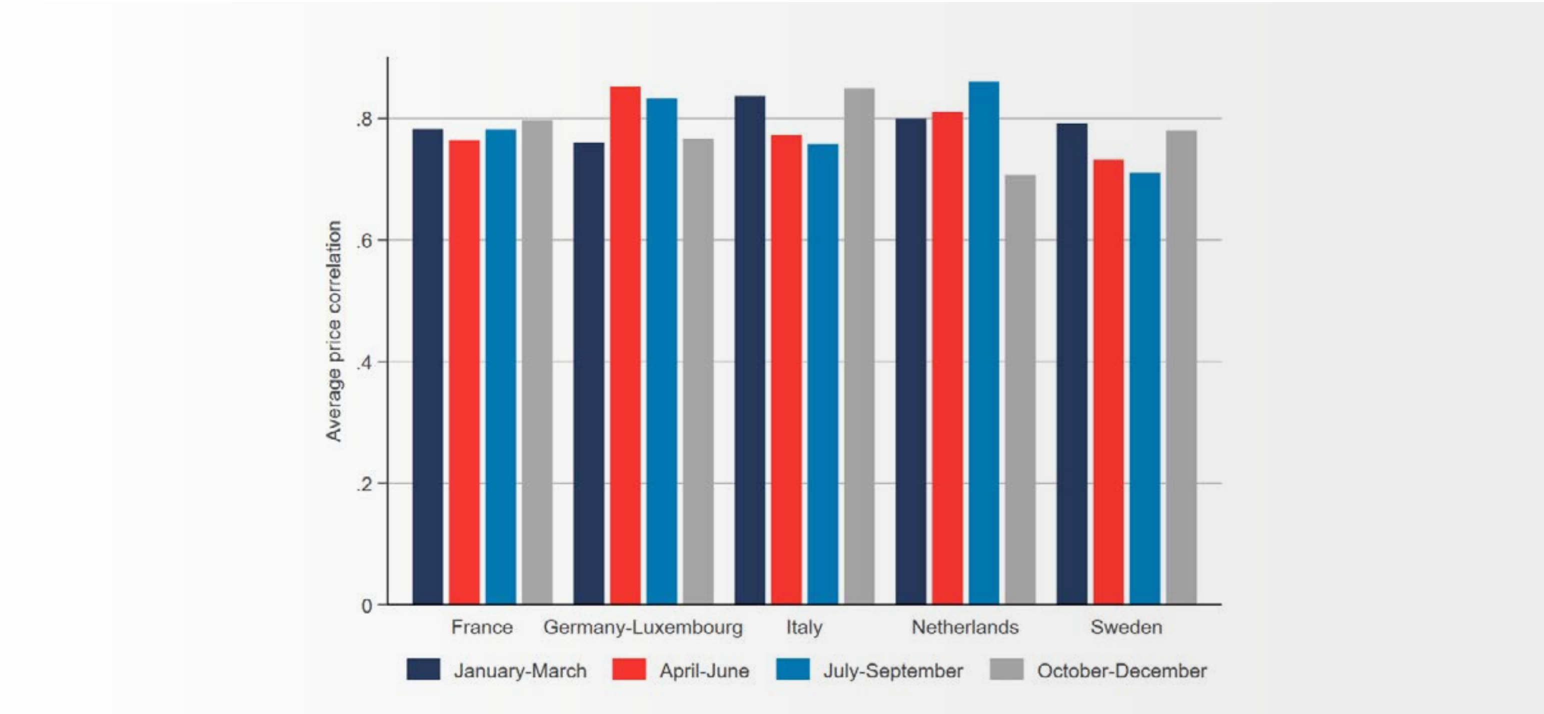
Figure 3.28 exhibits average price correlations by peak and off-peak hours for the regions in focus and their respective neighbouring BZs. All regions in focus exhibit the same pattern, namely that correlations of DA prices between these regions and their neighbours are higher during off-peak hours than peak hours. For Germany–Luxembourg and the Netherlands, the difference between correlations during day- and nighttime is less pronounced than for France, Italy, and Sweden.

Regarding seasonal differences in price correlations, Figure 3.29 shows that price correlations with adjacent zones tend to be stronger during colder months for France, Italy, and Sweden. Here, price correlations are strongest from October to March. Germany and the Netherlands exhibit a reverse pattern, with the strongest correlations between April and September. Across all seasons, stronger price correlations are observed during off-peak compared to peak hours.



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

Figure 3.28: Average price correlation during peak and off-peak hours (regions in focus and neighbouring BZs)



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

Figure 3.29: Average price correlation by quarter (regions in focus and neighbouring BZs)

Granger causality and price developments

To investigate whether price movements in one zone are driven by price developments in another, we applied a Granger causality test, which studies the predictive power that one variable might have on another (Granger, 1969). It should be highlighted that Granger causality analyses test the 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 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, and most of the Italian BZs, as well as the respective 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 affect those in Sicily, but not the other way round. Hence, given that 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 to evaluate 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. We further analyse simultaneous alternative configurations in Germany–Luxembourg and the Netherlands, i.e. simulations that jointly consider alternative configurations in the two regions. For each alternative configuration:
  - We first outline the possible alternative configuration and the data used for the liquidity analysis.
  - We then explain the results of the analysed parameters regarding market size, market concentration, price correlation, price volatility, supply-demand imbalance, and participant mix.
  - Based on these simulated market parameters, we draw conclusions on the expected impact of the proposed BZ 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.[41] Subsequently, 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- and short-term markets or differentiate trades executed on organised markets or OTC. It follows that we cannot perform the same analysis of short- and long-term liquidity that 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 that we have available.

41 We base this analysis on data provided to us by the TSOs between May and June 2024 for the individual alternative configurations and between October 2024 and March 2025 for the joint alternative configurations (see Appendix 1).

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 with liquidity metrics in historical data (as described in Chapters 2 and 3).[42]

These parameters are:

- **Market size** is approximated by the parameters generation and load volume as provided by the TSOs. Based on the results of the historical analysis, we consider increases in market size as – *ceteris paribus* – increases in liquidity metrics both for short- and long-term markets.[43] The market size is expected to have a positive effect on liquidity, other things being equal. However, this relationship might be non-linear for large changes in market size.
- **Market concentration** is portrayed by HHI values for the Nordics and RSI (Residual Supply Index) and PSI (Pivotal Suppler Index) values for central Europe. The different concentration indicators for the Nordics and central Europe are explained by the fact that these two regions were analysed by different modelling teams who set up the competition assessment differently. An increase in the market concentration indicated by either an increase in the HHI or a decrease in RSI or PSI tends to imply a reduced level of liquidity metrics both for short- and long-term markets. The RSI and PSI values are provided in three instances to account for the uncertainty of available import capacity.[44] 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 market liquidity. The parameter applied is calculated as the market size-weighted average of price correlation across directly connected BZs to the BZ in question and can take values between –1 and 1.[45] Based on the results of the historical analysis, we consider that increases in price correlation improve liquidity, other things being equal.[46] We assessed the robustness of the correlations by computing the parameter twice: first, we only included neighbouring BZ that are also part of the CORE region, then we included all neighbouring BZ, i. e. also those that assume a net transfer capacity (NTC) border in the model. Finally, we compared the results in direction and extent and conclude that the model simplification used for NTC borders does not influence the robustness of the parameter. Therefore, we use the price correlation parameter that includes all connected BZs.
- **Price volatility** is calculated based on the simulated price data provided by the TSOs. We compute price volatility as the daily standard deviation of prices per BZ and analyse the development of the monthly average of daily price volatility in each alternative configuration compared to the status quo. The impact of changes in price volatility depends on the time horizon considered. In particular, an increase in price volatility is expected to improve short-term market liquidity as trading with long-term products is less attractive than short-term products in case of fluctuating prices. Inversely, increasing spot price volatility is expected to reduce liquidity in the forward markets.

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

43 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".

44 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 regarding the ownership of renewable energy sources. Given the limitations of this computation, we exercise caution when interpreting this indicator.

45 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 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. The implicit price correlation of 1 among regions within a status quo configuration is not included in the calculation, because this parameter assesses cross-border trade explicitly. The potential impact of potential trade shifts between regions within a status quo configuration on liquidity is already accounted for through the market size indicator. Including the implicit price correlation of 1 in the calculation of the weighted average correlation would lead to double-counting the effect of changes in market size.
Cross-zonal capacity might 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.

46 This parameter is based on the positive statistical relationship between price correlation and liquidity metrics found in the historical analysis. However, the historical analysis might not fully capture the theoretical effects of proxy hedging. For example, if market participants decide to hedge indirectly, this could reduce liquidity in the domestic market. As a result, we interpret the findings related to this parameter cautiously.

- **Supply-demand imbalance** is based on the simulated generation and demand for each alternative configuration. For the analysis, we first compute the share of supply over the sum of demand and supply, as well as the share of demand over the sum of demand and supply per BZ. Subsequently, we take the absolute difference between the two shares to assess potential supply-demand imbalances per BZ. The gap between the share of supply and demand is then expressed in percentage points (p. p.). An increase in the indicator represents a widening of the gap between the supply and demand share, i. e. an increasing imbalance that is expected to reduce liquidity. The indicator is given as a percentage.
- **Participant mix** is used as a proxy for a more diverse participant mix and represents the intensity of renewable generation per BZ. For this purpose, we calculate the share of renewable generation in total generation per month (given as a percentage). Renewable generation is given by the sum of onshore wind, offshore wind, and PV generation. Following the findings of the previous section, we expect an increase of the RES share to be favourable for market liquidity.

The simulated data provided 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 analysing 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 regarding their absolute value and in relative terms, i. e. the change between the status quo and the alternative configuration. The results show the change in direction and which alternative BZ configurations might lead to critical changes in market characteristics. More specifically, 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 might not be the same after the reconfiguration.
- We identify the **BZ with the minimum and maximum parameter values** based on the annual average of the parameter considered for each alternative configuration and each parameter. To further assess the extremes of the most or least liquid BZ identified over a year, we also analyse the minimum and maximum monthly values. This approach allows us to study the impact on the least and most liquid individual BZs, i. e. extremes that might arise with a specific reconfiguration.

Forming expectations on liquidity metrics

The identified changes and absolute values of the market characteristics are assessed to determine the corresponding likely implications for liquidity metrics in the alternative configurations. For this purpose:

- for each BZ, we consider the direction of change of each individual market characteristic, the degree of change, and the level of the resulting parameter;
- for each market characteristic and alternative configuration, we conclude the direction and size of change across BZs;
- for each market characteristic and alternative configuration, we assess the changes and their implications for market liquidity in light of the generalised identified relationship between the market characteristic and liquidity metrics;[47]
- considering the findings on liquidity changes across all analysed market characteristics, we conclude the expected liquidity metric changes for short- and long-term products in each alternative configuration (see Tables 5.1 and 5.2).

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 predominantly identified relationships based on comparisons within a BZ or across BZs. By contrast, the simulated data considers reconfigured BZs that 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 in liquidity metrics for the individual BZ and the alternative configurations as a whole.

47 We note that the assessment of expected liquidity changes based on market concentration is inconclusive for all regions but Sweden due to underlying data limitations for this market metric.

Besides data availability limitations, we acknowledge a set of additional limitations in terms of developing expectations:

- First, the liquidity levels and metrics resulting from a BZ reconfiguration might be subject to various 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 has not been considered.
- Second, we have previously identified non-linear relationships between market characteristics and liquidity metrics. We have further identified that some conceptual relationships between market characteristics and liquidity metrics can only be captured by linear relationships to a limited extent, if at all.
- Third, the BZ reconfigurations assessed here might lead to spillover effects affecting liquidity in BZs not directly affected by the reconfiguration. These spillover effects are not considered in the analysis.[48]
- Fourth, the relationships considered between market characteristics and liquidity metrics are not necessarily exhaustive. The analysis of additional market characteristics might further increase the robustness and portray a more exhaustive picture of the potential effects of the BZ reconfigurations.

Therefore, the approach implemented here focuses on the most direct effects of the BZ reconfiguration and not the other non-linear and secondary effects of BZ reconfigurations on changes in liquidity levels. Consequently, the concrete manifestation of liquidity might differ from expectations following 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 are each 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 market size, market concentration, price correlation, price volatility, supply-demand imbalance, and participant mix.
- 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.

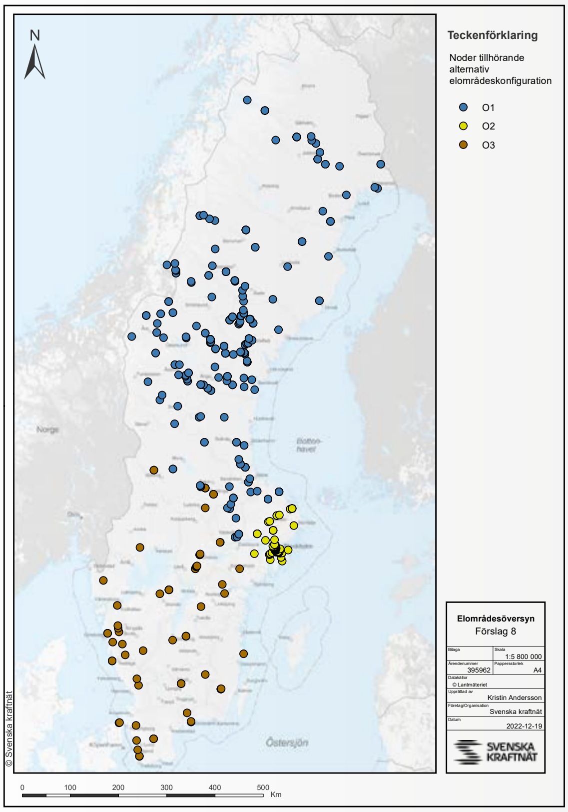
4.2 Swedish simulated data on proposed bidding zones

There are four alternative BZ configurations for the Nordic area, two based on recommendations by Svenska Kraftnät (alternative configurations 9 and 11). In two of the proposed alternative configurations, Sweden would continue to comprise 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 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 align with those proposed by the Nordic TSOs. Figure 4.1 displays the four alternative configurations. The numbering of the simulated zones is assigned from North to South.

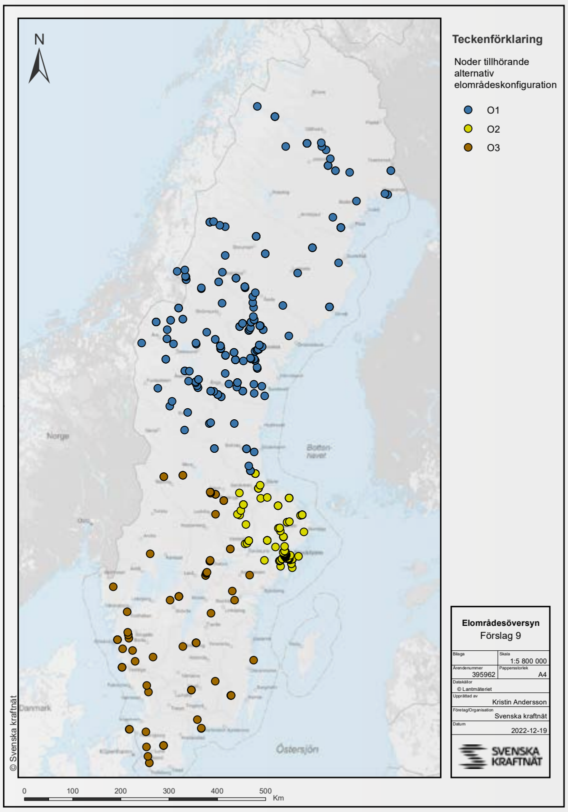
For each proposed alternative configuration and in the status quo – i.e. assuming that BZs remain the same – the Nordic TSOs simulated hourly dispatch of generation units to meet demand in a pan-EU model and provided us with hourly values of generation volume per technology, demand, HHI and prices for 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 BZs of Denmark, Estonia, Lithuania, the Netherlands, Poland, and the United Kingdom.

48 We further note that we have not identified robust potential implications for neighbouring BZs in the historical data analysis.

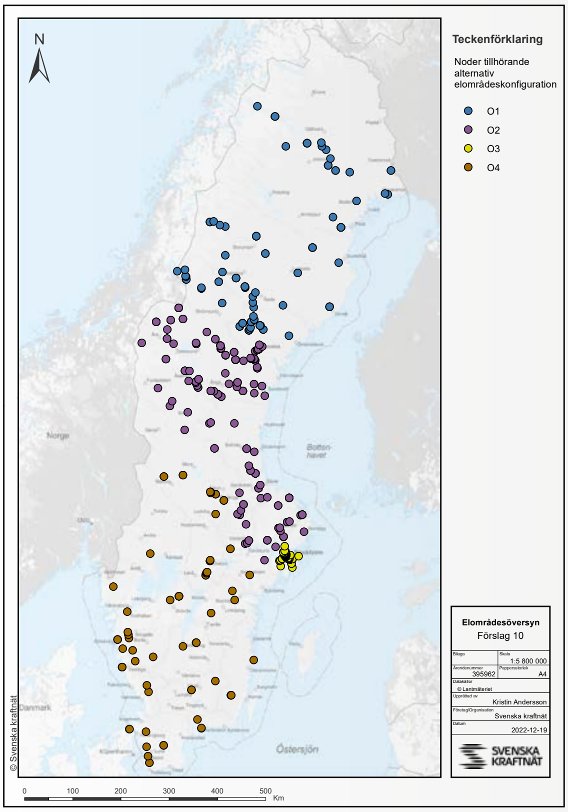
Alternative configuration 8



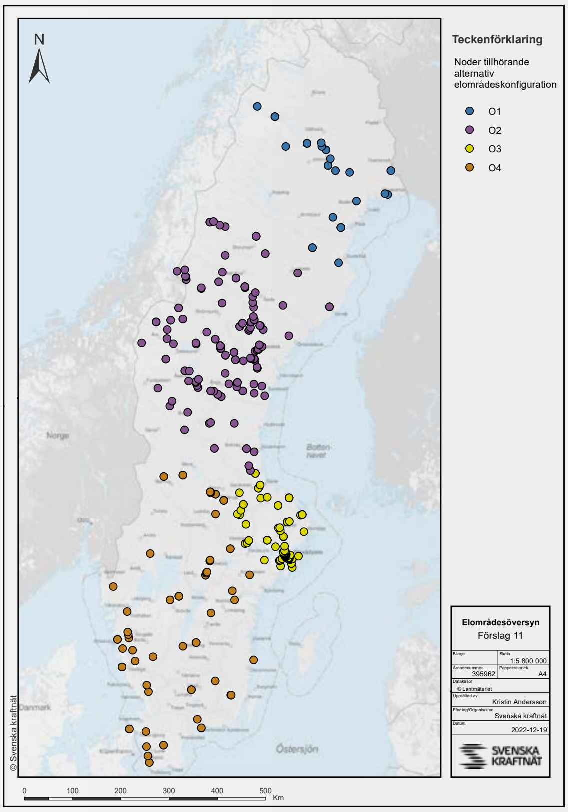
Alternative configuration 9



Alternative configuration 10

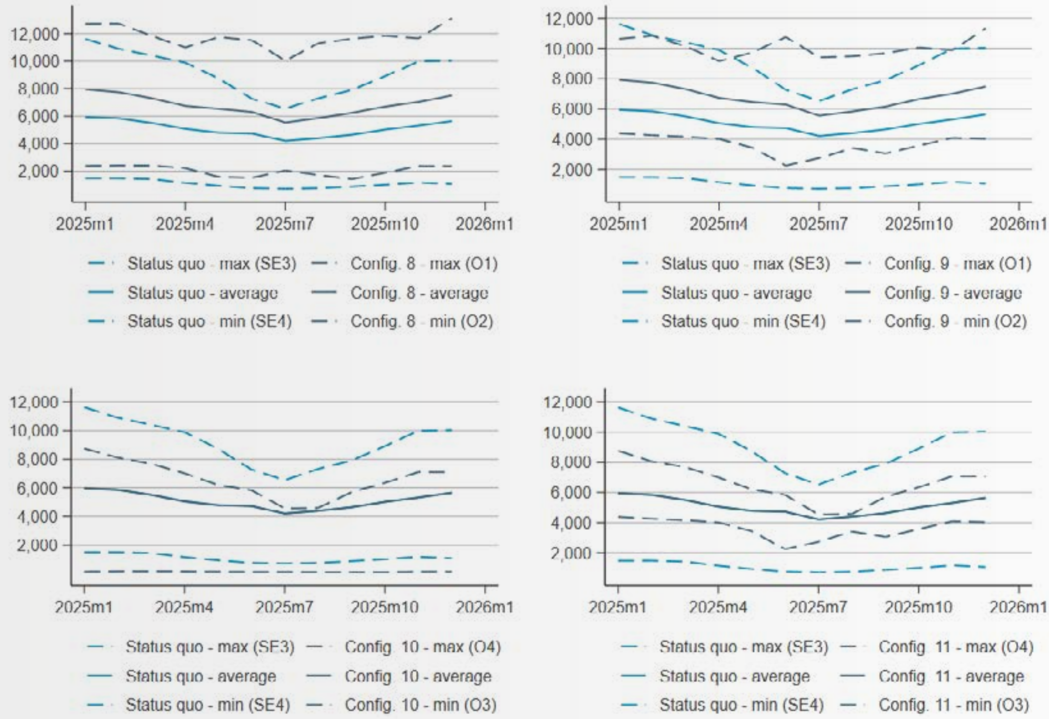


Alternative configuration 11



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

Figure 4.1: Alternative BZ configurations with three or four Swedish BZs



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

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

4.2.1 Market size approximated by generation

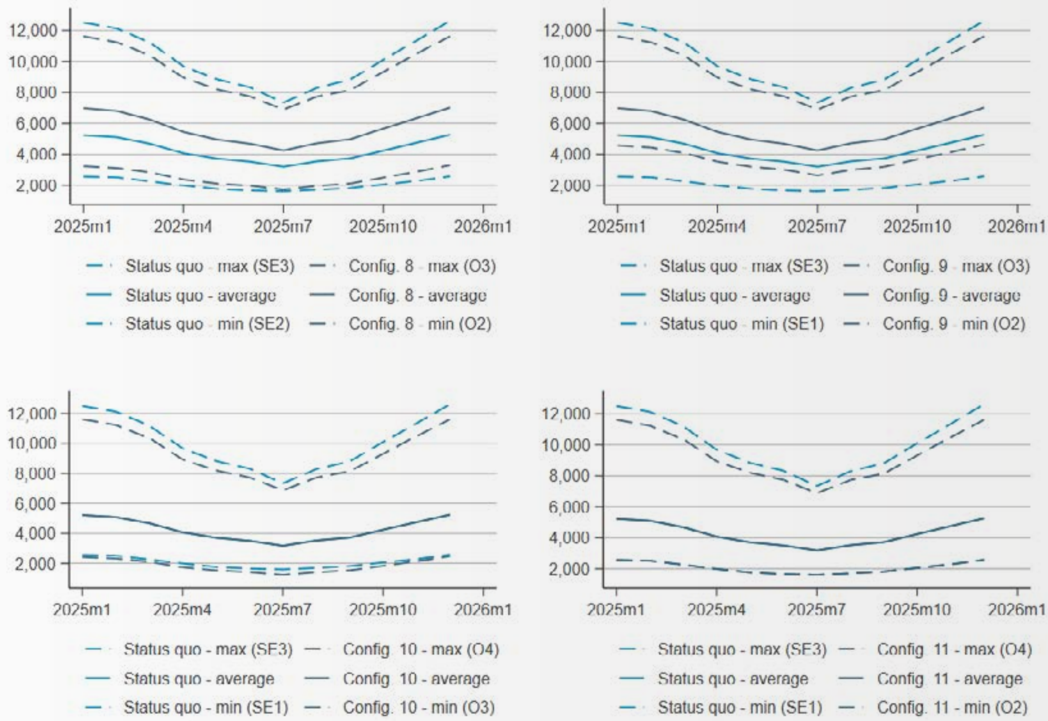
Figure 4.2 shows the average, minimum, and maximum generation volume in the status quo and the alternative configurations. The simulated liquidity metrics impact of the alternative configurations in terms of market size approximated by generation volume is as follows:

- 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 configuration, the largest zone used to be SE3 but is now O4 in alternative configurations 10 and 11, and O1 in alternative configuration 9. Alternative configuration 8 shows an increased size of the largest zone O1.
- Perhaps more importantly, we observe a decrease in the minimum generation of the smallest zone in alternative configuration 10 to 98 MWh. Moreover, the difference between supply and demand significantly increases for O3 in alternative 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 around 37%.[49] We further see a miniscule decrease in average generation in alternative configuration 10 to 5,092 MWh.

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

- For alternative configurations 8 and 9 (three zones), we mostly observe 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, albeit of smaller magnitude than in alternative configurations 8 and 9.

49 See Chapter 4.2.6 for a detailed analysis of this asymmetry.



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

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

- For alternative configuration 10 (four zones), we observe reductions in the maximum generation of the largest zone and average generation.
- A reconfiguration might 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 (see Figure 4.3) appear 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 they have the same number of BZs as in the status quo.

The impact of the reconfigurations in terms of market size, approximated by demand can 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 only become less extreme 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.

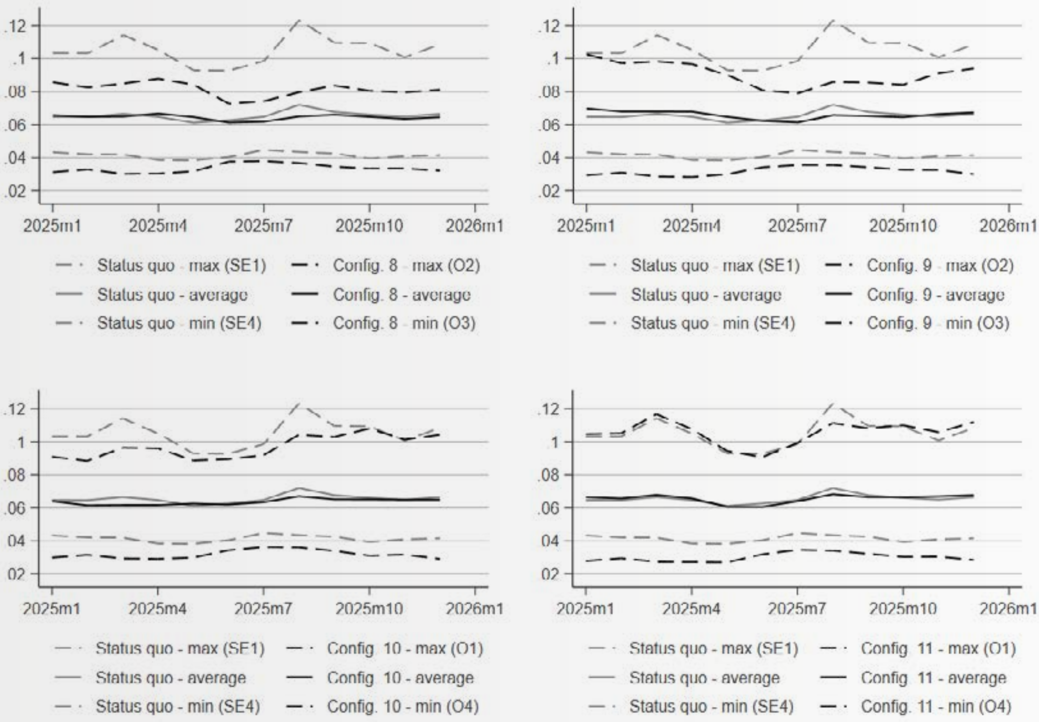
Therefore, this indicator shows that the proposed alternative configurations are unlikely to aggravate concerns due to liquidity metrics (or could even alleviate them) compared to the status quo, except potentially in alternative configuration 10. In that alternative configuration, over the summer period, the BZ O3 might 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[50] values calculated by the Nordic TSOs for each of the alternative BZ configurations in line with the BZR Methodology. The average, minimum, and maximum HHI levels in the status quo and alternative configurations are displayed in Figure 4.4. 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 configurations 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 of the most concentrated BZ in alternative configuration 11 remains the same as the status quo, and hence concentration concerns would remain unchanged.



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

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

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 is standard for HHI calculations in electricity markets, the interconnection capacity of this area was also considered as part of the relevant market, which 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.

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

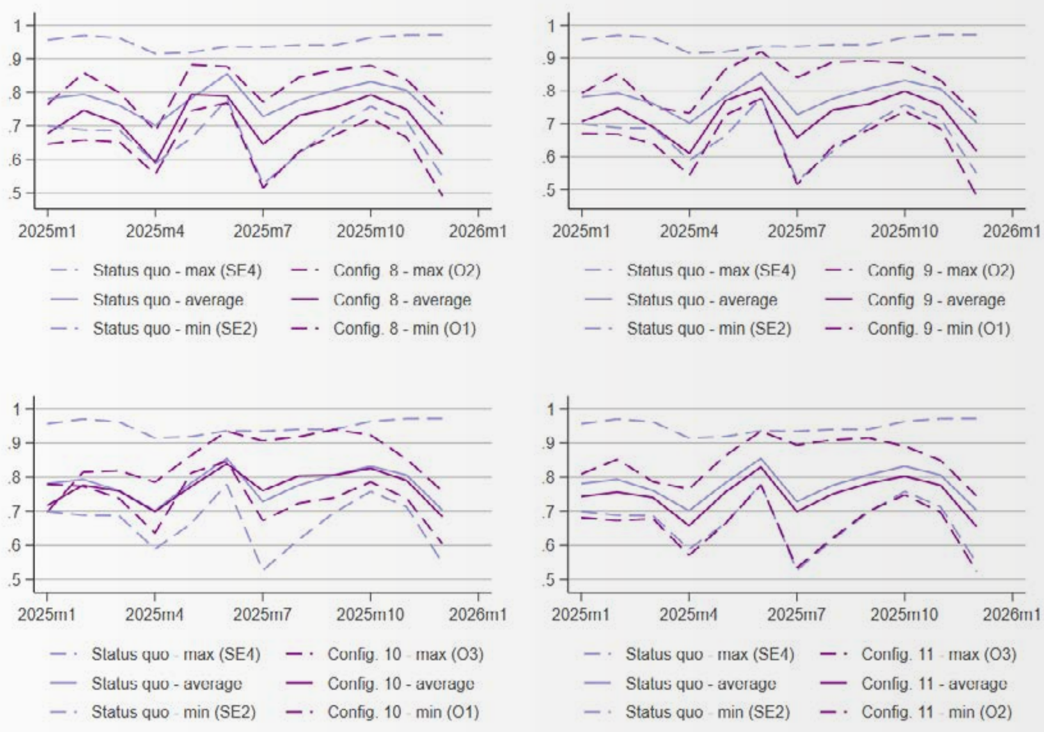
4.2.4 Price correlations

Figure 4.5 illustrates the average, minimum, and maximum price correlations in the status quo and the alternative configurations. The correlation analysis of the simulated wholesale prices suggests that market liquidity metrics are not affected extensively in any alternative configurations in accordance with 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 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 only decrease to a minor extent in alternative configurations 8, 9 and 11. The minimum price correlation only slightly increases in alternative configuration 10, from 0.53 in the status quo 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 indicates that liquidity concerns might be more present in O1 than in other BZs.

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.



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

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

4.2.5 Price volatility

Figure 4.6 shows the average, minimum, and maximum price volatilities in the status quo and alternative configurations. The analysis of price volatility of the simulated wholesale prices suggests that market liquidity metrics are not affected extensively in any of the alternative configurations. We base this on the following observations:

- Average price volatility does not extensively change in any of the alternative configurations (ranging from 4.44 €/MWh to 4.85 €/MWh) compared the status quo (4.48 €/MWh). Hence, no substantial improvements or impediments are expected for short- and long-term liquidity.
- As for average price correlation, minima of price volatility do not change extensively in the alternative configurations (ranging from 1.07 €/MWh to 1.45 €/MWh) compared to the status quo (1.09 €/MWh).
- For price volatility maxima, we observe only slight decreases for the alternative configurations 8, 9 and 11 compared to the status quo, and hence slight liquidity improvements in the short-term and impairments in the long-term market might occur, if at all. A slightly larger change in price volatility is observed in the alternative configuration 10 where the maximum price volatility observed increases to 12.38 €/MWh (in SE 3) compared to 9.35 €/MWh in the status quo (SE 4). Although limited, slight liquidity improvements in short-term markets and impairments in long-term markets might be observed in SE 3 of alternative configuration 10.

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

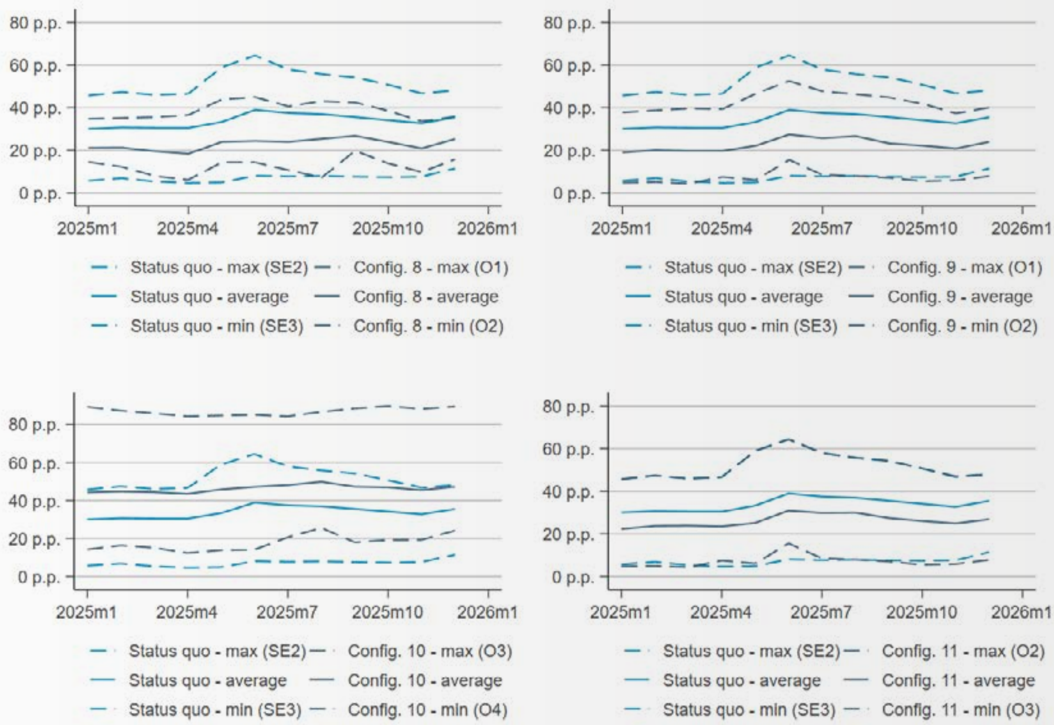
Figure 4.6: Average, minimum, and maximum price volatility in the status quo and alternative configurations (in €/MWh)

As price volatilities of the reconfigured BZs do not change extensively – except for potential extreme cases in alternative configuration 10 – this indicator shows that the proposed alternative configurations are unlikely to aggravate liquidity concerns compared to the status quo.

4.2.6 Supply-demand imbalance

Figure 4.7 illustrates the average, minimum, and maximum supply-demand imbalances in the status quo and alternative configurations. The indicator for supply-demand imbalance suggests liquidity improvements for alternative configurations 8, 9, and 11 but potential impairments for BZs in alternative configuration 10.

- In configurations 8, 9, and 11, the average supply-demand imbalance decreases to between 23 and 26 p.p. compared to an average supply-demand imbalance of 34 p. p. in the status quo. Moreover, in the alternative configurations 8 and 9, the largest observed supply-demand imbalance is lower than in the status quo, i.e. indicating an improvement of liquidity. In all three alternative configurations, the smallest observed imbalance does not strongly vary compared to the status quo.
- However, in configuration 10, all metrics – i.e. the average, maximum, and minimum imbalance gap – worsen compared to the status quo. In particular, the largest supply-demand imbalance is observed in SE3 with 90 p. p. compared to 64 p. p. in SE2 of the status quo configuration.



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

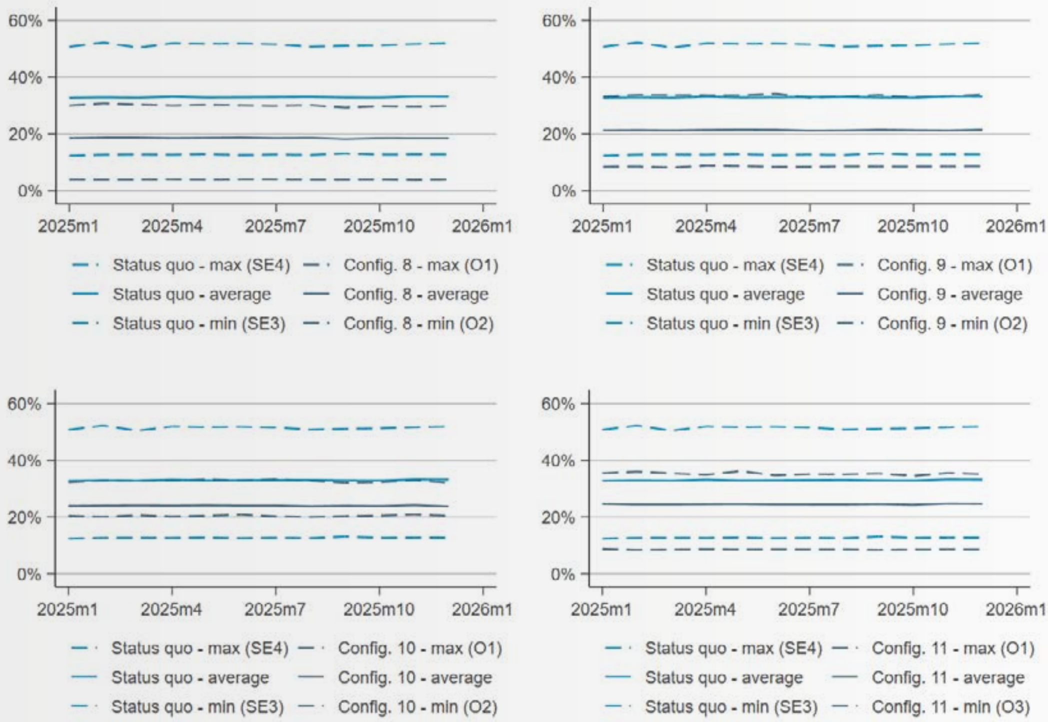
Figure 4.7: Average, minimum, and maximum supply-demand imbalance in the status quo and alternative configurations

We conclude that in particular SE3 of alternative configuration 10 might experience liquidity impairments due to a widening supply-demand imbalance. For the remaining configurations, the indicator rather points towards liquidity improvements.

4.2.7 Participant mix

The indicator for participant mix – i.e. the share of renewable electricity generation (see Figure 4.8) in each BZ – decreases in all alternative configurations compared to the status quo configuration.

- The largest average decrease is observed for configuration 8 where the participant mix decreases to 19% compared to 33% in the status quo configuration. The average share of renewables in alternative configurations 9, 10, and 11 ranges between 21% and 25%.
- Further, the maximum observed shares of renewables decline from 52% in the status quo to 31% to 36% across alternative configurations.
- As for the maxima, the smallest observed shares of renewables decrease in most cases, except for alternative configuration 10 with 20%, up from 13% in the status quo configuration.



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

Figure 4.8: Average, minimum, and maximum participant mix in the status quo and alternative configurations

Overall, we conclude that the indicator for the participant mix mostly indicates liquidity impairments in all alternative configurations.

4.2.8 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 the different proposed alternative configurations in Sweden.

Country	Descriptive statistics	Market concentration	Price		Market Size		RES share	Supply-demand imbalance
		HHI	Correlation	Volatility	Generation	Demand		
Status quo	Max	SE1: 0.12	SE4: 0.97	SE4: 9.35	SE3: 11,614	SE3: 12,250	SE4: 52	SE2: 64
	Average	0.07	0.78	4.48	5,094	4,250	33	34
	Min	SE4: 0.04	SE2: 0.53	SE2: 1.09	SE4: 722	SE2: 1,608	SE3: 13	SE3: 5
Config. 8	Max	↓ 02: 0.09	↓ 02: 0.88	↓ SE3: 8.12	↑ 01: 13,110	03: 11,628	↓ SE1: 31	↓ SE1: 45
	Average	0.07	↓ 0.72	↓ 4.44	↑ 6,789	↑ 5,667	↓ 19	↓ 23
	Min	↓ 03: 0.03	↓ 01: 0.49	↑ SE1: 1.16	↑ 02: 1,432	↑ 02: 1,721	↓ SE2: 4	↑ SE2: 6
Config. 9	Max	↓ 02: 0.1	↓ 02: 0.92	↓ SE3: 8.77	↓ 01: 11,344	↓ 03: 11,623	↓ SE1: 34	↓ SE1: 52
	Average	0.07	↓ 0.72	↑ 4.85	↑ 6,767	↑ 5,667	↓ 21	↓ 23
	Min	↓ 03: 0.03	↓ 01: 0.48	↑ SE1: 1.20	↑ 02: 2,252	↑ 02: 2,641	↓ SE2: 8	↓ SE2: 4
Config. 10	Max	↓ 01: 0.11	↓ 03: 0.94	↑ SE3: 12.38	↓ 04: 8,741	↓ 04: 11,623	↓ SE1: 33	↑ SE3: 90
	Average	0.07	↓ 0.77	↑ 4.75	↓ 5,092	4,250	↓ 24	↑ 46
	Min	↓ 04: 0.03	↑ 01: 0.61	↑ SE1: 1.45	↓ 03: 98	↓ 03: 1,238	↑ SE2: 20	↑ SE4: 12
Config. 11	Max	01: 0.12	↓ 03: 0.94	↓ SE4: 9.24	↓ 04: 8,762	↓ 04: 11,623	↓ SE1: 36	SE2: 64
	Average	0.07	↓ 0.75	↓ 4.46	↑ 5,095	4,250	↓ 25	↓ 26
	Min	↓ 4: 0.03	↓ 02: 0.52	↓ SE2: 1.07	↑ 03: 2,252	02: 1,608	↓ SE3: 8	↓ SE3: 4

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 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. Grey indicates that the change is an improvement or impairment, depending on the market timeframe considered. The displayed averages are annual averages across all BZs in the reconfiguration considered. The displayed minima and maxima show the highest and lowest observed monthly values of the stated BZ. The stated BZ has been identified based on the average annual value of the market characteristic parameter considered.

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

Overall, our analysis suggests potential slight liquidity metric improvements for alternative configurations 8 and 9, 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.
- Similarly to the generation, average demand increases in the alternative configurations 8 and 9 compared to the status quo and 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. Therefore, while competitiveness does not deteriorate in the larger zones, it slightly improves in the smallest zone.
- In both alternative configurations, the average supply-demand imbalance decreases, and the largest observed imbalance decreases compared to the status quo. At the same time, the smallest observed imbalances do not change extensively.
- 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 the changes, liquidity concerns seem unlikely to be aggravated compared to the status quo.
- Average price volatility is not altered extensively in the alternative configurations 8 and 9. Similarly, the smallest observed price variations do not strongly differ in terms of volatility in the status quo. Only maximum price volatilities decrease, although, the change is rather small.
- The only slight impairment is observed from changes in the participant mix. For both alternative configurations, the averages and extremes of renewable generation share decrease compared to the status quo, pointing to slight liquidity impairments.

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

- Alternative configuration 10 shows a substantially smaller minimum market size in terms of generation. This reduces liquidity metrics and might place the BZ at greater dependency on other zones than in other alternative configurations or the status quo.
- In alternative configuration 10, over the summer period, the BZ O3 might 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 configuration 10, the average, maximum, and minimum imbalance gap worsens compared to the status quo. In particular, the largest supply-demand imbalance is observed in SE3, which might intensify the BZ's dependence on other zones and suggest liquidity impairments.
- 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 might 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, albeit 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 might be larger in alternative configurations 10 and 11 given the development of the other liquidity metrics.
- We observe only slight decreases in price volatility for alternative configuration 11 compared to the status quo, and hence only slight liquidity improvements in the short-term and impairments in the long-term market might occur, if at all. A slightly larger change in price volatility is observed in alternative configuration 10, with potentially slight liquidity improvements in short-term markets and impairments in long-term markets SE3.
- The only increase in the smallest observed shares of renewables occurs in alternative configuration 10, although this is not expected to have a pivotal effect on liquidity.

Following the changes in market characteristics for the individual BZ, the following overall conclusion can be derived:[51]

- Alternative configurations 8 and 9 see changes in market characteristics that 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 03 shows exceptionally small generation volumes and increasing supply-demand asymmetry.
- Alternative configuration 11 shows an inconclusive picture regarding 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.

4.3 German–Luxembourg simulated data on proposed bidding zones

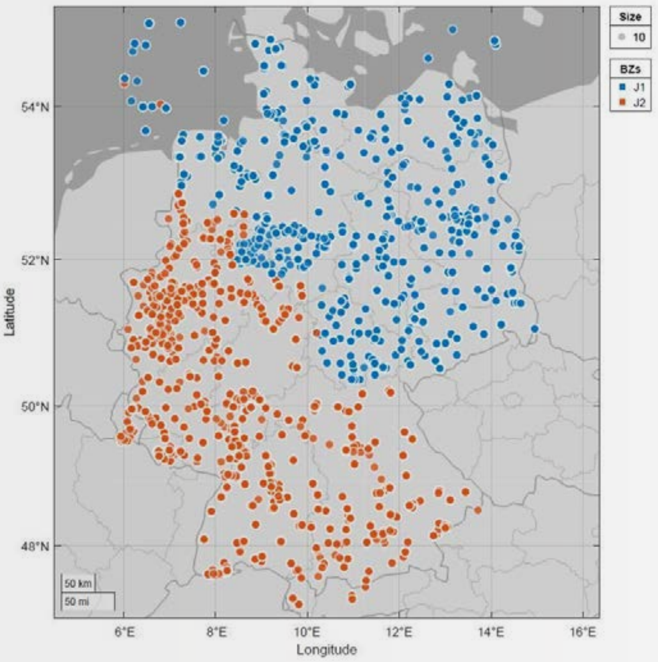
There are four alternative BZ configurations for the German–Luxembourg BZs. In accordance with ACER decision 11-2022 on alternative BZ configurations, TSOs decided to assess the fallback configurations for the German–Luxembourg BZ in the BZR such that the final specifications analysed here are alternative 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 southwest and northeast 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 northeast area of the region, resulting in three zones in total. Similarly, in alternative configuration 13, the southwest area of the German–Luxembourg region is divided into two more BZs, forming four BZs in total. Note that the borders of the two zones in the northeast of alternative configuration 12 differ from the border between the two zones in the northeast of alternative configuration 13. Alternative configuration 14 foresees a fifth BZ, which splits the far northern part of the northeastern zone into two, otherwise matching with all other borders in alternative configuration 13. Figure 4.9 shows the four alternative configurations.

For each proposed alternative configuration and the status quo – i.e. assuming that 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 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.

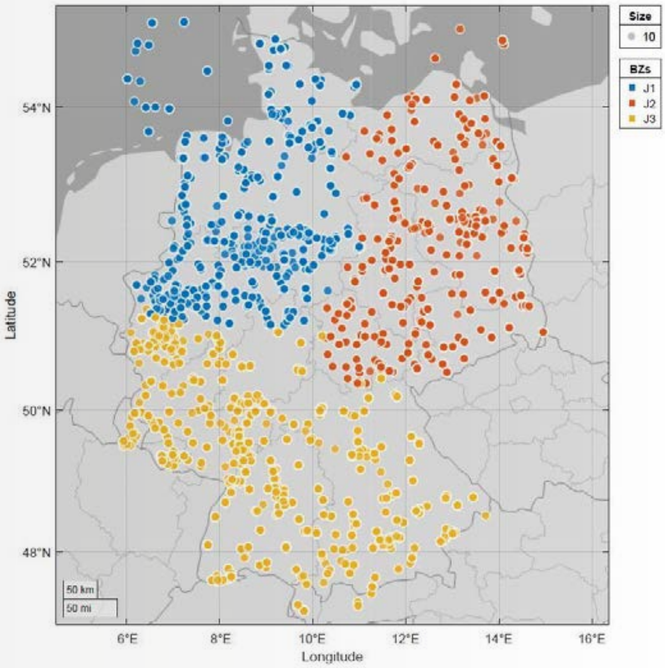
51 Noting the historic relevance of the DA market and the Nordic system price on market liquidity, the identified expected impact on individual BZs might or might not further affect the overall liquidity of the Nordics. The analysis of these indirect effects are out o the scope of this study.

Alternative configuration 2

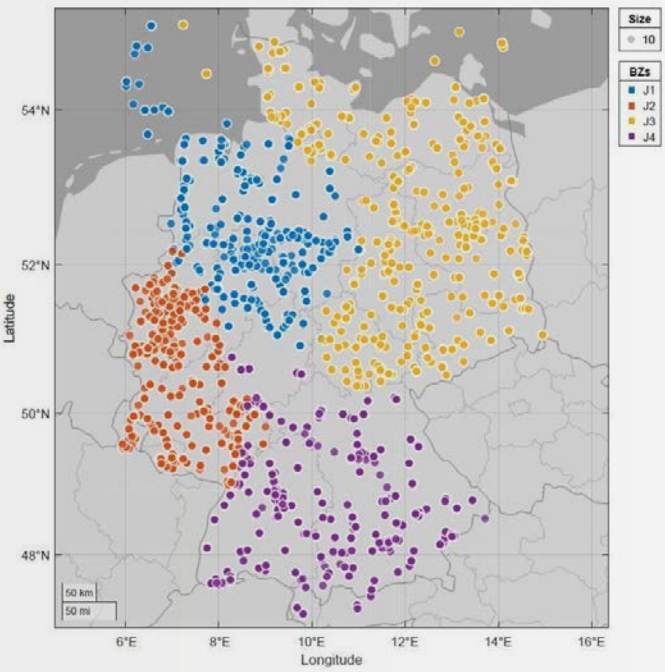


Note: J1 and J2 are the two newly-defined German-Luxembourgish bidding zones.

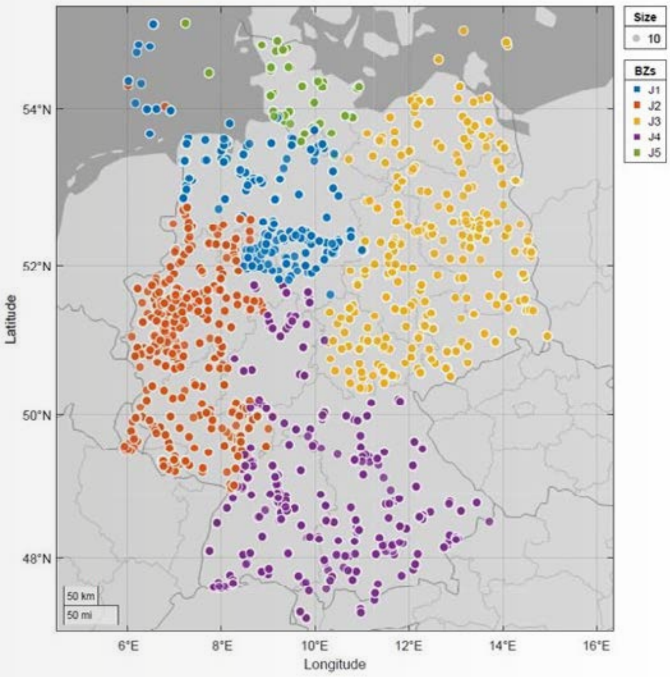
Alternative configuration 12



Alternative configuration 13



Alternative configuration 14



Source: ACER

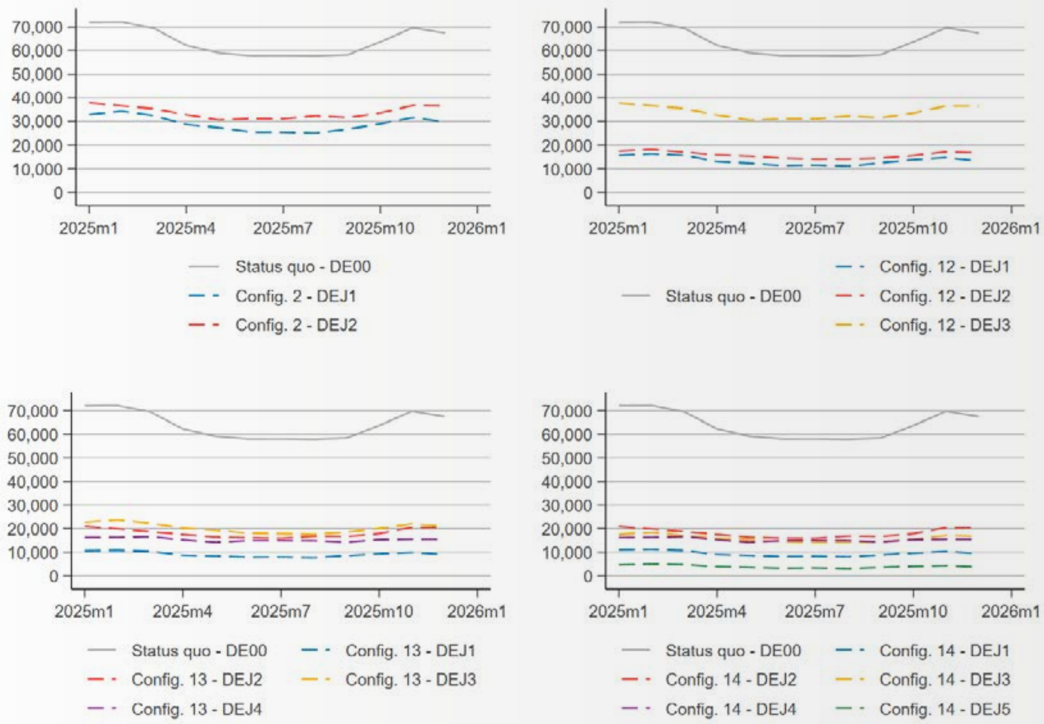
Figure 4.9: Alternative BZ configurations with two to five German–Luxembourg BZs

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 around 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 in liquidity metrics might 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 northeastern zones DEJ1 and DEJ2 by around 50,000 MWh/h per zone compared to the status quo. The simulation results of the southwestern zone DEJ3 shows a lower decline in generation compared to DEJ1 or DEJ2, with a simulated decline by only 30,000 MWh/h.
- **Alternative configurations 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.



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

Figure 4.10: Monthly average of hourly generation in the status quo and different reconfigurations (in MWh)

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 might imply that 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.

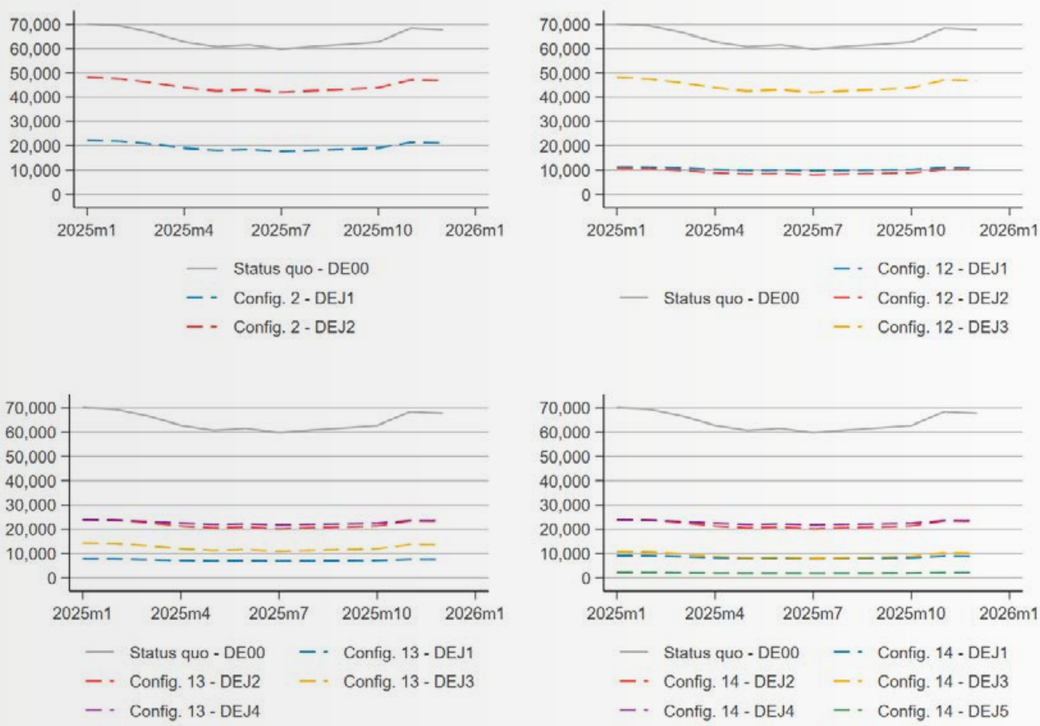
The parameter shows the following changes:

› **For all four alternative configurations,** the demand in each zone decreases as the region is diagonally divided between the northeast and the southwest 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 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 southwestern zone and jointly around 20,000 MWh in the northeastern zone(s), respectively. Notably, in alternative configuration 12, where the northeastern 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 compared to the decreases implied by the market size approximation by generation:

  - In alternative configuration 2, load decreases significantly more strongly in DEJ1 compared to DEJ2 in contrast to generation.

  - In alternative configuration 12, load decreases significantly in both DEJ1 and DEJ2, while load decreases by only 20,000 MWh in DEJ3, 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.



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

Figure 4.11: Monthly average of hourly demand in the status quo and alternative configurations (in MWh)

- 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 southwest (into zones DEJ2 and DEJ4 each) with an average hourly load of around 21,000 MWh each and in the north into zone DEJ1 with around 10,000 MWh each. The only difference is that alternative configuration 14 foresees a split of the eastern region into two, which means that the larger part (zone DEJ3) is simulated to have a demand of around 10,000 MWh and the smaller part (zone DEJ5) of around 5,000 MWh, whereas in alternative configuration 13 the eastern region is one large zone with around 15,000 MWh of demand. For alternative reconfiguration 14, the reduced demand in DEJ3 and DEJ5 results in a significant increase in supply-demand asymmetry compared to the status quo, where demand and supply roughly balance.

Therefore, this indicator for market size 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[52] 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. An increase in the RSI value and a decrease in the PSI value implies a decrease in market concentration. Notably, RSI values at or below 1 indicate high concentration.

Unlike 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 decreasing RSI, the changes are mostly limited. No BZ shows monthly average values below the threshold of 1, with the exception of DEJ2 (western region), which shows significant increases in the ratio of the PSI values when assuming limited import capacity in alternative configurations 13 and 14.

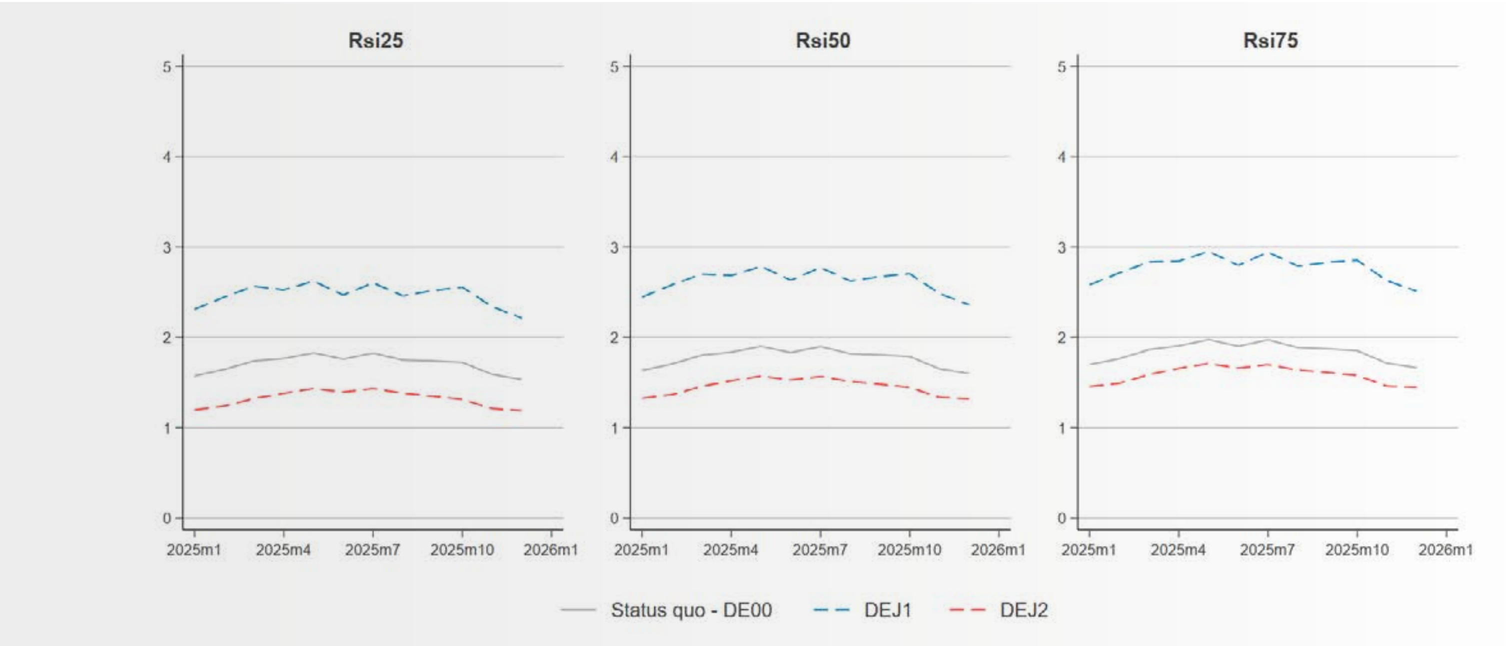
In the following, we discuss the market concentration parameters for each alternative configuration individually.

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 values remain above 1, but when considering the PSI value, the value indicates a 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 gradually increase with the increase in the correction factor.

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.



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

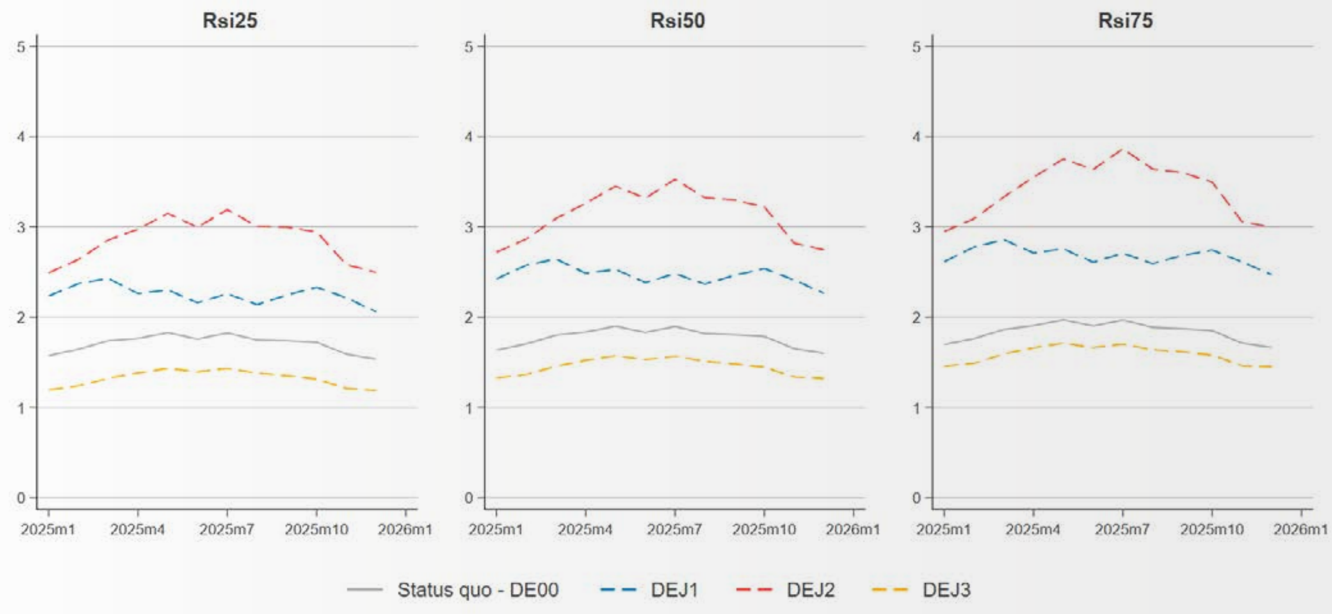
Figure 4.12: Monthly average of hourly market concentration given by the RSI in the status quo configuration and alternative configuration 2

52 Indicative results in the literature on the relationship between RSI and market liquidity are presented in Chapter 2.2.2.

Alternative configuration 12

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, aside from the southern zone showing a ratio of 3 %, indicating an increase in market concentration that 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 gradually increase with the increase in the correction factor.
Figure 4.13 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.



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

Figure 4.13: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration 12

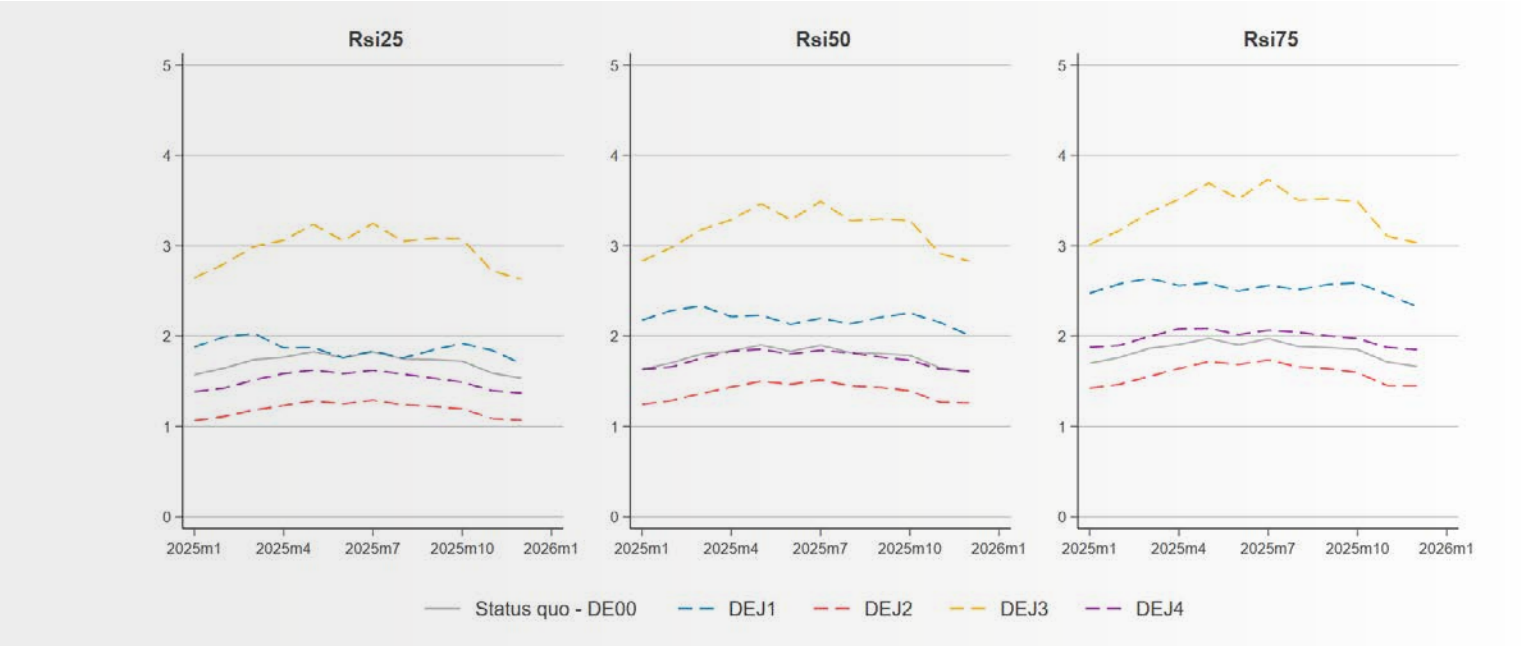
Alternative configuration 13

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 in import capacity.

In detail, the RSI of the northeastern zone (DEJ3) significantly increases compared to the status quo. DEJ1 values are slightly higher when assuming little import capacity, although the difference increases as import capacity is assumed to be 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 4.14 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.



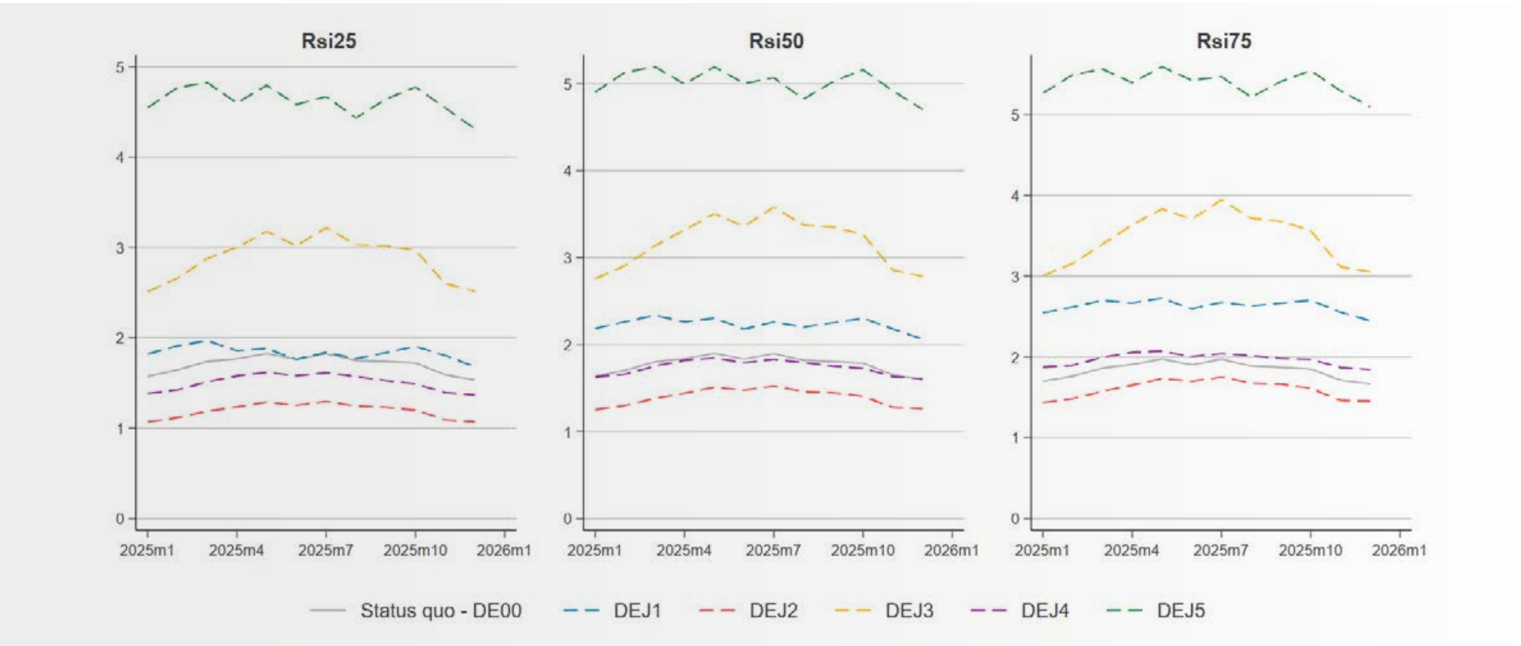
Source: Compass Lexecon analysis of simulated data as provided by TSOs

Figure 4.14: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration 13

Alternative configuration 14

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 might 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 might be expected to supply a relatively large part of the electricity in this new northern BZ.

Figure 4.15 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.



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

Figure 4.15: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration 14

4.3.4 Price correlations

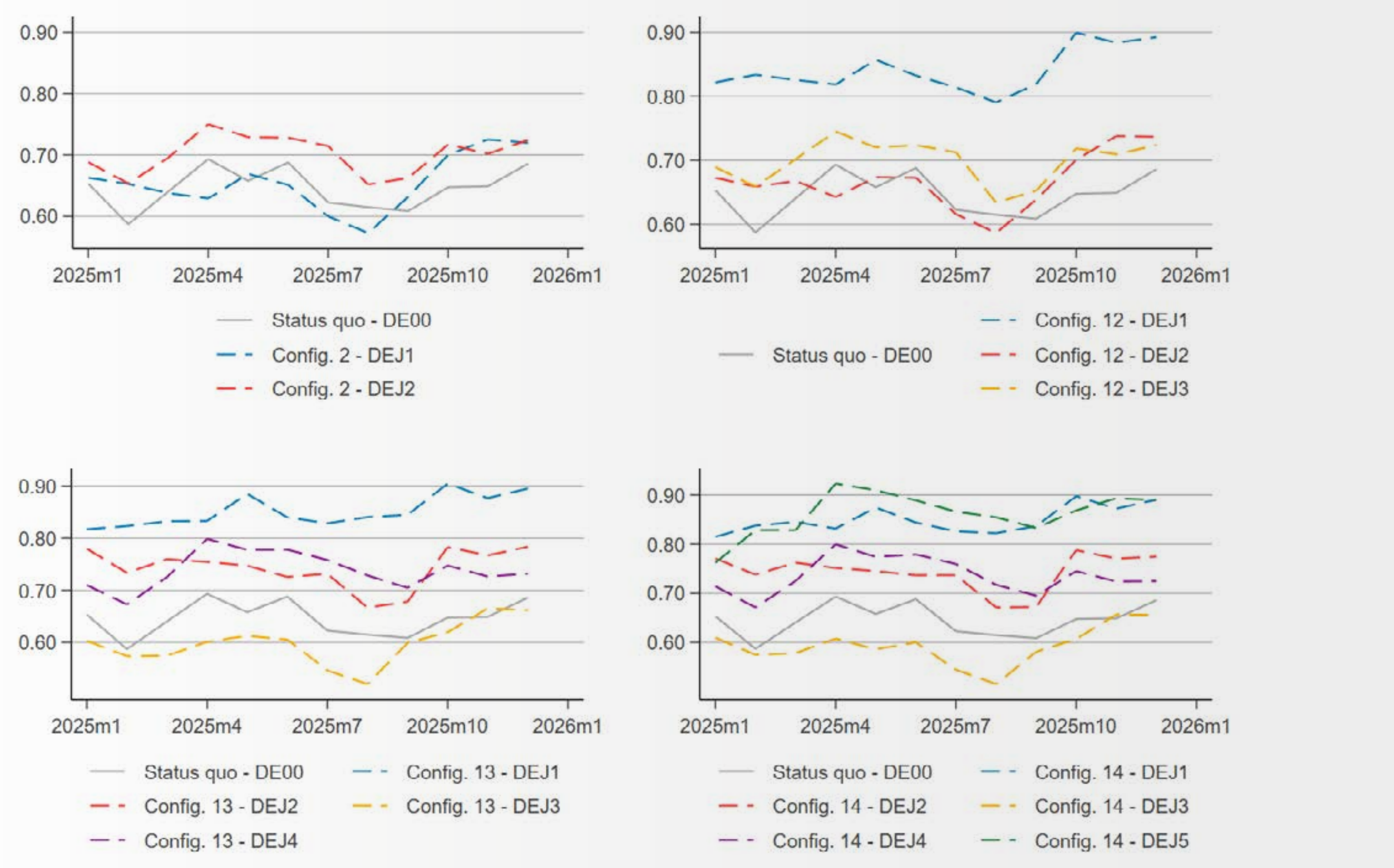
The simulated weighted average wholesale price correlation to the connected BZs is assessed for each BZ for each alternative configuration and the status quo. The results show a picture with an overall trend of increases in cross-border correlation.

The individual alternative configurations show the following picture:

- **Alternative configuration 2:** When split into only two zones, the price correlation increases for the southwestern zone DEJ2 for all months 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 southwestern 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 stronger 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 parts of Germany–Luxembourg and slightly lower price correlations in the northeastern zone. The decrease in correlation in the eastern BZ might be explained by the comparably low correlation to the Polish and Czech BZ. Alternative configuration 12 shows overall stronger price correlations in all of the new zones, suggesting better cross-border hedging opportunities, which might positively affect liquidity metrics.

Figure 4.16 shows the monthly average weighted price correlations for the different BZs and the status quo.



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

Figure 4.16: Monthly average of hourly price correlations in the status quo and alternative configurations

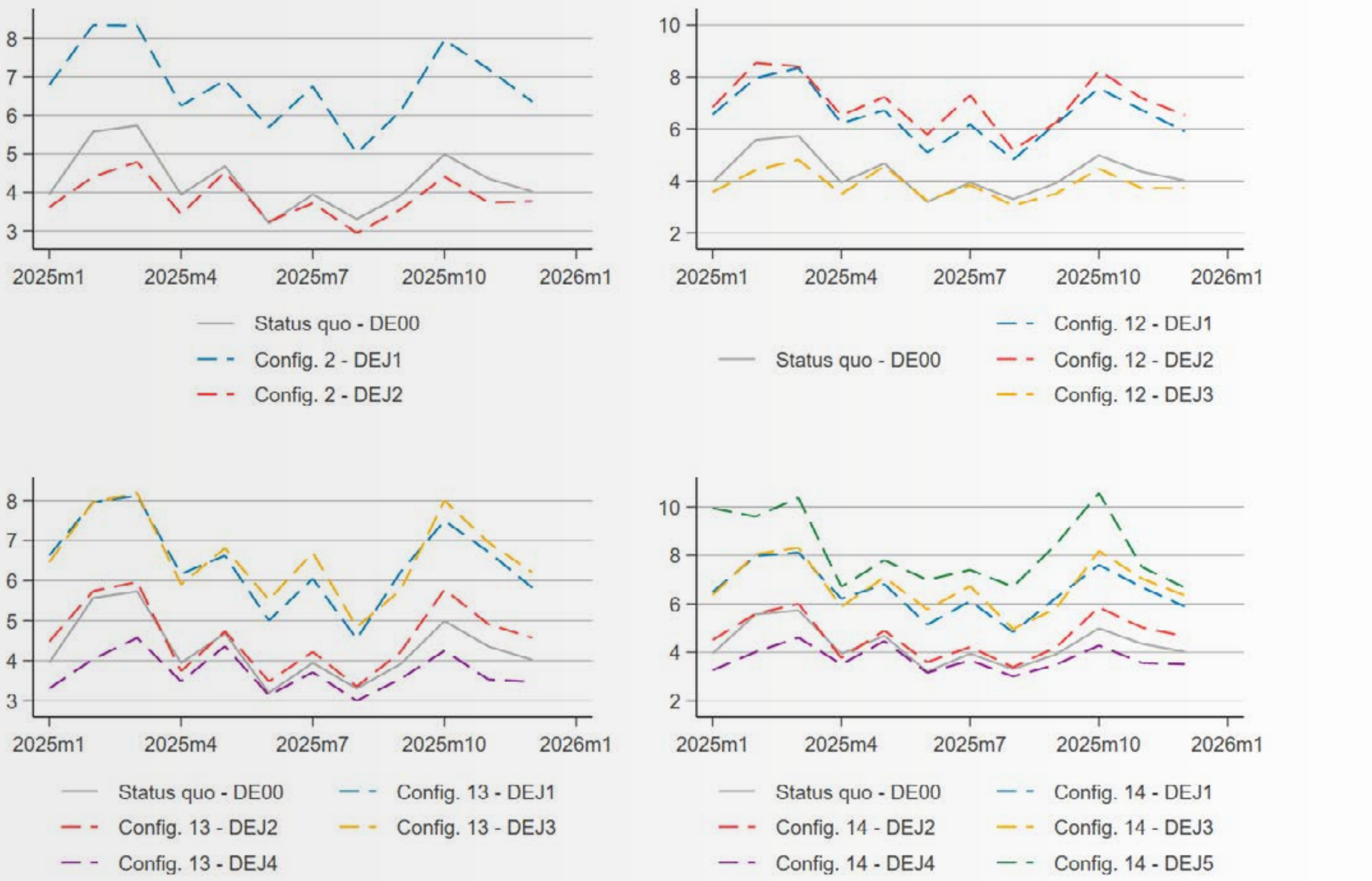
Therefore, as a standalone indicator, this parameter suggests an overall increase in liquidity metrics for short-term markets compared to the status quo, except for a tendency towards slightly lower liquidity metrics for the northeast.

4.3.5 Price volatility

The analysis of price volatility for the BZs in Germany–Luxembourg uses the monthly of average daily standard deviation (SD). The analysis of price volatility in the simulated wholesale prices suggests that short-term market liquidity metrics are generally positively affected, in particular in the northern regions, or remain unaffected in the alternative configurations. This conclusion is based on the following observations:

- **Alternative configurations 2 and 12:** The average price volatility in the simulated northern BZs increases substantially compared to the status quo for all periods analysed, while price volatility remains similar to the status quo for all periods in the simulated southern BZs.
- **Alternative configurations 13 and 14:** The average price volatility increases across all periods for the simulated northern BZs, DEJ1, DEJ3, and DEJ5. It remains almost unchanged for the western BZ – DEJ2 – and slightly decreases in the southern BZ – DEJ4 – especially in the first and last months of the simulated year.

Figure 4.17 shows the monthly average of daily SD for the different BZs and the status quo.



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

Figure 4.17: Monthly average of daily price standard deviation in the status quo and alternative configurations

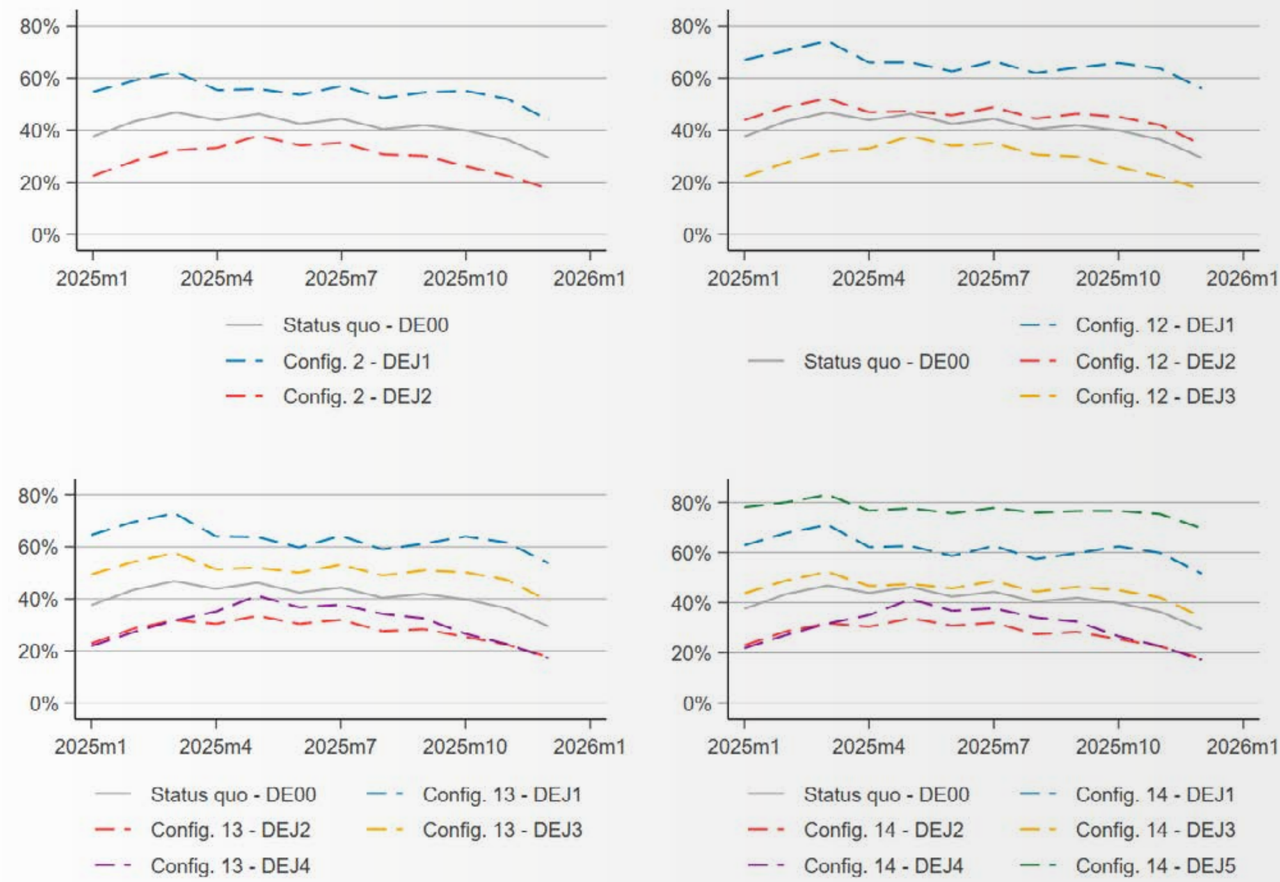
Therefore, as a standalone indicator, this parameter suggests an overall increase in liquidity metrics for short-term markets compared to the status quo, except for a tendency towards slightly lower liquidity metrics for the southern region. Vice versa, the observed increases in price volatility point to decreases in liquidity metrics for the long-term markets.

4.3.6 Participant mix

The reconfiguration of BZs in Germany–Luxembourg has a different effect on each BZ regarding the participant mix, i.e. the share of renewable electricity generation. While the effect is positive for some BZs in terms of market liquidity metrics, it is negative for others. This conclusion is based on the following analysis.

- **Alternative configuration 2:** The average RES share increases for the northern region DEJ1 across all months compared to the status quo, now consistently exceeding 40 %. By contrast, the participant mix decreases in the southern region DEJ2, remaining below 40 % across all months.
- **Alternative configuration 12:** The average RES share increases for the northwest region DEJ1 across all months compared to the status quo, reaching levels above 60 % for most periods. It slightly increases for the northeast region DEJ2, while it decreases for the southern region DEJ3, in a similar manner to configuration 2.
- **Alternative configuration 13 and 14:** As in configuration 12, the average RES share increases for the northern regions, reaching its highest values in the northernmost region DEJ5 in configuration 14, where it hovers around 80 % across all periods. By contrast, it decreases in the southern regions, reaching very low levels at the beginning and end of the year.

Figure 4.18 shows the monthly average hourly RES share values for the different BZs and the status quo.



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

Figure 4.18: Monthly average of hourly RES share in the status quo and alternative configuration

Therefore, as a standalone indicator, this parameter suggests an overall increase in liquidity metrics compared to the status quo for the northern regions, while showing an overall decrease for the southern regions.

4.3.7 Supply-demand imbalance

The supply-demand imbalance indicator shows consistent liquidity impairments across all alternative BZ configurations for the BZs in Germany and Luxembourg compared to the status quo. In the status quo, the imbalance never exceeds 10 p. p. With the alternative configurations, it is consistently above 10 p. p. for most BZs and months, reaching over 30 p. p. in DEJ5 during some periods in alternative configuration 14.

Figure 4.19 shows the monthly average hourly RES share values for the different BZs and the status quo.

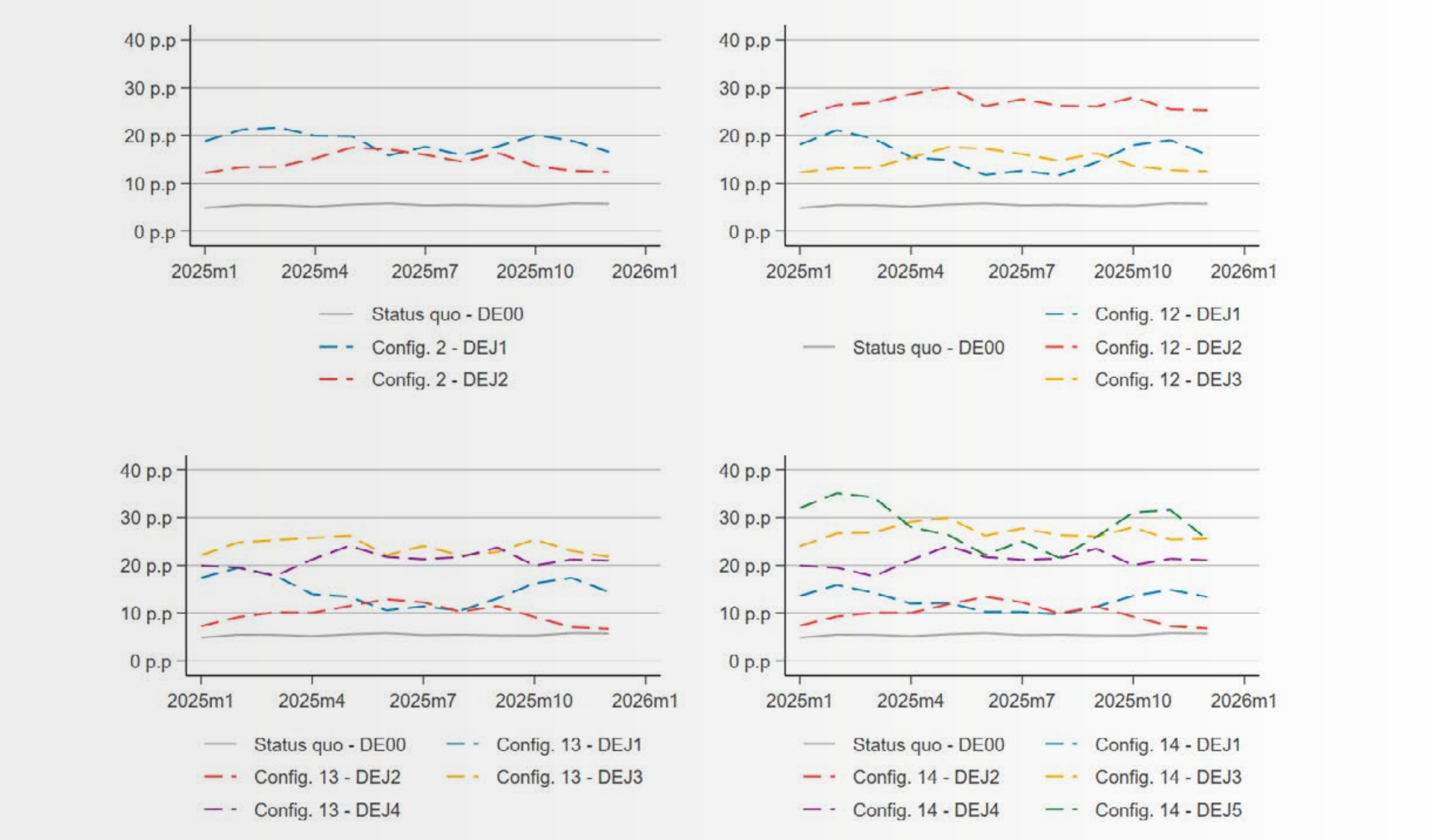


Figure 4.19: Monthly average of hourly supply-demand imbalance share in the status quo and alternative configuration

In all four alternative configurations, the BZs of the German–Luxembourg region have a higher supply-demand imbalance than the BZs in the status quo. This might imply – *ceteris paribus* – that the proposed alternative configurations would lead to significantly lower liquidity metrics compared to the status quo.

4.3.8 Conclusions

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

Overall, our analysis shows a mixed picture. While the alternative BZ configurations substantially reduce the market size by construction, on average we observe an improvement in the market concentration and price correlation parameters. However, the supply-demand imbalance considerably increases, and the effect on liquidity metrics related to price volatility and participant mix varies across the alternative BZs.

Therefore, the negative effects on the market liquidity of reducing the size of the BZs could be partly outweighed by the increases in several other liquidity drivers, such as the price correlation and decrease in market concentration, at least for a subset of BZs. However, in light of the examined decrease in price correlation, such an increase in liquidity metrics would not be expected in the northeast zone.

This overall conclusion can be explained in particular by the following observations:

- Monthly average hourly generation and load volumes decrease across all four alternative configurations compared to the status quo, albeit to different degrees, indicating smaller market sizes and lower liquidity metrics for both short- and long-term markets.
- Price correlation across all four alternative configurations increases in the western zones but not in the eastern BZs compared to the status quo configuration.
- Price volatility and participant mix across all four alternative configurations increase in the northern zones but not in the southern BZs compared to the status quo configuration.
- The supply-demand imbalance significantly increases across all four alternative configurations for all simulated BZs compared to the status quo.
- Market concentration across all alternative configurations is likely to increase in the southwest and decrease in the northeast. 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 BZs with high shares of RES, according to the TSOs the ownership database for calculating the RSI / PSI values is potentially incomplete.
- Regardless of the alternative configuration, the simulated northeastern zones show less demand (particularly visible in alternative configurations 2 and 12) and lower short-term market integration due to a weaker price correlation between neighbours compared to western BZs in all four alternative configurations. However, market concentration (particularly visible in alternative configurations 13 and 14) is expected to be significantly lower.

Case	Descriptive statistics	Market concentration			Price		Market Size		RES share	Supply-demand imbalance
		Rsi 25	Rsi 50	Rsi 75	Correlation	Daily SD	Generation	Demand		
Status quo		DE00: 1.71	DE00: 1.77	DE00: 1.84	DE00: 0.65	DE00: 4.30	DE00: 64,018	DE00: 64,434	DE00: 41.06	DE00: 5.41
Alt config. 2	Max	↑ DEJ1: 2.47	↑ DEJ1: 2.62	↑ DEJ1: 2.77	↑ DEJ2: 0.70	↑ DEJ1: 6.80	↓ DEJ2: 33,938	↓ DEJ2: 44,795	↑ DEJ1: 54.64	↑ DEJ1: 18.66
	Average	↑ 1.89	↑ 2.04	↑ 2.18	↑ 0.68	↑ 5.33	↓ 31,524	↓ 32,248	↑ 41.93	↑ 16.58
	Min	↓ DEJ2: 1.32	↓ DEJ2: 1.45	↓ DEJ2: 1.58	↑ DEJ1: 0.65	↓ DEJ2: 3.85	↓ DEJ1: 29,111	↓ DEJ1: 19,700	↓ DEJ2: 29.22	↑ DEJ2: 14.51
Alt config. 12	Max	↑ DEJ2: 2.86	↑ DEJ2: 3.14	↑ DEJ2: 3.41	↑ DEJ1: 0.84	↑ DEJ2: 7.00	↓ DEJ3: 33,846	↓ DEJ3: 44,734	↑ DEJ1: 65.36	↑ DEJ2: 26.71
	Average	↑ 2.14	↑ 2.35	↑ 2.56	↑ 0.74	↑ 5.80	↓ 21,050	↓ 21,498	↑ 46.6	↑ 19.1
	Min	↓ DEJ3: 1.32	↓ DEJ3: 1.45	↓ DEJ3: 1.59	↑ DEJ2: 0.67	↓ DEJ3: 3.87	↓ DEJ1: 13,429	↓ DEJ2: 9,265	↓ DEJ3: 28.94	↑ DEJ3: 14.58
Alt config. 13	Max	↑ DEJ3: 2.97	↑ DEJ3: 3.18	↑ DEJ3: 3.39	↑ DEJ1: 0.85	↑ DEJ3: 6.61	↓ DEJ3: 20,273	↓ DEJ4: 22,830	↑ DEJ1: 63.2	↑ DEJ3: 23.77
	Average	↑ 1.88	↑ 2.12	↑ 2.37	↑ 0.73	↑ 5.34	↓ 15,740	↓ 16,124	↑ 42.89	↑ 17.32
	Min	↓ DEJ2: 1.19	↓ DEJ2: 1.39	↓ DEJ2: 1.58	↓ DEJ3: 0.60	↓ DEJ4: 3.70	↓ DEJ1: 9,145	↓ DEJ1: 7,308	↓ DEJ2: 27.58	↑ DEJ2: 9.81
Alt config. 14	Max	↑ DEJ5: 4.62	↑ DEJ5: 5.01	↑ DEJ5: 5.40	↑ DEJ5: 0.86	↑ DEJ5: 8.20	↓ DEJ2: 18,153	↓ DEJ4: 22,829	↑ DEJ5: 76.9	↑ DEJ5: 28.2
	Average	↑ 2.41	↑ 2.71	↑ 3.02	↑ 0.76	↑ 5.94	↓ 12,562	↓ 12,902	↑ 48.39	↑ 19.7
	Min	↓ DEJ2: 1.19	↓ DEJ2: 1.40	↓ DEJ2: 1.60	↓ DEJ3: 0.59	↓ DEJ4: 3.70	↓ DEJ5: 3,884	↓ DEJ5: 2,038	↓ DEJ2: 27.66	↑ DEJ2: 9.89

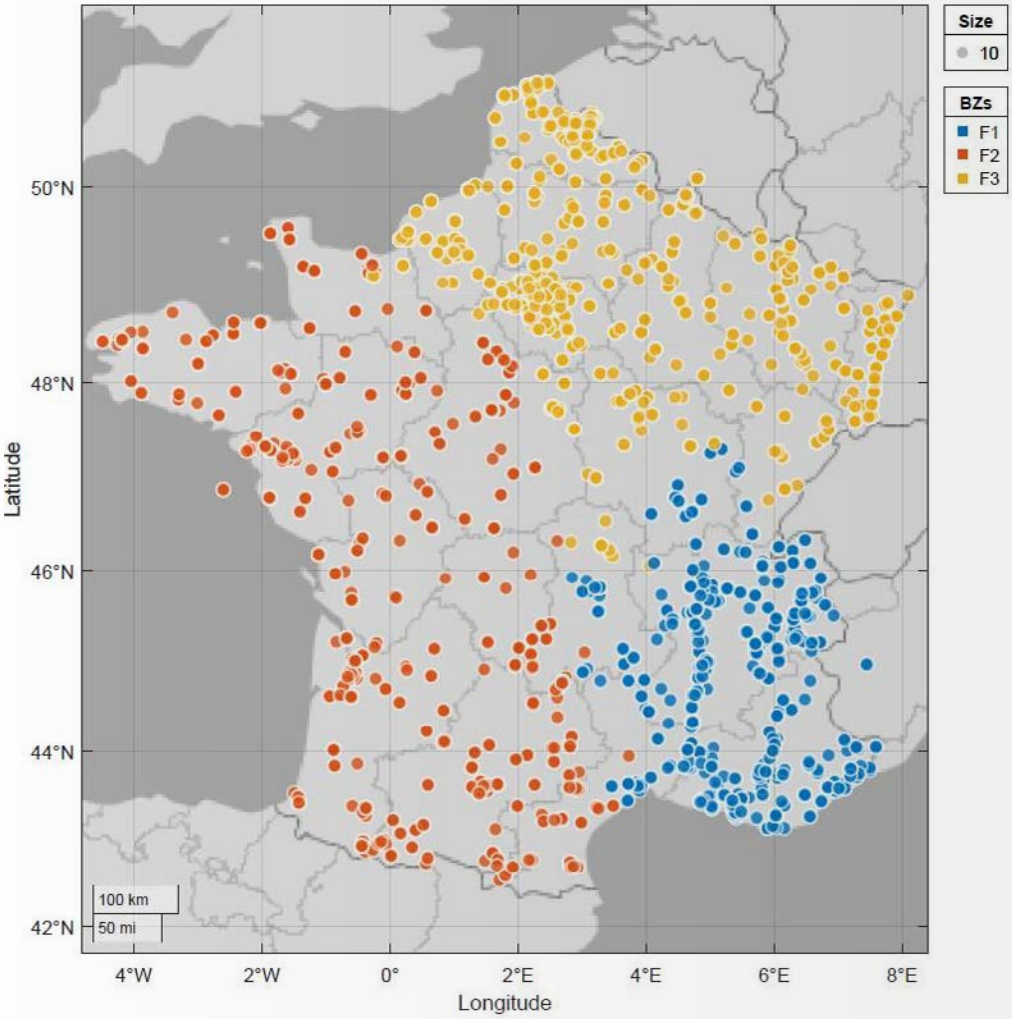
Source: Compass Lexecon analysis of simulated data as provided by TSOs

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 alternative configuration considered. The minima and maxima displayed show the highest and lowest observed monthly values of the stated BZ. The stated BZ has been identified based on the average annual value of the market characteristic parameter considered.

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

4.4 France simulated data on proposed bidding zones

There is one alternative configuration for the French BZ. The proposal foresees three different BZs, with one large zone in the west and two smaller zones in the east. Figure 4.20 displays the configuration with the three BZs.



Source: ACER

Figure 4.20: Alternative BZ configuration with three French BZs

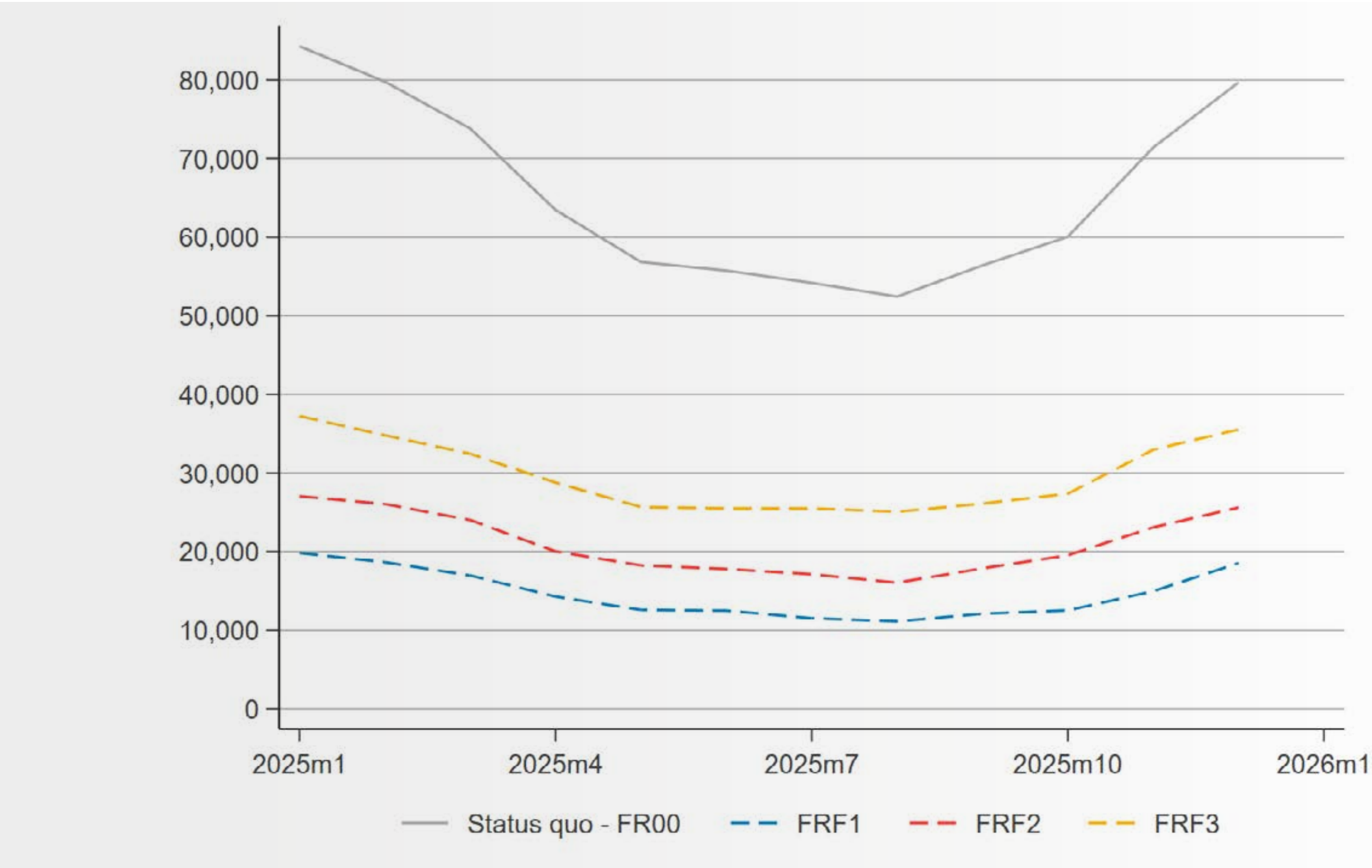
For the alternative configuration and status quo configuration – i. e. assuming that the BZ remains the same as today – the Central European TSOs simulated hourly dispatch of generation units to meet demand in a pan-EU model. They provided hourly values of generation volume, demand, RSI and PSI, and wholesale market prices for 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 can be summarised as follows:

- Generation volume decreases across all three BZs, although the decrease is strongest for the southeastern zone FRF1. There, hourly generation is on average around 16,000 MWh, while it is around 30,000 MWh in FRF3 and 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 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 at the beginning of 2025 until the end of summer, after which it increases again towards the end of 2025. Zone FRF3 in the northeast 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.



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

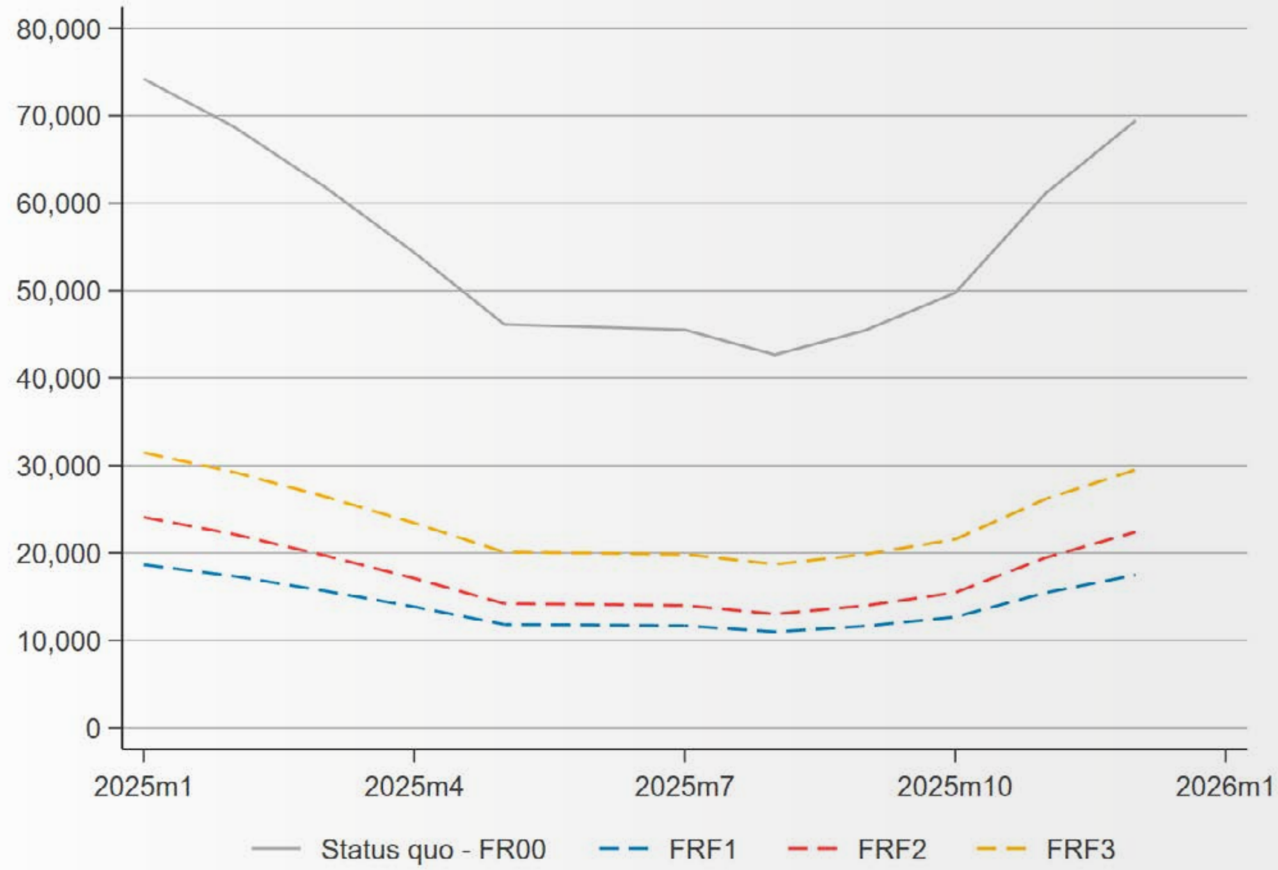
Figure 4.21: Monthly average of hourly generation in the status quo and alternative configuration (in MWh)

Considering the relationship between identified 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 most strongly decreases for FRF1 and the least for FRF3, although all decreases are substantial compared to the status quo. In detail, we observe the following:

- All BZs experience a similar decline in demand over the summer, albeit starting at different demand levels. For zone FRF3 in the northeast, demand in winter is around 30,000 MWh and plateaus 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 southeast (FRF1) is even lower at 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 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 also higher than load in the reconfigured BZs.



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

Figure 4.22: Monthly average of hourly demand in the status quo and alternative configuration (in MWh)

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.

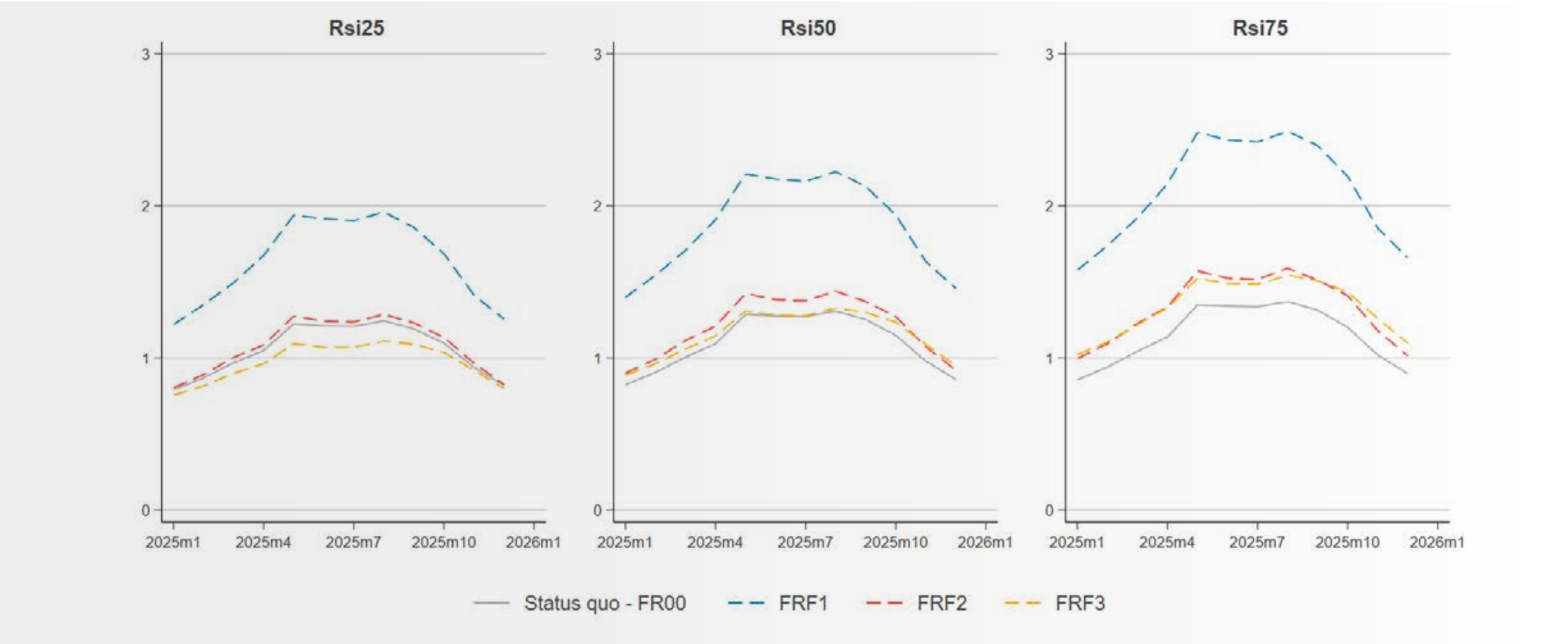
4.4.3 Market concentration

The analysis of the market concentration for the BZs in the French region uses the average hourly RSI[53] values averaged across climate years as calculated by the Central European TSOs for each BZ alternative configuration. 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 4.23 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.



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

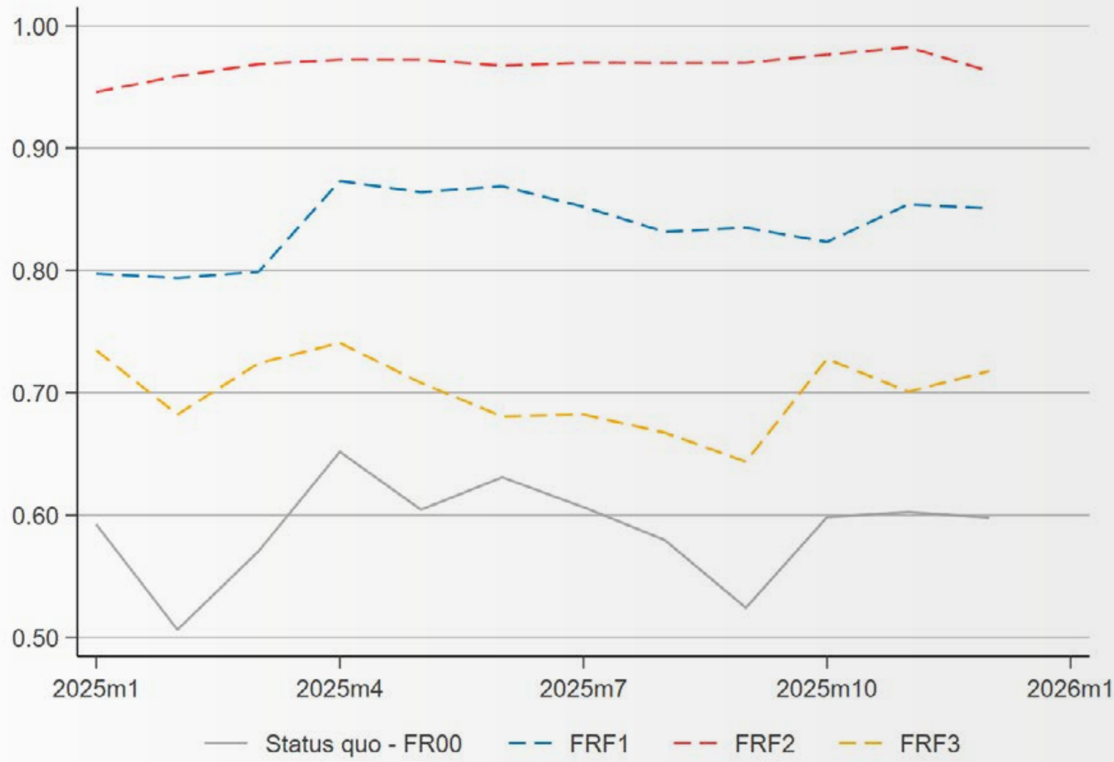
Figure 4.23: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration

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

4.4.4 Price correlations

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

Figure 4.24 shows the monthly averages of the price correlation for the different BZs and the status quo.



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

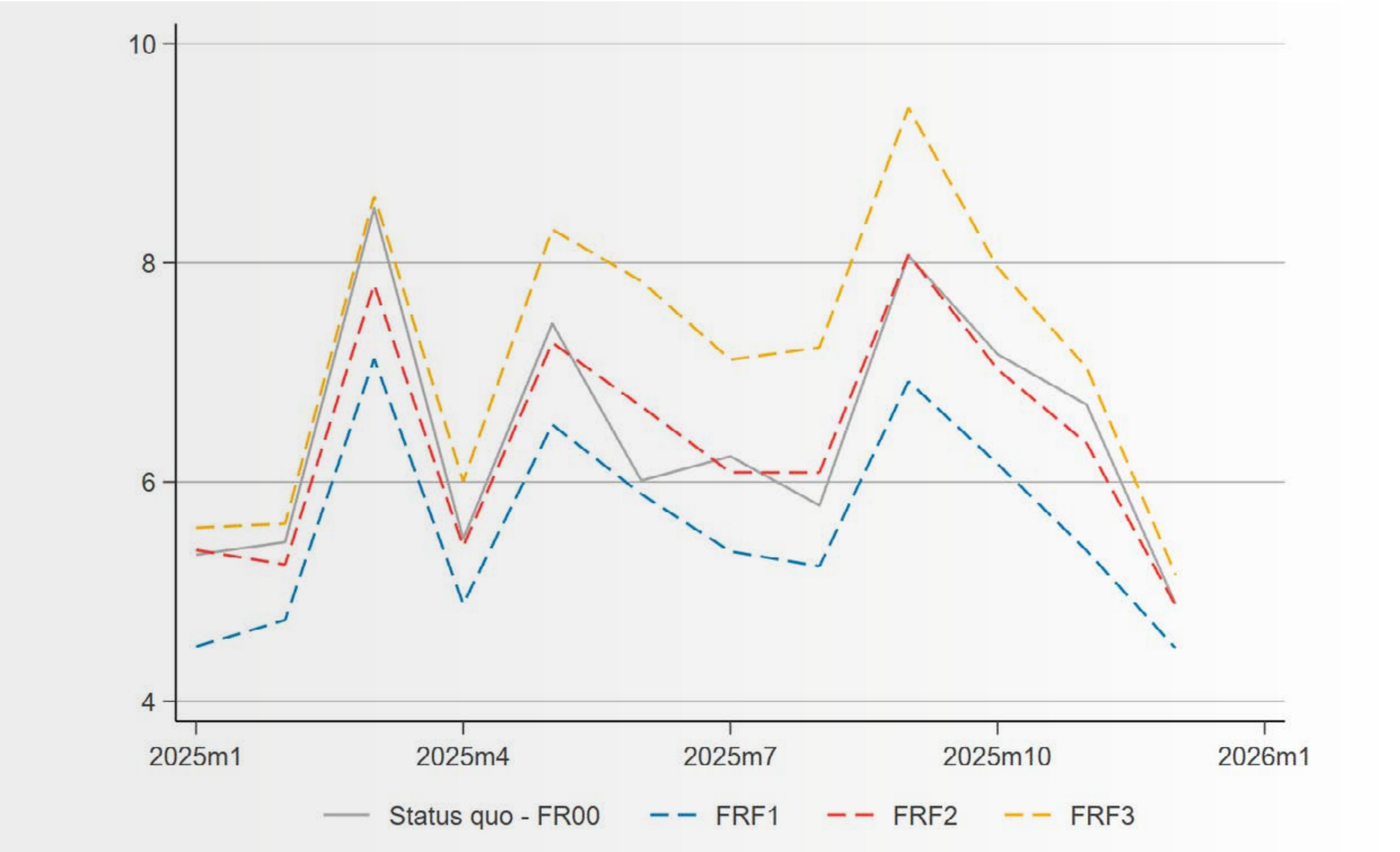
Figure 4.24: Monthly average of hourly price correlations in the status quo and alternative configuration

4.4.5 Price volatility

The analysis of price volatility for the BZs in the French region uses the monthly average daily SD. It does not indicate a clear overall trend for liquidity metrics as the direction of change in volatility differs between the new BZs:

- Price volatility is higher for the new northeast French BZ – FRF3 – compared to the status quo throughout the year. Over the year, the average daily SD for the reconfigured BZ is 7.16 € / MWh, above the status quo average of 6.42 € / MWh.
- Regarding the other two new French BZs, the daily SD for FRF2 is quite similar to the status quo in most periods, while for FRF1 the daily SD decreases across all periods, resulting in a yearly average of 5.60 € / MWh.
- On average, volatility changes insignificantly, with a national average of 6.37 € / MWh, slightly lower than the status quo volatility level.

Figure 4.25 shows the monthly average daily SD values for the different BZs and the status quo.



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

Figure 4.25: Monthly average of daily standard deviation in the status quo and alternative configuration

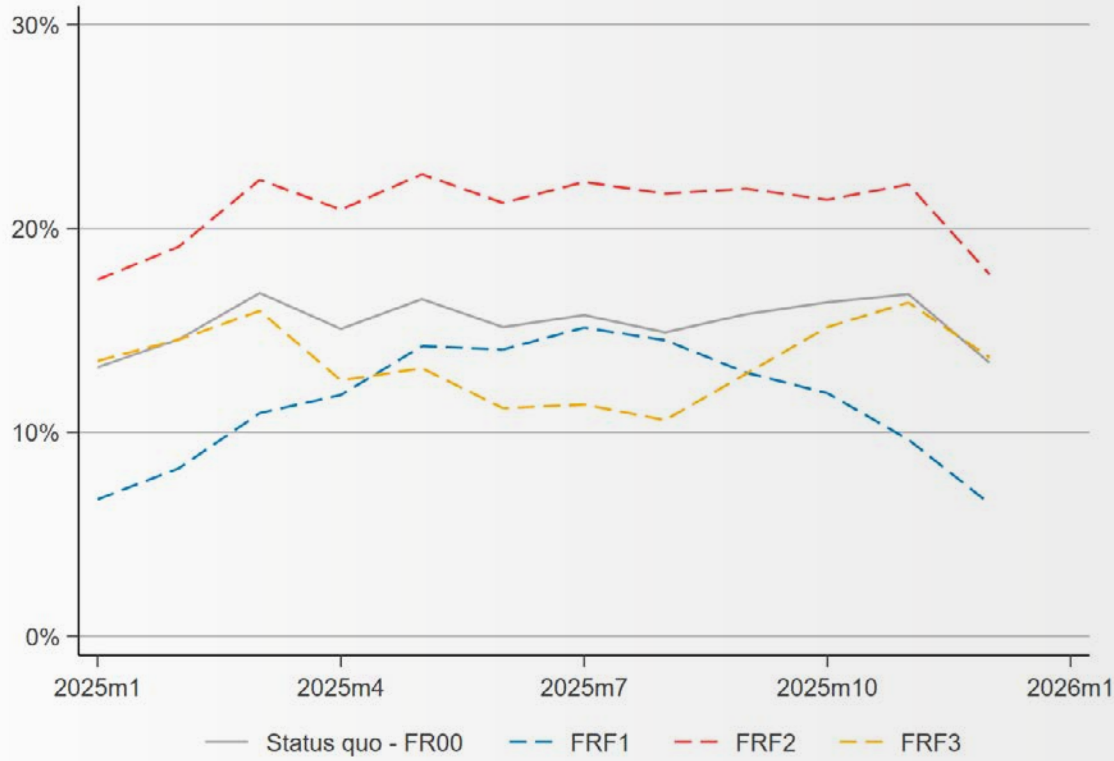
As changes in price volatilities of the reconfigured BZs are two-sided, this indicator shows that expected improvements for one BZ would coincide with an expected impairment for another. No overarching trend for either short- or long-term markets can be identified.

4.4.6 Participant mix

The analysis of the participant mix for the BZs in the French region uses the monthly average hourly RES share, calculated as the percentage of PV and wind generation over total generation. The changes in the RES share indicate the following:

- The RES share in the new western French BZ – FRF2 – increases compared to the status quo across all periods considered. While the BZ in the status quo has an average RES share of approximately 15.36 %, the share rises to 20.92 % for the reconfigured BZ FRF2.
- Conversely, the RES share for the other two BZs – FRF1 and FRF3 – falls below the status quo RES share for most periods.
- Overall, on average the regions would experience a slightly lower RES share with the new BZs, dropping to 15.24 %.

Figure 4.26 shows the monthly average hourly RES share values for the different BZs and the status quo.



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

Figure 4.26: Monthly average of hourly RES share in the status quo and alternative configuration

As the RES share shows changes in different directions in the alternative BZs, this indicator shows no clear trend regarding changes to liquidity metrics. While a slight increase in liquidity metrics might be expected for FRF2, liquidity metric impairments would be expected for FRF1 and FRF3.

4.4.7 Supply-demand imbalance

The supply-demand imbalance is calculated as the absolute difference between the share of demand and the share of supply over the sum of demand and supply for a specific BZ.

The supply-demand imbalance decreases in the new south-east French BZ – FRF1 – compared to the status quo across all periods considered. While the status quo BZ has an average imbalance of 8.95 p. p., the imbalance in the reconfigured BZ FRF1 falls to 5.87 p. p.

Conversely, in the other two new BZs – FRF2 and FRF3 – the supply-demand imbalance is higher than in the status quo for all periods considered.

Overall, the effect of the reconfiguration on the total French market is a slight increase in the supply-demand imbalance, with an average imbalance of 9.17 p. p.

Figure 4.27 shows the monthly average supply-demand imbalance for the different BZs and the status quo.

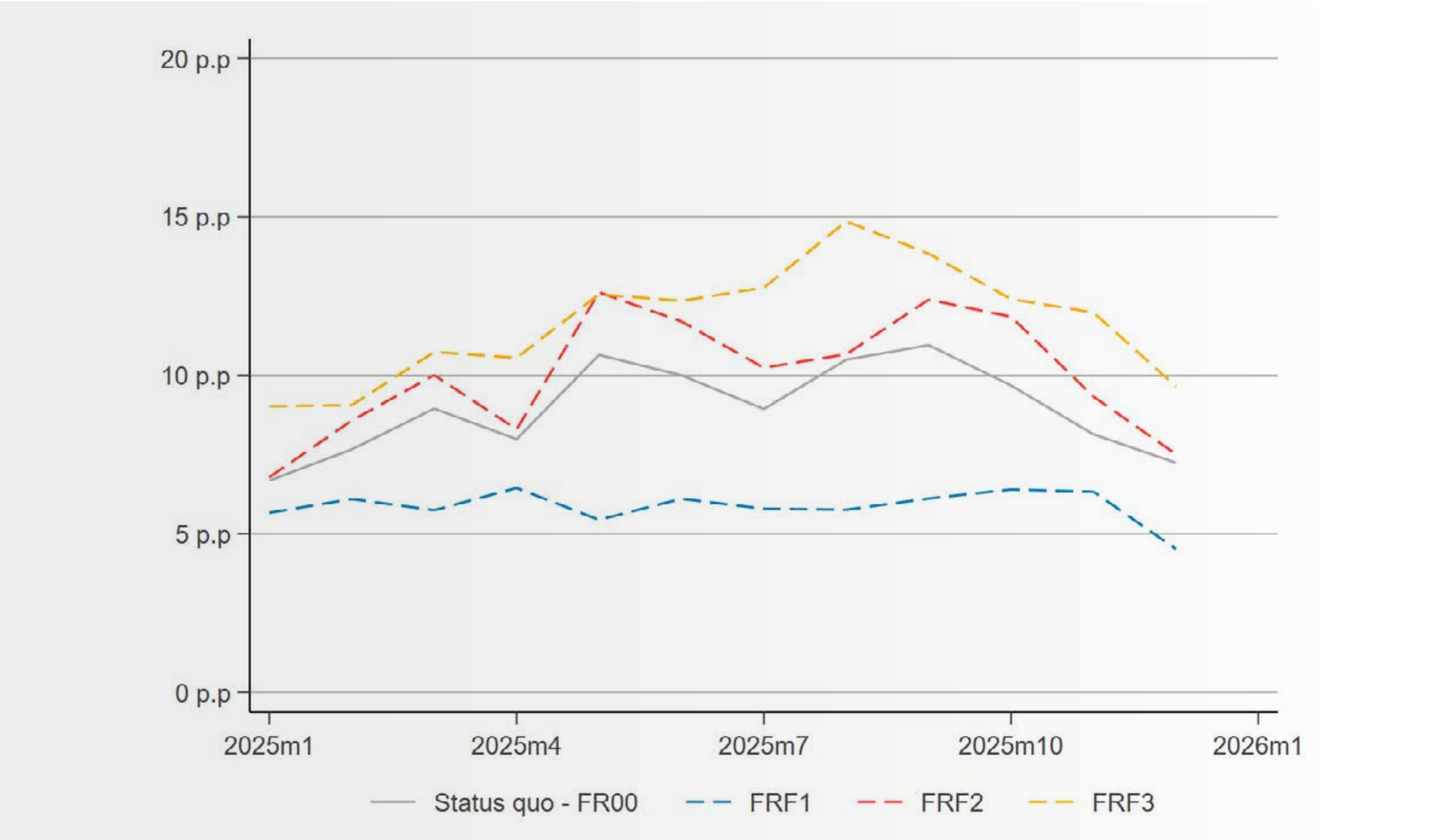


Figure 4.27: Monthly average of hourly supply-demand imbalance share in the status quo and alternative configuration

As for the price volatility and participant mix indicators, the supply-demand imbalance features opposing effects in different BZs. While FRF1 shows a decrease in the imbalance, suggesting improved liquidity metrics, FRF2 and FRF3 experience an increase, resulting in impaired liquidity metrics.

4.4.8 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 that while the alternative BZ implies a reduced market size and associated possible negative effects on liquidity by construction, there are several offsetting effects of the alternative BZ configuration. In particular, there is a clear improvement in the competition and price correlation across all three alternative BZs. The results are mixed for the remaining market parameters, such as price volatility, participant mix, and supply-demand imbalance, indicating effects in the opposite directions depending on the zone. These findings are supported by the following observations:

- By construction of the BZ configurations, the market size as approximated by generation volume and demand decreases across all three zones. Among the reconfigured zones, FRF3 in the northeast 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 the status quo where electricity generation exceeds demand by about 20 %.
- Market concentration as simulated by the RSI is expected to decrease particularly in the southeastern zone FRF1.
- Price correlation is expected to increase in all three zones, albeit largely driven by strong correlation among the new zones.
- Price volatility is expected to slightly decrease in France, mainly driven by the decrease in BZ FRF1. However, it is expected to increase in one of the new BZs, FRF3.
- The participant mix is expected to increase in the western BZ – FRF2 – while it will decrease in the eastern BZs, FRF1 and FRF3.
- The supply-demand imbalance will increase in BZs FRF2 and FRF3, while it will decline in the southeastern BZ, FRF1.

Case	Descriptive statistics	Market concentration			Price		Market Size		RES share	Supply-demand imbalance
		Rsi 25	Rsi 50	Rsi 75	Correlation	Daily SD	Generation	Demand		
Status quo		**FR00:** 1.05	**FR00:** 1.10	**FR00:** 1.15	**FR00:** 0.59	**FR00:** 6.42	**FR00:** 65,692	**FR00:** 55,430	**FR00:** 15.36	**FR00:** 8.95
Alt config. 5	Max	↑ **FRF1:** 1.64	↑ **FRF1:** 1.87	↑ **FRF1:** 2.11	↑ **FRF2:** 0.97	↑ **FRF3:** 7.16	↓ **FRF3:** 29,748	↓ **FRF3:** 23,863	↑ **FRF2:** 20.92	↑ **FRF3:** 11.65
	Average	↑ 1.23	↑ 1.41	↑ 1.59	↑ 0.84	↓ 6.37	↓ 21,803	↓ 18,474	↓ 15.24	↑ 9.17
	Min	↓ **FRF3:** 0.97	↑ **FRF3:** 1.15	↑ **FRF2:** 1.33	↑ **FRF3:** 0.70	↓ **FRF1:** 5.60	↓ **FRF1:** 14,625	↓ **FRF1:** 14,084	↓ **FRF1:** 11.39	↓ **FRF1:** 5.87

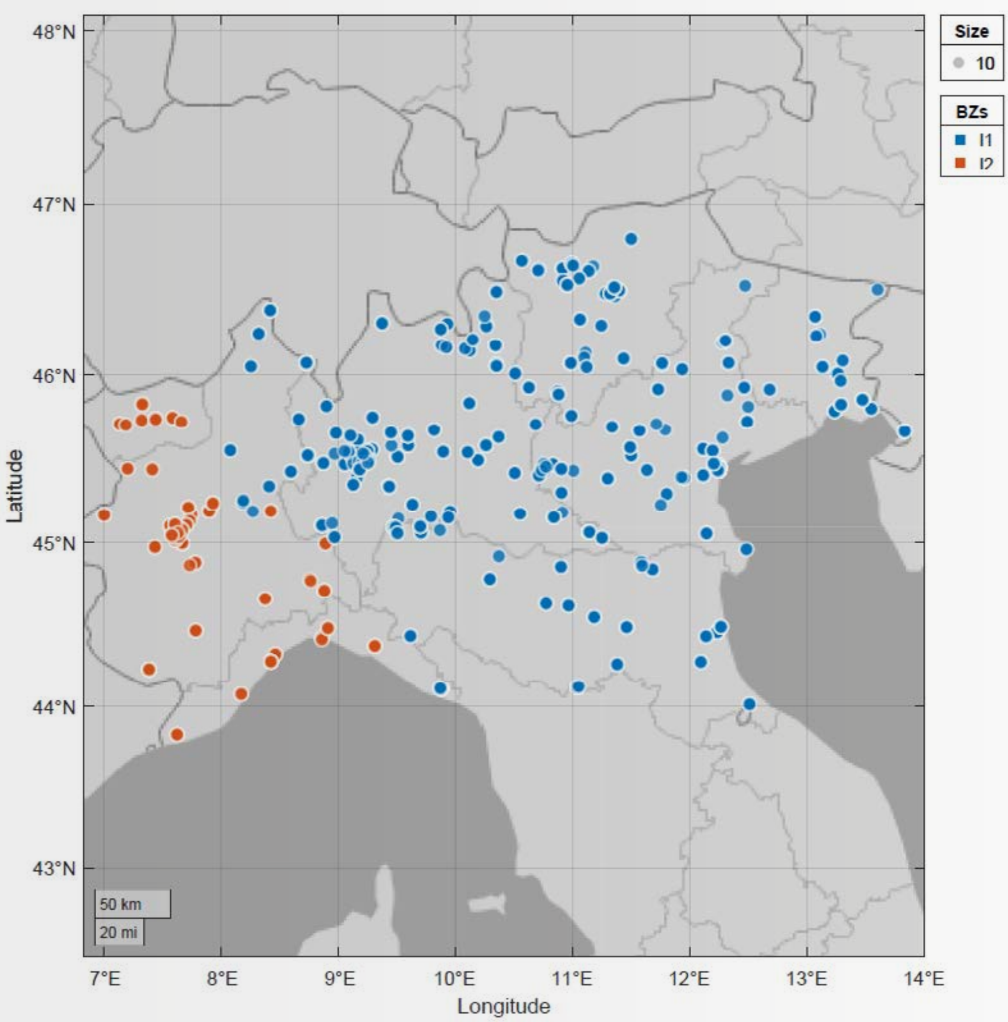
Source: Compass Lexecon analysis of simulated data as provided by TSOs

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 alternative configuration considered. The minima and maxima displayed show the highest and lowest observed monthly values of the stated BZ. The stated BZ has been identified based on the average annual value of the market characteristic parameters considered

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

4.5 Italy simulated data on proposed bidding zones

There is one alternative configuration for the Italian BZ configuration. The proposal foresees splitting the northern BZ into two different BZs, with one geographically large zone in the east (I1) and one smaller zone in the west (I2). Figure 4.28 displays this BZ reconfiguration.



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

Figure 4.28: Alternative BZ configuration with two Italian BZs

For the alternative configuration and the status quo configuration – i.e. assuming that 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 2025 in each BZ.

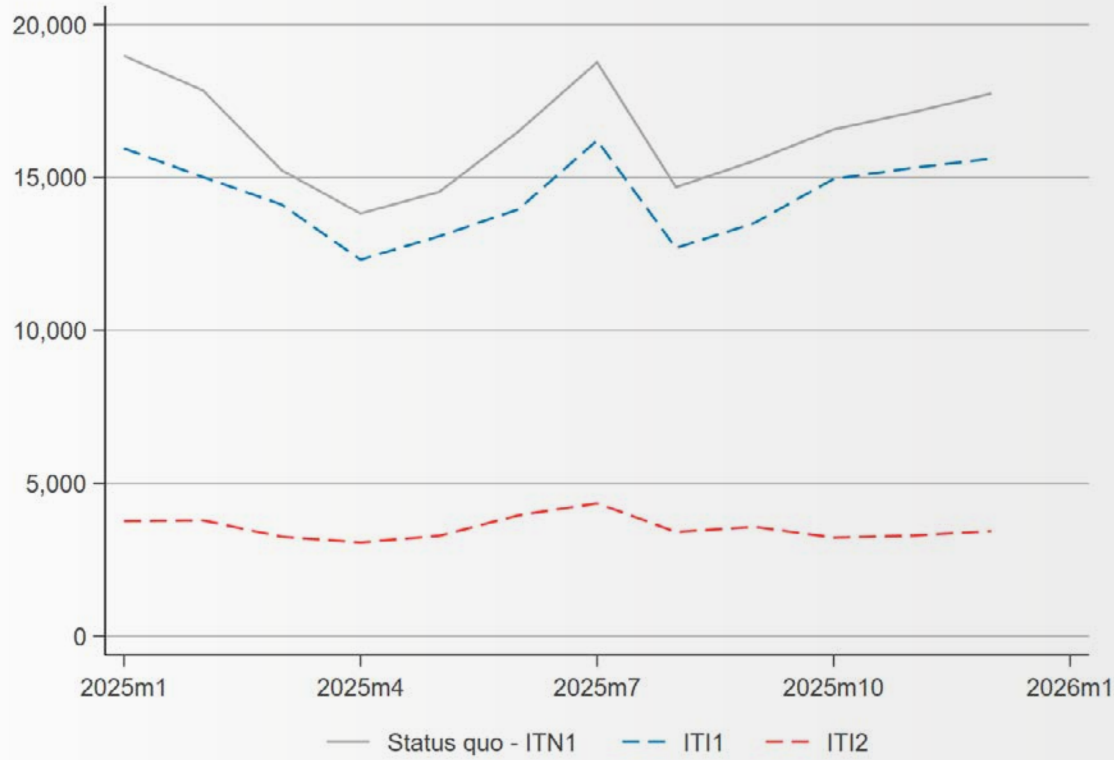
Further, for each alternative configuration, the simulation was carried out for three different climate scenarios based on the climate observed in 1989, 1995, and 2009. Apart from the Central European BZs, the regional scope of the data provided by the Central European TSOs includes the currently adjacent 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 slightly decreases.

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

- The simulated generation volume in the eastern zone ITI1 slightly decreases compared 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, before dropping back and gradually increasing until the end of the year. This pattern is less pronounced in ITI2, where the summer peak is stronger while the increase for winter is nearly muted.



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

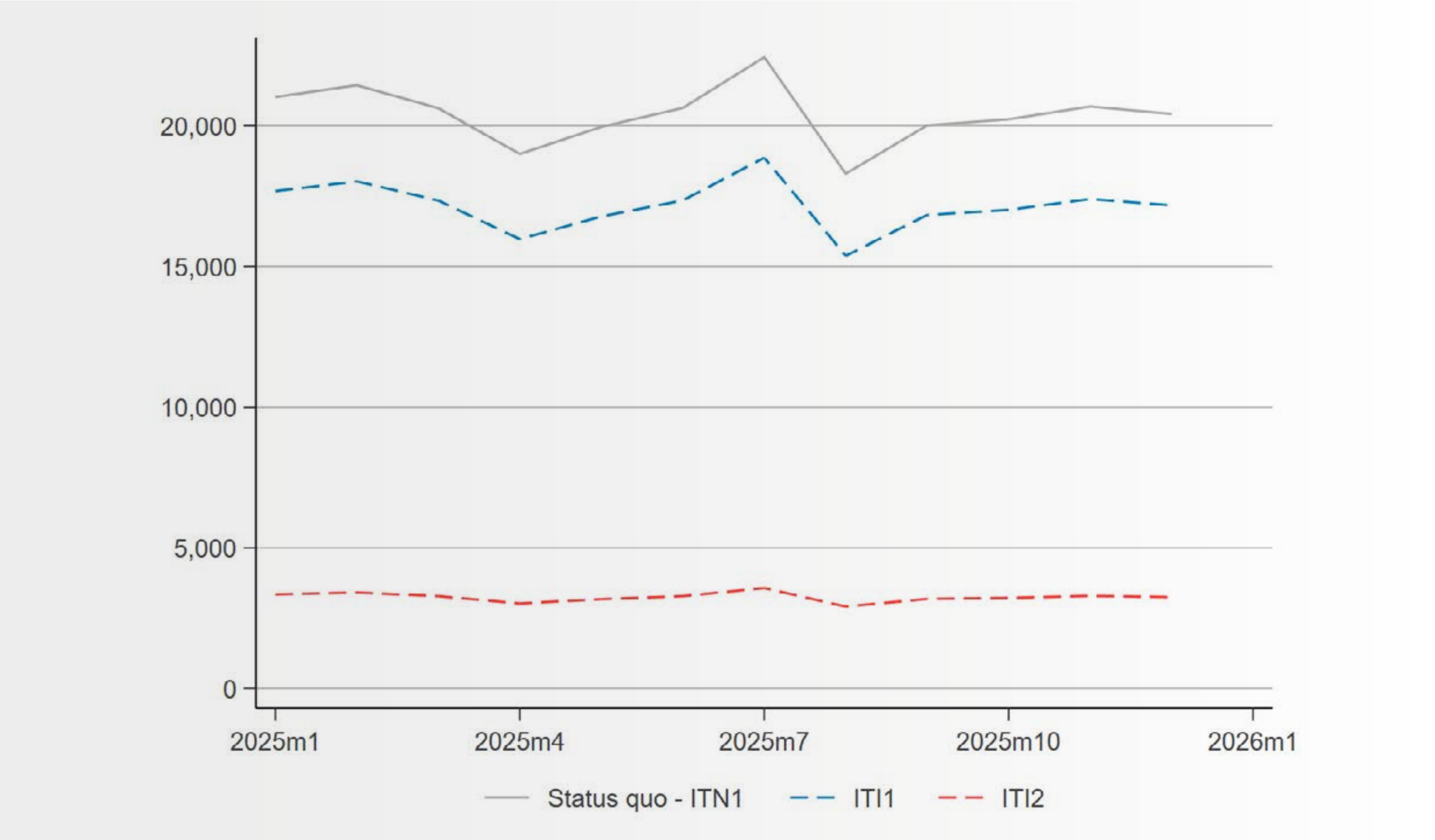
Figure 4.29: Monthly average of hourly generation in the status quo and alternative configuration (in MWh)

The market size as approximated by generation volume implies a significant decrease for the zones ITI2, while ITI1 only decreases to a limited extent in comparison to the status quo, suggesting that – *ceteris paribus* – 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 significantly decreases for ITI2 and only to a limited extent for ITI1 compared to the status quo. In detail, we observe the following:

- The two reconfigured BZs experience a different decline in demand compared to the status quo. Zone ITI1 matches the demand pattern throughout the year of the status quo, albeit starting around an average demand of 17,000 MWh per hour in January compared to 21,000 MWh for 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 2025. The peak in summer is less pronounced than for generation volume.



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

Figure 4.30: Monthly average of hourly demand in the status quo and alternative configuration (in MWh)

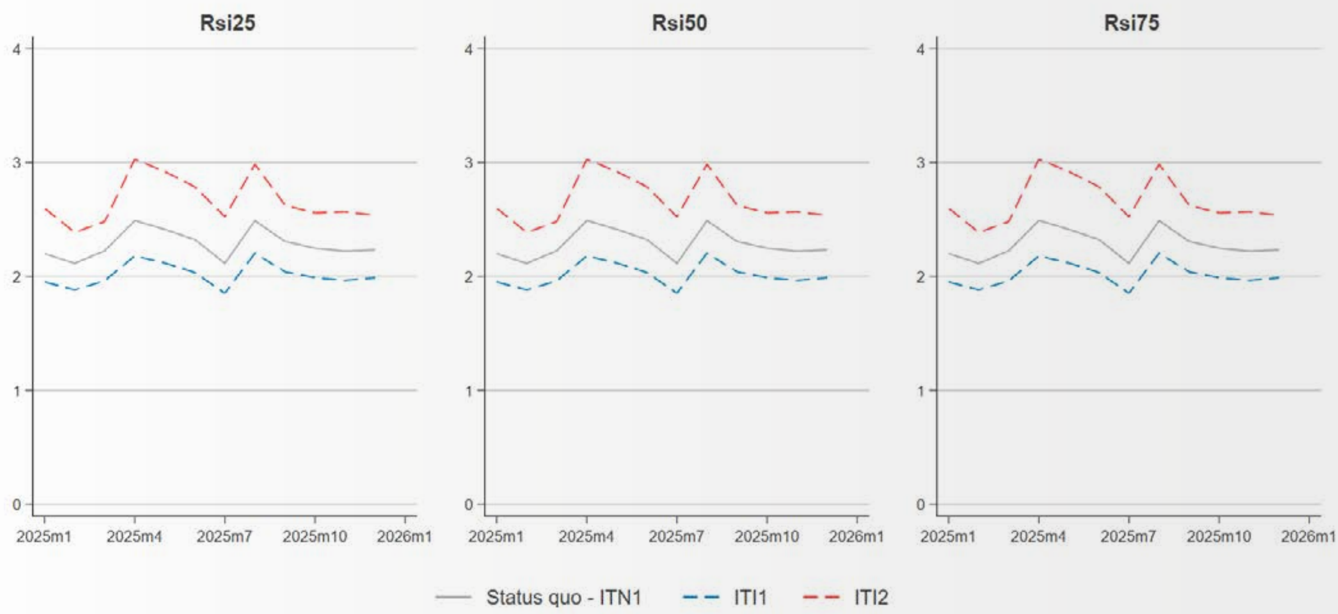
It follows that both indicators for market size tend to show that the proposed reconfiguration is likely to reduce liquidity metrics compared to the status quo in the respective zones, assuming no other changes.

4.5.3 Market concentration

The analysis of the market concentration for the northern Italian region uses the average hourly RSI [54] values, averaged across climate years as calculated by the Central European TSOs for each BZ alternative configuration. 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[55].

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 significantly change. This suggests that changes in market concentration are not expected to significantly influence the liquidity metrics. If at all, liquidity metrics would – ceteris paribus – slightly increase in ITI2 and decrease in ITI1. Figure 4.31 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.



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

Figure 4.31: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration

54 Indicative results in the literature on the relationship between RSI and market liquidity are presented in Chapter 2.2.2.

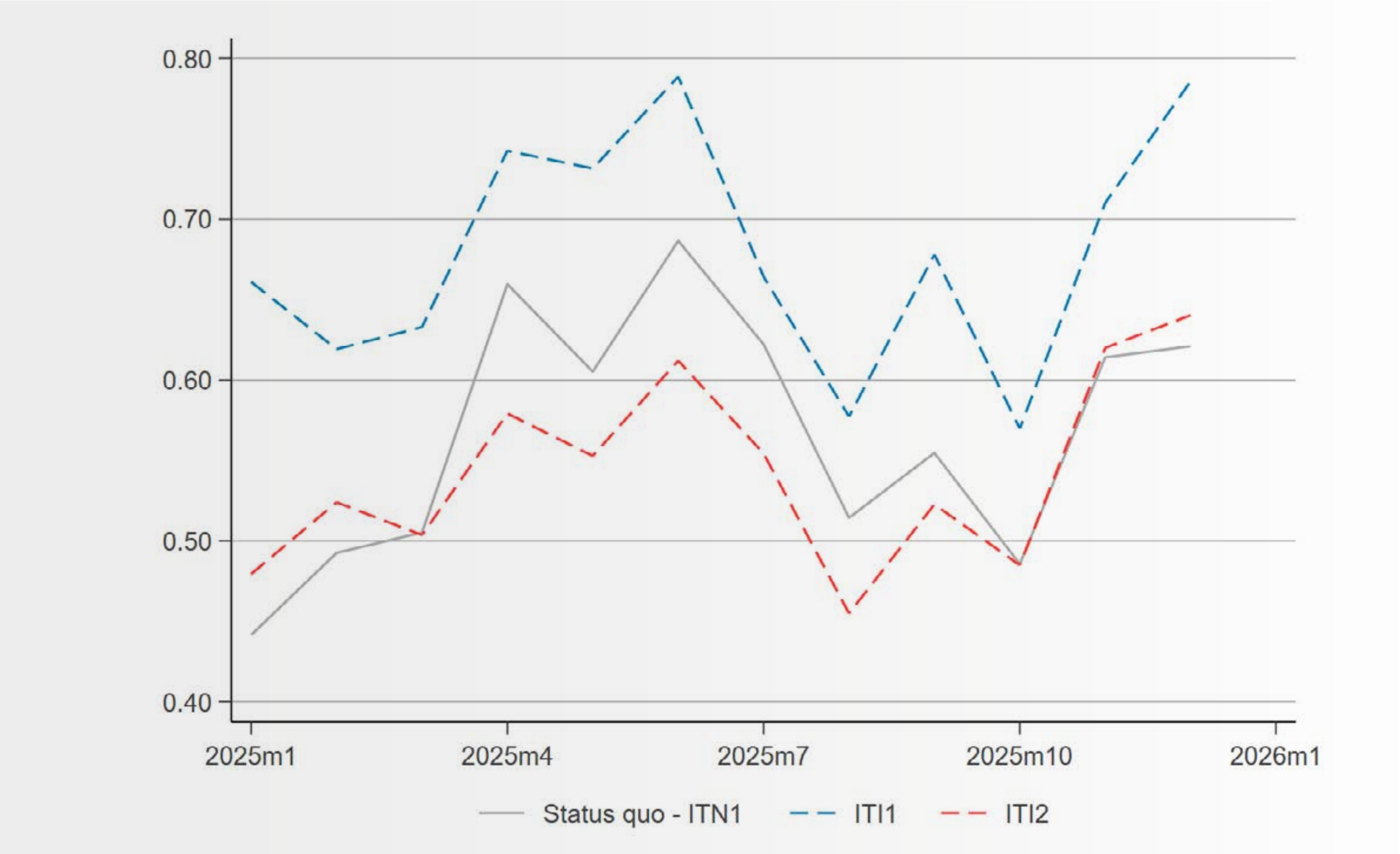
55 The parameter values provided for the three instances are the same across all instances.

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, the correlation increases to 0.68 for the reconfigured BZ ITI1.

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

Figure 4.32 shows the monthly averages of the price correlation for the different BZs and the status quo.



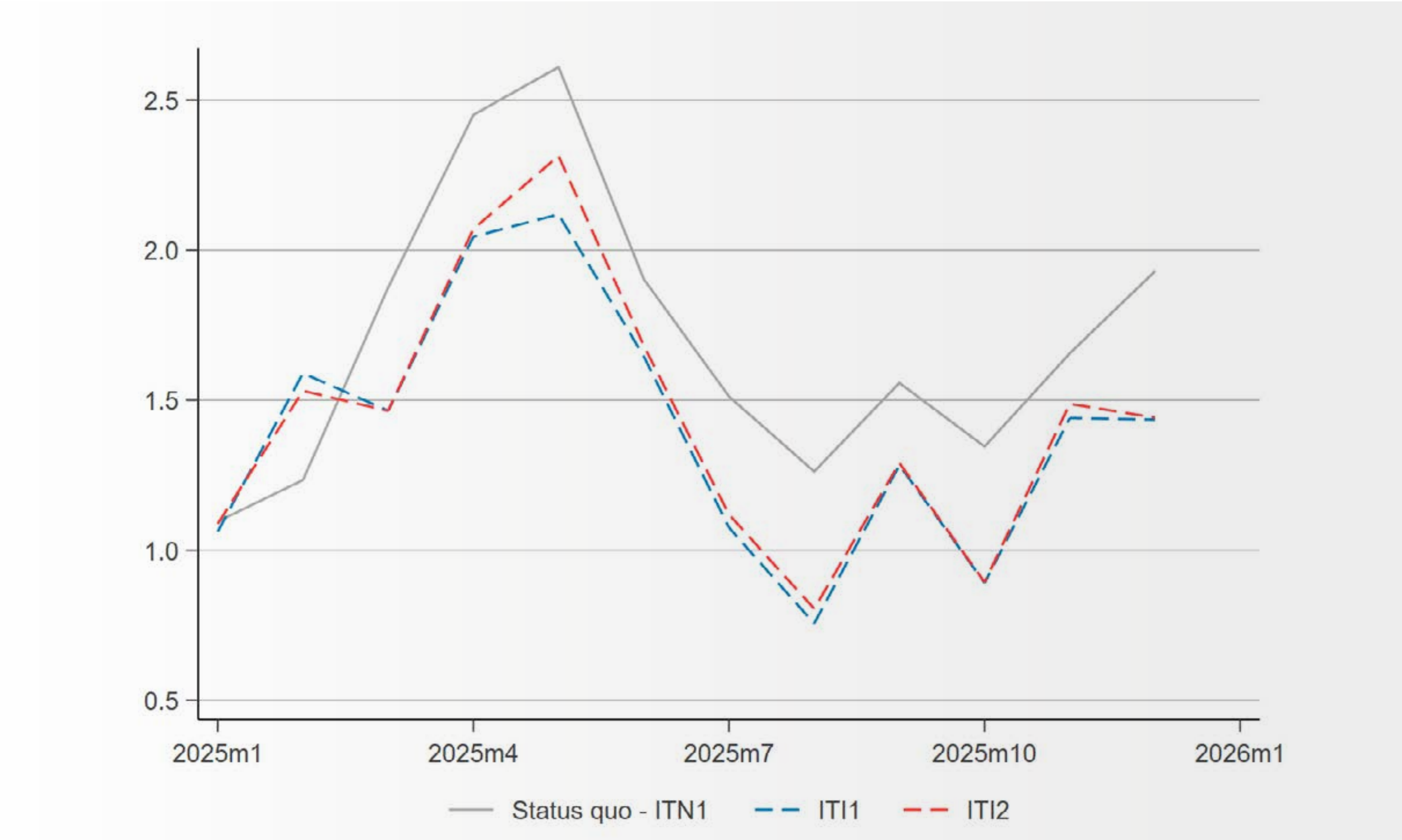
Source: Compass Lexecon analysis of simulated data as provided by TSOs

Figure 4.32: Monthly average of hourly price correlations in the status quo and alternative configuration

4.5.5 Price volatility

The analysis of price volatility for the BZs in the Northern Italy region uses the monthly average daily SD. Price volatility is lower for both new Northern Italy BZs – ITI1 and ITI2 – in most periods compared to the status quo from the second quarter of the year onward. The average daily SD is 1.70 € / MWh in the status quo, while it falls to 1.40 € / MWh and 1.43 € / MWh for the new BZs, ITI1 and ITI2, respectively.

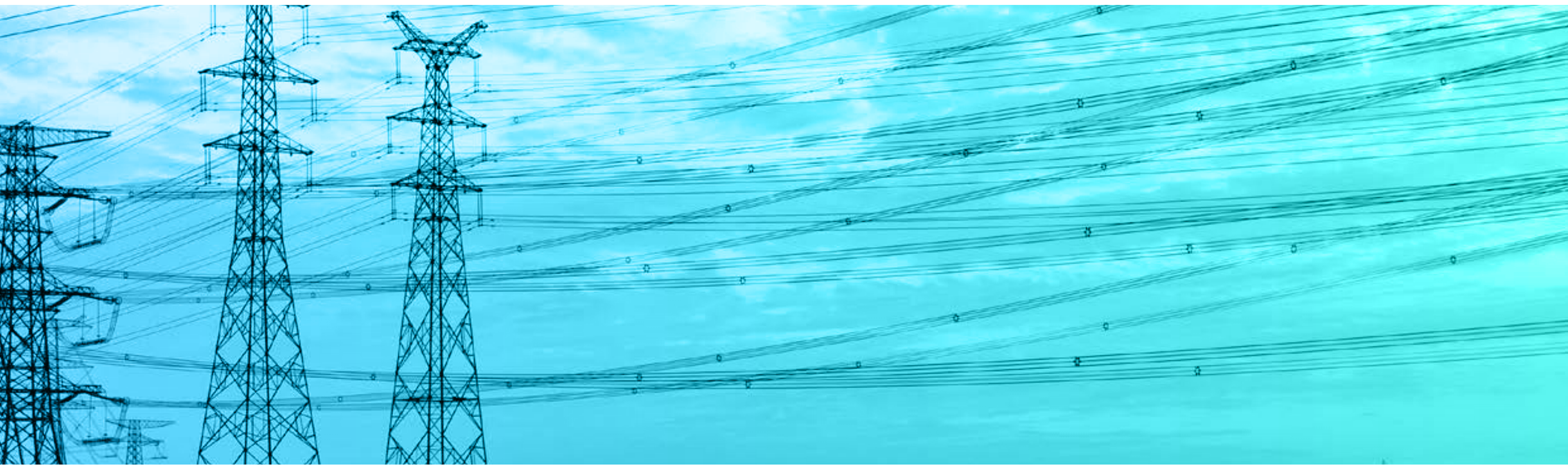
Figure 4.33 shows the monthly average daily SD values for the different BZs and the status quo.



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

Figure 4.33: Monthly average of daily standard deviation in the status quo and alternative configuration

In summary, the reconfiguration of BZs reduces price volatility in the Northern Italy region. However, since volatility is already quite low in the status quo configuration, the reconfiguration is unlikely to generate significant changes in liquidity metrics.

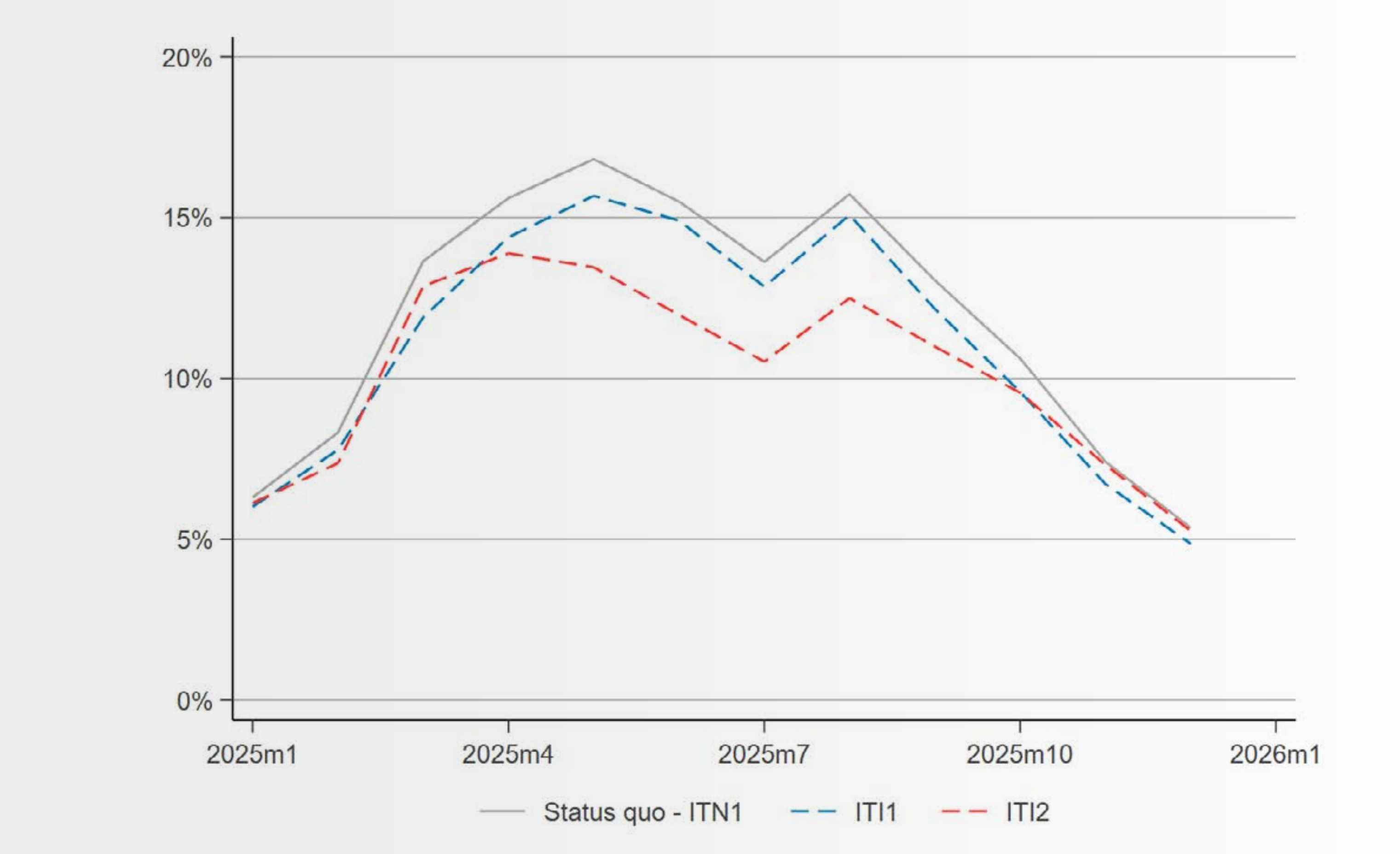


4.5.6 Participant mix

The analysis of the participant mix for the BZs in the Northern Italy region uses the monthly average hourly RES share, calculated as the percentage of PV and wind generation over total generation.

The RES share of the new Northern Italy BZs decreases compared to the status quo across most periods considered. While the BZ in the status quo has an average RES share of approximately 11.83 %, the share falls to 10.99 % for ITI1 and 10.15 % for ITI2 in the reconfigured BZs. Overall, there is a decline in the RES generation mix in Northern Italy due to the reconfiguration of BZs.

Figure 4.34 shows the monthly average hourly RES share values for the different BZs and the status quo.



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

Figure 4.34: Monthly average of hourly RES share in the status quo and alternative configuration

Considering that the changes in RES share are only limited, no relevant change in liquidity metrics is implied from this indicator.

4.5.7 Supply-demand imbalance

The supply-demand imbalance decreases in both alternative Northern Italy BZs compared to the status quo across all periods considered in the analysis. On average, the status quo has a supply-demand imbalance of 14.31 p. p., while BZ ITI1 has an average imbalance of 11.97 p. p., and BZ ITI2 has an average imbalance of 8.24 p. p.

Figure 4.27 shows the monthly average supply-demand imbalance for the different BZs and the status quo.

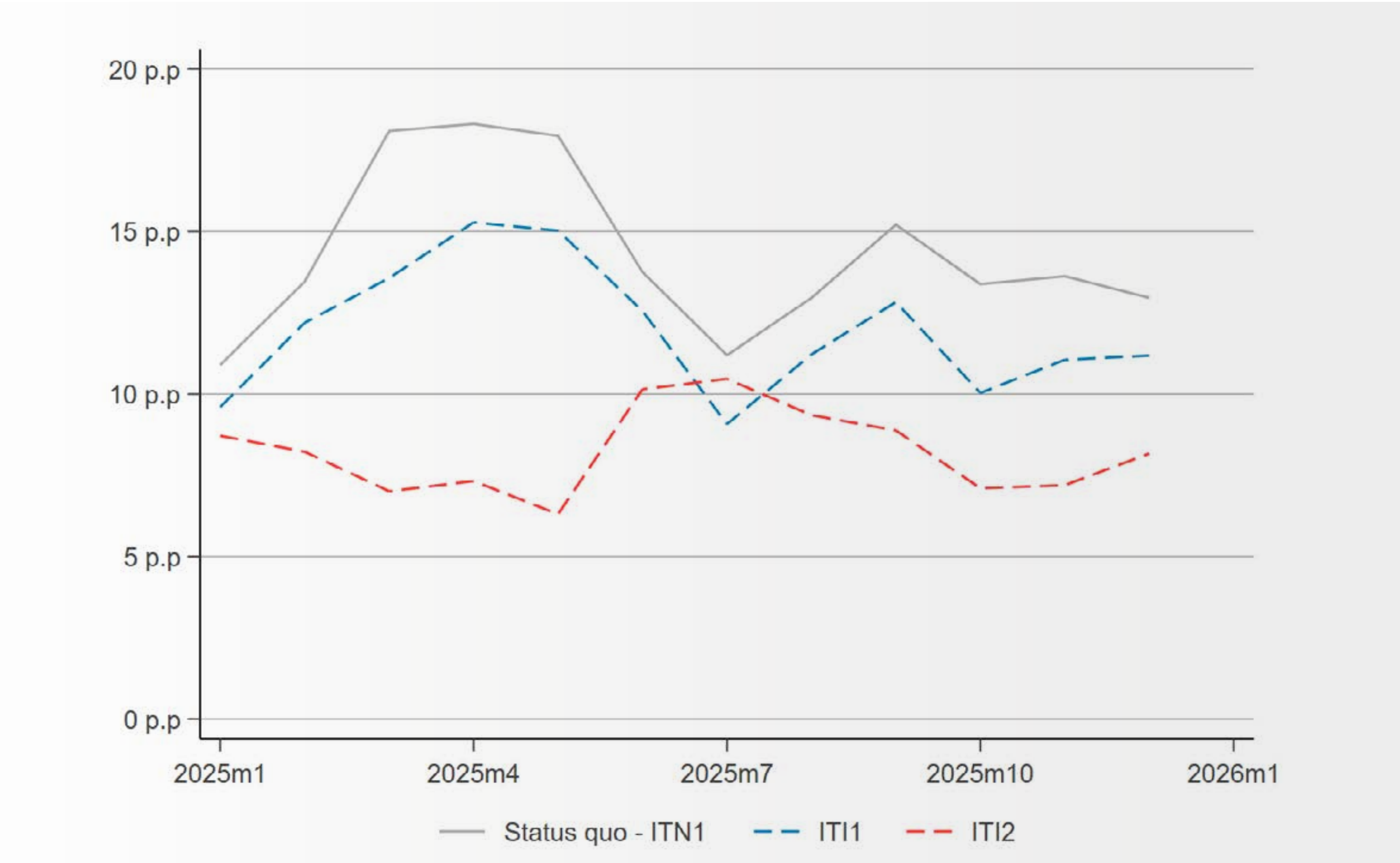


Figure 4.35: Monthly average of hourly supply-demand imbalance share in the status quo and alternative configuration

The reconfiguration of BZs implies a reduction in the supply-demand imbalance in Northern Italy, which – *ceteris paribus* – should coincide with an increase in liquidity metrics.

4.5.8 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.

First, we notice that the proposed BZ reconfiguration features the creation of two new zones that strongly differ in market size.

In particular, the ITI2 zone is materially smaller than the current IT N1, potentially leading to reduced liquidity, other things being equal.[56] Nevertheless, in ITI2, negative size effects on liquidity could be partly offset by the positive impacts on the liquidity of increased competition, a reduced supply-demand imbalance, and reduced spot price volatility. However, price correlation and RES share might have further reducing effects on liquidity metrics.

While the size of ITI1 is similar to that of the initial ITN1 zone, competition effects might suggest further liquidity reduction, while the increased price correlation and reduced supply-demand balance might provide an offsetting effect on liquidity.

These findings are supported by the following observations:

- Generation and demand in both BZs decrease due to the reconfiguration in Italy indicating a smaller market size. Notably, ITI2 – the much 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.
- Market concentration decreases in the smaller zone, while increasing in the larger BZ.
- Price correlation for the smaller BZ ITI2 remains almost unchanged compared to the status quo, while the price correlation slightly increases between the northeastern zone and its neighbours.
- The price volatility and the participant mix decreases for both new BZs, although at least only to a minor extent for the participant mix.
- Finally, the supply-demand imbalance will also decrease in both new BZs, improving the liquidity, other things being equal.

Case	Descriptive statistics	Market concentration			Price		Market Size		RES share	Supply-demand imbalance
		Rsi 25	Rsi 50	Rsi 75	Correlation	Daily SD	Generation	Demand		
Status quo		ITN1: 2.28	ITN1: 2.28	ITN1: 2.28	ITN1: 0.57	ITN1: 1.70	ITN1: 16,447	ITN1: 20,399	ITN1: 11.83	ITN1: 14.31
Alt config. 6	Max	↑ ITI2: 2.67	↑ ITI2: 2.67	↑ ITI2: 2.67	↑ ITI1: 0.68	↓ ITI2: 1.43	↓ ITI1: 14,394	↓ ITI1: 17,150	↓ ITI1: 10.99	↓ ITI1: 11.97
	Average	↑ 2.34	↑ 2.34	↑ 2.34	↑ 0.61	↓ 1.42	↓ 8,962	↓ 10,196	↓ 10.57	↓ 10.11
	Min	↓ ITI1: 2.01	↓ ITI1: 2.01	↓ ITI1: 2.01	↓ ITI2: 0.54	↓ ITI1: 1.40	↓ ITI2: 3,531	↓ ITI2: 3,243	↓ ITI2: 10.15	↓ ITI2: 8.24

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

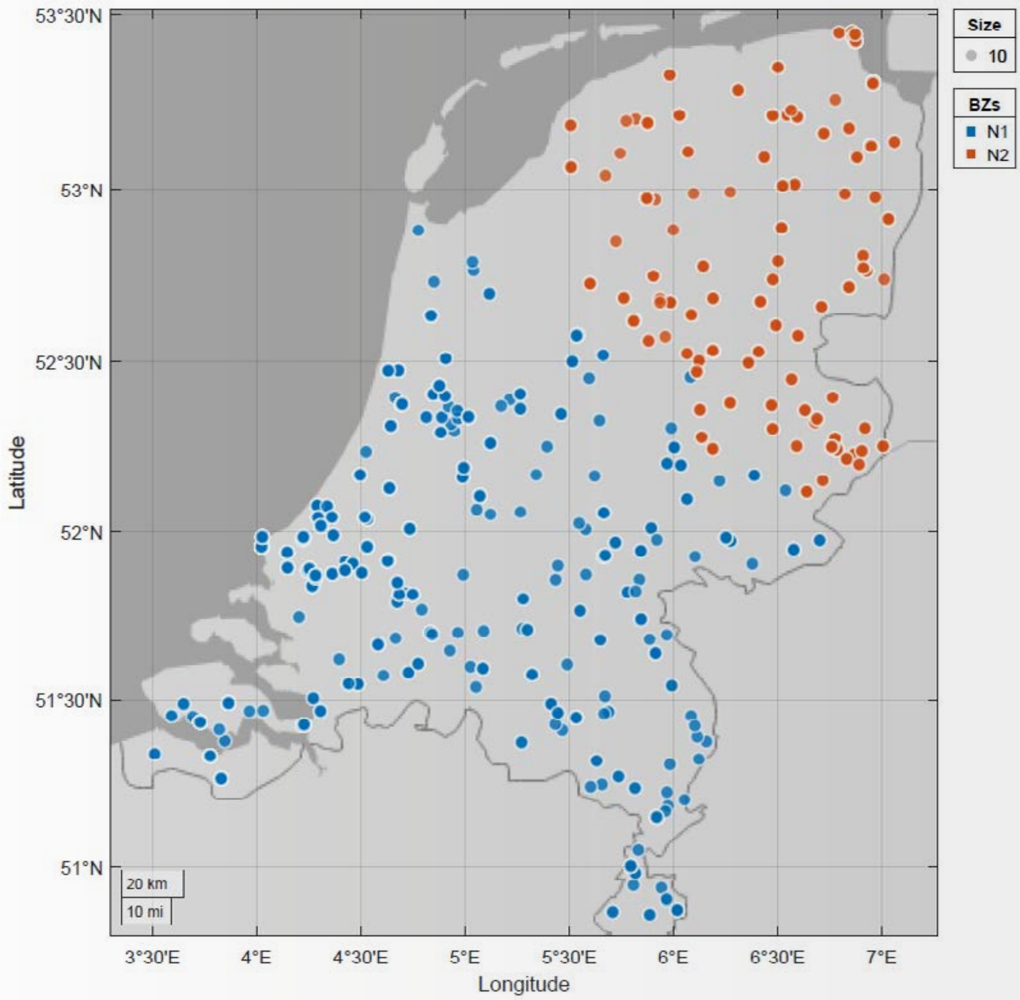
Note: Demand and generation are presented in MWh/h on average throughout the year. Upward arrows indicate increases compared to the status quo. Downward arrows indicate a decrease compared to the status quo. Green indicates a liquidity metric-enhancing effect. Red indicates a liquidity metric-dampening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

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

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

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, whereby NLN1 (N1 in the figure below) would be geographically slightly larger and in the southwest of the Netherlands, while NLN2 (N2 in the figure below) would be the region in the northeast. Figure 4.36 displays the reconfiguration.



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

Figure 4.36: Alternative BZ configuration with two Dutch BZs

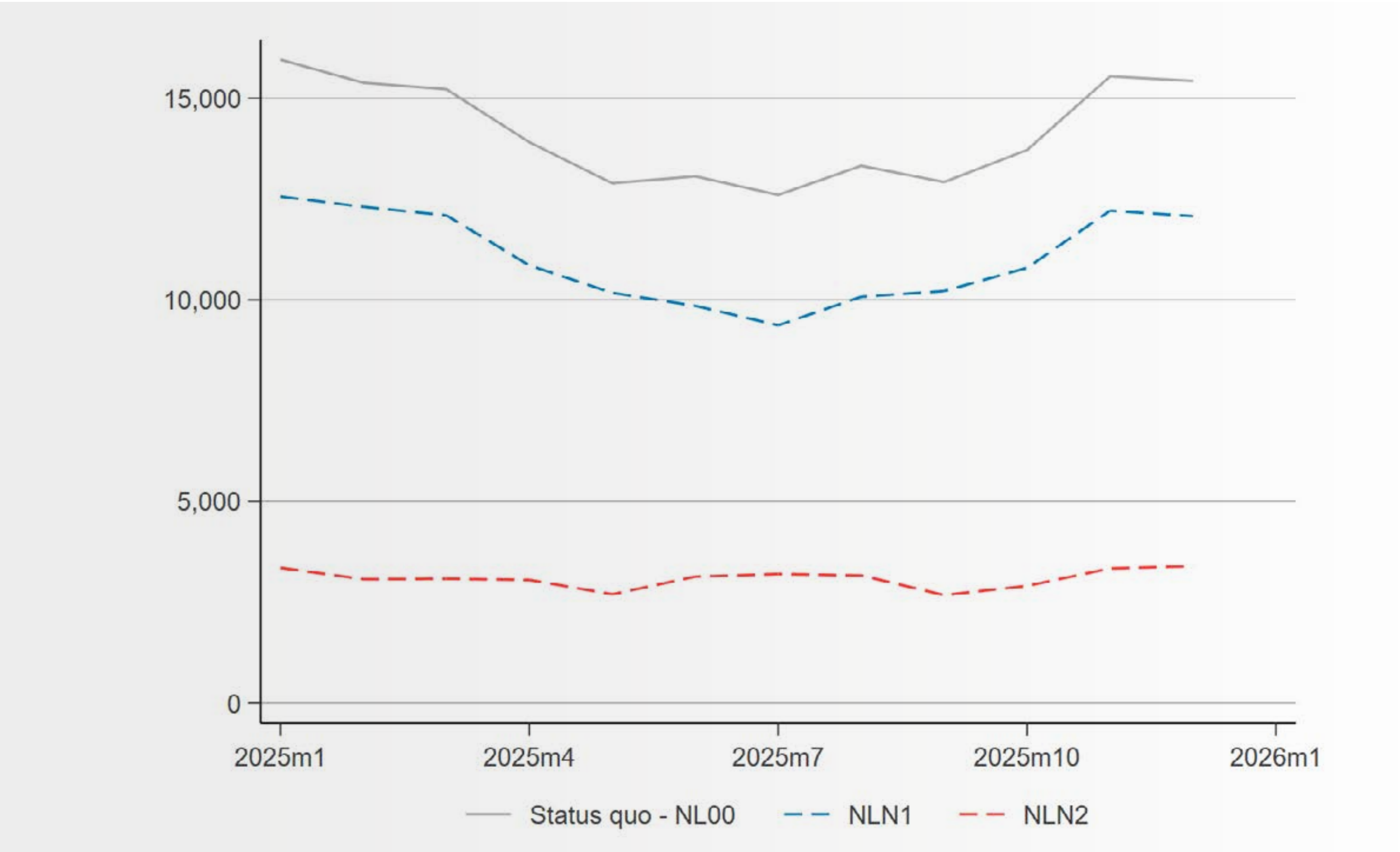
For the alternative configuration and status quo – i. e. assuming that BZs remain the same – the Central European TSOs simulated hourly dispatch of generation units to meet demand in a pan-EU model and provided us with hourly values of generation and demand volume, RSI, and PSI values, and wholesale prices for 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 slightly decreases.

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

- Generation in the southern zone – NLN1 – is simulated to slightly decrease in comparison to the status quo. By 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, increasing again 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. By contrast, generation in the smaller northern zone – NLN2 – is simulated to be rather constant throughout the year, at between 3,000 MWh and 4,000 MWh.



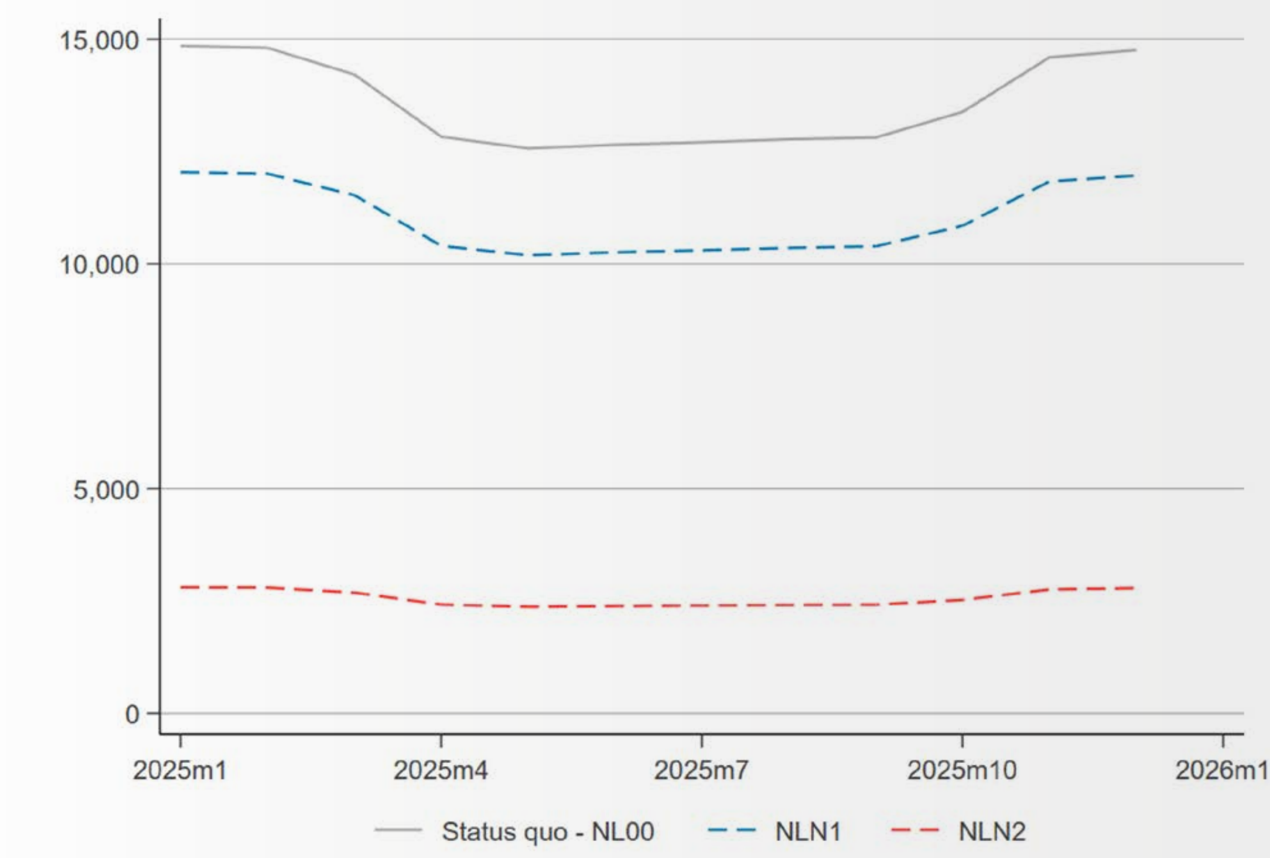
Source: Compass Lexecon analysis of simulated data as provided by TSOs

Figure 4.37: Monthly average of hourly generation in the status quo and alternative configuration (in MWh)

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 significantly decreases for NLN2 and to only a limited extent for NLN1 compared to the status quo. In detail, we observe the following:

- The parameters indicating market size show a varying decrease across both BZs compared to the market size indicators in the status quo.
- The two BZs experience a different decline in demand compared to the status quo. Zone NLN1 matches the pattern of demand throughout the year as the status quo, albeit starting around 12,000 MWh of demand compared 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 at between around 2,500 MWh and 3,000 MWh throughout 2025.



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

Figure 4.38: Monthly average of hourly demand in the status quo and alternative configuration (in MWh)

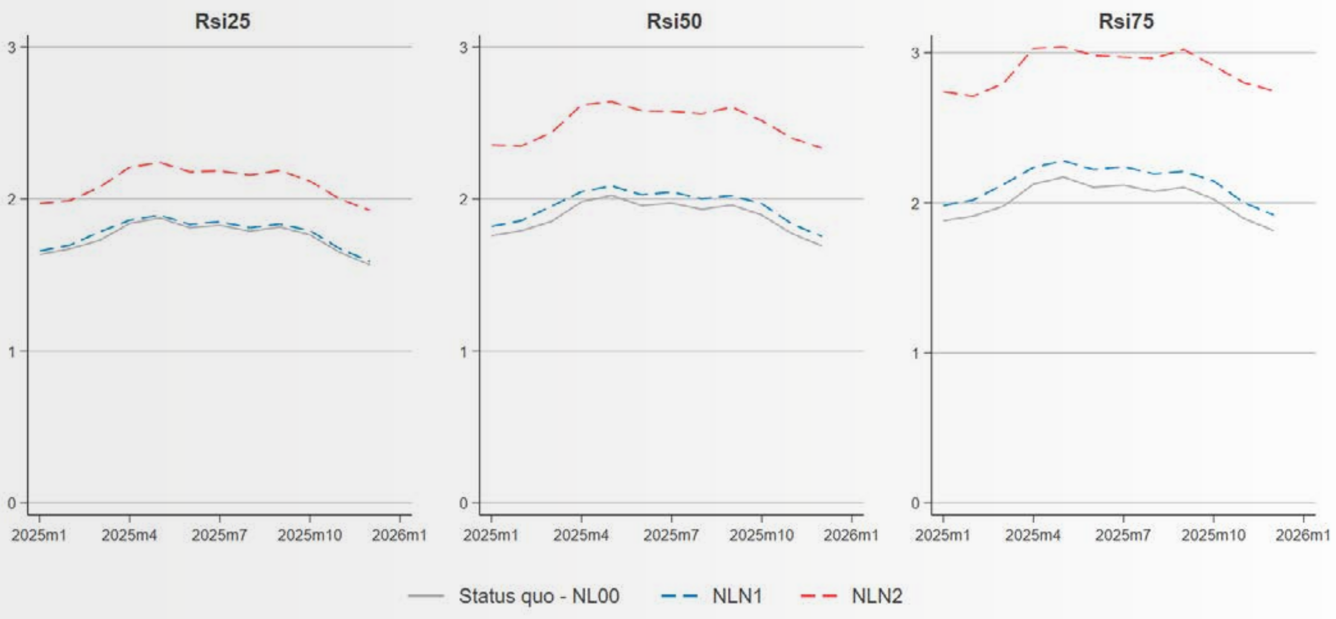
It follows that both indicators for market size tend to show that the proposed alternative configuration is likely to reduce liquidity metrics compared to the status quo in the respective zones, assuming no other changes.

4.6.3 Market concentration

The analysis of the market concentration for the Dutch region uses the average hourly RSI[57] values, averaged across climate years as calculated by the Central European TSOs for each BZ alternative configuration. 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 marginally increases 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 significantly change in most cases. This suggests that changes in market concentration are not expected to significantly influence the liquidity metrics. If at all, liquidity metrics could benefit from the reconfiguration in NLN2 when high import capacity materialises. Figure 4.39 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.



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

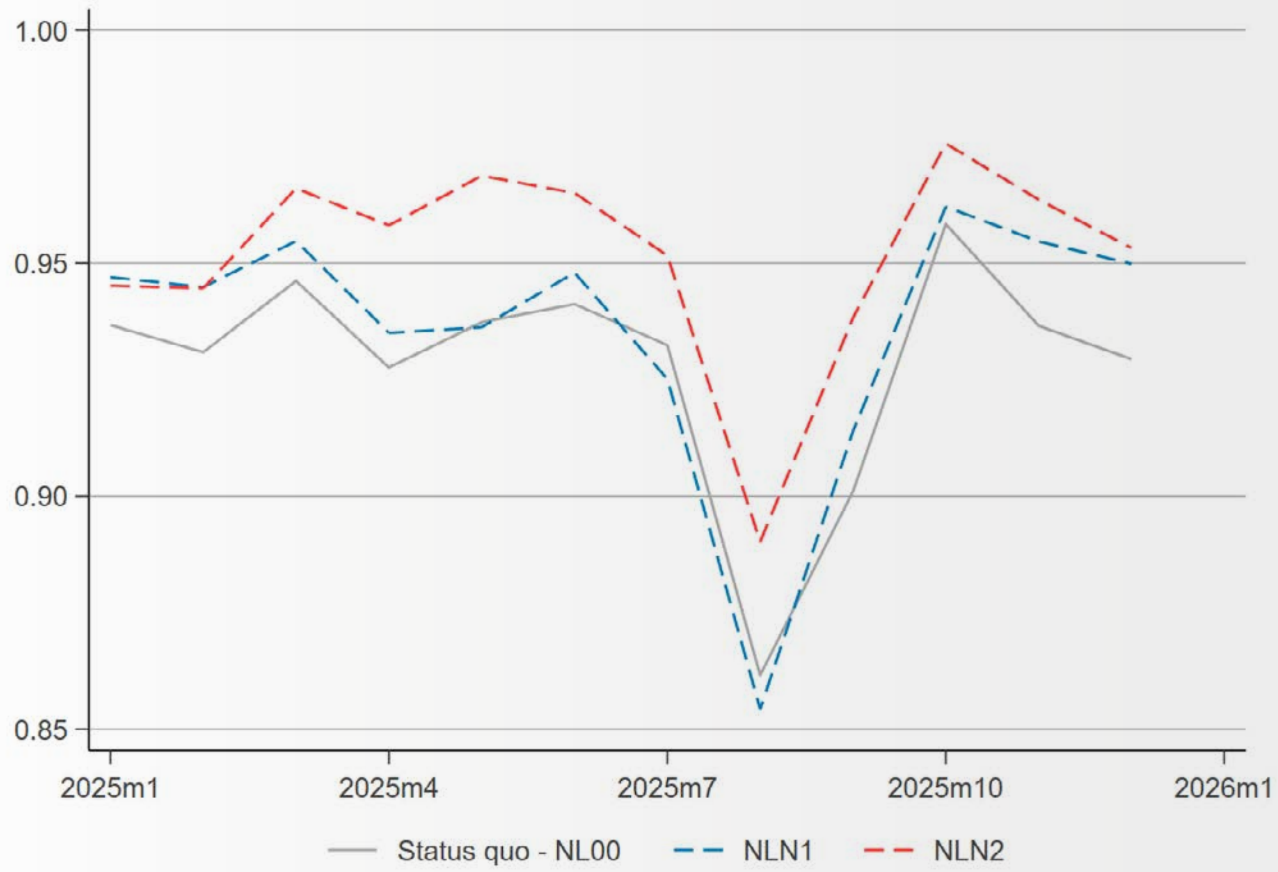
Figure 4.39: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration

57 Indicative results in the literature on the relationship between RSI and market liquidity are presented in Chapter 2.2.2.

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 strong correlation in the status quo and the limited change, the change in price correlation does not provide an indication of expected liquidity metric changes.

Figure 4.40 shows the monthly averages of the price correlation for the different BZs and the status quo.



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

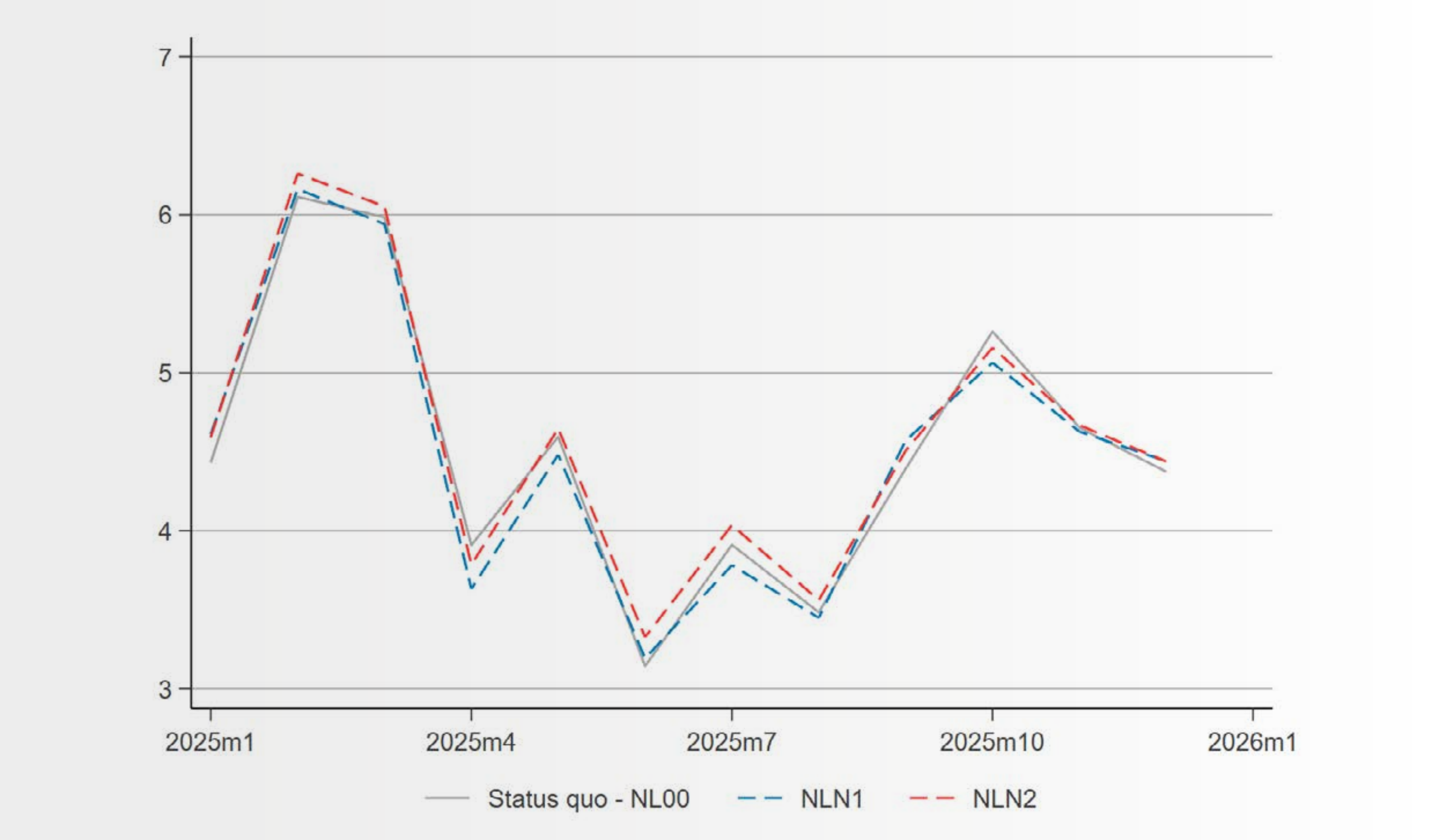
Figure 4.40: Monthly average of hourly price correlations in the status quo and alternative configuration

4.6.5 Price volatility

The analysis of price volatility for the BZs in the Dutch region uses the monthly average daily SD.

The price volatility of the new Dutch BZs – NLN1 and NLN2 – remains very similar to the status quo across all periods considered. On average, the daily SD in the new southern Dutch BZ – NLN1 – slightly decreases compared to the status quo, at 4.50 € / MWh versus 4.52 € / MWh, while the daily SD in the new northern Dutch BZ – NLN2 – slightly increases to 4.59 € / MWh.

Figure 4.41 shows the monthly average daily SD values for the different BZs and the status quo.



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

Figure 4.41: Monthly average of daily standard deviation in the status quo and alternative configuration

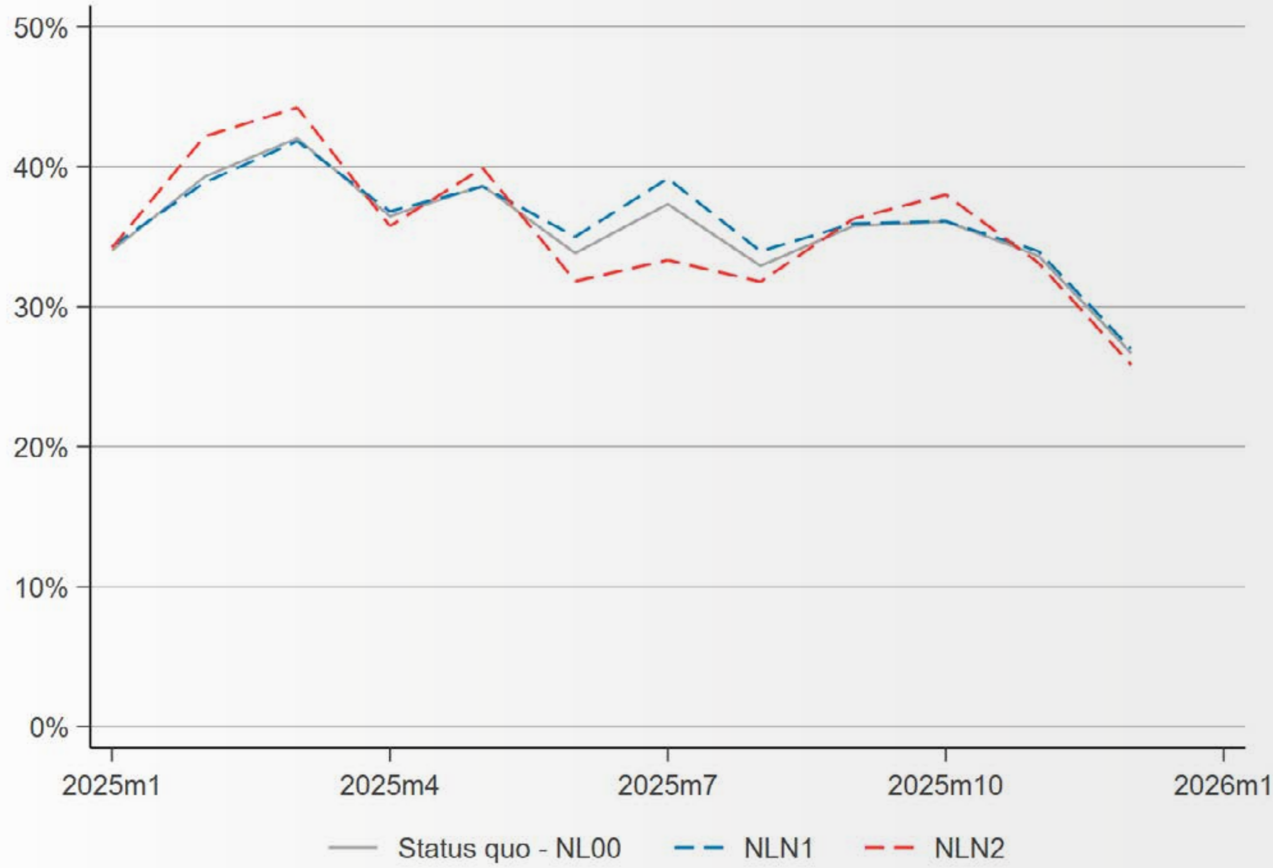
Overall, the reconfiguration has an insignificant effect on price volatility in the Netherlands.

4.6.6 Participant mix

The analysis of the participant mix for the BZs in the Netherlands region uses the monthly average hourly RES share, calculated as the percentage of PV and wind generation over total generation.

The RES share of the new Dutch BZs – NLN1 and NLN2 – remains very similar to the status quo across most periods considered. On average, the RES share in the new southern Dutch BZ – NLN1 – slightly increases compared to the status quo at 35.96 % versus 35.56 %, while the RES share in the new northern Dutch BZ – NLN2 – slightly decreases to 35.54 %.

Figure 4.42 shows the monthly average hourly RES share values for the different BZs and the status quo.



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

Figure 4.42: Monthly average of hourly RES share in the status quo and alternative configuration

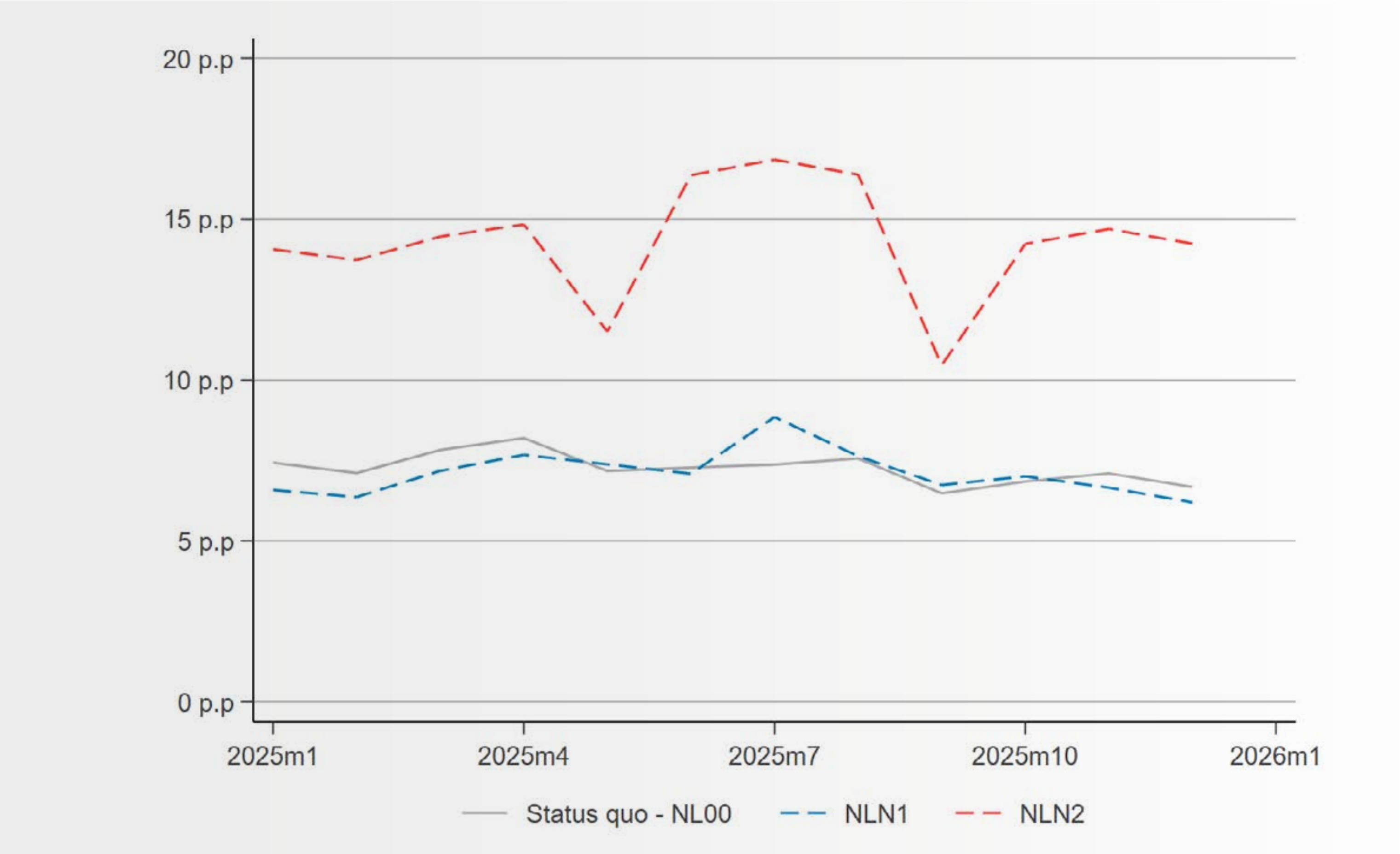
As for price volatility, the participant mix is not expected notably to change. Therefore, no expectation of changes in liquidity metrics can be formed based on this indicator.

4.6.7 Supply-demand imbalance

The supply-demand imbalance in the alternative northern Dutch BZ – NLN2 – increases compared to the status quo across all periods considered. While the status quo BZ has an average supply-demand imbalance of approximately 7.26 p. p., the imbalance rises to 14.32 p. p. for the reconfigured BZ NLN2.

In contrast, the supply-demand imbalance for the other new BZ – NLN1 – does not significantly vary across any of the periods considered compared to the status quo.

Figure 4.41 shows the monthly average hourly RES share values for the different BZs and the status quo.



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

Figure 4.43: Monthly average of hourly supply-demand imbalance share in the status quo and alternative configuration

Overall, considering the changes in both BZs, the reconfiguration results in an increase in the supply-demand imbalance for the total Dutch market, with an average imbalance of 10.72 p. p. being higher than the status quo level.

4.6.8 Conclusions

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

The analysis suggests while the two reconfigured BZs have a smaller size than the initial NL BZ by construction, the other market indicators might suggest quite limited additional effects on liquidity. One can notice the offsetting effect of competition and the price correlation in the smaller NLN2 zone and a deterioration of the supply-demand imbalance in this zone contributing to a further liquidity reduction. At the same time, the larger NLN1 zone does not seem to feature any material additional liquidity factors other than the market size.

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 the alternative configuration.
- Price correlation is slightly improved from an already strong correlation through the reconfiguration in both BZs.
- The effect of the reconfiguration on price volatility and the participant mix is minimal in both new Dutch BZs.
- The supply-demand imbalance slightly decreases in the southern zone NLN1 while it nearly doubles in the northern zone NLN2, leading to an overall increase across the Netherlands.

Country	Descriptive statistics	Market concentration			Price		Market Size		RES share	Supply-demand imbalance
		Rsi 25	Rsi 50	Rsi 75	Correlation	Daily SD	Generation	Demand		
Status quo		NL00: 1.75	NL00: 1.88	NL00: 2.02	NL00: 0.93	NL00: 4.52	NL00: 14,165	NL00: 13,579	NL00: 35.56	NL00: 7.26
Alt config. 7	Max	↑ NLN2: 2.10	↑ NLN2: 2.50	↑ NLN2: 2.89	↑ NLN2: 0.95	↑ NLN2: 4.59	↓ NLN1: 11,051	↓ NLN1: 11,011	↑ NLN1: 35.96	↑ NLN2: 14.32
	Average	↑ 1.94	↑ 2.22	↑ 2.51	↑ 0.94	↑ 4.54	↓ 7,070	↓ 6,789	↑ 35.75	↑ 10.72
	Min	↑ NLN1: 1.77	↑ NLN1: 1.95	↑ NLN1: 2.13	↑ NLN1: 0.94	↓ NLN1: 4.50	↓ NLN2: 3,088	↓ NLN2: 2,568	↓ NLN2: 35.54	↓ NLN1: 7.11

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 alternative configurations considered. The minima and maxima displayed show the highest and lowest observed monthly values of the stated BZ. The stated BZ has been identified based on the average annual value of the market characteristics parameter considered.

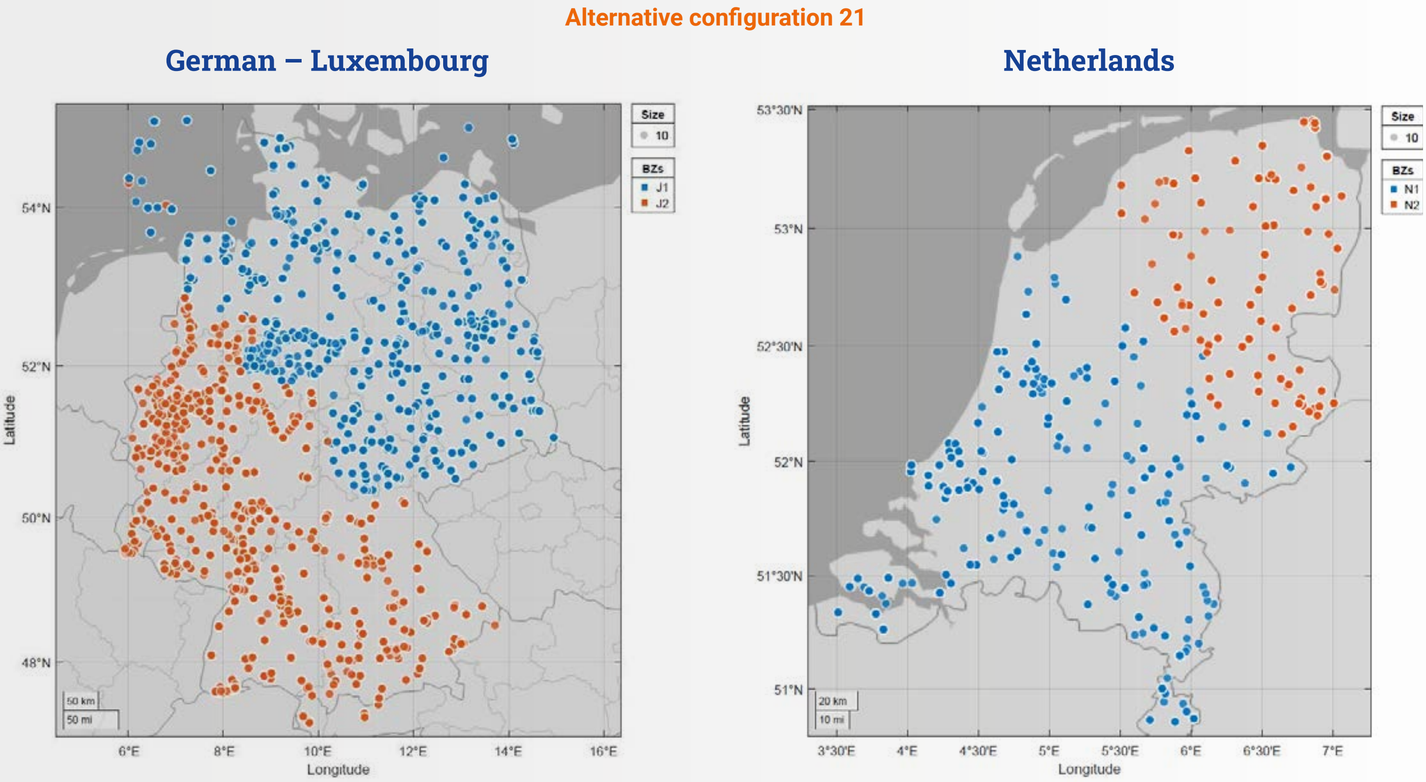
Table 4.5: Average and extreme values of liquidity metrics in the status quo and alternative configuration for the Netherlands

4.7 Combined reconfiguration Germany–Luxembourg and the Netherlands

Additionally, we analyse three alternative configurations where the alternative configurations for Germany–Luxembourg and the Netherlands are applied simultaneously. These are defined as follows:

- **Alternative configuration 21:** Alternative configurations 2 (DE2) and 7 (NL2) are applied simultaneously.
- **Alternative configuration 22:** Alternative configurations 14 (DE5) and 7 (NL2) are applied simultaneously.
- **Alternative configuration 23:** Alternative configurations 13 (DE4) and 7 (NL2) are applied simultaneously.

For the alternative configurations and the status quo configuration – i.e. assuming that 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 by generation type and load volume, RSI and PSI, as well as wholesale prices for 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.

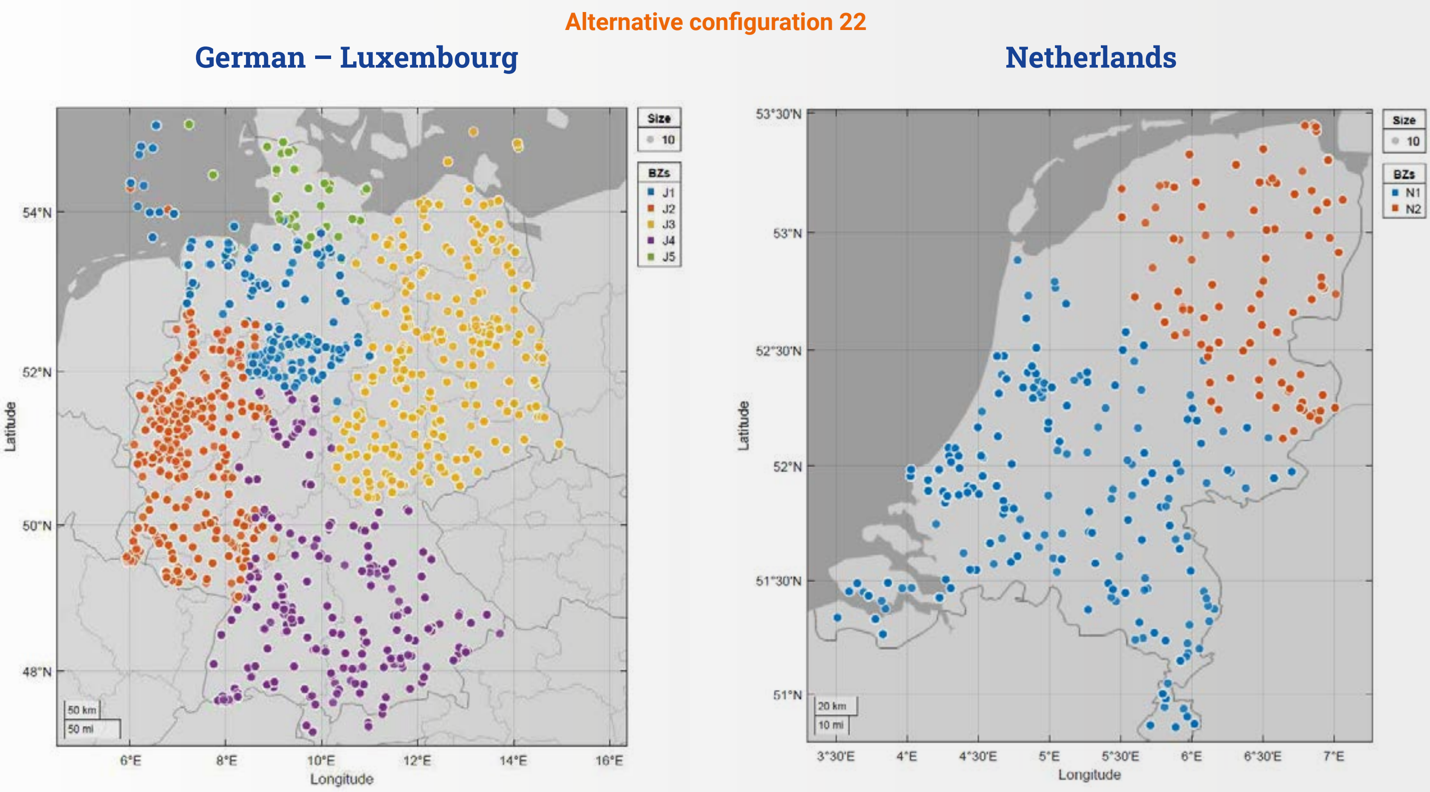


Note: J1 and J2 are the two newly-defined German-Luxembourgish bidding zones.

Note: N1 and N2 are the two newly-defined Dutch bidding zones.

Source: ACER

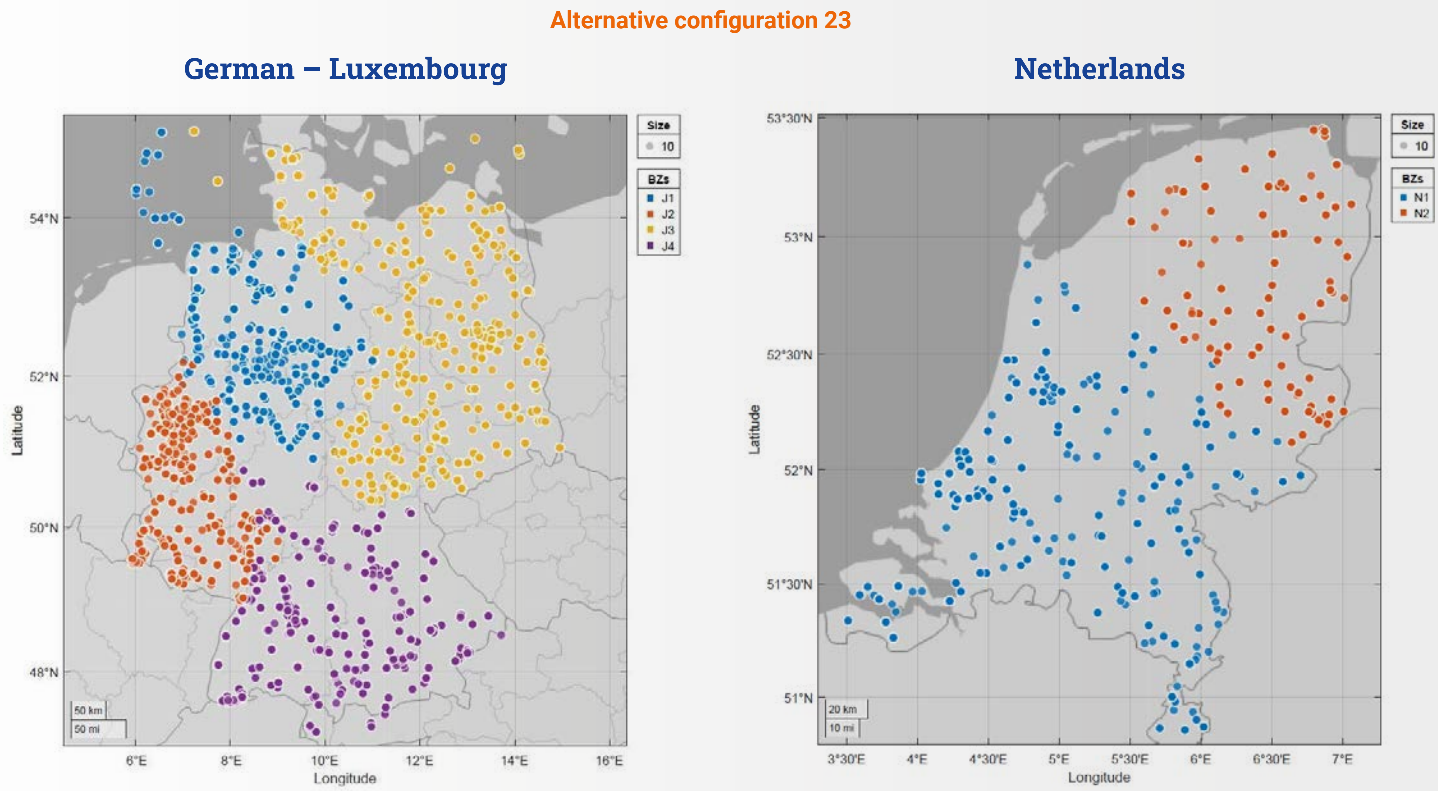
Figure 4.44: Alternative BZs in Germany–Luxembourg and the Netherlands in alternative configuration 21



Note: N1 and N2 are the two newly-defined Dutch bidding zones.

Source: ACER

Figure 4.45: Alternative BZs in Germany–Luxembourg and the Netherlands in alternative configuration 22



Note: J1, J2, J3 and J4 are the four newly-defined German-Luxembourgish bidding zones.

Note: N1 and N2 are the two newly-defined Dutch bidding zones.

Source: ACER

Figure 4.46: Alternative BZs in Germany–Luxembourg and the Netherlands in alternative configuration 23

4.7.1 Market size approximated by generation

Considering the simultaneous alternative configuration in Germany–Luxembourg and the Netherlands does not alter the previous conclusions on market size – approximated by generation – when analysing each alternative configuration in isolation. For instance:

› **In alternative configuration 21:**

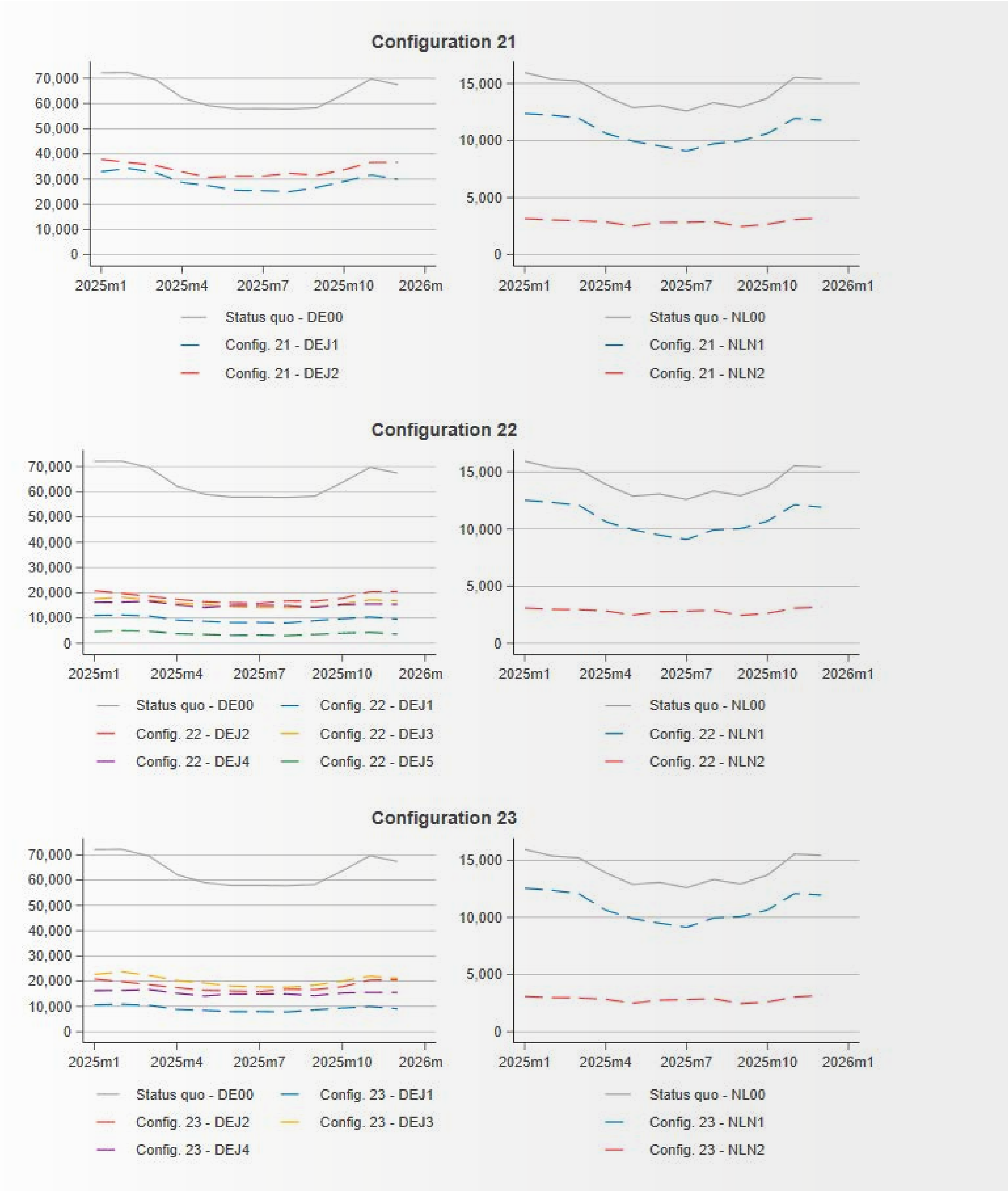
- In Germany, generation decreases similarly in both DEJ1 and DEJ2 compared to the status quo. Generation in these zones declines from an average of 60,000 – 70,000 MWh/h in the status quo to around 25,000 – 37,000 MWh/h each.
- In the Netherlands, generation in the southern zone – NLN1 – slightly decreases compared to the status quo, while the northern zone – NLN2 – sees a significantly lower generation volume.

› **In alternative configuration 22:**

- In Germany, all simulated zones generate below 25,000 MWh/h, compared to 60,000 – 70,000 MWh/h in the status quo.
- In the Netherlands, the results are very similar to those in alternative configuration 21.

› **In alternative configuration 23:**

- As observed for configuration 22, generation volumes in all simulated zones fall below levels in the status quo with a single BZ in Germany.
- As observed for configuration 22, the results for the Netherlands remain very similar to those in alternative configuration 21, i.e. lower generation levels in both BZs compared to the status quo.



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

Figure 4.47: Monthly average of hourly generation in the status quo and alternative configuration (in MWh)

Overall, the combinations reduce the market size for each individual BZ in similar proportions to when each alternative configuration is considered in isolation. Therefore, the effect on liquidity metrics is expected to be negative.

4.7.2 Market size approximated by demand

As with market size approximated by generation, when we consider the market size approximated by demand, our previous conclusions do not change. More specifically, considering the alternative configurations for Germany–Luxembourg and the Netherlands simultaneously does not yield different findings compared to analysing the reconfigurations in isolation. The alternative configurations 21, 22 and 23 reduce the market size for each alternative BZ, consequently leading to an impairment of liquidity metrics.

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

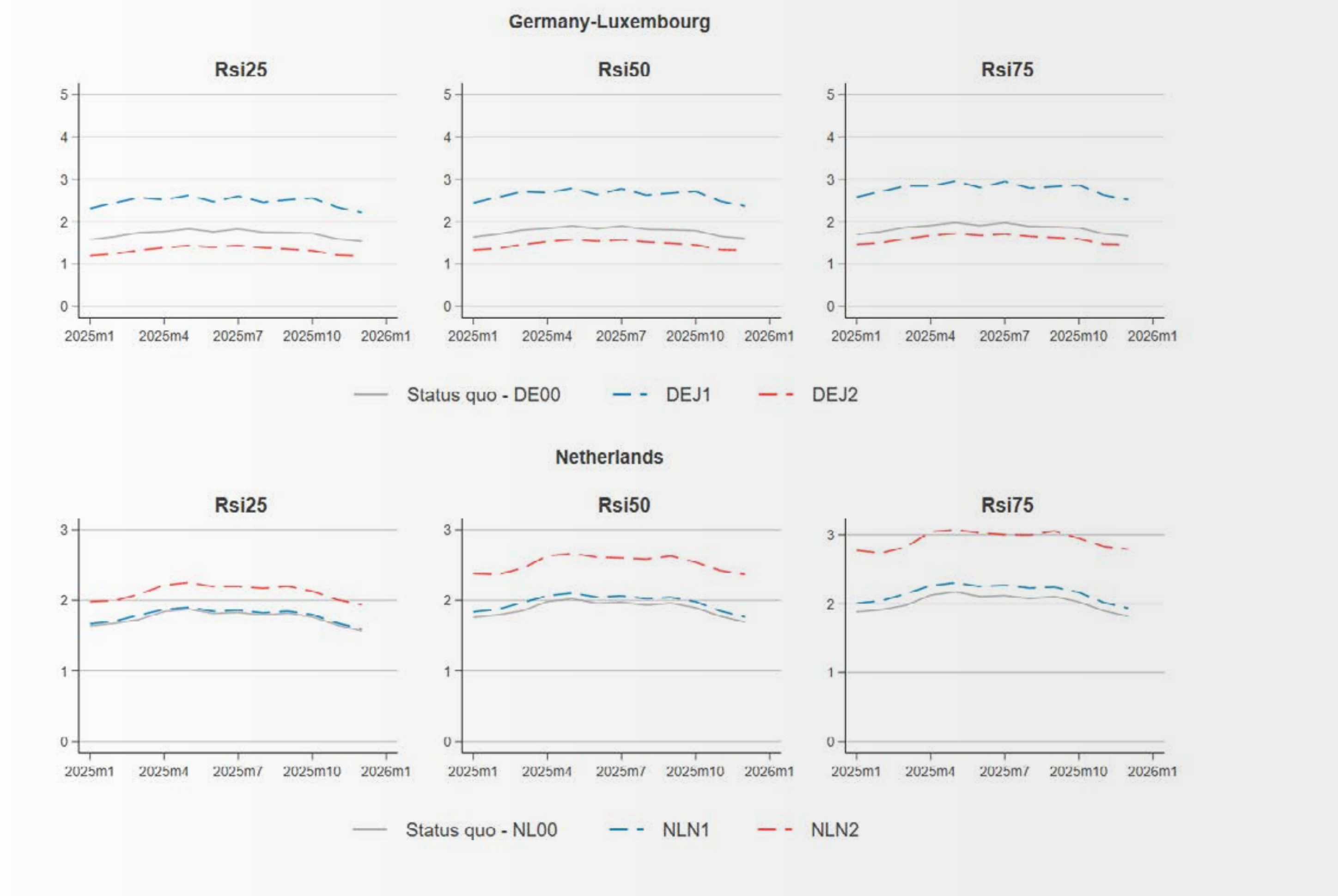
Figure 4.48: Monthly average of hourly demand in the status quo and alternative configuration (in MWh)

4.7.3 Market concentration

The analysis of market concentration uses the average hourly RSI values. The effects on the simultaneous alternative configurations are mostly similar to the analysis results of the isolated configurations. Specifically:

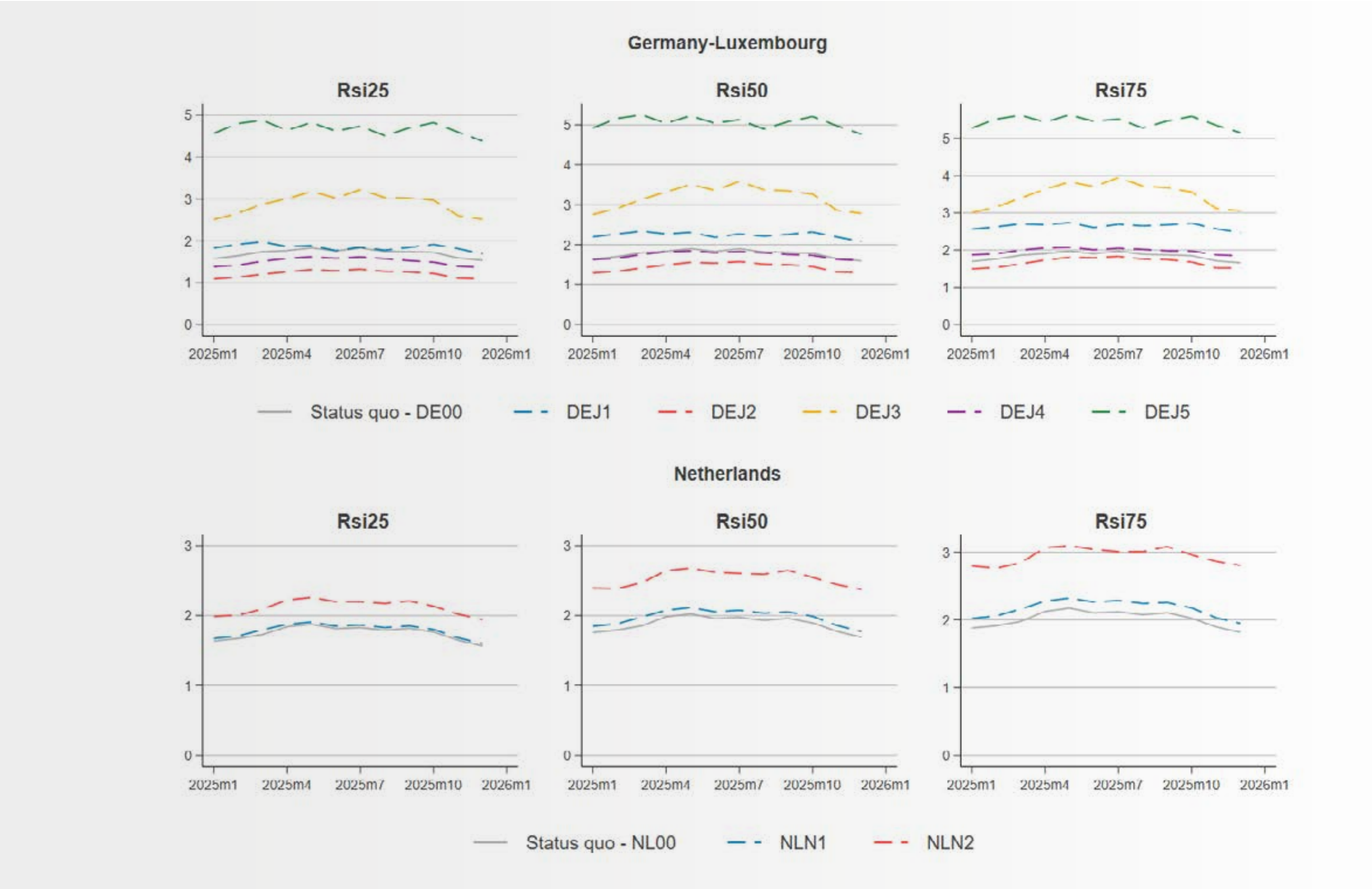
› **In alternative configuration 21:**

- For Germany, the RSIs of the alternative 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.
- For the Netherlands, the RSI increases compared to the status quo for both alternative BZs. While the RSI only increases marginally for NLN1, the increase in RSI is particularly significant for NLN2 when assuming relatively high import capacity.



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

Figure 4.49: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration in configuration 21

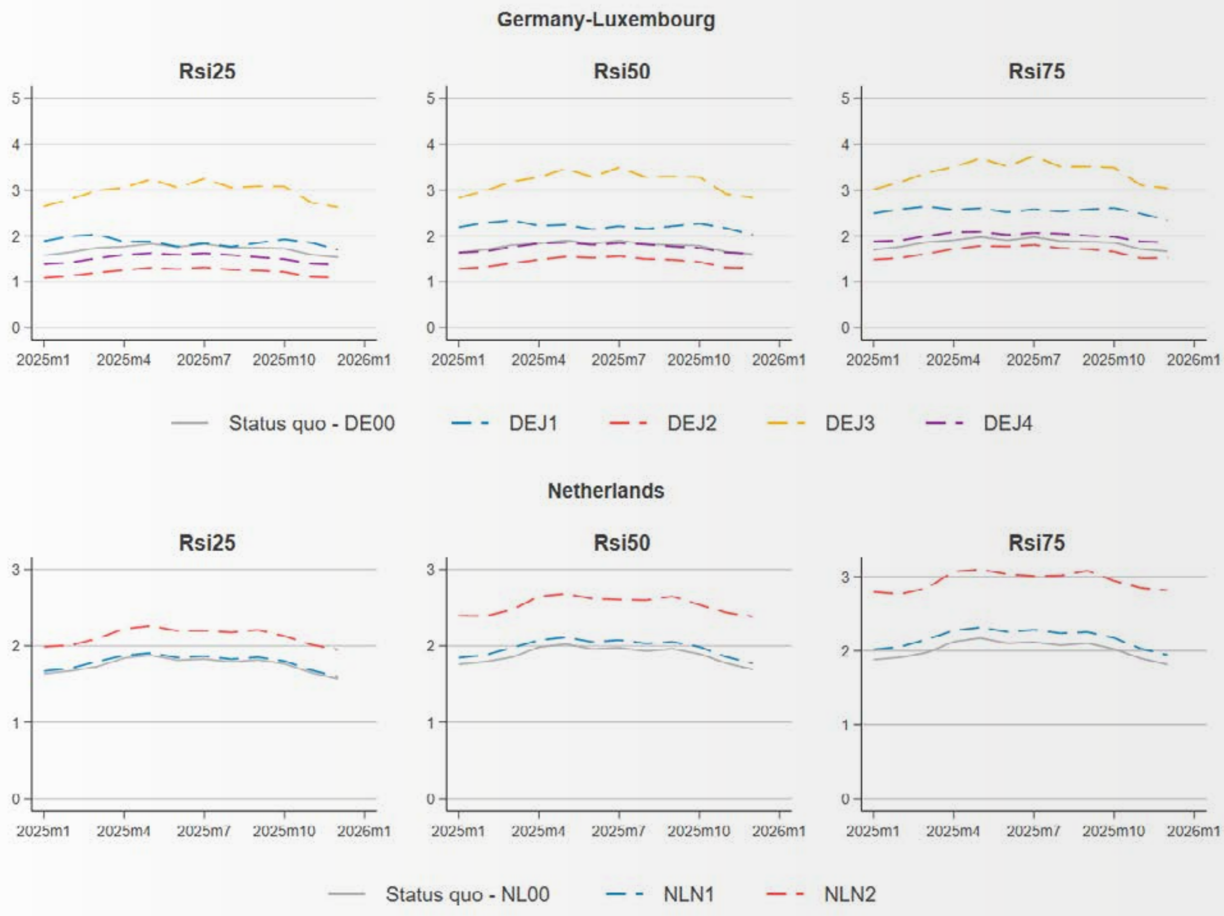


Source: Compass Lexecon analysis of simulated data as provided by TSOs

Figure 4.50: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration in configuration 22

› **In alternative configuration 22:**

- For Germany, the status quo BZ is split into five in this configuration. As with alternative configuration 21, some BZs show an improvement in market concentration compared to the status quo, while others show a deterioration.
- For the Netherlands, there are no visible changes compared to configuration 21 and the isolated case in alternative configuration 7.



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

Figure 4.51: Monthly average of hourly market concentration given by the RSI in the status quo and alternative configuration in configuration 23

› **In alternative configuration 23:**

- The alternative configuration considers configuration 13 for Germany, i.e. splitting the single status quo BZ into four. As with alternative configurations 21 and 22, improvements as well as deteriorations are observed for simulated BZs which is in line with the isolated case in alternative configuration 13.
- As for configuration 21 and 22, there are no visible changes for the Netherlands compared to the isolated case in alternative configuration 7.

Overall, in Germany, the simultaneous alternative configuration in the Netherlands does not alter previous conclusions. The effect on expected liquidity metrics does not show a clear trend across the alternative configurations. Notably, in all configurations, some zones exhibit a higher RSI than the status quo, while others have a lower RSI. Where RSI decreases occur, the changes are mostly limited.

For the Netherlands, the conclusion also remains unchanged when considering the Dutch alternative configuration alongside alternative configurations 2, 13 and 14 in Germany, with a positive projected effect on liquidity metrics remaining evident.

4.7.4 Price correlations

We further study changes in the monthly average hourly price correlations for the simultaneous alternative configurations in Germany and the Netherlands compared to the status quo and isolated alternative configurations. The results do not differ extensively from those for the separate analysis of alternative configurations, although we observe slightly lower levels of price correlation for the Dutch BZs in alternative configurations 21, 22 and 23. More specifically:

› **In alternative configuration 21:**

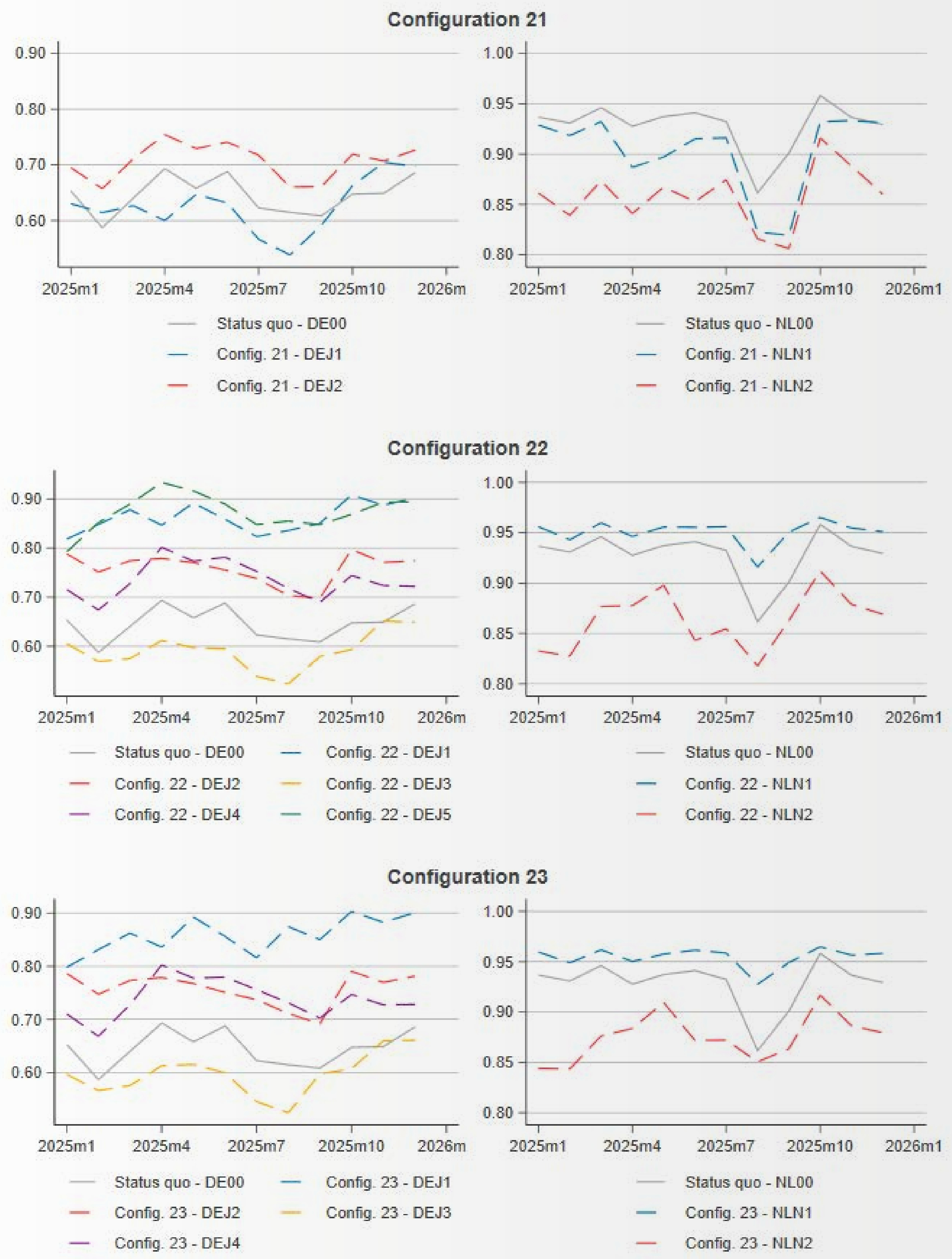
- As in the isolated alternative configuration 2, we observe slight increases for the southwestern zone DEJ2 for all months compared to the status quo, and slight decreases for DEJ1.
- Average price correlation in the Dutch BZs decreases from 0.93 in the status quo to 0.88. By contrast, in the isolated configuration 7 in the Netherlands, there is a minimal increase in average price correlation.

› **In alternative configuration 22:**

- As for alternative configuration 21, price correlations do not differ extensively from those observed in the isolated alternative configuration 14. Hence, we still observe that the eastern BZ DEJ3 tends to have a weaker price correlation than the status quo. The other four zones consistently have a stronger price correlation than the status quo.
- As in alternative configuration 21, price correlations in the Dutch zones would slightly decrease compared to the status quo, in contrast to the slight increase observed in the isolated alternative configuration 7.

› **In alternative configuration 23:**

- As for alternative configurations 21 and 22, price correlations in alternative configuration 23 in Germany do not differ significantly from those in the isolated alternative configuration 13. While price correlation in the eastern BZ falls below status quo levels in most cases, correlations increase for the other three simulated BZs.
- For the Netherlands, the results for alternative configuration 23 are also in line with those of alternative configurations 21 and 22, and particularly similar to those in configuration 22. Price correlations in the Dutch zones would slightly decrease compared to the status quo, in contrast to the slight increase observed in the isolated alternative configuration 7.



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

Figure 4.52: Monthly average of hourly price correlations in the status quo and alternative configuration

Overall, we conclude that the simultaneous alternative configurations 21, 22 and 23 would not yield different results for price correlations in Germany–Luxembourg than the isolated alternative configurations 2, 14 and 13, respectively, i.e. slight decreases in the northeast and east and increases in the remaining BZs. However, the combined configurations suggest slight decreases in price correlations in the Dutch zones, i.e. liquidity impairments, which is not the case in the isolated alternative configuration 7.

4.7.5 Price volatility

The analysis of price volatility is based on the monthly average of daily SDs of simulated price data in each BZ. As for price correlation, the changes in price volatility in the combined alternative configurations 21, 22 and 23 align with those observed for the alternative configurations 2, 14 and 13, respectively, in Germany. For the Netherlands, price volatility increases compared to the status quo and the isolated alternative configuration 7.

› **In alternative configuration 21:**

- As in the isolated alternative configuration 2 in Germany, price volatility substantially increases in the northeastern BZ while slightly decreasing in the southern zone.
- While price volatility does not extensively change compared to the status quo in alternative configuration 7 (average of 4.54 € / MWh across BZs), volatility in the Dutch BZs in alternative configuration 21 increases (average of 5.32 € / MWh across BZs) compared to the status quo, in particular in the northern BZ.

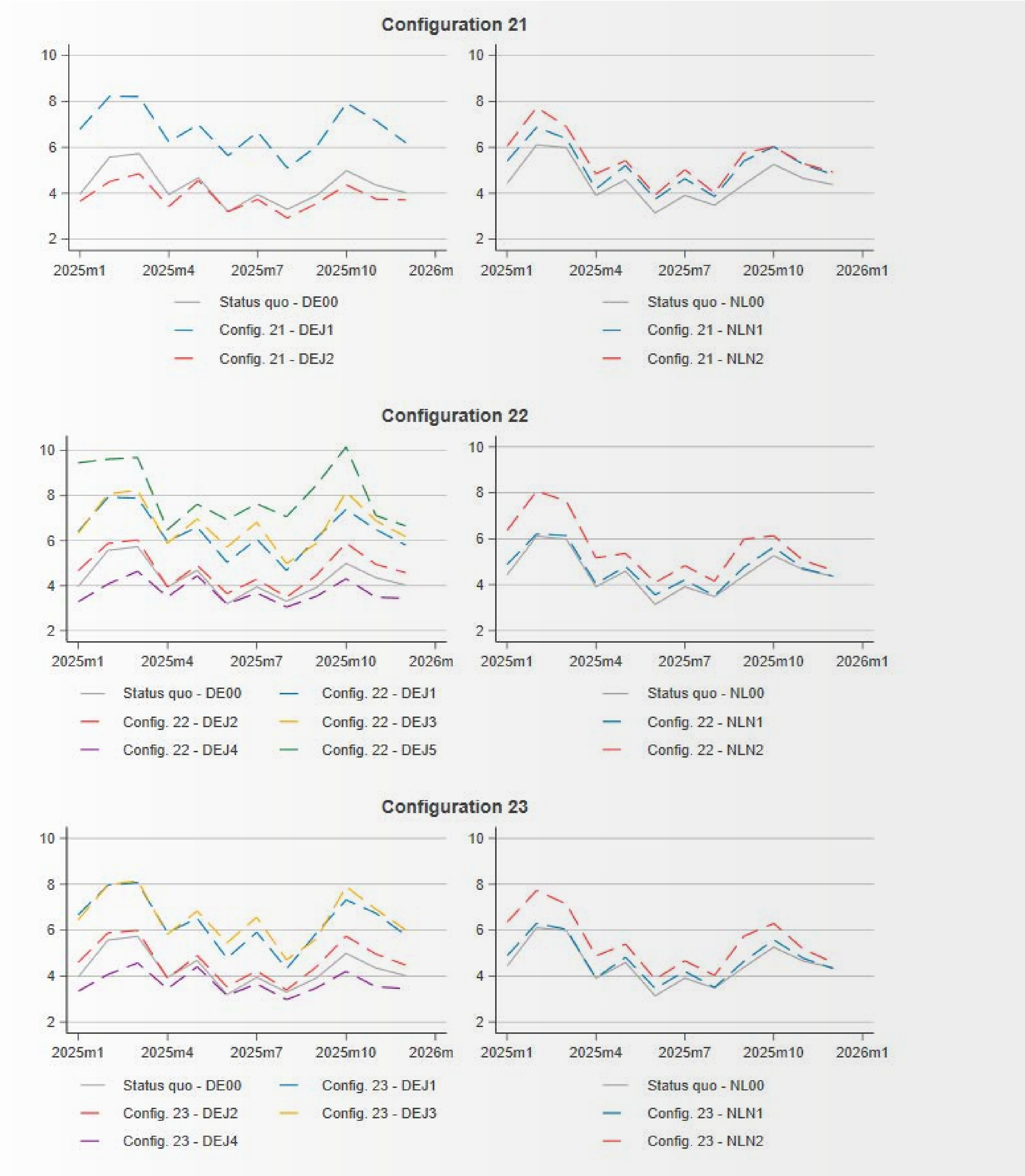
› **In alternative configuration 22:**

- As in the isolated alternative configuration 14, price volatility in BZs DEJ1, DEJ3, and DEJ5 – i. e. in the northeastern BZs – increases compared to the status quo, while only limited changes are observed for the southwestern BZs.
- As in alternative configuration 21, price volatility increases compared to the status quo and the isolated alternative configuration 7 in the Netherlands, in particular in the northern BZ.

› **In alternative configuration 23:**

- As for alternative configuration 22, price volatility increases in the northeastern German BZs in alternative configuration 23 compared to the status quo. This is also the case in the isolated alternative configuration 13. Southwestern BZs observe only limited changes.
- As for alternative configurations 21 and 22, price volatility increases compared to the status quo and the isolated alternative configuration 7 in the Netherlands, in particular in the northern BZ.

We conclude that alternative configurations 21, 22 and 23 indicate an increase in price volatility in the northeastern BZs in Germany, as in the isolated alternative configurations 2, 14 and 13, respectively. While price volatility remains relatively unchanged in the Dutch BZs in alternative configuration 7, the simultaneous configurations show higher price volatility, in particular in the northern Dutch BZ. Based on our prior findings (see Chapter 3.2), we note that the price volatility increases in the northern regions could point to improvements in liquidity metrics in short-term markets and impairments in long-term markets.



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

Figure 4.53: Monthly average of daily standard deviation in the status quo and alternative configuration

4.7.6 Participant mix

We further study changes in the participant mix – i.e. the share of renewables in the generation mix – compared to the isolated alternative configurations in Germany–Luxembourg and the Netherlands and the status quo in the simultaneous configurations in the two regions. For Germany–Luxembourg, we observe similar results as for the isolated alternative configurations 2, 13 and 14, while for the Netherlands the participant mix tends to be higher than in alternative configuration 7. More specifically:

› **In alternative configuration 21:**

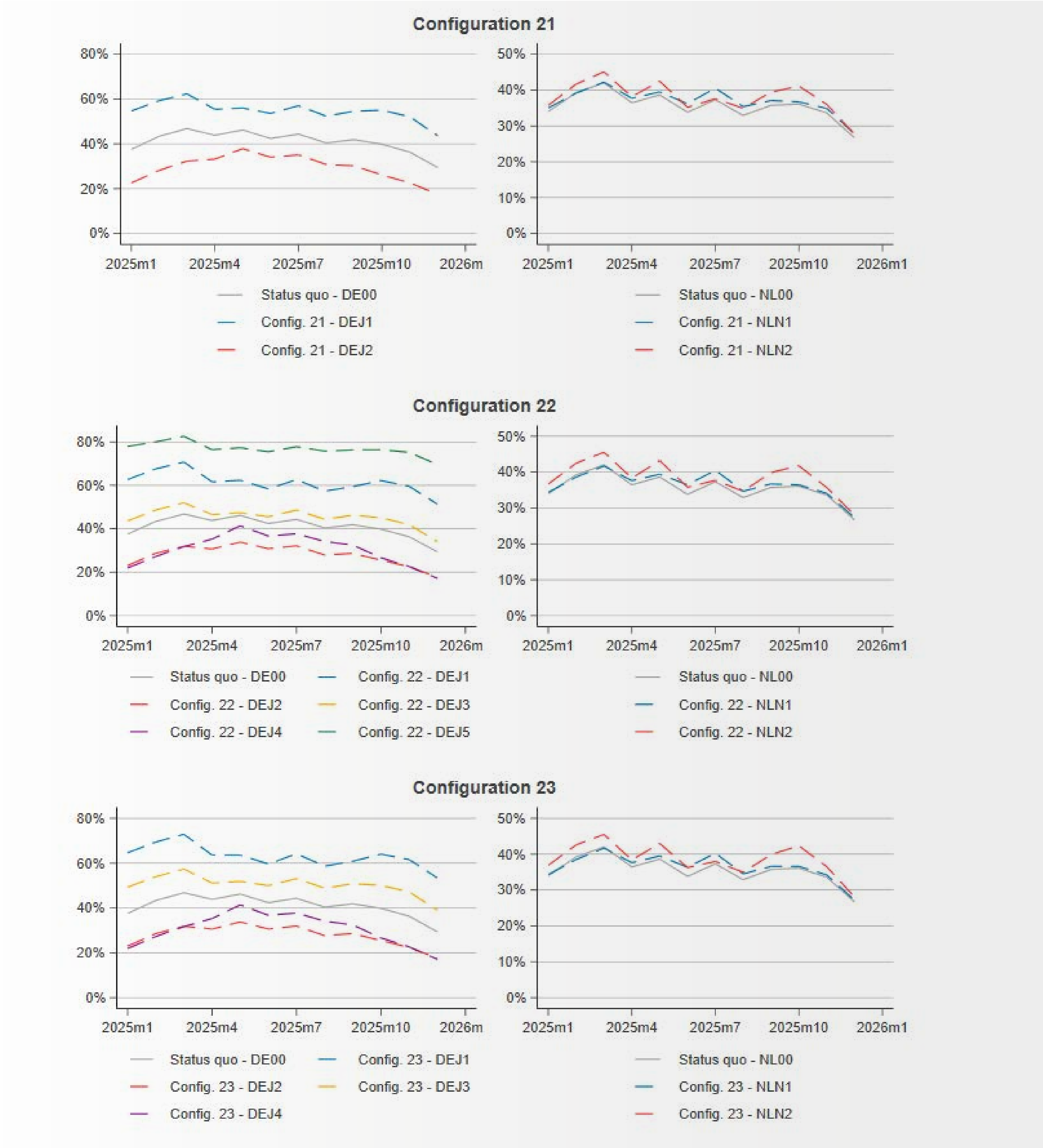
- As in alternative configuration 2, the share of renewables increases in the northern BZ DEJ2 compared to the status quo, while it decreases in the southern BZ.
- The shares of renewables in the generation mix in BZs NLN1 and NLN2 remain at or above levels in the status quo across all months. By contrast, in alternative configuration 7, the participant mix is only higher than in the status quo in some months.

› **In alternative configuration 22:**

- As in alternative configuration 14 and similar to the simultaneous alternative configuration 21, the share of renewables increases in the northern BZs – i.e. in DEJ1, DEJ3, and DEJ5 – compared to the status quo, and decreases in the southern BZ.
- Similar to alternative configuration 21, the participant mix tends to be higher than in alternative configuration 7. However, the increases – including compared to the status quo – are more pronounced for the northern BZ NLN2 than for NLN1.

› **In alternative configuration 23:**

- As in alternative configuration 13 and comparable to alternative configurations 21 and 22, the share of renewables increases in the northeastern German BZs compared to the status quo, and decreases in the southwestern BZs.
- For the Netherlands, the results are in line with alternative configurations 21 and 22, indicating a higher participant mix than in alternative configuration 7 and compared to the status quo, in particular in the northern BZ.



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

Figure 4.54: Monthly average of hourly RES share in the status quo and alternative configuration

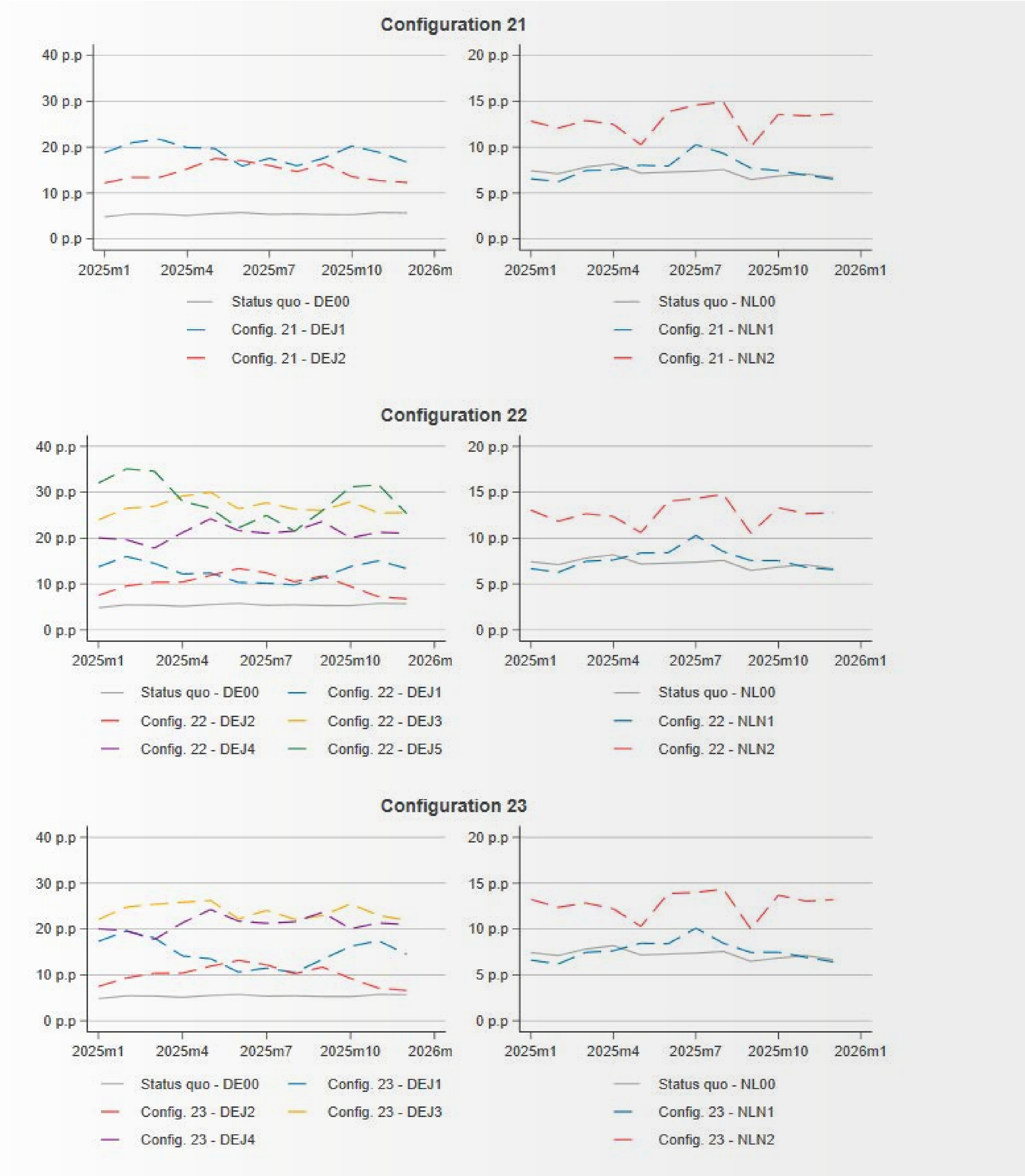
Overall, we conclude that the simultaneous alternative configurations yield similar results as the isolated alternative configurations 2, 13 and 14 for Germany–Luxembourg, where the participant mix tends to increase in the northeastern BZs and decrease in the southwestern zones. This observation could point to a slight improvement in liquidity metrics in the northern region, although this is expected to be limited. For the Netherlands, we observe slightly higher levels of renewable shares than in the isolated alternative configuration 7.

4.7.7 Supply-demand imbalance

As explained in Chapter 4.1, the supply-demand imbalance indicates the gap between electricity generation and electricity demand per BZ. We observe that imbalances in the simultaneous alternative configurations align with those observed in the isolated alternative configurations in Germany and the Netherlands.

- In alternative configuration 21, the supply-demand imbalance increases in all BZs compared to the status quo, in particular in DEJ1 in the northeast of Germany as well as NLN2 in the north of the Netherlands.
- Similarly, in alternative configuration 22, the German northeastern BZs – i.e. DEJ3 and DEJ5 –exhibit the largest increases in imbalances compared to the status quo, as well as NLN2 in the Netherlands.
- The same holds for alternative configuration 23 where the northeastern BZ DEJ3 and NLN2 exhibit the largest increases in imbalances compared to the status quo.

Overall, we note that the simultaneous alternative configurations lead to the same conclusions for supply-demand imbalance as in the case of individual alternative configurations for Germany and the Netherlands. The gap between electricity generation and demand tends to widen in all BZs compared to the status quo, hence indicating a liquidity impairment. The impairment is particularly pronounced for the northern BZs in both regions.



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

Figure 4.55: Monthly average of hourly supply-demand imbalance share in the status quo and alternative configuration

4.7.8 Conclusions

Table 4.6 summarises the observations on the market characteristics parameters across the status quo BZs and in the simultaneous alternative configurations in Germany–Luxembourg and the Netherlands.

The analysis suggests a decrease in liquidity metrics based on changes in the market size and supply-demand imbalance. For the remaining parameters, the picture is mixed as changes suggest slight improvements in liquidity metrics in some BZs and impairments for others. For example, changes in price correlation suggest a slight impairment in northern Germany but a slight improvement in the southern BZs.

- The simultaneous alternative configurations reduce the market size in terms of both generation and demand for each individual BZ in similar proportions to when each alternative configuration is considered in isolation. Therefore, the effect on liquidity metrics is expected to be negative.
- For Germany, the effect of changes in market concentration on expected liquidity metrics does not show a clear trend across the alternative configurations, whereas for the Netherlands changes in market concentration are expected to have an overall positive effect on liquidity metrics.
- The simultaneous configurations yield slight decreases in price correlation in the northeast of Germany and the Dutch zones, hence suggesting slight liquidity impairments. However, the remaining BZs for Germany–Luxembourg observe increases in price correlation.
- Price volatility increases in the northeastern BZs in Germany and the northern Dutch BZ, hence pointing to improvements in liquidity metrics in short-term markets and impairments in the long-term markets.
- The participant mix in the northeastern BZs in Germany–Luxembourg and the Dutch BZs tends to increase, although the effect on liquidity metrics is expected to be limited. In the southern zones of Germany–Luxembourg, the share of renewables tends to decrease.
- The supply-demand imbalance tends to widen in all BZs in the two regions compared to the status quo, hence indicating a liquidity impairment. The impairment is particularly pronounced for the northern BZs in both regions.

Country	Case	Descriptive statistics	Market concentration			Price		Market Size		RES share	Supply-demand imbalance
			Rsi 25	Rsi 50	Rsi 75	Correlation	Daily SD	Generation	Demand		
DE	0		DE00: 1.71	DE00: 1.77	DE00: 1.84	DE00: 0.65	DE00: 4.30	DE00: 64,018	DE00: 64,434	DE00: 41.06	DE00: 5.41
DE	21	Max	↑ DEJ1: 2.47	↑ DEJ1: 2.62	↑ DEJ1: 2.78	↑ DEJ2: 0.71	↑ DEJ1: 6.77	↓ DEJ2: 33,919	↓ DEJ2: 44,797	↑ DEJ1: 54.67	↑ DEJ1: 18.68
DE	21	Average	↑ 1.90	↑ 2.04	↑ 2.18	↑ 0.67	↑ 5.31	↓ 31,523	↓ 32,249	↑ 41.95	↑ 16.61
DE	21	Min	↓ DEJ2: 1.32	↓ DEJ2: 1.46	↓ DEJ2: 1.59	↓ DEJ1: 0.63	↓ DEJ2: 3.86	↓ DEJ1: 29,127	↓ DEJ1: 19,701	↓ DEJ2: 29.22	↑ DEJ2: 14.54
DE	22	Max	↑ DEJ5: 4.67	↑ DEJ5: 5.06	↑ DEJ5: 5.44	↑ DEJ5: 0.87	↑ DEJ5: 8.08	DEJ2: 18,087	DEJ4: 22,831	↑ DEJ5: 76.78	↑ DEJ5: 28.26
DE	22	Average	↑ 2.42	↑ 2.73	↑ 3.04	↑ 0.76	↑ 5.91	↓ 12,555	↓ 12,902	↑ 48.35	↑ 19.82
DE	22	Min	↓ DEJ2: 1.22	↓ DEJ2: 1.44	↓ DEJ2: 1.67	↓ DEJ3: 0.59	↓ DEJ4: 3.72	↓ DEJ5: 3,886	↓ DEJ5: 2,037	↓ DEJ2: 27.81	↑ DEJ2: 10.12
DE	23	Max	↑ DEJ3: 2.97	↑ DEJ3: 3.18	↑ DEJ3: 3.39	↑ DEJ1: 0.86	↑ DEJ3: 6.53	↓ DEJ3: 20,293	↓ DEJ4: 22,830	↑ DEJ1: 63.08	↑ DEJ3: 23.84
DE	23	Average	↑ 1.89	↑ 2.14	↑ 2.39	↑ 0.74	↑ 5.30	↓ 15,736	↓ 16,125	↑ 42.87	↑ 17.43
DE	23	Min	↓ DEJ2: 1.21	↓ DEJ2: 1.43	↓ DEJ2: 1.65	↓ DEJ3: 0.60	↓ DEJ4: 3.69	↓ DEJ1: 9,174	↓ DEJ1: 7,307	↓ DEJ2: 27.71	↑ DEJ2: 9.98
NL	0		NL00: 1.75	NL00: 1.88	NL00: 2.02	NL00: 0.93	NL00: 4.52	NL00: 14,165	NL00: 13,579	NL00: 35.56	NL00: 7.26
NL	21	Max	↑ NLN2: 2.11	↑ NLN2: 2.52	↑ NLN2: 2.92	↓ NLN1: 0.90	↑ NLN2: 5.50	↓ NLN1: 10,823	↓ NLN1: 11,023	↑ NLN2: 37.93	↑ NLN2: 12.89
NL	21	Average	↑ 1.95	↑ 2.24	↑ 2.54	↓ 0.88	↑ 5.32	↓ 6,859	↓ 6,797	↑ 37.39	↑ 10.28
NL	21	Min	↑ NLN1: 1.78	↑ NLN1: 1.97	↑ NLN1: 2.15	↓ NLN2: 0.86	↑ NLN1: 5.15	↓ NLN2: 2,895	↓ NLN2: 2,572	↑ NLN1: 36.85	↑ NLN1: 7.67

Country	Case	Descriptive statistics	Market concentration			Price		Market Size		RES share	Supply-demand imbalance
			Rsi 25	Rsi 50	Rsi 75	Correlation	Daily SD	Generation	Demand		
NL	22	Max	↑ NLN2: 2.12	↑ NLN2: 2.53	↑ NLN2: 2.94	↓ NLN1: 0.95	↑ NLN2: 5.62	↓ NLN1: 10,900	↓ NLN1: 11,011	↑ NLN2: 38.33	↑ NLN2: 12.74
NL	22	Average	↑ 1.95	↑ 2.26	↑ 2.56	↓ 0.91	↑ 5.18	↓ 6,872	↓ 6,792	↑ 37.42	↑ 10.21
NL	22	Min	↑ NLN1: 1.79	↑ NLN1: 1.98	↑ NLN1: 2.17	↓ NLN2: 0.86	↑ NLN1: 4.74	↓ NLN2: 2,844	↓ NLN2: 2,574	↑ NLN1: 36.51	↑ NLN1: 7.68
NL	23	Max	↑ NLN2: 2.12	↑ NLN2: 2.53	↑ NLN2: 2.95	↑ NLN1: 0.95	↑ NLN2: 5.49	↓ NLN1: 10,910	↓ NLN1: 11,009	↑ NLN2: 38.55	↑ NLN2: 12.76
NL	23	Average	↑ 1.95	↑ 2.25	↑ 2.56	↓ 0.91	↑ 5.10	↓ 6,876	↓ 6,791	↑ 37.51	↑ 10.2
NL	23	Min	↑ NLN1: 1.79	↑ NLN1: 1.98	↑ NLN1: 2.17	↓ NLN2: 0.87	↑ NLN1: 4.71	↓ NLN2: 2,842	↓ NLN2: 2,572	↑ NLN1: 36.47	↑ NLN1: 7.64

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 alternative configurations considered. The minima and maxima displayed 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 market characteristics parameter considered.

Table 4.6: Average and extreme values of liquidity metrics in the status quo and alternative configuration for Germany–Luxembourg and the Netherlands

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. This study's objective 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 and a correlation analysis.
- Analysed the simulated data provided by the TSOs to assess how BZ reconfigurations might affect liquidity metrics.

5.1 Main findings of the literature review and series of interviews

The literature review suggests that the main relevant metrics to assess liquidity include 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 that a trader incurs for executing the trade. Therefore, the bid-ask spreads are analysed as an indicator of liquidity and a proxy for transaction costs.

Academic literature and industry reports mostly consider the most important drivers of liquidity to be 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 might positively correlate with liquidity due to the increased number of market participants, while the liquidity of hedging instruments in smaller zones is usually poor. However, other articles and reports conversely highlight 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. However, it is difficult to conclude that a BZ split would necessarily lead to a less competitive environment that is 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 capacity also plays an important role. Higher cross-zonal capacity stimulates liquidity in the market, e.g. through its positive countervailing impact on market concentration. Moreover, it facilitates proxy hedging, i.e. the ability to hedge in another, more liquid BZ. Finally, available cross-zonal capacity is decisive for short-term product liquidity through implicit auctions and market coupling (SDAC and SIDC).

Market participants additionally stressed the supply-demand balance, price volatility, and market participant mix characteristics. Specifically:

- The supply-demand imbalance could be detrimental to liquidity because potential buyers or sellers might find it difficult to find suitable trading counterparts. Furthermore, supply-demand imbalances imply that fewer orders on the less dominant side limit competition, and fewer participants exist to absorb price movements.

- Price volatility influences liquidity via its impact on margining requirements, adjustments to hedging policies, and rebalancing needs. Higher volatility might lead to increased capital needs and lower trading limits, while it also prompts adjustments to hedging strategies as participants might hedge more or less depending on price movements. Finally, traders often rebalance or adjust positions in response to price swings, while prop traders might seize profit opportunities.
- The market participant mix might influence liquidity. On the one hand, a higher share of variable generation assets such as wind and solar power might imply increased liquidity levels due to the need created for short-term trading adjustments. On the other hand, a generally more diverse mix of market participants brings varied trading needs and strategies, enhancing liquidity by creating more opportunities to find trade counterparts.

The Austrian / German–Luxembourg BZ split in 2018 had a significant effect on long-term market liquidity. Germany–Luxembourg remained a very liquid market leading the forward trade in central Europe, while the newly created Austrian long-term market has remained 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 concerning how liquidity on the Austrian short-term market has developed in the years after the split.

For Sweden, the BZ reconfiguration in 2011 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 on the state of liquidity in current EU markets

Liquidity for short-term products has generally been increasing over recent years. DA markets concentrate supply and demand in an auction through 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 ID markets, although ID liquidity has increased over recent years in most markets.

For long-term products, the German–Luxembourg BZ is 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 recent years. The high liquidity of the German-Luxemburg forward markets is also confirmed by the low bid-ask spreads. The difference in liquidity could be explained by the fact that Germany–Luxembourg – being the most liquid market – might be used by market participants to hedge their positions in neighbouring markets (proxy hedging), concentrating liquidity even further in this market. The Nordic market has seen a decrease in liquidity for both system price futures and EPADs over recent years, with churn rates for EPADs declining from 5 to 2. However, bid-ask spreads 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. By contrast, 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. Further, ID market liquidity tends to increase with price volatility. The participant mix – measured by the share of renewables – positively affects DA and ID market liquidity, albeit to a lesser extent. Moreover, our results suggest decreasing levels of market liquidity in the DA and ID markets with increasing supply-demand imbalances. The relationship between BZ size and liquidity is positive in terms of turnover, but – considering the different size of the coefficient per region – subject to other factors such as the market structure.

The econometric analysis for long-term markets shows that larger markets and those with a higher renewables share and higher average correlation tend to be more liquid in turnover, bid-ask spreads, and churn rate than smaller markets. Higher price volatility, market concentration, and supply-demand imbalance seem 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 regions. Neighbouring BZ generally show stronger correlation compared to non-neighbouring zones and price correlations tend to be higher during non-peak than during peak hours.

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. Compass Lexecon was provided with the outputs of these dispatch models, such as generation by generation type, demand, HHI, RSI, and PSI values, and wholesale prices in the different BZ reconfigurations.

Based on these data, we have derived indicators of market size, market concentration, price correlation, price volatility, supply-demand imbalance, and the participant mix for each BZ under various BZ reconfiguration scenarios. Subsequently, we have analysed the change in these indicators between the status quo BZ configuration and the alternative BZ configurations as proposed in ACER decision 11-2022 and in terms of their absolute value. Understanding the expected relationship between these indicators and market liquidity, we have assessed the likely effect of the proposed alternative BZ configurations on the liquidity metrics.

The derived assessment comes with several caveats:

- The data for the proposed alternative configurations is limited to the simulation results of a dispatch model. Such models do not capture the trading dynamics between long- and short-term markets or differentiate trades executed on organised markets or OTC. As a result, 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 that we have available.
- In practice, liquidity metrics after a BZ reconfiguration might be subject to mitigation measures, such as trading hubs and various forms and allocation approaches of the transmission rights. The analysis conducted here assumes no such mitigation measures, i.e. liquidity metrics of individual BZs if no changes in market design are made. Exploring the effect of potential mitigation measures on the results and conclusions lies beyond the scope of the current version of this study.
- In analysing 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 only be captured by linear relationships 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 might lead to spillover effects affecting liquidity in BZs not directly affected by the reconfiguration. These spillover effects are not considered in the analysis.
- Finally, the relationships considered between market characteristics and liquidity metrics are not necessarily exhaustive. The analysis of additional market characteristics might further increase the robustness and portray a more exhaustive picture of the potential effects of the BZ reconfigurations.

We have conducted the analysis for the proposed alternative BZ configurations in Germany–Luxembourg, France, Italy, the Netherlands, and Sweden, as well as a combined simulation of alternative configurations in Germany–Luxembourg and the Netherlands. The analysis aims to evaluate whether market liquidity metrics are expected to be impaired or enhanced, or potentially remain unaffected by the proposed reconfigurations.

The analysis of the market characteristics shows the following:

- **Market size** decreases for most alternative configurations (except for Sweden and Italy) which is a direct consequence of considering BZ configurations with smaller than national zones. The only exceptions are alternative configurations 8, 9, and 11 of the Swedish BZ reconfiguration, which 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 decreases in most cases or at least remains below critical levels, such as RSI values below 1.[58] 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 significantly increases 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 previously strongest correlation.
- **Price volatility** tends to increase in the alternative configurations for Germany, which might support liquidity in short-term markets but impair it in long-term markets. For the alternative configuration in Northern Italy, the decrease in price volatility implies that the opposite might be the case.

58 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.

- **Supply-demand imbalance** increases in particular in alternative configuration 10 (Sweden) and the alternative configurations for Germany, suggesting liquidity impairments. It also appears to be a concern for the northern Dutch zone in reconfiguration 7. This is also the case in the simultaneous configurations 21, 22 and 23 for Germany–Luxembourg and the Netherlands.
- **Participant mix as measured by the share of RES** appears to change only to a limited extent and is not expected to be pivotal to changes in liquidity.

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

The expectations on changes to liquidity metrics – noting the caveats – can be summarised as follows:

- **The Swedish alternative configurations** 8 and 9 see changes in market characteristics that point to 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 tends to slightly decrease, the positive impact is 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 liquidity metrics is primarily driven by decreases in market size without strong offsets by other market characteristics such as price correlation. In particular, BZ 03 shows exceptionally small generation volumes and a significant increase in electricity supply-demand imbalance compared to the status quo configuration. Alternative configuration 11 shows an inconclusive picture regarding 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.[59]
- **The German–Luxembourg alternative configurations** are particularly affected 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, this suggests a negative effect on liquidity metrics, particularly for long-term markets.[60] Furthermore, price volatility increases in most BZs. The effect on short-term markets might be partially offset by increases in price correlation, although it remains inconclusive which change in direction will be decisive for the overall change.
- **The French alternative configuration** shows a tendency for an impairment of liquidity metrics for the short- and long-term markets. While multiple indicators show two-sided changes and price correlation increases for all BZs, the change in market size is significant and would be expected to outweigh a positive effect from improved cross-border trading opportunities. This effect might be weaker for the short-term market as the relationship between market size and traded volume in the French short-term markets has historically 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 northwestern BZ. This might be derived from the observation of a significant decrease in market size without substantial changes in other parameters that might counter this effect.[61]
- **The Dutch alternative configuration** sees similar changes as the Northern Italian alternative configuration, equally suggesting a negative effect on liquidity metrics for short- and long-term markets, at least in the northern alternative BZ. This follows particularly from the market size decreases and increases in supply-demand imbalance without significant potentially offsetting changes in other indicators.
- **The combined alternative configurations for Germany–Luxembourg and the Netherlands** are overall in line with the conclusions based on the isolated alternative configurations for the two regions. The observed changes suggest a decrease in liquidity metrics, associated with the significant decreases in market size and increases in supply-demand imbalance. For the remaining parameters, the picture is mixed as changes suggest slight improvements in liquidity metrics in some BZs and impairments for others. For example, changes in price correlation suggest a slight impairment in northern Germany but a slight improvement in the southern BZs. Hence, the potential for offsetting liquidity impairments associated with changes in market size and supply-demand imbalance appears to be limited.

59 Noting the historic relevance of the DA market and the Nordic system price on market liquidity, the identified expected impact on individual BZs might or might not further affect the overall liquidity of the Nordics. The analysis of these indirect effects lies beyond the scope of this study.

60 Noting the historic relevance of Germany as lead market for long-term products, the final effect on liquidity metrics might additionally be significantly influenced by changes in the perception of this lead market. Due to the inconclusive results of the analysis of proxy hedging and the potential impact from mitigation measures, an expectation on the effect from changes in the perception of the lead market cannot be formed here.

61 Noting the historic relevance of the DA market and the PUN mechanism on market liquidity, the identified expected impact on individual BZs might or might not affect the overall liquidity of Italy. The analysis of these indirect effects lies beyond the scope of this study.

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 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 might significantly differ from the expectations formed in a ceteris paribus analysis based on a necessarily simplified market modelling exercise such as this one.

Following the approach as described in Chapter 4.1, Tables 5.1 and 5.2 provide a detailed summary of the findings for liquidity metrics of short- and long-term markets.

Legend: Scale for market characteristic and liquidity assessment:

→ "**Limited change**" – majority of BZs without a change compared to the status quo.

↑↓ "**Increasing**" – all BZ changes show an increase. Symbol for liquidity impact: **↑** or **↓**, depending on the market characteristic.

↑↓ "**Decreasing**" – all BZ changes show decreases. Symbol for liquidity impact: **↑** or **↓**, depending on the market characteristic.

↑↓ "**Two-sided**" – same number of BZs show increases and decreases.

↗↘ Addition "**but only to a small extent**" used for upward/downward changes in price correlation that are small (c. 0.01-0.1). Symbol for liquidity impact: **↗** or **↘**, depending on the considered market characteristic.

( ) Addition "**mostly**" or "**partially**" – most BZ changes show increases/decreases, but at least one BZ change shows a decrease/increases. Symbol for liquidity impact: adding ( ) to arrows.

"**Significant**" means a change of 50 % or more.

— "**Inconclusive**" in the assessment of market characteristics indicates developments that are uncertain due to RSI data limitations. "Inconclusive" in the assessment of liquidity metrics indicates that no expectations can be formed based on the modelled changes in market characteristics.

↑↓ Symbol for liquidity impact: Arrows in bold.

Regions	ACER identifier	Market concentration[1]	Price correlation	Market size	Price volatility	Supply-demand imbalance	Participant mix	Assessment of liquidity metrics of ST markets
Sweden	8	(↑) Mostly decrease	↘ Decrease, but only to a small extent	(↑) Mostly increase	→ Limited change	↑ Decrease	↑ Decrease	Improvement
Sweden	9	(↑) Mostly decrease	↘ Decrease, but only to a small extent	(↑) Mostly increase	→ Limited change	↑ Decrease	↑ Decrease	Improvement
Sweden	10	(↑) Mostly decrease	(↘) Mostly decrease, but only to small extent	↓ Significant decrease	→ Limited change	↓ Significant increase	↑ Decrease	Impairment
Sweden	11	→ Limited change	↘ Decrease, but only to small extent	↑↓ Two-sided	→ Limited change	↑ Decrease	↑ Decrease	Inconclusive
Germany – Luxembourg	2	— Inconclusive	(↗) Mostly increase, but only to a small extent	↓ Significant decrease	(↑) Mostly increase	(↓) Partially significant increase	↑↓ Two-sided	Inconclusive with tendency to impairment
Germany – Luxembourg	12	— Inconclusive	(↗) Mostly increase, but partially to a small extent	↓ Significant decrease	(↑) Mostly increase	(↓) Partially significant increase	↑↓ Two-sided	Inconclusive with tendency to impairment
Germany – Luxembourg	13	— Inconclusive	(↑) Mostly increase	↓ Significant decrease	(↑) Mostly increase	(↓) Partially significant increase	↑↓ Two-sided	Inconclusive with tendency to impairment
Germany – Luxembourg	14	— Inconclusive	(↑) Mostly increase	↓ Significant decrease	(↑) Mostly increase	(↓) Partially significant increase	↑↓ Two-sided	Inconclusive with tendency to impairment
France	5	— Inconclusive	↑ Increase	↓ Significant decrease	↑↓ Two-sided	↑↓ Two-sided	↑↓ Two-sided	Impairment
Northern Italy	6	— Inconclusive	↑↓ Two-sided	↓ Significant decrease	↓ Decrease	↑ Decrease	↘ Decrease but to a small extent	Impairment
Netherlands	7	— Inconclusive	↗ Increase, but only to a small extent	↓ Significant decrease	→ Limited change	↓ Increase	→ Limited change	Impairment
Germany – Luxembourg and the Netherlands	21	— Inconclusive	↑↓ Two-sided	↓ Significant decrease	(↑) Mostly increase	(↓) Partially significant increase	→ Limited change	Inconclusive with tendency to impairment
Germany–Luxembourg and the Netherlands	22	— Inconclusive	↑↓ Two-sided	↓ Significant decrease	(↑) Mostly increase	(↓) Partially significant increase	→ Limited change	Inconclusive with tendency to impairment
Germany–Luxembourg and the Netherlands	23	— Inconclusive	↑↓ Two-sided	↓ Significant decrease	(↑) Mostly increase	(↓) Partially significant increase	→ Limited change	Inconclusive with tendency to impairment

Notes: The BZ liquidity and its metrics materialising after a BZ reconfiguration might significantly differ from the expectations formed in a ceteris paribus analysis such as this one.
In line with the scale for the market characteristic assessment, the arrows indicate the expected short-term market liquidity change.
[1] Noting the data limitations, a stronger weight in the analysis is given to the conservative input assumption.

Source: Compass Lexecon analysis based on data from the TSOs

Table 5.1: Summary of assessed liquidity metrics of short-term markets of alternative BZ configurations

Regions	ACER iden-tifier	Market concentration[1]	Price correlation	Market size	Price volatility	Supply-demand imbalance	Participant mix	Assessment of liquidity metrics of ST markets
Sweden	8	(↑) Mostly decrease	↘ Decrease, but only to a small extent	(↑) Mostly increase	→ Limited change	↑ Decrease	↑ Decrease	Improvement
Sweden	9	(↑) Mostly decrease	↘ Decrease, but only to a small extent	(↑) Mostly increase	→ Limited change	↑ Decrease	↑ Decrease	Improvement
Sweden	10	(↑) Mostly decrease	(↘) Mostly decrease, but only to small extent	↓ Significant decrease	→ Limited change	↓ Significant increase	↑ Decrease	Impairment
Sweden	11	→ Limited change	↘ Decrease, but only to small extent	↑↓ Two-sided	→ Limited change	↑ Decrease	↑ Decrease	Inconclusive
Germany – Luxembourg	2	— Inconclusive	(↗) Mostly increase, but only to a small extent	↓ Significant decrease	(↓) Mostly increase	(↓) Partially significant increase	↑↓ Two-sided	Impairment
Germany – Luxembourg	12	— Inconclusive	(↗) Mostly increase, but partially to a small extent	↓ Significant decrease	(↓) Mostly increase	(↓) Partially significant increase	↑↓ Two-sided	Impairment
Germany – Luxembourg	13	— Inconclusive	(↑) Mostly increase	↓ Significant decrease	(↓) Mostly increase	(↓) Partially significant increase	↑↓ Two-sided	Impairment
Germany – Luxembourg	14	— Inconclusive	(↑) Mostly increase	↓ Significant decrease	(↓) Mostly increase	(↓) Partially significant increase	↑↓ Two-sided	Impairment
France	5	— Inconclusive	↑ Increase	↓ Significant decrease	↑↓ Two-sided	↑↓ Two-sided	↑↓ Two-sided	Impairment
Northern Italy	6	— Inconclusive	↑↓ Two-sided	↓ Significant decrease	↑ Decrease	↑ Decrease	↘ Decrease but to a small extent	Impairment
Netherlands	7	— Inconclusive	↗ Increase, but only to a small extent	↓ Significant decrease	→ Limited change	↓ Increase	→ Limited change	Impairment
Germany – Luxembourg and the Netherlands	21	— Inconclusive	↑↓ Two-sided	↓ Significant decrease	(↓) Mostly increase	(↓) Partially significant increase	→ Limited change	Impairment
Germany– Luxembourg and the Netherlands	22	— Inconclusive	↑↓ Two-sided	↓ Significant decrease	(↓) Mostly increase	(↓) Partially significant increase	→ Limited change	Impairment
Germany– Luxembourg and the Netherlands	23	— Inconclusive	↑↓ Two-sided	↓ Significant decrease	(↓) Mostly increase	(↓) Partially significant increase	→ Limited change	Impairment

Notes: The BZ liquidity and its metrics materialising after a BZ reconfiguration might significantly differ from the expectations formed in a ceteris paribus analysis such as this one.
In line with the scale for the market characteristic assessment, the arrows indicate the expected long-term market liquidity change.
[1] Noting the data limitations, a stronger weight in the analysis is given to the conservative input assumption.

Source: Compass Lexecon analysis based on data from the TSOs

Table 5.2: Summary of assessed liquidity metrics of long-term markets of alternative BZ configurations

5.4 Limitations of this study in terms of scope and methodology

In the above, the expected development of liquidity was derived based on relationships identified through literature, interviews and econometrically. These relationships were then applied to simulated market outcomes of the newly to-be-formed BZs.

The following section makes the limitations of this study transparent, which are likely mainly in the areas of a) market participant behaviour and b) regulation / market design. The section is based on feedback received in the public consultation, interviews with market practitioners, and the project team's experience.

Market participant behaviour

- Liquidity and transaction costs might be affected by shifts in market participant behaviour that cannot be fully captured through the quantitative analysis described above. The BZ reconfiguration itself might trigger behavioural changes, while there might be trends in participant behaviour that occur irrespective of the BZ reconfiguration.
- **Uncertainty during the transition period:** Moving from one BZ configuration to another introduces significant uncertainty for market participants. Identifying fair value for electricity on both short- and long-term markets becomes more difficult, which might affect liquidity. Conversely, some specialised market participants might take advantage of this uncertainty by offering products at higher risk premiums, further influencing market dynamics.
- **Impact on asset valuation and investment:** Changes in price levels and capture rates influence the valuation of generation and demand assets. This might have consequences for investments and hence liquidity in the long term.
- **Concentration of liquidity and non-linearities:** Historically, liquidity tends to cluster in certain markets, making them "hub markets". In the context of a BZ reconfiguration, it is unclear whether market participants would shift their trading activity and which changes in costs and risks would coincide with such changes. Such effects are a likely reason for some of the possible non-linear relationships between liquidity metrics and drivers of liquidity.
- **Changes in netting and hedging behaviour:** Vertically integrated suppliers might continue netting generation and demand as long as both remain within the same BZ. However, if supply and demand are split between BZs, market participants might opt for increased participation in coupled short-term markets or adjust their ownership portfolio altogether. Their decision will largely depend on the expected profitability of the affected assets, weighed against higher transaction costs and added risks such as increased volatility and basis risk.
- **Energy transition and clean energy investments:** As the market continues its transition towards clean energy, investments in generation and consumption assets might be driven more by decarbonisation policies than by market characteristics of BZ configurations alone. The growing share of intermittent renewable generation might influence how participants manage their hedging strategies and induce market liquidity. Potentially, liquidity might increase irrespective of BZ reconfigurations due to increased electrification and growing electricity demand.
- **Participation of prop traders:** Prop trading plays a relevant role in the electricity market and market participants have claimed to observe an inflow of additional prop traders. This inflow could further affect liquidity irrespective of the market characteristics affected by a BZ reconfiguration.
- **Regulatory risk:** A BZ reconfiguration might alter the perception of regulatory risk, influencing long-term liquidity. One the one hand, market participants might anticipate further reconfigurations, viewing the current case as setting a precedent. On the other hand, they might expect fewer future changes, assuming that the new BZ configuration already accounts for anticipated network constraints.

Regulation/market design

- **Mitigation measures:** A key factor affecting liquidity is the implementation of mitigation measures, including virtual trading hubs, long-term transmission rights (LTTRs or FTRs), and innovative approaches such as the provision of supply or demand by TSOs (e. g. SVK's pilot initiative; Svenska Kraftnät, 2024). Mitigation measures have been considered by the TSOs in the final BZRR when concluding the assessment on the liquidity and transaction costs criteria.
- **Other market design changes:** A BZ reconfiguration would coincide with other market design changes that might affect liquidity, including changes to ID coupling, the introduction of ID auctions, and the provision of new or alternative long-term products.

A 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 BZ reconfigurations, detailing the analysis requiring the data and the source providing it. Historic data cover from 2016 to 2022, if 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	DA hourly wholesale prices by BZ	ENTSO-E transparency platform
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
Price volatility	Standard deviation of future wholesale prices	Simulated DA wholesale prices by BZ › For three different climate scenarios based on the climate observed in 1989, 1995, and 2009	TSOs
Supply-demand imbalance	Absolute difference of relative electricity generation and relative electricity demand	Load and generation volume by BZ › For three different climate scenarios based on the climate observed in 1989, 1995, and 2009 (climate years)	TSOs
Participant mix	Future share of renewable electricity generation as a proxy for participant mix	Electricity generation volume by generation type by BZ For three different climate scenarios based on the climate observed in 1989, 1995, and 2009 (climate years)	TSOs

Compass Lexecon understands that the TSOs made the following methodological assumptions when calculating HHI values: The methodology for calculating the HHI value requires 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 critical network element contingency (CNECs) in the capacity calculation region (in this case, the Nordics). Nordic TSOs have therefore approximated the corresponding NTC capacity for each BZ border. 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 BZs, unlike with NTC. This means that market price areas constituting more than one BZ can never be created if all 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 conduct an in-depth methodological review of how to best consider interconnection capacity.

Compass Lexecon understands that the PSI as provided by the TSOs uses a binary value of 1 if the supplier is pivotal, or 0 if the supplier is not pivotal. It measures whether 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 measuring 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 of a flow-based domain, reflecting the theoretical maximum import capacity of a BZ if the net positions of all zones were optimised for this. However, when using this proxy the TSOs further highlighted 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 of i25, i50 and i75, accounting for 25 %, 50 %, and 75 %, respectively, of the minimum net position of a given BZ in a certain MTU.

In addition, the TSOs provided the following explanation of 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 incomplete ownership data as well as lack of information on the party responsible for bidding behaviour set limitations to the study and might 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.

B Public Consultation Responses

In accordance with the ACER decision 29/2020 of 24 November 2020 on the methodology and assumptions to be used in the BZR process and the alternative bidding zone configurations to be considered (BZR Methodology), TSOs of all BZRRs jointly held a public consultation (19 July to 4 September 2024) to gather stakeholder feedback on the following subjects:

- Market liquidity and transaction costs
- Transition costs
- Measures to mitigate negative impacts
- Practical implementation considerations

The questions in the public consultation related to the reports on:

- The report on liquidity and transaction costs (version for public consultation, 17 July 2024)
- The report on transition costs (version for public consultation, 6 December 2023)

The responses to the public consultation were used to finalise both reports and assess the acceptability of alternative BZ configurations, and as an input for TSOs to identify practical considerations when deciding on a BZ configuration change.

B.1 Statements addressing the study itself

B.1.1 Statements on the scope

Some stakeholders provided feedback on the scope of the study, noting that:

- further analysis of the effects of liquidity changes on intraday and balancing markets is necessary;
- the impact of zone splits on OTC trading was overlooked;
- the impact across the entire European internal electricity market was insufficiently addressed;
- important factors such as cross-border effects, market participant behaviour, and impacts on PPAs, RES projects, state subsidies, contracts, and potential compensations for industrial consumers in southern Germany were not covered;
- a deeper study of direct liquidity indicators, particularly for long-term markets would have been beneficial;
- direct liquidity indicators such as the market depth – especially for longer-term contracts (Y+2, Y+3) – would enhance understanding;
- due to the limited scope of the analysis and the caveats mentioned, no conclusions can be drawn from the study.

B.1.2 Statements on the methodology

Some stakeholders provided comments on the methodology underlying the analyses presented in the study:

- stakeholder(s) noted that of the three parameters used as proxies for liquidity and transaction costs in the study, they only deem market size to have a direct link with market liquidity and a transparent calculation methodology;
- the churn rate was criticised in particular;
- one stakeholder suggested that we should have analysed how the merit order curve and price would react to one additional bid unit.

We appreciate the feedback and updated the study accordingly. In particular, we expanded the number of parameters assessed based on a series of interviews with market participant stakeholders. In addition, we have clarified and adjusted the treatment of the price correlation and market concentration indicators. Finally, we agree that analysing the changes to the merit order curve – i.e. a market depth analysis – would have been interesting. Based on stakeholder discussions at the outset of this study, we agreed to exclude a market depth analysis for this study.

B.1.3 Statements on the conclusions

Some stakeholders provided comments on the conclusions drawn from the study:

- Stakeholders strongly disagree that **market concentration** would decrease in all alternative configurations for Germany.
- Concerns were raised about **liquidity** losses in split markets, disputing that higher cross-zonal capacities would offset them. They also noted that the decrease in liquidity in southern German BZ(s) was underestimated in the study and that the finding of non-linear relationships between market characteristics and liquidity metrics is especially worrying because it might imply that slight changes to the BZ design might severely deteriorate liquidity.
- On **electricity prices**, some stakeholders disagree with the conclusion that the price signal in the current, more liquid large BZ is not correct. Furthermore, it was highlighted that likely price increases in the southern BZ(s) have been underestimated in the study.
- On **price correlation**, some stakeholders challenged the conclusion that price correlation increases with smaller BZs and that this might result in higher liquidity in smaller BZs.
- There is disagreement on coupling **forward markets**, which some stakeholders believe should not be subject to coupling as forward markets manage financial rather than physical risks.
- Finally, some stakeholders believe that the positive impact on the **short-term intraday market** is underestimated as companies with assets in several (new) BZs will need to adjust their bids on the ID market rather than self-regulating.

B.2 Statements on the expected impact of the proposed bidding zone reconfigurations on liquidity and transaction costs

B.2.1 Statements on the expected impact on **liquidity**

Asked how they expect the proposed BZ reconfigurations to affect liquidity, stakeholders responded that:

- They expect liquidity to considerably decline in both the short and long term, potentially causing Germany to lose its role as a European reference for hedging and trading.
- In the Netherlands, the decline in short- and long-term liquidity could have unintended consequences for cross-border capacity trading.
- They expect long-term trading to concentrate in one BZ, with the smaller zones experiencing lower liquidity, highlighting a strong correlation between BZ size and liquidity in most cases.
- Reduced market liquidity could make it difficult for retail companies without their own generation assets to secure long-term electricity supplies.

B.2.2 Statements of the expected impact on **transaction costs**

Asked how they expect the proposed BZ reconfigurations to impact transaction costs, stakeholders responded that:

- They expect transaction costs to considerably increase due to reduced liquidity in the split markets.
- Market prices might stop reflecting the true value of the electricity being traded, leading to more expensive trading.
- Bid-ask spreads might considerably widen due to increased market concentration following the split.
- The split will require market participants to trade and hedge in more products on potentially a wider variety of market infrastructure providers. As a result, identifying fair value and offsetting long and short positions with each other will not be possible to the same extent as before, increasing transaction costs.

B.3 Statements on other potential impacts of the bidding zone reconfigurations

Stakeholders also shared their views on effects beyond liquidity and transaction costs.

B.3.1 Statements on **volatility and risks**

- They expect volatility to increase, with even small orders being able to cause major price moves due to a decline in market participants per BZ. This effect is particularly expected for smaller BZs.
- The expected increase in trading activity might increase risks in both the short and long term.

B.3.2 Statements on **market power**

- Individual participants' market power – and along with it the risk of market abuse – will increase due to the declining market size.
- Market concentration might further increase in the long term as rising costs (including due to other regulatory measures) are expected to make proprietary trading profitable for a decreasing number of market participants.
- There must be a fairly even distribution between consumption and production to create an efficient financial market.

B.3.3 Statements on the overall investment environment

- The BZ split will likely be detrimental to international competitiveness.
- The market value of renewable energy assets in the north will decrease, placing the nationwide target for the expansion of renewables at risk.

B.3.4 Statements on competitiveness

- Respondents expressed concerns that, with electricity prices already elevated, a BZ split would further reduce the competitiveness of electricity-intensive consumers as higher transaction, hedging and administrative costs would be passed on to end customers.

B.3.5 Statements on existing contracts

- Respondents highlighted that changes to BZs could impact existing contracts, leading to a redistribution of wealth and potentially causing significant financial consequences for both market participants and end customers.

B.3.6 Statements on trading activity

- With a larger number of BZs, fewer trading (and for industrial consumers) hedging opportunities are available due to delivery constraints.
- The German market will become less attractive for European hedging and trading activities.

B.3.7 Statements on spot, DA and ID markets

- The disruption and uncertainty resulting from the BZ split will result in increased prices and a decrease in liquidity in spot markets.
- The split might lead to a decrease in ID trading.

B.3.8 Statements on forward and futures market/hedging opportunities

- A significant deterioration of hedging opportunities is expected vis-à-vis the status quo, with the disruption and uncertainty caused by the BZ split resulting in increased future market prices and a decrease in liquidity.
- Only one liquid BZ is expected to remain in the medium to long term.
- Hedging opportunities might not suffice in zones where market size will significantly decrease and in particular in the northern zones of Germany and the Netherlands due to the limited diversity of market participants, resulting in limited volume and increased bid-ask spreads. Changes in market design and mitigation measures will not be able to compensate for these drawbacks in liquidity.
- All four alternative configurations would split and downsize the forward market. Consequently, Europe's most liquid forward market would disappear.
- Alternative configuration 14 would probably not ensure sufficient liquidity in the longer-term timeframe for J5. Alternative configurations 2, 12 and 13 would be large enough to ensure sufficient liquidity in all timeframes for hedging.
- In alternative configuration 5, as the market size in France would significantly decrease in case of a split into three zones, hedging opportunities would likely be insufficient in such a case with increased bid-ask spreads.
- In alternative configuration 11, BZ O1 looks too small to create liquidity with a dominant producer.
- In alternative configuration 10, BZ O3 looks too small to create liquidity.
- In alternative configuration 9, BZ O2 looks like it will be one dominant producer.
- In alternative configuration 8, it looks like BZ O2 will be rather small with a lack of production but rather high population density, so there might be a bias with market power for the producers in that zone.
- Merging SE1 and SE2 in alternative configuration 8 and 9 can create some liquidity, although it will not solve the structural skewness of demand and supply in the north.

B.3.9 Statements on intra-company transactions

- While some respondents stated that they do not expect any effects from the BZ split, others expect the intra-company effects to be similar to the external effects of the reconfiguration.
- They expect an increase in intra-company transactions resulting from the need to design more complex hedging strategies, especially for generators with assets originally hedged as a portfolio and now located in many different BZs.
- For companies active in two BZs after the split, the number of transactions executed via exchanges is expected to drastically increase because internal netting will no longer be possible.

B.4 Statements on previous bidding zone reconfigurations and their impact on liquidity and transaction costs

B.4.1 Statements on the impact of previous BZ reconfigurations on liquidity

- In the aftermath of the Germany–Luxembourg / Austria split, there was a drastic reduction in long-term liquidity in the Austrian market. At the same time, there was an increase in liquidity in the DA and ID markets, which can be explained by the fact that long-term hedging now takes place in Germany–Luxembourg and must then be transferred DA to Austria, which leads to double turnover in Germany and Austria.
- In general, there was higher liquidity in the BZ to which the market activity refocused post-split and lower liquidity in the other one(s).
- The market area merger in the natural gas market led to a strong increase in liquidity of the German gas market.
- Some stakeholder(s) noted that the former BZ STO in Sweden was very liquid, with the new BZs post-split being much less liquid (especially SE4, SE2, and SE1) due to an imbalance of buyers and sellers, fewer market participants per BZ, and – in some cases – an almost monopoly / oligopoly in production.
- Other stakeholder(s) noted that short-term liquidity was unchanged or even increased in Sweden as generators with generation in several (new) BZs could no longer self-regulate between BZs.
- The Italian 2021 reconfiguration was implemented with an adequate lead time and did not have any negative impact on the liquidity of both spot and forward markets, partly because the regulatory, market, and contractual framework in Italy had already accommodated a zonal market.

B.4.2 Statements on the impact of previous BZ reconfigurations on transaction costs

- Following the Germany–Luxembourg / Austria split, transaction costs have considerably increased.
- In Austria, the derivatives market dried up, which resulted in additional costs for market participants there, which persists until today.

B.4.3 Statements on the impact of previous BZ reconfigurations on volatility and risks

- Especially in the smaller BZ, risks and therefore costs significantly increase.
- Following the Germany–Luxembourg / Austria split, the supply and demand curves in the short-term DA market have more discontinuities, leading to increased volatility.

B.5 Statements on the study itself related to mitigation measures

Respondents provided the following remarks on the study:

- It was noted that it is not appropriate to include stakeholders' proposals on mitigation measures in the final study, as the effectiveness of any such proposal would require additional in-depth analysis. If stakeholders' proposals were to be included, they would need to be highlighted as such, indicating that they are ideas rather than proven concepts.
- The study's approach of claiming that several mitigation measures are available and expected to influence the results without presenting an idea or list of measures was criticised.

B.6 Statements on and propositions for mitigation measures

B.6.1 Statements on short-term markets

Respondents provided the following statements on mitigation measures related to short-term markets:

- **DA market dispatch** is a powerful mitigation measure, and the effects of a split would be more detrimental without it. However, respondents do not agree that the measure proves a clear improvement compared to larger BZs.
- **Implicit coupling** in the ID and DA timescales should ensure that short-term markets remain liquid with reliable price formation.
- The risk of market concentration in the ID market can be reduced by **extending the SIDC** to the trading products that are closest to fulfilment.
- The re-introduction of **price coupling with British** borders should be considered to minimise flows against the price differential, which could lead to inefficient energy flows and increased use of countertrading by TSOs.
- It was suggested to improve the framework to incentivise the **locational usage of electricity** to reduce the need for congestion management, e.g. through **sector coupling**.
- Generally, **measures are not needed** as smaller BZs could lead to increased liquidity in the short timeframes. It could also add transparency, which in turn can boost liquidity.

B.6.2 Statements on long-term markets

Respondents provided the following statements on mitigation measures related to long-term markets:

- Mechanisms such as **contracts for differences (CfDs)** could help to alleviate price risks, and hence providing clarity on such measures could help to reduce uncertainty.
- **Cross-zonal PPAs** should be effectively supported, including introducing LTTRs that span the duration of PPAs (5-10 years or more).
- To protect investments in renewable projects, retroactive protection of **PPAs** needs to be in place, such as **grandfathering**. Without them, there is a risk that recovery could be detrimental to a project.
- The ability of market participants to hedge price risks in the internal electricity market should be improved, e.g. by **enhancing cross-border hedging**.
- Hedging opportunities should be facilitated across borders through improved allocation of **LTTRs or equivalent measures** (such as EPADs in the Nordics) within the existing regulation. However, this is no substitute for liquid forward markets.
- Transaction costs and risk exposure in long-term trading can be achieved by **expanding FTR auctions**, which must take place more frequently and it must be possible to sell already acquired rights in the primary auction. An expansion of secondary FTR trading under REMIT without EMIR/MiFID reporting obligations would be desirable.
- The Nordic model with a **system price and EPADs** is a better way to handle low liquidity than the continental model. The problem with the Nordic model comes when splitting up BZs such that there is insufficient liquidity in each BZ and the correlation between a specific illiquid BZ and the system price is too low. Hence, BZ must be as large as possible in terms of the number of active market players in the BZ, and balanced regarding consumption and production. In contrast to LTTRs, EPADS would not transfer any wealth between the TSO and private companies.
- **Grid expansion** is recommended to reduce redispatch costs, in this context improving grid planning and investment to ensure sufficient capacity is recommended.
- Improving framework to consider **locational criteria in renewable auctions** at grid-compatible locations to reduce the need for congestion management, e.g. through auctioning PV in combination with on-site energy storage (as already applied in Germany).Easing **collateral regulations** in forward markets by widening the types of non-cash collateral accepted.
- It is doubtful that a **regional virtual hub** model effectively addresses the challenges of the electricity forward market, considering the problems of low liquidity splits and collateral requirements. The same applies for the Nordic market concept.
- It should be considered introducing a **voluntary mechanism for market makers** in forward markets to stimulate demand and supply at longer horizons, therefore stimulating liquidity.

B.6.3 Overarching statements

Respondents provided the following overarching statements:

- Improving the framework to improve and/or introduce **capacity mechanisms** is necessary to reduce the need for congestion management and enhance security of supply in parallel.
- Increased risk exposure can be expected as the number of trading transactions will rise for required hedging, affecting transaction costs, workload, and financial requirements for hedging transactions. A potential mitigation measure is to create simple and unbureaucratic **access to hedging instruments**, e.g. in the form of bank guarantees from state institutions such as KfW. Another measure could be to facilitate access to financial instruments (exchange futures trading) by creating far-reaching exemptions in MiFID, EMIR, and REMIT for hedging transactions for exposures that must be physically settled.
- Support mechanisms such as **CfDs** could help to alleviate price risks, whereby providing clarity on the introduction of such measures could help to reduce uncertainty. Existing **subsidy mechanisms with floors** should lower the floor to incorporate lower price levels after the split.
- Efforts should be made to improve the framework for fair **distribution of grid tariffs** between high- and low-RES regions.
- The framework to **reduce taxes and levies** to lower electricity prices for end consumers should be improved.
- It is important for member states that implement BZ reconfigurations to develop a launch plan that monitors and **eliminates external barriers** (e.g. for land acquisition, permitting) in tandem with implementing BZs.

- A **compensation scheme** financed by congestion income similar to TAG could be a solution for compensating producers in low-price BZs like they are intended to be in OBZs. This would increase the application of schemes such as the TAG to not only cover producers in OBZs, although it could be financed by the new congestion incomes from the new BZ borders.
- Given the socioeconomic impact of the BZ configuration, it was noted that congestion can also be efficiently managed through alternative coordination measures such as flow-based **capacity calculation and allocation, countertrading, and redispatching**, targeting a maximisation of socioeconomic welfare.
- Potential mitigation measures include a **suitable lead time** for the implementation of the reconfiguration, an increase in the **number of auctions of hedging instruments** issued by TSOs, and enhancements in **transmission grid investments** at both the country and cross-border levels.
- One suitable and sustainable measure is to strengthen the existing German BZ by maximising cross-border trade by **strengthening interconnector capacity**, reducing the need for congestion management through faster **grid expansion**, additional dispatchable power plants, and sufficient economic incentives for voluntary demand side flexibilities, and improving the investment and planning security.
- It should be ensured that all technologies contribute to **system flexibility** and that the BZ delineation is conducive to fast **storage roll-out** and more **demand response** alongside the development of power generation.
- Grid usage should be enhanced through **improved TSO-TSO and TSO-DSO cooperation, cross-border redispatch** and cost-sharing arrangements, and advanced cross-capacity calculation processes.
- Support for RES-E installations under the German Renewable Energy Act would have to be substantially adapted. Solutions for existing installations would be needed. For new installations, a switch to **investment support** could be envisaged.
- To mitigate the risk of an uneven impact on electricity prices for end consumers, it is reasonable and feasible to implement measures such as **targeted financial support for affected regions**, enhanced grid infrastructure, and improved market mechanisms to balance regional price disparities.
- There is a fear that inconsiderate **state interventions** could result in higher costs for final customers such as consumers and industry. Moreover, negative impacts on the level playing field and the cross-subsidisation of less efficient market participants are possible. Furthermore, such compensation will also come with detrimental effects regarding flexibilisation, ability, and the willingness to react to short-term price signals.
- A **longer lead time** before any BZ reconfiguration will help to mitigate the exposure shifts, although the greater or lower exposure in itself is inherent to the BZ modification and cannot be avoided as such.
- A **stable regulatory framework** for all market timeframes should be ensured by **removing revenue caps** on existing inframarginal production.
- The **redistribution of the scarcity rent** from grid bottlenecks is not a suitable measure to compensate for increased electricity prices.
- While acknowledging the need for **locational price signals** for the investment stage, some respondents are convinced that these can be developed by maintaining the uniform BZ (status quo). Positive incentives should be created to reward existing capacities for **grid-friendly use**.
- In order to mitigate these risks, the **distribution of the number and size of the participants** (consumers, producers, integrated companies, suppliers, etc.) in a BZ needs to be diversified.
- The superior goal should be to **incentivise flexibility processes** within the industry to factually realise a reduced need for redispatch than the configuration of a BZ accompanied with compensation mechanisms for the industry.
- There are no reasonable and feasible mitigation measures available. The costs and risks will increase and thus the current BZ **configuration should be maintained**.

B.7 Statements on expected impacts on liquidity and transaction costs

B.7.1 Statements on short-term markets

Respondents provided the following statements on expected liquidity impacts and transaction costs in short-term markets:

- Lower liquidity and smaller zones raise **balancing costs** as the **asset distribution** across zones is eliminated, which is problematic with the growing share of renewables.
- Lower liquidity also **influences investmen**t decisions, particularly for those assets and services that rely extensively on spot markets and balancing mechanisms.
- The main adverse impact will be on the **ID market**, where already today **liquidity** in some BZs is limited, and **access to cross-zonal capacity is low compared to the DA market**.
- Liquidity in the short-term markets will probably not be affected by the proposed BZ reconfigurations. Liquidity could even increase, especially in the ID timeframe as described above.
- Functioning **short-term trading will become increasingly important**, as here hedging positions are transferred to the fulfilment markets in which physical fulfilment must take place with considerable significance for system stability. Further, there is a **dependence on individual market participants** (e.g. EPEX Spot problem on 27 June).

B.7.2 Statements on long-term markets

Respondents provided the following statements on expected liquidity impacts and transaction costs in long-term markets:

- The development of the **PPA market** is further negatively affected if renewable assets are located in low-price zones or if the potential to enter PPA in the same zone is reduced or producers and off-takers up being in different zones, potentially requiring re-negotiation or a threat to the business case.
- The BZ reconfiguration will significantly reduce the **number of possible OTC trading partners** (e.g. EFET agreement as a prerequisite, potential partners active on other trading platforms) and thereby hedging opportunities.
- Smaller BZs will create **smaller and less liquid markets**, negatively affecting the current forward market and affecting neighbours (e.g. Germany).
- The **flat price risk** (uncertainty about the future electricity price level) increases and becomes more difficult to hedge in smaller BZ with less liquid futures markets.
- The **locational spread risk** (difference between the hedged DA price and the reference price used for the financial settlement of the long-term forward product) will increase.
- Significant **basis risks** will occur when hedging a non-liquid zone with a moderately liquid zone. Consequently, **transaction costs** will rise, and with lower liquidity, **prices for final customers** will be higher in the long run.
- Given the limited amount of cross-zonal capacity (in terms of volume and maturity), there is **limited scope of pooling liquidity across BZ borders** unless through proxy hedging with residual basis risk.
- **Resource estimation uncertainty** is present in fragmented zones due to greater difficulties in developing assumptions/calculation/simulation methods related to limited geographic perimeters, with the risk of making the choice of ideal resource location less efficient and effective in the long term.

B.7.3 Overarching statements

Respondents provided the following overarching statements on the expected liquidity impacts and transaction costs:

- Higher **volatility** is expected in smaller BZs (depending on the production portfolio) due to more discontinuities in the bidding curve, as suggested based on observations in smaller zones, e.g. Austria and Belgium.
- **Price volatility** might decrease, particularly in Sweden, due to the high degree of interconnection and development in Germany.
- There is a risk of northern Germany becoming a **low-price zone** with more frequent price collapses. Significant risk will exist for producers in such a BZ, affected business cases (e.g. for Danish resources).
- Smaller and less liquid zones are expected to distort wholesale market price setting, increase bid-ask spreads, increase risk premiums in supply contracts, and drive up electricity prices for consumers.
- Higher transaction costs through increased price volatility and higher risk for market participants would also influence **investment decisions** (generation, storage, demand response) and the efficient operation of generation units (especially with limited reserves, making revenues for peaking generation and demand response units riskier), ultimately affecting the **energy transition**.
- With extensive reconfiguration, **trust in the stability of design will decline**, which will halt further investments and make support schemes necessary for any sort of new infrastructure development.
- Higher **financing risks** cannot be borne by all market players (small or medium-sized market players). As a result, the additional expansion and the existing capacity (through resale) can only be realised by a few larger players, which in turn significantly exacerbates the examined criterion of **market power** in the case of electricity BZ sharing.
- **Price risks** will emerge between the owned electricity production units and the consumption units in different BZs.
- Smaller BZs will create smaller and more illiquid markets so that individual market participants might exercise greater market power, leading to **higher energy prices for consumers and affecting the international competitiveness of energy-intensive industry**.
- A trade-off exists between a perfect market from a **grid perspective** versus a **sufficiently large market** to function. Restrictions on the grid might be better for society than having a market that does not function.
- There will be higher transaction costs and reduced possibilities for market participants to **balance their portfolios / balancing groups** and thus increased prices for end consumers in smaller, less liquid BZs.
- It is complex to trade in case of **production / consumption bias** and a flow-based system where the flows can be non-intuitive and come from a BZ with higher prices, more dynamic and difficult-to-predict bottlenecks, aggravated by lack of liquidity. The focus should be placed on having BZs that are as large as possible and slowly shift to account for all measures and potential counterproductive effects.
- **The BZ configuration is not the only market revision** (flow-based, REMIT), meaning that the aggregate of all fundamental changes will have an extensive impact that is difficult to predict.
- In particular, smaller market participants are **not in a position to expand exchange trading activities** as liquidity management poses considerable challenges and considerable **funding for collateral required**.
- This is no reason why effects would **fade over time** (e.g. futures market liquidity after the Germany–Luxembourg / Austria split in 2018 is de facto still zero).
- Less liquidity will deteriorate the **quality of price signals**, e.g. quarters indicating summer-winter spreads or base-peak spreads lose information value when fewer trades occur.
- Splitting large BZs might pose a risk of reduced liquidity, although in a **mature market** the **impact is often minimal** or might even lead to increased liquidity.
- Impacts are **difficult to judge** given uncertainty about the configuration specificities (borders).

B.8 Statements on liquidity distribution and different impacts on market participants

Respondents provided the following overarching statements on liquidity distribution and impacts on market participants:

- Liquidity is expected to be **distributed unequally geographically** (based on the experience of the Germany-Luxembourg / Austria zone split, liquidity is expected to be concentrated in the largest remaining BZ and sharply fall to almost zero in all others).
- In some cases, **new balancing group contracts** will have to be concluded to continue hedging, while trading might be made temporarily impossible due to a lack of trading partners.
- A geographically uneven liquidity distribution across BZs would also lead to different costs and risk levels between the BZs, creating an **uneven competitive playing field**, e. g. for **power-intensive companies or SMEs**.
- There will be **risk of uneven competition**, depending on whether there are only a few or one **large / vertically integrated producer** (with a major production compared to the size of the BZ in total). Large vertically integrated companies would benefit due to internal hedging opportunities. The situation would worsen for small suppliers, in particular if more trading / hedging is OTC.
- Lower liquidity and higher transaction costs are expected to **harm end consumers and households** through higher electricity prices.
- An unequal impact would require **governments to add additional spending**, which is not reflected in any of the cost-benefit calculations concerning a BZ reconfiguration.
- The issue of fair competition between market participants is in the **scope of competition law,** at the national and European level.
- The distribution of risk will depend on the size and geographical distribution of individual market participants' assets. In principle, this market risk should be **handled by the market participants themselves**.
- Based on these additional financing risks, it has been proven that electricity BZ sharing cannot lead to the same **expansion of renewables or flexibility**.

B.9 Other comments

- In general, more transparency and larger BZs are generally beneficial for participants in the DA and ID markets due to increased liquidity and hence lower transaction costs.
- A division of the German BZ in any alternative configuration would negatively affect neighbouring European markets as Germany is the reference market in Europe.
- In the case of a division of a single BZ, the period between the announcement and entry into force of any division entails the risk that the physical transmission grid will have changed so much by the time that it comes into force as a result of expansion that the previously planned division will no longer correspond to the actual circumstances. During the construction and completion process of the high voltage direct current (HVDC) lines, the requirements will therefore constantly change, whereby previously defined structures and mechanisms for bottlenecks in the separate zones would have to be constantly adapted.

C 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 liquidity metric considered and explanatory variables included are specified in each table.

Day-ahead market: Traded volume as a liquidity metric

DA traded volume	(1)	(2)	(3)	(4)	(5)	(6)
Total load	0.829***	0.799***	0.796***	0.164***	0.103***	0.102***
Share of renewables	232,959.3***	174,348.1***	167,268.5***	75,045.1***	−28,963.6**	−10,511.8
Flow-weighted price correlation	7,825.8	47,510.0***			55,548.6***	51,724.7***
HHI	−43.83***				−64.67***	−65.01***
Temperature	−115.4	126.1	83.56	−1,638.7***	−3,835.6***	−3,761.5***
Price volatility	299.6***	−184.9***	−233.7***	−79.88	1,254.2***	1,501.6***
Supply-demand imbalance	−42,678.6***	−60,155.4***	−70,452.8***	−42,712.8***	442,180.8***	443,248.5***
IT X Square of temperature	7.888	−4.653	−5.725	97.74***	383.9***	385.2***
DE_LU X Total load	−0.724***	−0.714***	−0.714***			
FR X Total load	−0.766***	−0.737***	−0.732***			
DE_LU	234,501.9***	368,630.8***	370,854.7***	41,249.3***		
FR	254,805.7***	126,969.7***	114,857.1***	−244,777.3***		
IT	−110,120.0***	−5,805.7	−6,020.2*	244,797.0***		
NL		−225,650.1***	−236,074.9***	−270,121.5***		
Time trend	8.109***	5.476***	8.910***	10.45***	11.59***	
Constant	129,326.4***	14,185.1**	50,529.3***	305,374.1***	435,672.6***	448,194.8***
R2 within	0.714	0.646	0.682	0.256	0.197	0.194
R2 between	1.000	1	1	1	0.982	0.982
R2 overall	0.960	0.973	0.976	0.943	0.863	0.862
Observations	6,983	9,623	10,354	10,354	6,983	6,983

Note: Significance: "***" p < 0.001, "**" p < 0.01, "*" p < 0.05; Models 1 to 6 comprise multivariate ordinary least squares regressions.

Day-ahead market: Churn ratio as a liquidity metric

DA churn ratio	(1)	(2)	(3)	(4)	(5)	(6)
Total load	−0.000000205***	−0.000000231***	−0.000000210***	−0.000000139***	−0.000000584***	−0.000000583***
Share of renewables	0.112***	0.140***	0.131***	0.147***	−0.0704***	−0.0837***
Flow-weighted price correlation	0.0273***	0.0916***			0.198***	0.201***
HHI	−0.0000558***				−0.0000502***	−0.0000499***
Temperature	0.000961***	0.000437***	0.000472***	0.000612***	−0.00755***	−0.00760***
Price volatility	0.000495***	0.0000644	−0.0000184	−0.0000647	0.00123***	0.00106***
Supply-demand imbalance	0.0969***	0.0193*	0.00407	−0.00657	0.170***	0.169***
IT X Square of temperature	−0.0000191**	−0.00000340	−0.0000120*	−0.0000219***	0.000368***	0.000367***
DE_LU X Total load	−4.52e−08***	−3.70e−08***	−6.29e−08***			
FR X Total load	0.000000126***	0.000000132***	0.000000116***			
DE_LU	−0.454***	−0.308***	−0.298***	−0.458***		
FR	−0.607***	−0.729***	−0.746***	−0.661***		
IT	−0.148***	−0.0258***	−0.0358***	−0.0634***		
NL		−0.721***	−0.740***	−0.736***		
Time trend	−2.49e−08	0.00000228*	0.00000786***	0.00000746***	−0.00000831***	
Constant	1.166***	0.993***	1.052***	1.024***	1.210***	1.201***
R2 within	0.428	0.358	0.338	0.300	0.196	0.195
R2 between	1	1	1	1	0.999	0.999
R2 overall	0.986	0.984	0.983	0.982	0.948	0.948
Observations	6,983	9,623	10,354	10,354	6,983	6,983

Note: Significance: "***" $p < 0.001$, "**" $p < 0.01$, "*" $p < 0.05$; Models 1 to 6 comprise multivariate ordinary least squares regressions.

Intraday market: Traded volume as a liquidity metric

ID traded volume	(1)	(2)	(3)	(4)	(5)	(6)
Total load	0.0764***	0.0673***	0.0693***	0.0336***	0.0784***	0.0767***
Share of renewables	77,775.0***	49,282.2***	49,943.9***	42,270.6***	88,268.4***	102,978.5***
Flow-weighted price correlation	18,561.4***	15,946.3***			−13,473.8***	−18,374.0***
HHI	−11.13***				−24.43***	−24.57***
Temperature	574.6***	442.2***	434.0***	370.8***	1,218.2***	1,280.3***
Price volatility	241.5***	128.6***	148.4***	166.1***	210.5***	470.8***
Supply-demand imbalance	−35,340.1***	−34,252.3***	−33,485.5***	−30,482.7***	−33,818.0***	−40,791.6***
IT X Square of temperature	−30.52***	−26.42***	−28.86***	−23.79***	−58.86***	−57.28***
DE_LU X Total load	0.00607	0.00995**	0.00881*			
FR X Total load	−0.0597***	−0.0542***	−0.0556***			
DE_LU	37,524.9***	76,002.9***	75,412.3***	124,439.6***		
FR	54,508.2***	25,581.0***	22,755.8***	−15,811.3***		
IT	25,392.8***	53,194.0***	55,280.3***	69,456.9***		
NL		7,647.5***	4,058.2***	2,093.5***		
Time trend	9.833***	8.299***	7.169***	7.224***	11.89***	
Constant	−33,005.6***	−48,882.1***	−36,274.3***	−21,966.0***	19,175.3***	35,705.6***
R2 within	0.313	0.258	0.248	0.187	0.218	0.174
R2 between	1	1	1	1	1.000	1.000
R2 overall	0.941	0.943	0.940	0.935	0.926	0.920
Observations	6,258	8,084	8,450	8,450	6,258	6,258

Note: Significance: "***" $p < 0.001$, "**" $p < 0.01$, "*" $p < 0.05$; Models 1 to 6 comprise multivariate ordinary least squares regressions.

Intraday market: Churn ratio as a liquidity metric

ID churn ratio	(1)	(2)	(3)	(4)	(5)	(6)
Total load	−4.36e−08***	−4.34e−08***	−4.38e−08***	−1.73e−08***	4.38e−08***	4.21e−08***
Share of renewables	0.0702***	0.0523***	0.0535***	0.0588***	0.0601***	0.0747***
Flow-weighted price correlation	0.0157***	0.0299***			0.00821*	0.00337
HHI	−0.00000457***				−0.0000195***	−0.0000197***
Temperature	0.0000677	0.000146***	0.000112***	0.000164***	0.00106***	0.00112***
Price volatility	0.000182***	0.000142***	0.000170***	0.000156***	0.000308***	0.000565***
Supply-demand imbalance	−0.0386***	−0.0138***	−0.0136***	−0.0155***	0.0954***	0.0885***
IT X Square of temperature	−0.0000166***	−0.0000197***	−0.0000222***	−0.0000261***	−0.0000125***	−0.0000109***
DE_LU X Total load	−1.72e−09	−1.78e−10	1.11e−09			
FR X Total load	3.51e−08***	3.75e−08***	3.90e−08***			
DE_LU	0.131***	0.143***	0.141***	0.115***		
FR	0.0122***	−0.00181	−0.00822***	0.0175***		
IT	0.104***	0.110***	0.115***	0.104***		
NL		0.0157***	0.00884***	0.0103***		
Time trend	0.00000848***	0.0000118***	0.0000103***	0.0000103***	0.0000118***	
Constant	0.0145***	−0.0123***	0.0124***	0.00177*	0.0130***	0.0293***
R2 within	0.323	0.364	0.315	0.293	0.0698	0.0368
R2 between	1	1.000	1.000	1.000	0.986	0.985
R2 overall	0.931	0.917	0.910	0.907	0.871	0.863
Observations	6,258	8,084	8,450	8,450	6,258	6,258

Note: Significance: "***" p < 0.001, "**" p < 0.01, "*" p < 0.05; Models 1 to 6 comprise multivariate ordinary least squares regressions.

Long-term products: Minimum bid-ask spread as a liquidity metric

Minimum BAS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Intercept	−0.57**	−0.65**	−0.08	1.120 *	−1.65**	−1.60**	−1.21**	−1.56**	−1.21**		
Volatility	0.024**	0.035**	0.025**	0.025**	0.019**	0.019**	0.022**	0.023**	0.022**	0.022**	0.020**
Market size	−0.01**	−0.01**	−0.01**	−0.01**	−0.00 *	0	0	0.01	0	0	0.009**
Supply-demand imbalance	−1.13**	0.42	0.56		2.217**	1.420**	−0.36	−0.06	−0.36	−0.36	1.071 *
Lagged traded volume	−0.00**					−0.00**					0
Price difference to German futures		−0.00**									
Share of renewables		−1.22**									
Average weighted correlation			−1.18**					0.18			0.13
HHI				8.322**	9.326**	5.020**					−0.00**
Date				−0.00**							
Germany							−0.73**	−0.78**	−0.73**		
Italy							−0.01	−0.02	−0.01		
Netherlands							0.522**	0.665**	0.522**		
Nordics							−0.28**		−0.28**		
R2	0.68	0.81	0.67	0.51	0.52	0.57	0.82	0.87	0.82	0.54	0.61
Observations	329	192	238	251	251	247	335	238	335	335	155

Note: Significance: "***" p < 0.001, "**" p < 0.01, "*" p < 0.05; Models 1 to 9 comprise multivariate ordinary least squares regressions, while Models 10 and 11 control are fixed effects regression models.

Long-term products: Mean bid-ask spreads as a liquidity metric

Mean BAS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Intercept	−0.50**	−0.54**	−0.29**	−0.91**	−0.95**	−0.93**	−0.40**	−0.47**	−0.40**		
Volatility	0.026**	0.029**	0.025**	0.028**	0.028**	0.028**	0.025**	0.025**	0.025**	0.025**	0.026**
Market size	0	0	−0.00 *	−0.01**	−0.00 *	0	0	0	0	0	0
Supply-demand imbalance	0.06	0.46	0.793 *		2.238**	1.780**	−0.2	−0.38	−0.2	−0.2	0.39
Lagged traded volume	−0.00**					−0.00**					0
Price difference to German futures		−0.00**									
Share of renewables		−0.38 *									
Average weighted correlation			−0.42**					0.12			0.11
HHI				7.219**	7.522**	5.008**					−0.00**
Date				0							
Germany							−0.53**	−0.55**	−0.53**		
Italy							−0.03	−0.01	−0.03		
Netherlands							−0.05	−0.02	−0.05		
Nordics							−0.28**		−0.28**		
R2	0.7	0.78	0.56	0.71	0.77	0.79	0.78	0.76	0.78	0.69	0.81
Observations	329	192	238	251	251	247	335	238	335	335	155

Note: Significance: "***" p < 0.001, "**" p < 0.01, "*" p < 0.05;Models 1 to 9 comprise multivariate ordinary least squares regressions, while Models 10 and 11 control are fixed effects regression models.

Long-term products: Churn ratio as a liquidity metric

Churn ratio	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Intercept	2.473**	2.478**	−1.07	−11.8 *	5.197**	4.081**	4.540**	4.331**	4.540**		
Volatility	−0.01**	−0.02**	−0.04	−0.05 *	−0.01	−0.01	−0.03**	−0.03**	−0.03**	−0.03**	−0.02
Market size	−0.04**	−0.01	0.045 *	0.310**	0.157**	−0.05**	−0.04**	−0.04 *	−0.04**	−0.04**	−0.05**
Supply-demand imbalance	−1.99	−3.10**	−22.7**		−31.2**	−8.85**	−2.93 *	−1.19	−2.93 *	−2.93 *	−4.73
Lagged traded volume	0.022**					0.020**					0.009**
Price difference to German futures		0									
Share of renewables		1.647 *									
Average weighted correlation			9.797**					−0.34			−0.73
HHI				−0.00**	−0.00**	−0.00**					0
Date				0							
Germany							10.34**	10.41**	10.34**		
Italy							−0.56	−0.58	−0.56		
Netherlands							−1.32**	−1.22 *	−1.32**		
Nordics							0.35		0.35		
R2	0.91	0.2	0.31	0.59	0.67	0.91	0.91	0.92	0.91	0.15	0.19
Observations	334	192	241	253	253	249	340	241	340	340	155

Note: Significance: "***" p < 0.001, "**" p < 0.01, "*" p < 0.05; Models 1 to 9 comprise multivariate ordinary least squares regressions, while Models 10 and 11 control are fixed effects regression models.

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

Overall traded volume	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Intercept	6.44	15.13 *	−138.**	−640.**	69.07	23.93	61.77**	58.09	61.77**		
Volatility	−0.21	−0.67**	−1.18	−1.92 *	−0.36	−0.27	−1.18**	−1.14**	−1.18**	−1.18**	−0.8
Market size	0.17	1.701**	3.900**	15.15**	9.778**	1.04	0.88	0.9	0.88	0.88	0.6
Supply-demand imbalance	−34.14	−107.**	−917.**		−1,106**	−183. *	−68.05	−16.04	−68.05	−68.05	−14.36
Lagged traded volume	0.937**					0.854**					0.341**
Price difference to German futures		0.01									
Share of renewables		65.38**									
Average weighted correlation			412.7**					−2.09			−26.81
HHI				−0.05**	−0.05**	−0.00**					0
Date				0.023 *							
Germany							430.1**	431.3**	430.1**		
Italy							−11.97	−16.9	−11.97		
Netherlands							−28.43	−30.65	−28.43		
Nordics							13.89		13.89		
R2	0.93	0.64	0.42	0.66	0.7	0.92	0.93	0.94	0.93	0.08	0.14
Observations	334	192	241	253	253	249	340	241	340	340	155

Note: Significance: "***" p < 0.001, "**" p < 0.01, "*" p < 0.05; Models 1 to 9 comprise multivariate ordinary least squares regressions, while Models 10 and 11 control are fixed effects regression models.

D 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%
	21	DEJ1	0%	0%	0%
		DEJ2	3%	0%	0%
	22	DEJ1	0%	0%	0%
		DEJ2	15%	0%	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%
	21	NLN1	0%	0%	0%
		NLN2	0%	0%	0%
	22	NLN1	0%	0%	0%
		NLN2	0%	0%	0%

Source: Compass Lexecon analysis based on data from the TSOs

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Acronyms

ACER	Agency for the Cooperation of Energy Regulators
BZ	Bidding zone
BZR	Bidding zone review
BZRR	Bidding zone review region
DA	Day-ahead
EEX	European Energy Exchange
EPAD	Electricity price area differential
ESMA	European Securities and Markets Authority
FTR	Financial transmission rights
HHI	Herfindahl-Hirschman index
HVDC	High voltage direct current
ID	Intraday
LEBA	London Energy Broker Association
NEMO	Nominated electricity market operator
NRA	National regulatory authority
NTC	Net transfer capacity
OTC	Over-the-counter
PPA	Power purchase agreement
PSI	Pivotal supplier index
PUN	Prezzo Unico Nationale
RSI	Residual supply index
SD	Standard deviation
SDAC	Single day-ahead coupling
SIDC	Single intraday coupling
TSO	Transmission system operator

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Publisher

ENTSO-E AISBL
8 Rue de Spa | 1000 Brussels | Belgium
www.entsoe.eu | info@ entsoe.eu

Design

DreiDreizehn GmbH, Berlin | www.313.de

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Publishing date

April 2025