ENTSO-E Main Report

Bidding Zone Review of the 2025 Target Year

April 2025

ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the **association for the cooperation of the European transmission system operators (TSOs)**. The 40 member TSOs, representing 36 countries, are responsible for the **secure and coordinated operation** of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E **brings together the unique expertise of TSOs for the benefit of European citizens** by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the **security of the interconnected power system in all time frames at pan-European level** and the **optimal functioning and development of the European interconnected electricity markets**, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first **climate-neutral continent by 2050** by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires **sector integration** and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources.

ENTSO-E acts to ensure that this energy system **keeps consumers at its centre** and is operated and developed with **climate objectives** and **social welfare** in mind.

ENTSO-E is committed to use its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in **solidarity** as a community of TSOs united by a shared **responsibility.**

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by **optimising social welfare** in its dimensions of safety, economy, environment, and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and **innovative responses to prepare for the future** and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with **transparency** and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its legally mandated tasks, ENTSO-E's key responsibilities include the following:

- Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy;
- Assessment of the adequacy of the system in different timeframes;
- Coordination of the planning and development of infrastructures at the European level (Ten-Year Network Development Plans, TYNDPs);
- Coordination of research, development and innovation activities of TSOs;
- Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the **implementation and monitoring** of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

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1 Executive Summary

This report covers the work undertaken by the transmission system operators (TSOs) in Central Europe (CE) and the Nordics on assessing alternative bidding zones (BZs) for each of the two bidding zone review regions (BZRRs). The work was initiated on 8 August 2022 following Agency for the Cooperation of Energy Regulators (ACER) decision no. 11/2022 on the alternative bidding zone configurations to be considered in the bidding zone review (BZR). The alternative BZ configurations approved by ACER were based on the results from the locational marginal pricing simulations conducted by the TSOs between 24 November 2020 and 4 March 2022. The table below presents a list of the alternative BZ configurations assessed in the BZ Study.

Configuration identifier according to ACER decision	BZRR	Member states	Number of bidding zones	Identifier in this report
2	Central Europe	Germany – Luxembourg	2	DE2
5	Central Europe	France	3	FR3
6	Central Europe	Italy	2	IT2
7	Central Europe	Netherlands	2	NL2
8	Nordic	Sweden	3	Config 8
9	Nordic	Sweden	3	Config 9
10	Nordic	Sweden	4	Config 10
11	Nordic	Sweden	4	Config 11
12	Central Europe	Germany – Luxembourg	3	DE3
13	Central Europe	Germany – Luxembourg	4	DE4
14	Central Europe	Germany – Luxembourg	5	DE5

Table 1: Alternative BZ configurations to be assessed in the BZ Study according to ACER decision 11/2022

The alternative BZ configurations have been assessed according to ACER decision 29/2020 issued on 24 November 2020 on the methodology and assumptions to be used in the BZR process and the alternative BZ configurations to be considered (BZR Methodology).

The target year for the study is 2025, and the scenario is based on input data and assumptions collected from TSOs in 2019 for European Network of Transmission System Operators for Electricity's (ENTSO-E) Mid-Term Adequacy Forecast (MAF) 2020 and the Ten-Year Network Development Plan (TYNDP) 2020. Three different climate years (1989, 1995, and 2009) were simulated to account for varieties in temperature, wind, solar, and hydro inflows.

The modelling chain in general is described as follows:

- The simulation starts with a capacity calculation using a flow-based and coordinated net transmission capacity (cNTC) approach resulting in available capacities for cross-zonal trade.
- The capacity calculation is followed by a day-ahead flow-based market coupling simulation where dispatch of generation and demand is optimised.
- Thereafter, a load flow calculation is conducted to determine the physical electricity flows and any resulting operational security violations, e.g. overloads on network elements.
- A remedial action optimisation is executed, optimising the remedial actions to solve the overloads detected during the load flow calculation in the previous step.
- Finally, a power flow decomposition is executed to calculate the loop flows after the day-ahead market dispatch and operational security analysis.

Extensive developments of the different modelling tools used in the BZ Study were necessary for both regions to adhere to the BZR Methodology.

The simulation results were thoroughly analysed and the alternative BZ configurations compared to the performance of the current setup of bidding zones, i.e. the "status quo". The assessment of the BZ configurations followed the four steps outlined in the BZR Methodology defined in ACER decision 29/2020, where 22 evaluation criteria are defined:

- In step 1, criterion 4 of "economic efficiency" is assessed. Alternative configurations that had a negative economic efficiency compared to the status quo were rejected and not further assessed.
- In step 2, alternative configurations with a positive economic efficiency were further assessed according to the remaining 21 criteria.
- In step 3, the TSOs determined whether any of the alternative BZ configurations performing worse in step 2 compared to the status quo for at least one criterion could be deemed unacceptable and thereby rejected. According to the BZR Methodology such decisions shall consider the views of the relevant national regulatory authorities (NRAs) and it has to be explained how those views have been taken into account.
- In step 4, the overall assessment of the alternative configurations for each region was consolidated and conclusions were drawn.

During step 1, for the CE BZRR, three additional alternative configurations combining individual splits[1] were identified, simulated, and evaluated alongside the original alternatives BZ configurations.

This report is the result of the BZ Study, and includes – as requested in the IME Regulation – a joint proposal for each region developed by the TSOs participating in the BZ Study and submitted to the relevant member states or their designated competent authorities to amend or maintain the BZ configuration following the steps defined in the BZR Methodology. Each joint proposal (for the CE and Nordic BZRRs) has been approved by the participating TSOs of the respective BZRRs.

In the following sections, the assessment and results for the CE and Nordic BZRRs are summarised.

1 Additional information on the selection of the combinations in the CE BZRR is available in section 6.2.3.

1.1 Central Europe Bidding Zone Review Region

The assessment of the alternative BZ configurations is based on the 22 evaluation criteria as outlined in the BZR Methodology (ACER decision 29/2020) and the alternative configurations following ACER decision no. 11/2022 as shown in Annex I.

Step 1: Monetised Benefits

The result for the CE assessment of alternative BZs according to step 1 and the economic efficiency criterion are presented in the table below.

Alternative BZ configuration compared to status quo	Change in market welfare [€ million]	Change in additional costs from redispatch [€ million]	Economic efficiency (change in socio-economic welfare) [€ million]	Accepted / rejected	Ranking according to economic efficiency only
DE5	−274	−613	339	Accepted	1
DE5 + NL2	−243	−576	332	Accepted	2
DE4	−291	−603	312	Accepted	3
DE4 + NL2	−298	−566	268	Accepted	4
DE2 + NL2	−331	−598	266	Accepted	5
DE2	−344	−607	264	Accepted	6
DE3	−390	−641	251	Accepted	7
NL2	14	5	9	Accepted	8
FR3	−42	−33	−9	Rejected	9
IT2	−214	−154	−60	Rejected	10

Table 2: Average change in socio-economic welfare over all climate years for the 2025 target year

The most important aspects of the economic efficiency result are listed below:

- Economic efficiency is calculated as the difference between the change in market welfare and the change in additional costs from redispatch with respect to the status quo configuration.
- The simulation results show a higher economic efficiency for all German – Luxembourgish split configurations (between 251 € million and 339 € million for the 2025 target year), where the DE5 split configuration performs the best among the analysed alternative configurations in terms of economic efficiency.
- For all German – Luxembourgish split configurations and combinations, the decrease in market welfare is compensated by the cost savings from redispatch of approximately 50 % compared to the redispatch costs in the status quo BZ layout.
- Based on the estimated transition costs, the minimum lifetime[2] for the German–Luxembourgish split configurations is 4 – 9 years. If a potential BZ reconfiguration became operational as of around 2030, the breakeven point would be reached by the mid to late 2030s.
- The Dutch split configuration also shows a slight positive effect on economic efficiency (9 € million for the 2025 target year). Based on the estimated transition costs, this results in a minimum lifetime of between 6 and more than 100 years.[3]
- The economic efficiencies of the combinations (DE5 + NL2, DE4 + NL2 and DE2 + NL2) are very close to the underlying individual German–Luxembourgish splits. This is in line with expectations given the negligible welfare benefits of the Dutch split.
- Consequently, the German–Luxembourgish and Dutch split configurations and combinations are accepted to continue with the remaining steps.
- FR3 and IT2 have a negative change in economic efficiency and are therefore rejected.

2 The minimum lifetime is calculated according to a formula described under criterion 11: transitions costs.

3 The maximum value for the minimum lifetime related to the NL2 split can be explained by the rather low monetised benefits calculated for this split of 9 € million / year (see also criterion 11: transition costs).

Step 2: Assessment of all other Criteria

	Configuration								
Criterion	**DE2**	**DE2 + NL2**	**DE3**	**DE4**	**DE4 + NL2**	**DE5**	**DE5 + NL2**	**NL2**	**Remarks**
1 – Operational security	Better	Better	Better	Better	Better	Better	Better	Same	
2 – Security of supply	Same	Same	Same	Same	Same	Same	Same	Same	Detailed assessment could not be performed, performance assumed the same as the status quo
3 – Degree of uncertainty in cross-zonal capacity calculation	Implicit assessment through criterion 4 (economic efficiency)								
5 – Firmness costs	Implicit assessment through criterion 4 (economic efficiency)								
6 – Market liquidity and transaction costs	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	
7 – Market concentration and market power	Same	Same	Same	Same	Same	Same	Same	Same	See section 6.3.6 for assessment of the sub-criteria
8 – Facilitation of effective competition	Same	Same	Same	Same	Same	Same	Same	Worse	See section 6.3.7 for assessment of the sub-criteria
9 – Price signals for building infrastructure	Same	Same	Same	Same	Same	Same	Same	Same	
10 – Accuracy and robustness of price signals	Same	Same	Same	Same	Same	Same	Same	Same	
11 – Transition costs (ranges in € mn)	[1,186; 1,540]	[1,233; 1,969]	[1,191; 1,566]	[1,263; 2,266]	[1,863; 2,695]	[1,269; 2,378]	[1,316; 2,807]	[47;429]	Used to calculate the minimum lifetime of a bidding zone
12 – Infrastructure costs	Same	Same	Same	Same	Same	Same	Same	Same	Assessed as criterion 9 and 10
13 – Market outcomes in comparison to corrective measures	Implicit assessment through criterion 4 (economic efficiency)								
14 – Adverse effects of internal transaction on other bidding zones	Better	Better	Better	Worse	Worse	Worse	Worse	Same	
15 – Impact on the operation and efficiency of the balancing mechanisms and imbalance settlement processes	Same	Same	Same	Same	Same	Same	Same	Same	See section 6.3.14 for assessment of the sub-criteria For sub-criterion 15.1, monetised assessment could not be performed For sub-criterion 15.2, assessed as criterion 10
16 – Stability and robustness of bidding zone over time	Better	Better	Better	Better	Better	Better	Better	Worse	
17 – Consistency across capacity calculation time frames	Same	Same	Same	Same	Same	Same	Same	Same	Assessment set upfront in the BZR Methodology
18 – Assignment of generation and load units to BZs	Same	Same	Same	Same	Same	Same	Same	Same	Assessment set upfront in the BZR Methodology
19 – Location and frequency of congestion	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Same	
20 – Short-term effects on CO_{∞} emissions	Same	Same	Same	Same	Same	Same	Same	Same	
21 – Short-term effects on RES integration	Same	Same	Same	Same	Same	Same	Same	Same	
22 – Long-term effects on low-carbon investments	Same	Same	Same	Same	Same	Same	Same	Same	Assessed as criterion 9 and 10
Evaluation	**Acceptable**	**Acceptable**	**Acceptable**	**Acceptable**	**Acceptable**	**Acceptable**	**Acceptable**	**Acceptable**	

Table 3: Assessment of non-monetised criteria (each alternative configuration compared to the status quo configuration) according to the BZR Methodology

As set forth in the BZR Methodology, among the 21 criteria to be evaluated under step 2, 10 criteria have not been individually assessed because they are:

- implicitly assessed as part of the economic efficiency described in step 1: #3 degree of uncertainty in cross-zonal capacity calculation, #5 firmness costs, and #13 market outcomes in comparison to corrective measures;
- preset by the BZR Methodology: #7 market concentration and market power,[4] #17 consistency across capacity calculation timeframes, and #18 assignment of generation and load units to BZs;
- based entirely on other non-monetised criteria: #12 infrastructure costs, #22 long-term effects on low-carbon investments, and #15.2 impact on the operation and efficiency of the imbalance settlement processes; or
- their assessment as set forth in the BZR Methodology is too complex to be considered within the scope of this BZ Study: #2 security of supply and #15.1 impact on the operation and efficiency of the balancing mechanisms.

This means that not all aspects of a possible BZ reconfiguration could be evaluated. The evaluation criteria assessed individually are briefly described below.

#1 Operational security

Operational security is assessed through a direct current (DC) load flow calculation performed after the flow-based market dispatch. All German–Luxembourgish splits show an overall less congested network (less congestions in N, N-1, and lower congestion index), whereas the changes in the Dutch alternative configuration do not appear to be significant but within the boundaries of the model accuracy.

The combinations also show an overall less congested network compared to the status quo. They present similar results to the individual German–Luxembourgish split used in the respective combination.

4 The BZR Methodology assumes that market power is structural and hence inevitably higher concentration in wholesale markets is associated with lower market concentration in redispatch mechanisms.

#6 Market liquidity and transaction costs

The market liquidity and transaction costs have been assessed through a study performed by an external consultant for both regions, i. e. the CE BZRR and the Nordic BZRR.

This criterion performs worse for all alternative configurations assessed in the CE BZRR.

The potential mitigation measures suggested during the public consultation do not allow TSOs to conclude ex-ante that they will be sufficient to mitigate the expected negative effects identified.

#7 Market concentration and market power

According to the methodology, this market concentration and market power comprises on sub-criteria wholesale markets and TSOs' mechanisms for resolving physical congestions. For their assessment, CE TSOs estimated the Residual Supplier Index (RSI) and Pivotal Supplier Index (PSI). Incomplete information available on plant ownership and uncertainty on the maximum expected import capacities limit the representativeness of the results. In line with the BZR Methodology, CE TSOs had to assume that market power is structural, i. e. if the indicators point towards higher market concentration in wholesale markets, it was necessary to assume the opposite for TSOs' mechanisms to resolve congestions. This is a questionable assumption as TSOs' mechanisms to resolve physical congestions significantly vary across Europe and might entail other effective measures to prevent market power. However, the provisions result in the same level of market concentration and market power in all alternative configurations as in the status quo configuration.

#8 Facilitation of effective competition

Criterion 8 (facilitation of effective competition) comprises three sub-criteria: 1) short-term competition, 2) long-term competition, and 3) competition for cross-zonal capacity. While the sub-criteria for short- and long-term competition are assessed based on other criteria (criteria 6, 7, 9 and 10), competition for cross-zonal capacity is assessed based on the comparison of zone-to-zone power transfer distribution factors (PTDFs). For the sub-criterion of "short-term competition", all alternative configurations are assessed to perform worse than the status quo while they are all assessed to perform the same for the sub-criterion of "long-term completion". With respect to "competition for cross-zonal capacity", all alternative configurations perform better than the status quo, except for the Dutch alternative configuration, which performs worse and the combination DE2 + NL2, which performs the same as the status quo.

#9 Price signals for building infrastructure

Criterion 9 is based on criterion 10 and an additional analysis of the market's ability to detect physical congestions. Following the assessment foreseen in the BZR Methodology, all alternative configurations are assessed to perform the same as the status quo.

#10 Accuracy and robustness of price signals

The evaluation of this criterion is based on a comparison of zonal prices in the different configurations with the nodal prices of the respective zones. Stronger price correlation implies a better performance, i. e. a more accurate and robust price signal. The results suggest that the performance remains the same in all configurations as only minor changes in correlation can be observed. This is the case because while the split country is positively affected, other CE countries are negatively affected. Note that the methodology focuses the criterion very narrowly on the accuracy of price signals, while the robustness of prices signals is omitted. The completeness and value of this criterion should thus be improved in future assessments.

#11 Transition costs

The transition costs are estimated in a range from 1.2 € billion to 2.4 € billion for the German – Luxembourgish split configurations depending on the number of splits, which corresponds to a minimum lifetime of 4 to 9 years. For a split of the Netherlands, they would range between 47 € million and 429 € million, corresponding to a minimum lifetime of between 6 and more than 100 years. The transition costs for the combinations are calculated as the sum of the transition costs of the individual splits. A combination of a split of Germany–Luxembourg and the Netherlands would lead to transition costs in a range from 1.2 € billion to 2.8 € billion and a minimum lifetime in a range from 5 to 13 years.

#14 Adverse Effects of internal transactions on other BZs

The assessment of the two indicators as prescribed by the BZR Methodology offers mixed results, with alternative configurations performing the same, better, and worse compared to the status quo. Many elements outside of Germany that are mostly affected by loop flows in the status quo configuration show a significant reduction in loop flows after a split of the German–Luxembourgish BZ. This is the case because part of the exchanges within the German–Luxembourgish BZ that give rise to loop flows in the status quo need to compete for the allocation of cross-zonal capacity in a split configuration and hence become exchanges between the new German BZs. The flows resulting from these exchanges are labelled market flows and no longer loop flows. Due to the German internal flows needing to compete for the same capacity, there will be a reduction of German internal trades, and thus lower loop flows and more room for cross-border trades and internal flows in other BZs. This will ultimately result in higher welfare because the flows that generate the highest welfare will be selected in the flow-based market coupling (FBMC).

On some internal elements in Germany, we observe a large increase in loop flows after a split of the German–Luxembourgish BZ. In the status quo configuration, flows on German elements resulting from exchanges within the German–Luxembourgish BZ are de facto labelled internal flows. In a split configuration, the DE elements are subject to both internal flows and loop flows, resulting from the remaining internal exchanges within the smaller German BZs. The NL2 split only leads to relatively small changes in loop flows and has been assessed as performing the same as the status quo.

#16 Stability and robustness of BZs over time

Criterion 16 shall demonstrate the stability and robustness of BZ over time and is assessed based on evaluating the economic efficiency of each alternative configuration (calculated as depicted under criterion 4) for the sensitivity analysis. The BZR Methodology does not foresee an assessment of this criterion through a comparison of performance across scenarios (by e.g. comparing the economic efficiencies of the main scenario with the economic efficiencies of the sensitivity scenario).

In the CE BZRR, TSOs performed one sensitivity analysis with increased fuel and CO_2 prices (including updated redispatch markups). The economic efficiencies of the German–Luxembourgish split configurations and the combinations remain positive for the sensitivity analysis, while the economic efficiency of a split of the Netherlands becomes negative. This criterion performs consequently better for the German–Luxembourgish split configurations and the combinations, while it performs worse for the Dutch split configuration.

#19 Location and frequency of congestion

The location and frequency of congestion criterion is assessed in two steps: (i) an indicator of the percentage of time when the physical congestion was not previously detected in the day-ahead market, and (ii) the share of market congestion that occurred on cross-zonal network elements over the total market congestion on internal and cross-zonal elements.

The first indicator is already assessed within the analysis of criterion 9 (price signals for building infrastructure). The second indicator shows that the share of market congestions on cross-border elements decreases in all German–Luxembourgish splits and does not significantly change in the Dutch split. This can be explained due to specificities of the flow-based system.

Having more BZs add more dimensions in the flow-based domains, which could lead to more limiting critical network elements and contingencies (CNECs) at a time. Irrespective of the number of CNECs, there is a higher likelihood that more CNECs could limit the domain, explaining why more market congestions are present in splits.

According to the BZR Methodology, a declining share of market congestion on cross-border elements implies that this indicator performs worse than the status quo configuration.

The location and frequency of congestion criterion performs worse for all German–Luxembourgish splits and combinations, whereas it remains the same for the NL2 configuration.

#20 Short-term effects on CO_2 emissions

For each of the BZ configurations under investigation, the total volume of CO_2 emissions is determined as the sum of CO_2 emissions from each generation unit in each MTU after the optimisation of remedial actions. The performance remains the same for all configurations, since the results show only minor relative changes with a very similar CE total system dispatch (fuel utilisation).

#21 Short-term effects on RES integration

The short-term effects on renewable energy source (RES) integration is assessed based on the total amount of simulated fed-in energy from RES after optimisation of remedial actions. The performance remains the same for all configurations since the results show only minor relative changes.

In conclusion, based on the BZR Methodology, the criteria evaluation offers a mixed picture regarding the performance of the alternative configurations assessed compared to the status quo.

Step 3: Acceptability Assessment

TSOs conclude that even though some alternative configurations perform worse on some criteria, when considering the relative performance of these indicators criteria and the need to consider all criteria assessed in steps 1 and 2, taken together, all remaining configurations perform as "acceptable".

Step 4: Consolidation of the Results

Based on the previous steps, the following proposal for a potential BZ reconfiguration in CE has been developed.

As per Article 13 (1) (d) (iii) (2) of the BZR Methodology defined by ACER, the TSOs shall make a recommendation on whether to maintain or amend the BZs based on the insights of the BZ Study, and specifically the analysis for the 2025 target year. The BZR Methodology envisages that based on the BZ study performed, the TSOs recommend the BZ configuration with the highest monetised benefits compared to the status quo OR, an alternative BZ configuration that is among the "acceptable" ones but different from the one with the highest monetised benefits compared to the status quo, if they can duly justify the recommendation. Alternatively, the TSOs may recommend maintaining the status quo configuration, if they can duly justify that this is a better option than any of the "acceptable" alternative BZ configurations.

Based on the BZ Study, and by strictly applying the BZR Methodology and data requirements defined by ACER without any additional considerations, the results of the BZ Study indicate that the configuration with the highest positive monetised benefit compared to the status quo would be the split of Germany / Luxembourg into 5 bidding zones (DE5).

Strictly applying the BZR Methodology, this configuration results in an estimated positive monetised benefit of 339 € million EUR for the 2025 target year, with the value being the sum of positive and negative effects of welfare change in different countries. Put in perspective: this value is less than 1 % of the simulated system costs in the CE region.

This result does not take important additional aspects into account and therefore should not be seen in isolation but rather in combination with certain considerations, which are key for the eventual decision by the relevant Member States on the future BZ configuration. These key considerations should be applied to the decision on both (1) whether a change in BZ configuration should be implemented or not and (2), as the case may be, which potential alternative configuration should be implemented.

In addition to the outcomes of the BZ Study, the following considerations should be thoroughly assessed prior to the eventual decision of the relevant Member State(s) affected by a split.

Considerations related to the BZR Methodology:

- **Consideration 1:** The target year assumed for the study and the simulation is 2025. A potential implementation of a revised BZ configuration would require a lead time of at least 3 – 5 years. Therefore, the conditional proposal of splitting the bidding zone should be verified and confirmed by assessing the impact of the change of key influencing factors between 2025 and a potential implementation date around 2030. These factors include in particular the envisaged grid expansions in Germany.
- **Consideration 2:** It is an unfortunate reality that the input data used in the BZR is outdated. The majority of the input data was created in 2019 for the 2025 target year. To meet the methodological requirements on data consistency throughout the process, the data set could not be updated by TSOs. Therefore, before taking any decision on changing a BZ configuration, the robustness of the outcome with regard to more up-to-date input data should be reevaluated.
- **Consideration 3:** The robustness of the results should be assessed for a number of years beyond the year of implementation corresponding to the payback period of the bidding zone split. Considering the implementation time of 3 to 5 years and assuming a payback time of 4 to 9 years, the breakeven point would be reached by mid-2030 at the earliest. It should be ensured that the benefits actually materialise and breakeven points are reached within a reasonable timeframe to grant the required robustness over time.
- **Consideration 4:** It should be assessed and ensured that the negative implications related to market liquidity and transaction costs, which could affect markets and participants throughout Europe, do not exceed the potential welfare gain computed in this study.
- **Consideration 5:** The BZR has not thoroughly assessed the impact on balancing markets in case of a BZ split. It should be ensured that a potential BZ split does not have negative impacts on balancing markets (e.g. higher prices, excessive volume requirements) that are substantially reducing the potential welfare gain computed in this study or placing undue strain on the TSOs or market participants in the region.

Further considerations beyond the application of the methodology:

Conclusions solely based on simulation results are not suitable for decision-making when seen in isolation. The BZR Methodology focuses on a quantitative assessment of the various criteria, which is largely based on simulation results and leaves insufficient room for interpretation or consideration of an expert assessment.

Simulation results can only offer an indication of a future situation and they should always be carefully evaluated against the background of qualitative considerations, including:

- **Consideration 6:** The distributional effects of a potential BZ split will lead to different electricity prices and hence costs for certain consumer groups. While several consumers across Europe may benefit from lower electricity prices, it should be ensured that higher electricity prices for other consumers do not have excessive overarching negative economic implications that extend beyond the electricity market. For example, higher prices for price-sensitive industrial customers should not lead to the closure of industrial production. While the overall impact of the split might balance out for certain countries, others are likely to experience predominantly negative effects on their industries without any clearly identifiable benefits.
- **Consideration 7:** A potential BZ split will create obstacles for (industrial) consumers in accessing (renewable) electricity in newly created BZs where they are not located, i.e. power purchase agreements. When reconfiguring BZs, it should be ensured that such existing and future access arrangements are not undermined.
- **Consideration 8:** The simulations show that market-based revenues for RES in lower price zones substantially decline. Against this background, a potential BZ split will have negative implications for certain types of renewable electricity producers/RES that are not flexible regarding their location (i.e. offshore wind). It should be ensured that there are no negative implications for the investment decisions of those electricity producers leading to substantial deferrals or withdrawals of investment decisions in renewable electricity generation.
- **Consideration 9:** The annual support costs for RES already amount to many billions of euros. Existing renewable electricity producers located in lower priced BZs with guaranteed feed-in tariffs will have to receive even higher compensation for their electricity generation. It should be ensured that this is accepted by Members States/electricity consumers having to pay these higher subsidies.

The arguments and considerations outlined above could have a considerable impact on the interpretation and the outcomes of the BZ Study performed by the TSOs.[5]

Therefore, the TSOs recommend taking the above considerations into account for the final decision by the relevant Member States.

5 For information on the limitations of the Study please refer to section 6.6.

1.2 Nordic Bidding Zone Review Region

In the Nordic BZ Study, the performances of four alternative configurations were assessed and compared to the status quo. The assessed configurations only comprise alternative BZ delineation for Sweden. This reflects the results from the locational marginal pricing study where no major structural congestions were identified in eastern Denmark nor Finland. Alternative BZs for Norway were not part of the study.

Two configurations (Config 8 and 10) were proposed by ACER and two (Config 9 and 11) were modifications of the ACER proposals suggested by the Swedish TSO Svenska kraftnät, based on operational experience. In the following figure, the assessed configurations are schematically presented, followed by a brief description of the configurations.

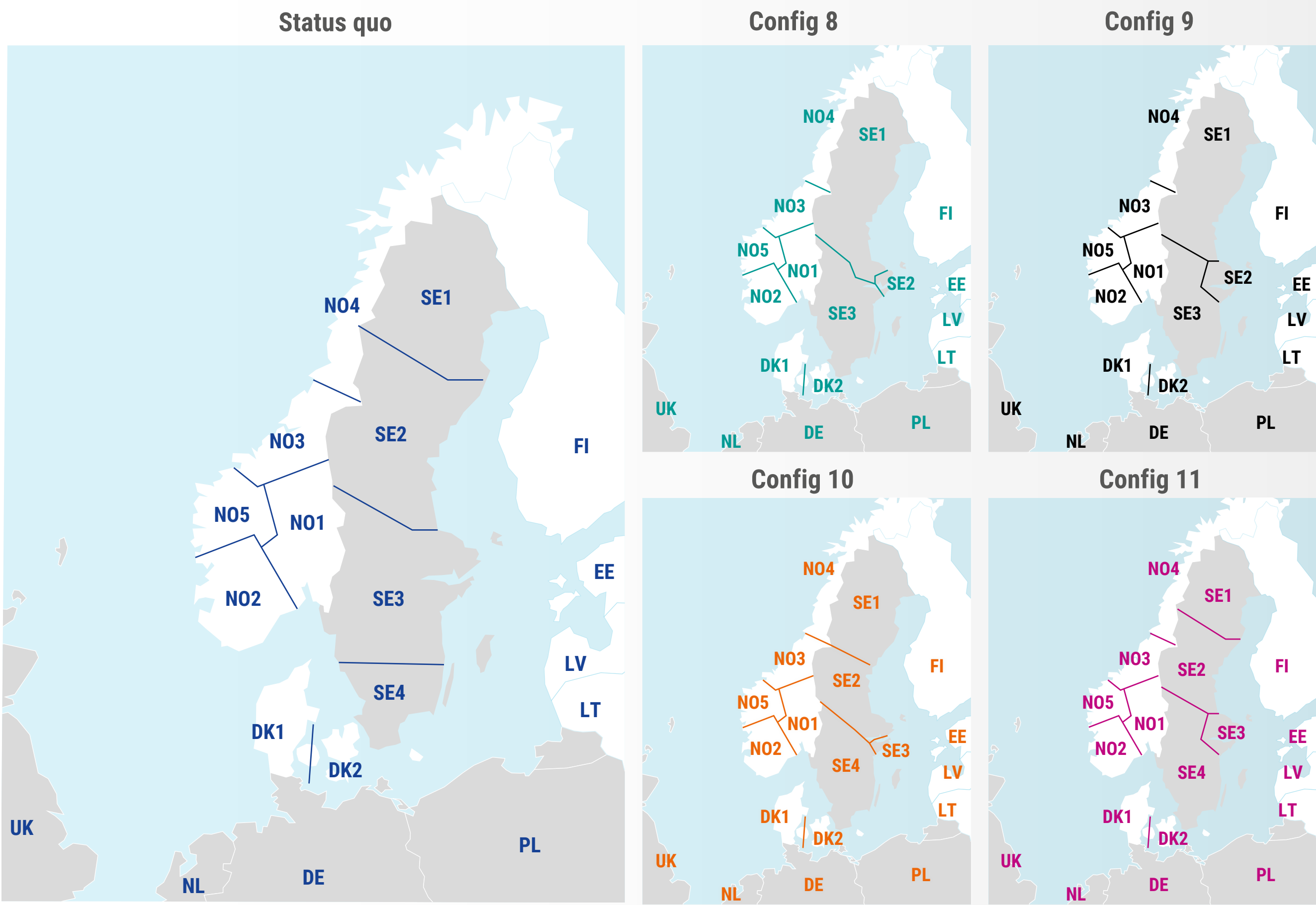


Figure 1: Schematic representation of the status quo and the four alternative configurations analysed in the Nordic BZ Study

- In the current configuration, Sweden comprises four BZs.
- In Config 8 and 9, Sweden has been split into three BZs where the two northern and two southern areas have been merged and a new area – referred to as the "central east area" – has been introduced.
- The central east area is also part of Config 10 and 11, although the setup and size of the BZ differs between the four configurations.
- In Config 10 and 11, Sweden is divided into four BZs as the two northern areas are maintained, although the borders are moved towards the south in Config 10.

The results for the Nordic assessment of alternative BZs according to step 1 and the economic efficiency criterion are presented in the table below.

Alternative BZ configuration compared to status quo	Change in market welfare [€ million]	Change in additional cost from redispatch [€ million]	Economic efficiency (change in socio-economic welfare) [€ million]	Accepted / rejected
Config 8	-1.5	5.5	-7.0	Rejected
Config 9	-38.4	-3.6	-34.8	Rejected
Config 10	-0.6	1.6	-2.2	Rejected
Config 11	-0.2	15.7	-15.9	Rejected

Table 4: Average change in socio-economic welfare over all climate years for the 2025 target year

The most important aspects of the economic efficiency result are listed below:

- For the Nordic region, none of the assessed alternative configurations perform better compared to the status quo.
- The market welfare from the DA market dispatch is lower for all configurations compared to the status quo. However, the changes in welfare are small for Config 8, 10 and 11.
- The costs for remedial actions from the redispatch simulations are higher for Config 8, 9 and 10 compared to the status quo, further contributing to the negative result for these configurations.
- Config 9 has an overall lower cost for remedial actions compared to the status quo. However, as the decrease in socio-economic welfare exceeds the redispatch cost-savings compared to the status quo, the overall result remains negative.

Following the result for step 1, all of the alternative BZ configurations were rejected and the recommendation from the Nordic study is to maintain the current BZ configuration in the region.

Due to the complexity of the study, simplifications were needed and issues encountered that have limited the study's outcome to some extent. The development of the model and the knowledge that has been built up during the course of the study are valuable aspects to include in potential future investigations to find improved BZ configurations for the Nordic region.

2 Introduction

The delineation of BZs is a major element in the design of the European electricity market. As defined by the regulation on the internal market for electricity (recast) (EU) 2019/943 (the IME Regulation), they are the largest geographical area within which market participants can exchange energy without capacity allocation. As part of the *Clean Energy for all Europeans* package, the entry into force of Article 14(3) of Regulation (EU) 2019/943 of the European Parliament and the Council on the Internal Market for Electricity triggered a BZR process. The output of the BZ Study – as requested in the IME Regulation – is a joint proposal of the TSOs participating in the BZ Study (CE BZRR and Nordic BZRR TSOs) to the relevant member states or NRAs to amend or maintain the BZ configuration ("the Proposal").

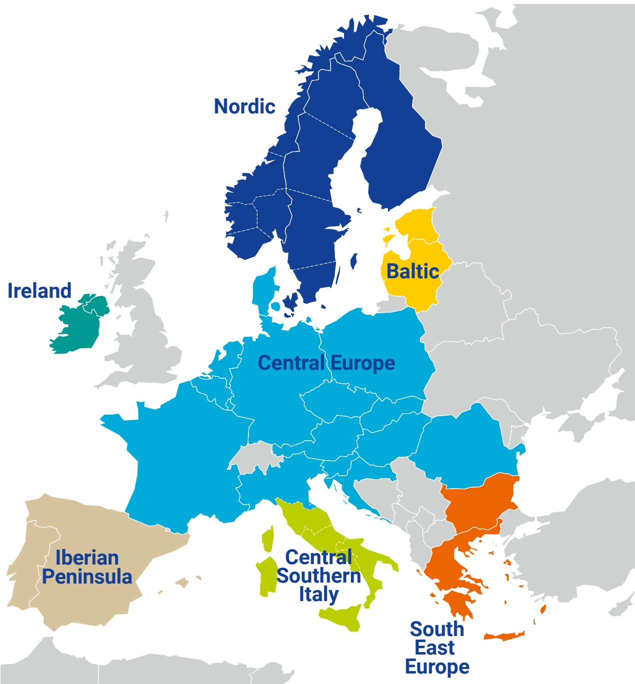


Figure 2: Definition of the bidding zone review regions as per Article 3(2) of the BZR Methodology

The BZR is a two-stage process. In the first stage (methodology, assumptions and alternative BZ configurations), the methodology and assumptions used in the review process and the alternative BZ configurations are defined. In the second stage (the BZ Study), the TSOs assess and compare the current BZ configuration and each alternative BZ configuration following the methodology and assumptions defined in the first stage.

This report is the result of the second stage, where two BZRRs – CE and the Nordics – were required to analyse alternative configurations, i.e. to perform the BZ Study.

According to Article 14(6) of the IME Regulation, the BZ Study is a twelve-month process in which alternative BZ configurations are assessed and compared to the status quo configuration, based on a wide variety of criteria including overall economic efficiency and social welfare, market liquidity, transition costs, and the ability to maintain operational security of the grid. The complexity of the exercise – among others – necessitated the additional time that the TSOs of the CE BZRR and Nordic BZRR took to finalise the BZ Study (28 months instead of 12 months as defined in the IME Regulation).

Luxembourg and Germany form a single integrated BZ. In this report, each time that reference is made to the German BZ, it is to be understood as the German–Luxembourgish bidding zone.

The report is organised into the following eight chapters:

- **Chapter 1** presents the executive summary of the report.
- **Chapter 2** is an introduction to the report.
- **Chapter 3** introduces the process, milestones and history of the current BZR process.
- **Chapter 4** describes the extensive interaction with stakeholders performed in the different phases of the process.
- **Chapter 5** presents the basis of the BZ Study, the BZR Methodology (decision ACER 29-2020), the regions participating in this BZ Study and the alternative BZ configurations (decision ACER 11-2022).
- **Chapter 6** describes the work performed in the CE region. The CE BZZR comprises the BZs of France, Belgium, the Netherlands, Germany – Luxembourg, Austria, Czech Republic, Poland, Slovakia, Hungary, Slovenia, Croatia, Romania, Denmark 1, and Italy 1 (Nord).
- **Chapter 7** describes the work performed in the Nordic region. The Nordic BZRR comprises the Swedish BZs SE1, SE2, SE3, and SE4, the Norwegian BZs NO1, NO2, NO3, NO4, and NO5, the Finnish BZ FI, and the Danish BZ DK2.

3 Current Bidding Zone Review Process

The BZR is performed in accordance with Articles 32–34 of the Commission Regulation (EU) 2015/1222 establishing a guideline on capacity allocation and congestion management (CACM) and in accordance with Article 14 of the IME Regulation.

In particular, Article 14(3) of the IME Regulation triggered a PAN-EU BZR process on 5 June 2019.

As explained in the introduction, the BZR is a two-stage process (CACM Art. 32.4):

- **Preparation:** In the first stage, the BZR Methodology has been developed according to Article 14(5) of the IME Regulation according to which the TSOs shall develop in three months a methodology and assumptions that will be used in the review process and the alternative BZ configurations, and NRAs shall approve it with unanimity within three months or send it to ACER, who shall also ultimately decide in three months.
- **Execution:** In the second stage, the BZ Study has been performed by the TSOs following the BZR Methodology defined in stage 1 within twelve months from the finalisation of stage 1 (IME Art. 14(6)).

3.1 Stage 1: Methodology, Assumptions and Alternative BZ Configurations

The preparatory step of the BZR included the following actions:

- **TSOs' BZR proposal on methodology and assumptions:** By 5 October 2019, All TSOs submitted a proposal for the methodology and assumptions to be used in the BZR process and for the alternative BZ configurations to All NRAs.
- **All NRAs feedback to TSOs' BZ review proposal:** By 17 December 2019, all NRAs requested TSOs to undertake the following in two months:
  - To complete the initial proposal for a BZR Methodology in view of the lack of alternative BZ configurations for the CE BZRR in the initial proposal for a BZR Methodology.
  - To provide data on historical congestions, on common grid models (CGMs) and results derived from locational marginal pricing (LMP) simulations, with a view to support the approval or develop additional alternative BZ configurations in case TSOs failed to provide them, including in the case of referral to ACER.
- **Updated TSOs' BZR proposal:** By 18 February 2020, the TSOs submitted an updated version of the initial proposal for a BZR Methodology to the NRAs.
- **Transfer of BZR decision from NRAs to ACER:** By 13 July 2020, the Chair of the Energy Regulators' Forum (ERF) – on behalf of all NRAs – informed ACER that they were unable to reach a unanimous decision and referred the decision to ACER as of 7 July 2020, pursuant to Article 14(5) of the IME Regulation.
- **ACER decision on BZR Methodology and assumptions:** By 24 November 2020, ACER issued its decision (Decision No 29/2020) on the methodology and assumptions to be used in the BZR process and the alternative BZ configurations to be considered. Additionally, Annex II of the BZR Methodology includes a request for TSOs to deliver the results of a European LMP simulation pursuant to Article 11 of the BZR Methodology. The results are intended as input for ACER to define the alternative BZ configurations for the BZR Study.

- **LMP Study:** Between 24 November 2020 and 4 March 2022, the Continental EU and Nordic TSOs performed the European LMP simulation and submitted the results to ACER, as requested by ACER decision 29/2020. The LMPs study has been published and is available on the ENTSO-E website.[6]
- **ACER's decision on alternative BZ configurations:** By 8 August 2022, ACER issued its Decision No 11/2022 on the alternative BZ configurations to be considered in the BZR process, pursuant to Article 5(7) of Regulation (EU) 2019/942 of the European Parliament and of the Council, and Article 14(5) of Regulation (EU) 2019/943 of the European Parliament and of the Council on the internal market for electricity.

On 8 August 2022, this decision triggered the start of stage 2 – the BZ Study – for the TSOs in the CE BZRR and Nordic BZRR, as alternative BZ configurations identified belonged to these two BZRRs.

The TSOs of the Baltic BZRR – in agreement with ACER – postponed their delivery of the LMP simulation due to the upcoming synchronisation. In its decision 17/2023 on the alternative BZ configurations to be considered in the BZR process for the Baltic region, ACER decided not to propose alternative BZ configurations for the BZRR Baltic, which also led to their exclusion from the BZ Study.

3.2 Stage 2: Bidding Zone Study

Based on the methodology and assumptions and alternative configurations approved by ACER in their two subsequent decisions (ACER 29-2020 and ACER 11-2022), the TSOs of the CE BZRR and Nordic BZRR started the BZ Study on 8 August 2022.

- On 8 December 2022, following the legal obligations set in Article 16 of the BZR Methodology, TSOs published the input data for the BZ Study. The input data[7] are available in Annex II and III of this report.
- On 3 May 2023, ACER and the NRAs provided feedback on the input data, scenario, sensitivity analyses, and assumptions to be used in the BZ Study.
- On 30 November 2023, TSOs participating in BZ Study responded to feedback from ACER and the NRAs on the input data, scenario, sensitivity analyses and assumptions to be used in the BZR of 3 May 2023.[8]

This report is the result of the BZ Study, and includes – as requested in the IME Regulation – a joint proposal for each region developed by the TSOs participating in the BZ Study and submitted to the relevant member states or their designated competent authorities to amend or maintain the BZ configuration following the steps defined in the BZR Methodology. Each joint proposal (for the CE BZRR and the Nordic BZRR) has been approved by the participating TSOs of the respective BZRRs.

6 https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Publications/Market%20Committee%20publications/ENTSO-E%20LMP%20Report_publication.pdf

7 During the course of the BZ Study the data and assumptions have been improved and hence the input data updated.

8 https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Network codes documents/NC CACM/BZR/240220_TSOs_formal_answer_to_ACER-NRAs_feedback_vF_CE_file_update.pdf

4 Stakeholder Involvement and Consultation Process

Stakeholder expertise is essential for any discussion of a fundamental market design element such as the adaptation of BZ configurations. ENTSO-E and the TSOs exchanged with a wide range of stakeholders from the start of the BZ Study, including the Bidding Zone Review Consultative Group (BZR CG), Market European Stakeholder Committee (MESC), and several interactions through public workshops and a public consultation.

4.1 Bidding Zone Review Consultative Group

The BZR CG serves as a platform for relevant stakeholders to interact with TSOs and facilitate exchanges with relevant stakeholders. It comprises representatives from seventeen stakeholders, including European market parties' associations, national market parties' associations from BZs of active BZRRs, as well as European research institutes and thinktanks.

From the start of the BZ Study, the following meetings had been organised with the consultative group. Minutes and slides are available for each consultative group meeting on the ENTSO-E website.[9]

- 5 November 2024: BZR CG online meeting
- 11 July 2024: BZR CG online meeting
- 5 December 2023: BZR CG online meeting
- 4 July 2023: BZR CG online meeting
- 3 March 2023: BZR CG online meeting
- 14 December 2022: BZR CG online meeting
- 13 October 2022: BZR CG physical meeting
- 1 September 2022: BZR CG online meeting
- 5 July 2022: BZR CG kick-off meeting

9 https://www.entsoe.eu/network_codes/bzr/#meetings

4.2 Market European Stakeholder Committees

The MESC has been established to inform and consult stakeholders on the implementation of the European Market network codes and guidelines. MESC participants are the key stakeholders involved in the implementation of European market network codes and guidelines.[10]

ENTSO-E and the TSOs provided regular updates to the MESC participants during the BZR process.

4.3 Public Consultation

Pursuant to Article 17 (4) of the BZR Methodology, the TSOs organised a public consultation between 19 July and 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 summary of the responses to the public consultation are available as an Annex of the reports on market liquidity and transaction costs and transition costs.

On 20 August 2024, a public webinar on the BZR public consultation was organised during the public consultation period. Slides and material for the meeting are available on the ENTSO-E website.[11]

4.4 Public Workshops and Publications

To ensure that all interested stakeholders were able to follow the BZR process, ENTSO-E and the TSOs organised additional public workshops and published several documents and material along the process.

Publications and public workshops[12] and further information and materials are available on the ENTSO-E website.

10 https://www.entsoe.eu/network_codes/esc/#market-stakeholder-committee
11 https://www.entsoe.eu/network_codes/bzr/#events
12 https://www.entsoe.eu/network_codes/bzr/#public-workshops

5 Starting Point of the Bidding Zone Study

This chapter describes the main output of the first stage of the BZR: the BZR Methodology (decision ACER 29-2020), as well as the alternative BZ configurations (decision ACER 11-2022).

5.1 Bidding Zone Methodology and Assumptions

The BZR Methodology was set by an ACER decision (ACER 29-2020) on 24 November 2020. It describes the methodology and assumptions to be used in the BZ Study as set forth in Article 14(5) of the IME Regulation and is the basis for this BZ Study.

The BZR Methodology Article 15 defines how the assessment of the performance of the alternative BZ configurations compared to the status quo configuration shall be performed along 22 criteria.

Article 13 of the BZR Methodology defines four steps to assess the performance of alternative BZ configurations, which shall lead to a recommendation:

Step 1: Assessment of the monetised benefits

In this step, TSOs shall assess the change in the economic efficiency according to Article 15(4), i.e. the difference between the change in total social economic welfare resulting from the day-ahead market dispatch and the change in costs of remedial action optimisation (RAO) between the status quo and alternative configuration. Alongside the economic efficiency, as far as technically possible, the benefits or losses derived from other criteria that can be potentially monetised shall also be included in the assessment. In general, if the result is positive (meaning that the alternative configuration has higher monetised benefits compared to the status quo), the assessment continues in step 2. If the result is not positive, the assessment will not continue and the process will stop after the first step.

Step 2: Assessment of all other criteria

All other criteria not assessed in step 1 are evaluated and conclusions are drawn concerning whether the alternative configurations perform better, worse, or the same compared to the status quo.

Step 3: Acceptability assessment of the alternative BZ configurations

For alternative BZ configurations that perform worse than the status quo configuration for at least one criterion pursuant to step 2, TSOs shall assess the acceptability of each of these configurations and consult NRAs in case they identify potentially unacceptable configurations.

Step 4: Consolidation of the results of the BZ study

This step comprises delivering the proposal from TSOs. As per Article 13(1)(d)(iii)(2) of the BZR Methodology defined by ACER, the TSOs shall make a recommendation on whether to maintain or amend the BZs based on the insights of the BZ Study, and specifically on the analysis for the 2025 target year. The BZR Methodology envisages that based on the BZ Study performed, the TSOs should recommend the BZ configuration with the highest monetised benefits compared to the status quo, and an alternative BZ configuration that is among the "acceptable" ones but different from the one with the highest monetised benefits compared to the status quo, if they can duly justify the recommendation.

Alternatively, the TSOs might recommend maintaining the status quo configuration if they can duly justify that this is a better option than any of the "acceptable" alternative BZ configurations.

The figures below summarise the assessment process.

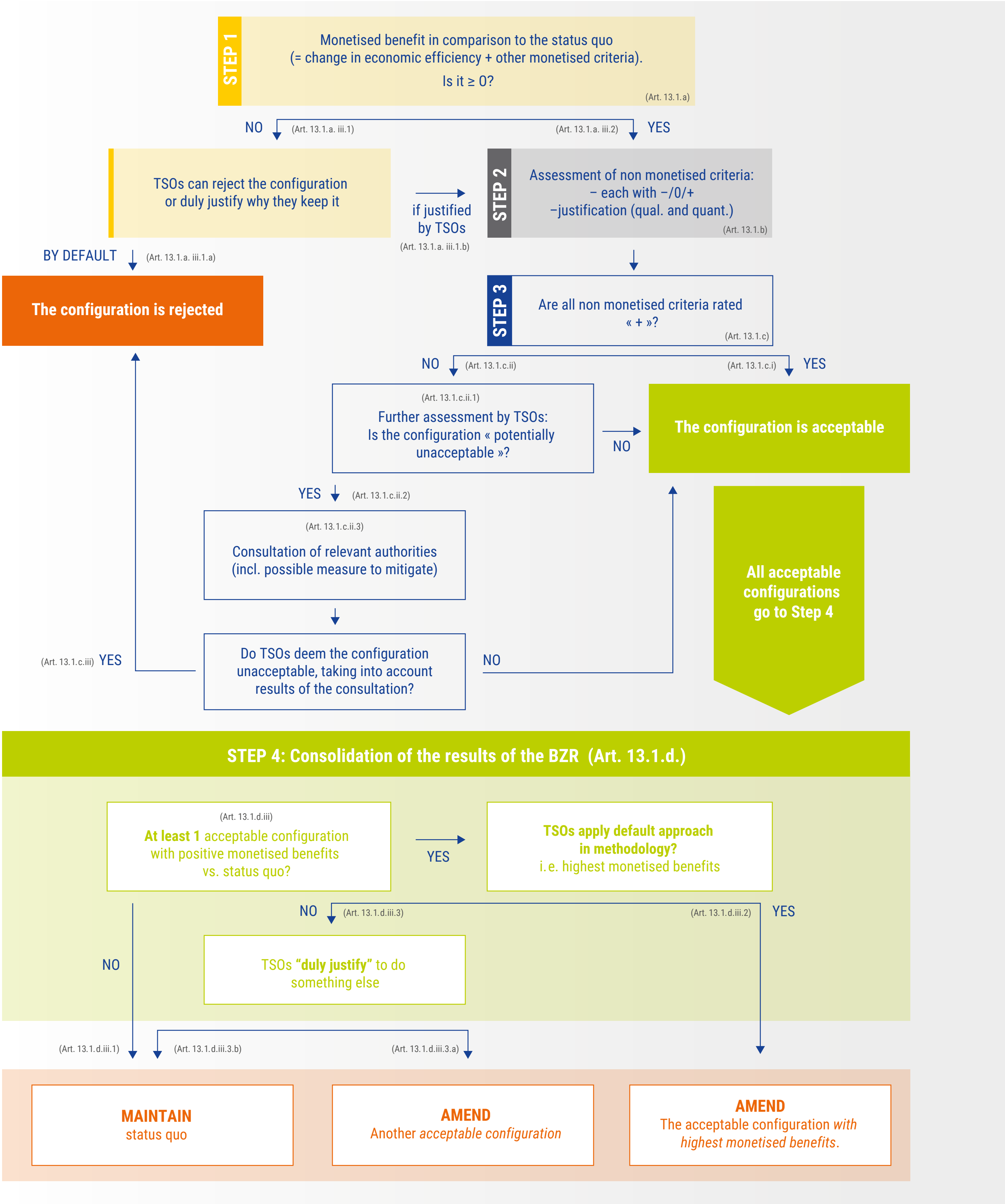


Figure 3: Illustration of Article 13 of the BZR Methodology

The BZ assumptions and input data are described in Annex II and III of this report.

5.2 Alternative Bidding Zone Configurations

The alternative configurations to be considered for the BZ Study for all EU member states were set for the CE BZRR and Nordic BZRR in ACER decision No 11/2022 of 8 August 2022. The alternative configurations are presented in Table 5. Detailed maps of the alternative configurations can be found in Annex I. In the BZ Study, the alternative configurations are compared to the status quo configuration (SQ).

Configuration identifier according to ACER decision	BZRR	Member state	Number of bidding zones	Identifier in this report
2	Central Europe	Germany – Luxembourg	2	DE2
5	Central Europe	France	3	FR3
6	Central Europe	Italy	2	IT2
7	Central Europe	Netherlands	2	NL2
8	Nordic	Sweden	3	Config 8
9	Nordic	Sweden	3	Config 9
10	Nordic	Sweden	4	Config 10
11	Nordic	Sweden	4	Config 11
12	Central Europe	Germany – Luxembourg	3	DE3
13	Central Europe	Germany – Luxembourg	4	DE4
14	Central Europe	Germany – Luxembourg	5	DE5

Table 5: Alternative BZ configurations [13]

5.3 BZ Review Regions Performing the Bidding Zone Study: Central Europe and Nordic Bidding Zone Review Regions

Following ACERs decision 11-2022, the regions performing the BZ Study are the ones for which alternative configurations have been defined, i. e. the CE BZRR and Nordic BZRR.

The Nordic BZRR comprises the Swedish BZs SE1, SE2, SE3, and SE4, the Norwegian[14] BZs NO1, NO2, NO3, NO4, and NO5, the Finnish BZ FI, and the Danish BZ DK2.

The CE BZRR comprises the BZs of France, Belgium, the Netherlands, Germany–Luxembourg, Austria, Czech Republic, Poland, Slovakia, Hungary, Slovenia, Croatia, Romania, Denmark 1, and Italy 1 (North).

13 An explanation of the reasons for choosing the fallback configurations identified as 12, 13 and 14 in ACER 11-2022 is provided in section 6.3.17.

14 The Nordic BZR comprises the BZs in the Nordic synchronous area. However, since Regulation (EU) 2019 / 943 has not been incorporated into the European Economic Area (EEA) agreement, alternative BZs in Norway will not be considered in this review.

6 Results in the Central Europe Bidding Zone Review Region

6.1 Introduction

This chapter offers insights into the setup chosen in the CE BZRR to perform the BZ Study based on the BZR Methodology. In particular, section 6.1.1 offers a brief description of the modelling chain that was developed. In section 6.1.2, the results of the simulations that led to the assessment of the four steps described in chapter 6 are detailed.

The BZ Study is a complex process, with a strong dependency on input data, assumptions, and the modelling chain to perform computationally intensive simulations. Overall, the status quo and ten alternative BZ configurations were analysed. Each configuration was assessed for three climate years at an hourly resolution, corresponding to a total of 33 simulation years. Additionally, a sensitivity analysis was conducted for one climate year for the nine most promising configurations, including the status quo. This leads to a total of 42 full-year simulations, performed across five distinct calculation steps, namely: 1) base case creation (market result forecast), 2) capacity calculation, 3) FBMC, 4) RAO, and 5) loop flow analysis. These calculation steps were executed sequentially as each step receives data from the preceding one. A very detailed model of the CE power system was used for the analysis, comprising approximately 17,000 nodes, 15,000 generators and energy storages, 17,500 lines, 5,000 transformers, and 7,000 CNECs. The vast dimension of this model necessitates an automated process for the analysis in the form of a modelling chain.

6.1.1 Modelling Chain

The modelling chain comprises five calculation modules using three different software applications. All calculations modules are executed in the Varied Market-Model Operation System (VAMOS) online simulation environment. VAMOS enables the automated execution of individual calculation modules in calculation chains. Different software tools (e.g. BID3, Integral and Transmission Network Analyzer; TNA) in the modelling chain are orchestrated with interfaces between the applications, a common VAMOS input data standard, and a scheduling algorithm. TSOs could modify data, carry out scenarios, and view the results in the VAMOS web-based user interface using personalised accounts.

Figure 4 and Table 6 provide an overview of the modelling chain and a brief description of the different calculation modules. Further details on the modelling chain and assumptions made are provided in Annex II.

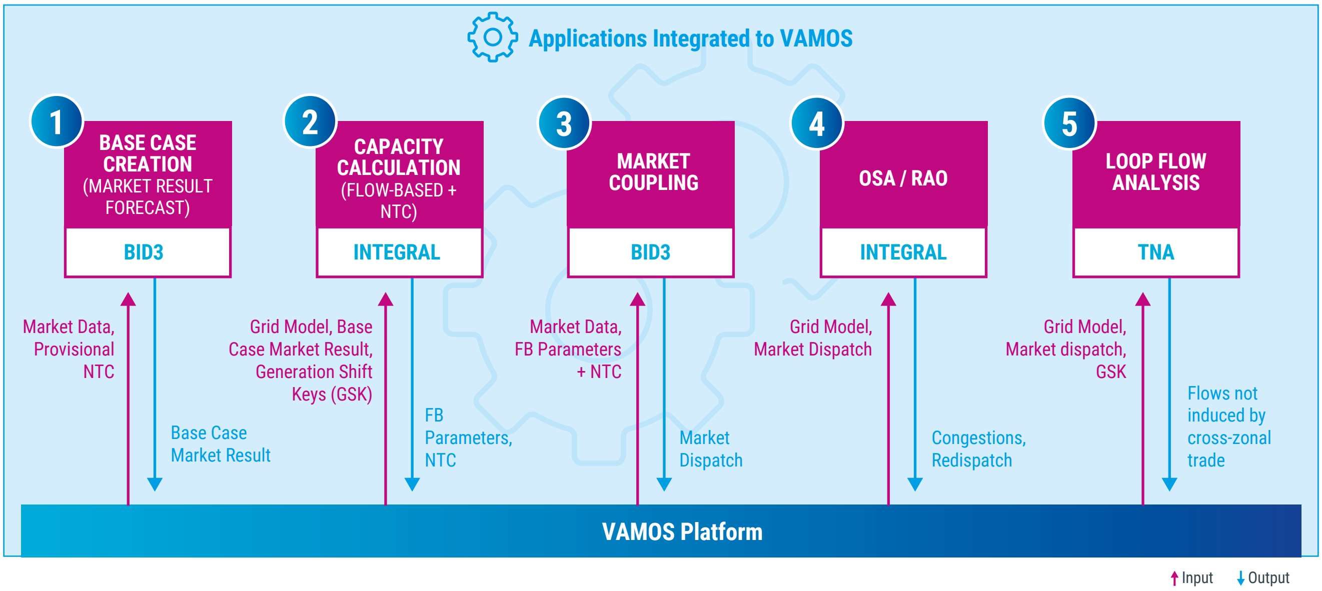


Figure 4: CE modelling chain

Module	Software Application	Brief Description
Base Case Creation	BID3	The purpose of this module is to obtain a market result forecast to be used for the capacity calculation. Hence, the market simulation is performed for the full EU using fundamental market data (generation, load, RES, and fuel prices). The base case market dispatch is used as a basis to perform the capacity calculation. Additionally, it sets the exchanges with the non-CE region for the flow-based CE simulation and estimates the welfare impacts of the BZ splits on the non-CE regions.
Capacity Calculation	Integral	The capacity calculation is performed using the flow-based and cNTC approaches. It comprises several steps, such as calculating GSKs, zonal PTDFs and RAMs, CNEC filtering, and presolve. The FB parameters and cNTC values obtained in the capacity calculation are used as input to the flow-based market coupling module.
Market Coupling	BID3	The flow-based market coupling simulation is performed using the FB parameters and cNTCs calculated for the CE region, as well as fundamental market data. Flows to CE-external regions are obtained by the base case creation results. The resulting market dispatch is used as input for the subsequent OSA / RAO and loop flow analysis modules.
Operational Security Analysis (OSA) and Remedial Actions Optimisation (RAO)	Integral	Besides the market dispatch, one of the main inputs for the OSA and RAO is the available remedial actions (redispatch potential available). A DC load flow is used to identify congestions, and a linear optimisation problem is solved to derive the cost-optimal solution for alleviating congestion. The final dispatch after RAO (including redispatching) is used as input for the loop flow analysis.
Loop Flow Analysis	TNA	The loop flow analysis is performed by applying a power flow colouring (PFC) approach. The main result of the loop flow analysis is the share of the flows not induced by cross-zonal trade.

Table 6: Brief description of the different calculation modules in the CE tool chain

Optimisation problems are solved on VAMOS hardware using 288 processor cores and 4.3 TB of RAM. The main results of each module of the modelling chain are briefly described in the following sections.

6.1.2 General Simulation Results

6.1.2.1 Base Case Creation: All-EU Net Transfer Capacity Market Coupling

The first step of the modelling chain is the base case creation, which serves as input for the flow-based capacity calculation. It is performed through an all-EU market coupling simulation in which all European BZs are modelled in terms of their zonal demand, available power plants, and fuel prices. The exchange of electricity between bidding zone borders (BZBs) is based on the net transfer capacity (NTC) approach. In this approach, the maximum bilateral exchange between neighbouring BZs is limited to a fixed value by TSOs based on thermal line limits, and a security margin to ensure the safe operation of the grid despite uncertainties in estimating flows, inaccuracies in measurements, and unintentional deviations in physical flows. BID3 runs a time-coupled market simulation for all hours of the year, optimising the dispatch of the power plants to maximise social welfare, while cross-border exchanges between BZs are limited to the fixed NTC constraints.

As this is the only step in the modelling chain where non-CE BZs are also modelled, several outputs from the all-EU NTC base case simulations are used as inputs for subsequent simulation steps:

- hourly net positions and generation dispatch for each BZ are used in the subsequent CE flow-based capacity calculation;
- flows towards regions external to CE, which are then fixed for the FBMC analysis; and
- economic welfare results for non-CE regions.

Figure 5 presents the change in the net position of different European regions for each alternative configuration. The main impacts are observed on the German–Luxembourgish splits and the corresponding combinations.

In this case, an increase in the CE net position is observed – and to a lesser extent in all other southern regions – together with a decrease for the Nordics and Baltics, corresponding to a reduction of exports from the Nordic region towards CE with respect to the status quo configuration. This effect is attributed to two main reasons. On the one hand, the split in the German–Luxembourgish BZ leads to forming an exporting zone in the north of Germany with high shares of renewables and low market prices. As the interconnectors from the Nordics are connected to this lower price zone, the split reduces imports from the Nordics towards Germany and the rest of CE while increasing exports from CE towards the Baltics. Furthermore, the German splits lead to an increase in market- based RES curtailment in the new RES-rich German zones (see the analysis in section 6.1.2.3.1). The reduction of imports translates into a reduction of the net position of the Nordics and a subsequent increase in the net position of the CE and other neighbouring regions.

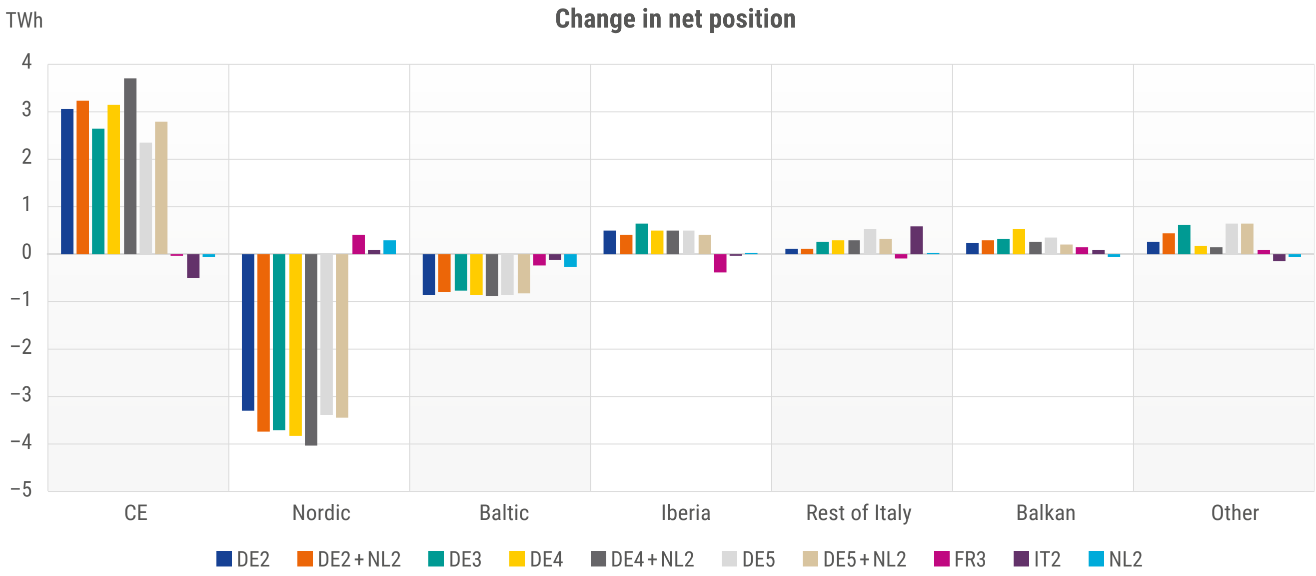


Figure 5: Change in net position relative to the status quo based on the all-EU NTC market coupling, averaged across climate years

6.1.2.2 Capacity Calculation

Available network capacities for electricity trading are determined in the capacity calculation process, considering the technical constraints of the electricity grid. There are two main methods to calculate the available capacities per border, namely coordinated NTC (cNTC) and the flow-based method. For the borders applying the cNTC method, three approaches can be applied depending on the specifics of that border.

As the CE BZRR comprises borders in several CCRs, it was necessary to simulate the capacity calculation using all four different methods:[15]

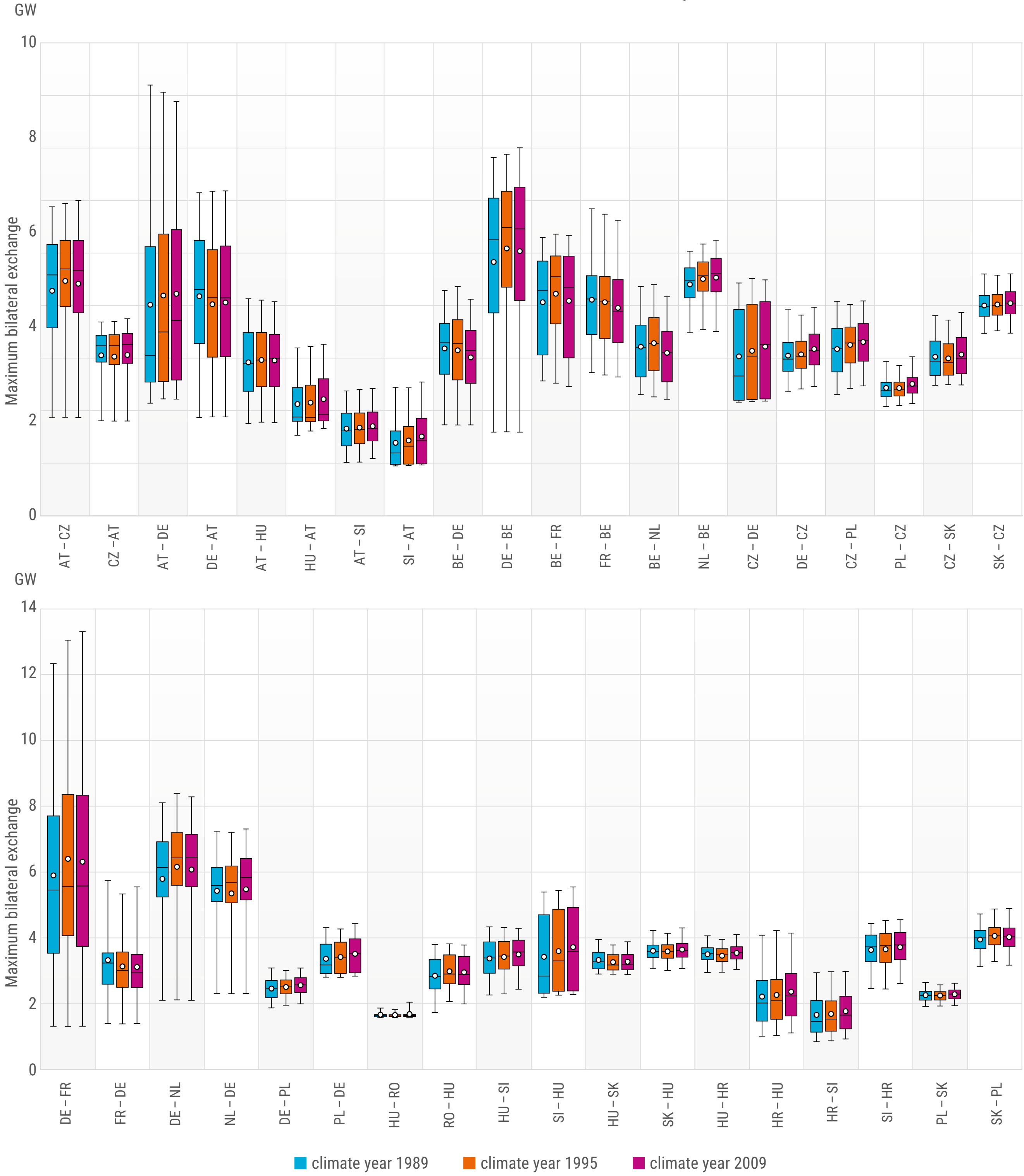
- The flow-based approach was used for BZBs in the Core CCR.
- The cNTC approach based on thermal ratings was used for BZBs in Hansa CCR (except the DE/LU-DK1 border) and PL-LT.
- The cNTC method based on CNECs and generation shift keys (GSKs) was used for BZBs in Italy North CCR and on the DE/LU-DK1 border, as elaborated upon in Annex VI.
- The cNTC approach based on TYNDP was used on all other borders as these are either not affected by changes in the BZ configuration or they are borders with third countries.

Flow-based Method

The available trading capacities are represented in a so-called flow-based domain, which is limited by a set of Critical Network Elements and Contingencies (CNECs) according to their Remaining Available Margins (RAMs), calculated within the capacity calculation process. Additionally, the impact of each change in net position of the individual market areas within the CCR on the RAM is determined within this step of the toolchain. In order to analyse the capacity calculation results, among others, the maximum bilateral exchanges (maxBEX[16]) of the market areas within the flow-based region are assessed. In the following, the effect of splitting a BZ on the capacity calculation results is exemplarily described using the status quo and DE2 scenarios.

15 Annex II, where the capacity calculation approach per border is clarified.
16 The maxBEX describes the maximum possible bilateral trade between two market areas, assuming no trade between all other market areas.

Figure 6 shows the maxBEX values for physically connected borders within the flow-based region for the three simulated climate years of the status quo configuration[17] in the form of boxplots.[18] The maxBEX values show strong variability for some borders, such as AT – DE, DE – BE, and DE – FR. This is due to the fact that all-EU dispatch results are the key input for the initial load flow calculation, which forms the basis for estimating the CNEC- and MTU-specific RAM and consequently the maxBEX values. For example, the maxBEX on the AT – CZ border varies between 2 and 6.5 GW across all simulated climate years and for 90 % of the MTUs.



Note: The whiskers of the boxplots represent the 5th and 95th percentiles. The white dots show the mean.

Figure 6: MaxBEX values for CE borders for the status quo configuration for the three simulated climate years

17 Please note that Luxembourg is part of the BZ labelled in the figures of this chapter as DE or – in case of the DE2-zone split – as DEJ2.

18 The box represents the interquartile range, capturing the middle 50 % of the data, and contains a horizontal line indicating the median. The whiskers represent the 5th and 95th percentiles, showing the general range of the maxBEX.

Figure 7 shows the maxBEX of the Austria–Germany and Germany–France borders in the positive direction for the status quo configuration for climate year 1989 as a series over time. As visible in the graphs, the maxBEX values of the capacity calculation vary considerably across the simulated MTUs. A seasonal pattern can be identified for the Germany–France maxBEX, whereby the load flow situation in the region during the summer period across the border between Germany and France is driven by photovoltaic in-feed in most simulated MTUs, leading to increased maximum bilateral trading capacities being available at this border.

From the graph, another aspect of the capacity calculation setup is notable, namely that due to the application of a minRAM, the maxBEX at least reaches a minimum of several hundred MW in every MTU.

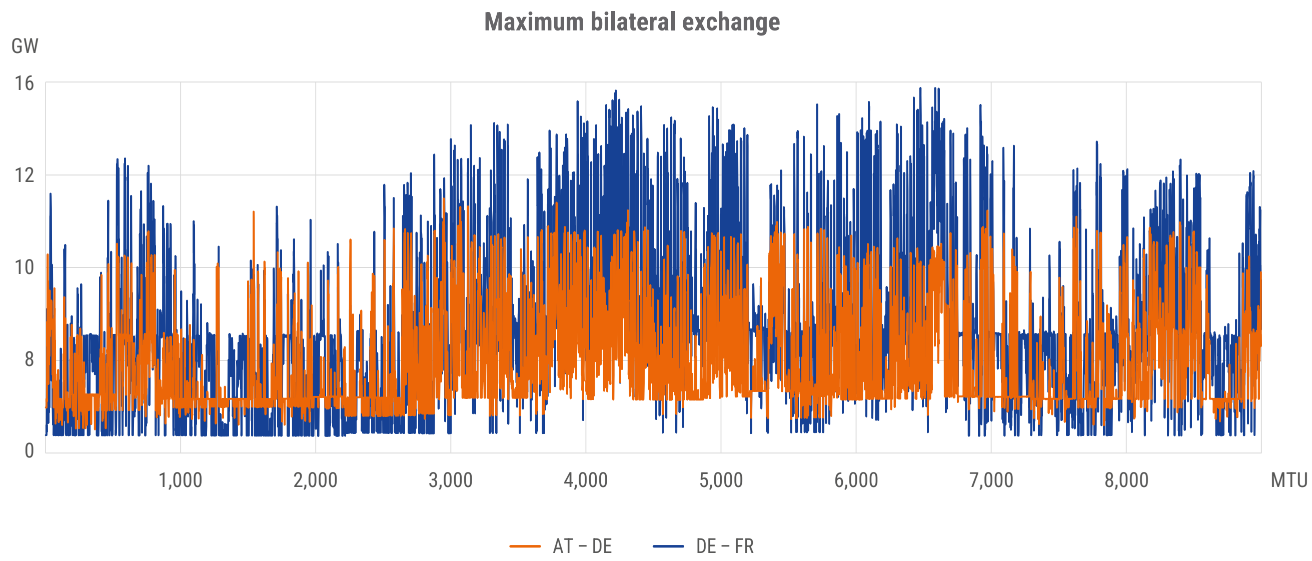


Figure 7: MaxBEX timeseries for selected borders in a positive direction for the status quo in climate year 1989

Figure 8 shows the maxBEX values for the three different climate year simulation results of the DE2 configuration. The resulting maxBEX values change due to the updated NTC simulation results, GSKs, and relevant CNECs resulting from the split. While in the status quo the trade within the single German–Luxembourgish BZ is unrestricted, the two-zone split leads to a maximum limit of possible trade. The impact on maxBEX values for borders surrounding Germany can also be noted. Among others, in the case of the DE2 zone split, the Netherlands has two market area borders with Germany instead of one in the status quo configuration. For example, the simulation results show that trade from the Netherlands to the southern German–Luxembourgish zone is possible between 2 GW and around 8 GW for 90% of the MTUs in the DE2 zone split scenario (assuming no other trade within the flow-based region).

Note: The whiskers of the boxplots represent the 5th and 95th percentiles. The white dots show the mean.

Figure 8: MaxBEX values for CE borders for the DE2 configuration for the three simulated climate years

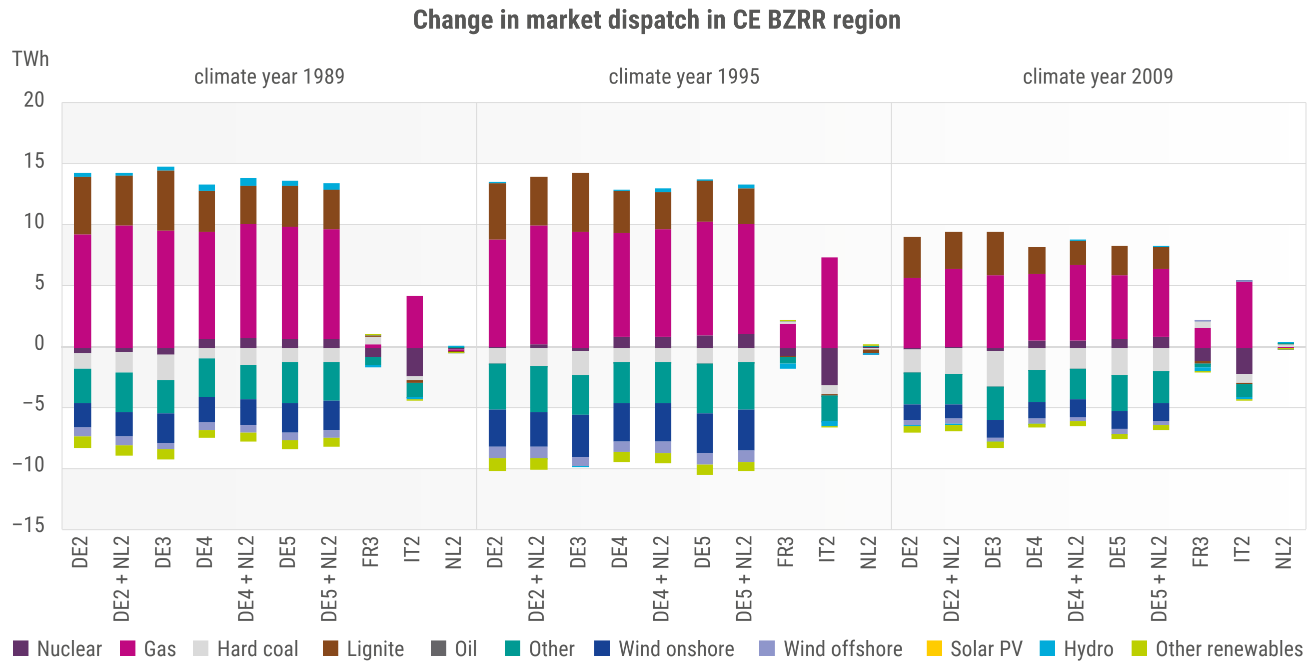
6.1.2.3 Flow-based Market Coupling

Following the all-EU market simulation and capacity calculation, an FBMC simulation is run for CE. For this simulation, the results for the zones outside of CE are fixed based on the results of the all-EU simulation and kept in the model as fixed hourly exchanges, while the available capacities for all internal borders are defined based on the results from the CC module. The CE FBMC simulations return the hourly dispatch for each power plant, hourly market clearing prices, and hourly net positions of each BZ, as well as the socio-economic welfare from the market dispatch, i.e. the sum of producer surplus, consumer surplus, and congestion revenue. These results are used as inputs for the next simulation modules and for the assessment of different criteria.

In terms of the results from the FBMC simulation, first the change in the market dispatch when moving from the status quo to a new configuration is presented (RES and conventional units). Next, the impact of this updated dispatch on the formation of zonal market prices is presented, followed by the consequent changes in net positions in each zone. Finally, the impact on the market welfare is discussed. The results are presented for the different alternative configurations, including the combinations as explained in section 6.2.

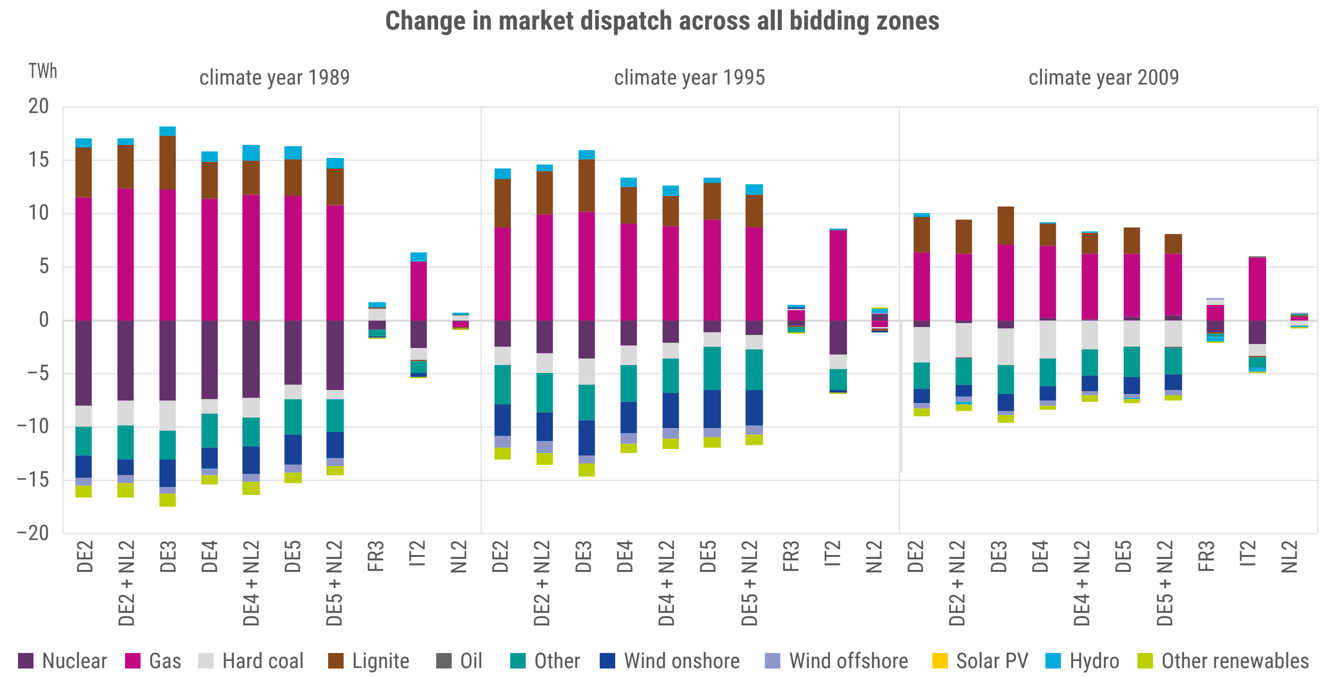
6.1.2.3.1 Market Dispatch

The implementation of BZ splits leads to changes in the market dispatch. Figure 9 and Figure 10 show the change in market dispatch relative to the status quo for the alternative BZ configurations for the CE region and all bidding zones, respectively. The figures show the largest changes in market dispatch for the German–Luxembourgish splits, followed by the Italian split. The main difference between the figures for only CE and all BZs is the change in nuclear generation. This will be further explained below, where more detailed graphs of the changes in generation for selected configurations are included.



Note: A reduction in renewable generation indicates that (additional) renewable generation will be curtailed in the market dispatch.

Figure 9: Change in market dispatch relative to the status quo based on the CE FB market simulation



Note: A reduction in renewable generation indicates that (additional) renewable generation will be curtailed in the market dispatch.

Figure 10: Change in market dispatch relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation

DE configurations: Figures 11 and 12 show detailed changes in market dispatch for the DE2 and DE5 configurations, respectively. The other alternative configurations for the German–Luxembourgish BZ show largely the same pattern.

Both splits result in a surplus of RES generation in the northern part of Germany due to a high concentration of RES in that region. When a surplus of RES generation cannot be exported from the northern German BZ, this will lead to market-based curtailment and negative prices. The figures confirm this with a reduction in wind generation and other renewables.[19] However, no solar PV curtailment is observed due to the lower accumulation of solar PV plants in the respective zones and the fact that solar PV was considered to bid at a lower price threshold (−20 € / MWh) than wind, reflecting solar PV plants' lower controllability due to their distributed nature.

Additionally, the following generation shifts are observed in the German–Luxembourgish splits: a) a reduction of imports from the Nordics, mainly reflected in a reduction in nuclear generation; b) a reduction of gas and other (non-renewable)[20] generation in northern DE zones (due to surplus RES generation); c) reduced gas and hard coal generation in the Netherlands due to reduced exports towards Germany; and d) a minor reduction in gas production in Poland and Belgium. The surplus in the northern part of Germany is associated with a deficit in the south of Germany. The main compensation of the energy deficit is gas production from Austria, Italy, the Czech Republic, France, and Hungary, and lignite in Germany and the Czech Republic. For the DE5 configuration (and DE4, not shown here), a slight increase in nuclear production is observed in France, reflecting increased exports.

19 Other renewables generation in Germany mainly reflects small-scale biomass plants.
20 Other (non-renewable) generation in Germany mainly reflects small-scale combined heat and power (CHP).

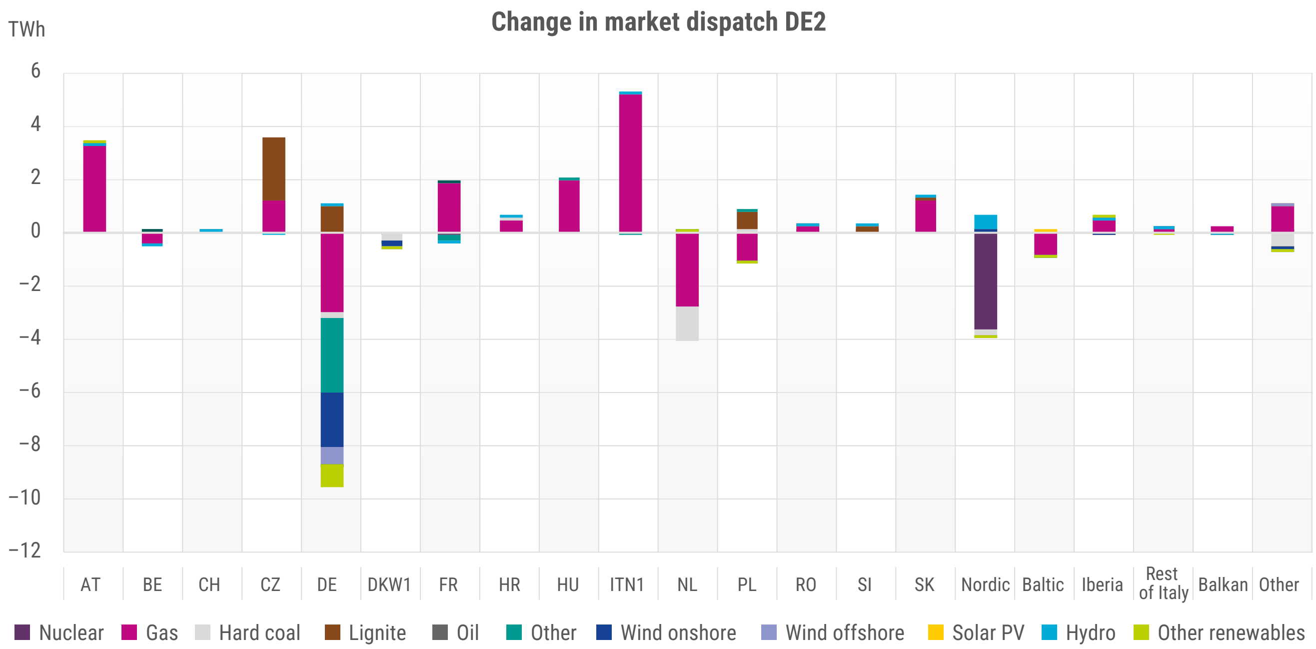


Figure 11: Change in market dispatch in the DE2 configuration relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation, averaged across three climate years

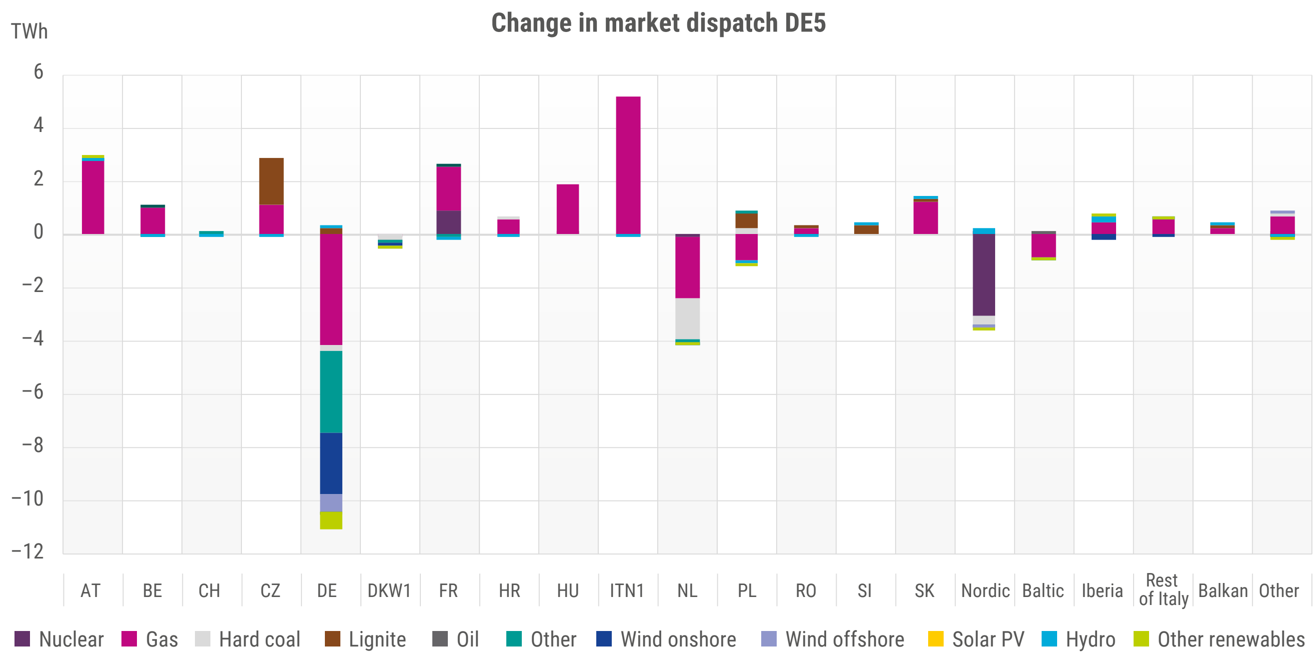


Figure 12: Change in market dispatch in the DE5 configuration relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation, averaged across three climate years

FR3 configuration: Figure 13 shows the change in market dispatch for the FR3 configuration. The FR3 configuration leads to reduced exports from France towards Italy. This results in an increase in gas generation in Italy. Also decreases in generation in Belgium and Germany are observed.

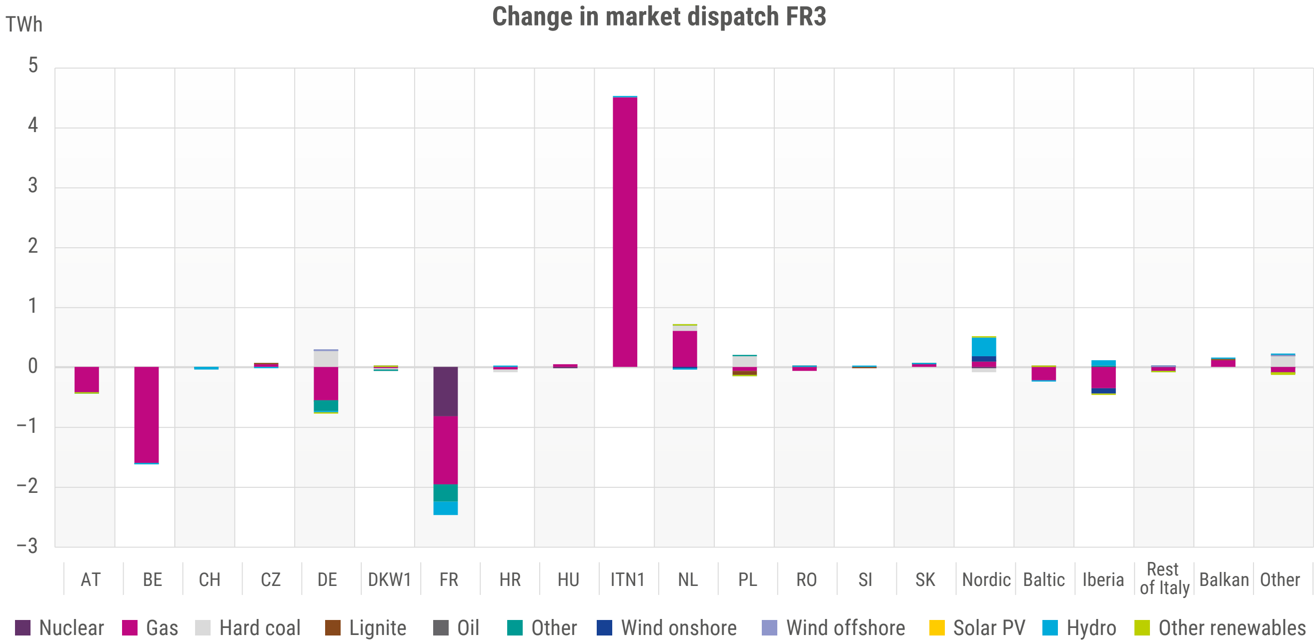


Figure 13: Change in market dispatch in the FR3 configuration relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation, averaged across three climate years

IT2 configuration: Figure 14 shows the change in market dispatch for the IT2 configuration. The introduction of the split leads to a better representation of capacity restrictions in northern Italy, especially in the eastern part of Italy North with respect to imports from France. This leads to reduced imports from France, resulting in the reduction of nuclear and gas generation in France, and – to a lesser extent – reduced gas generation in Germany and Belgium. This missing energy from imports is compensated by increased gas-based generation in Italy.

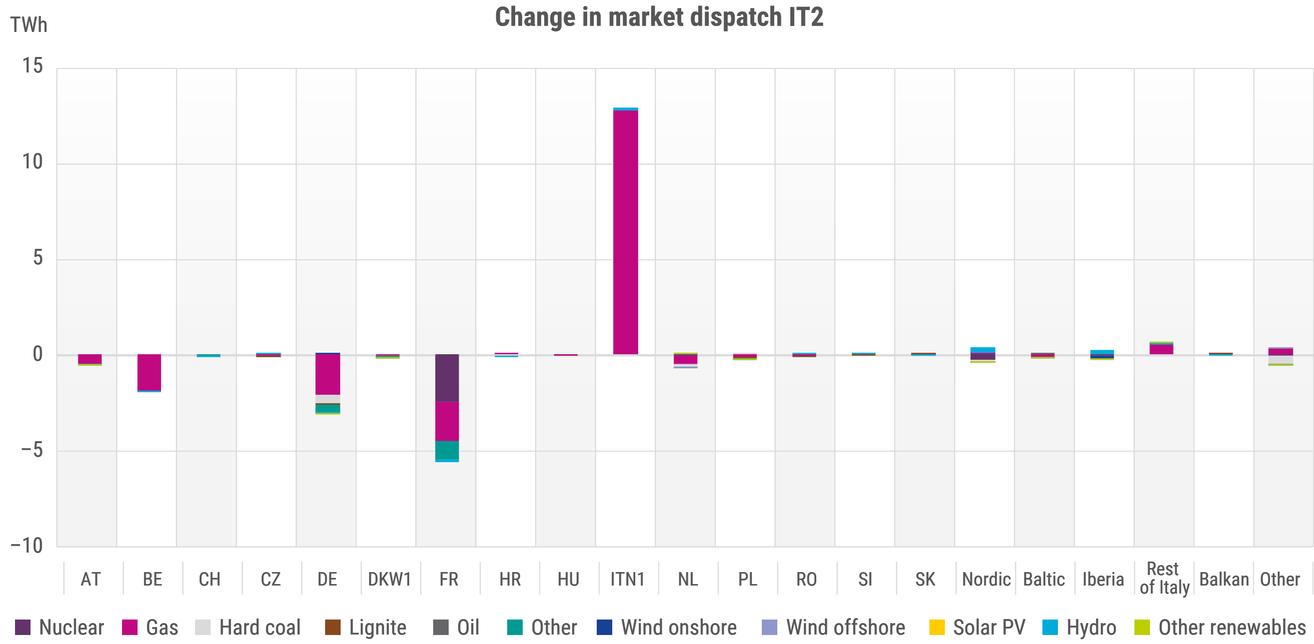


Figure 14: Change in market dispatch in the IT2 configuration relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation, averaged across three climate years

NL2 configuration: Figure 15 shows the change in market dispatch for the NL2 configuration. Compared to the other alternative configurations, there are only small changes in market dispatch in the NL2 configuration (note the y-axis in the graph).

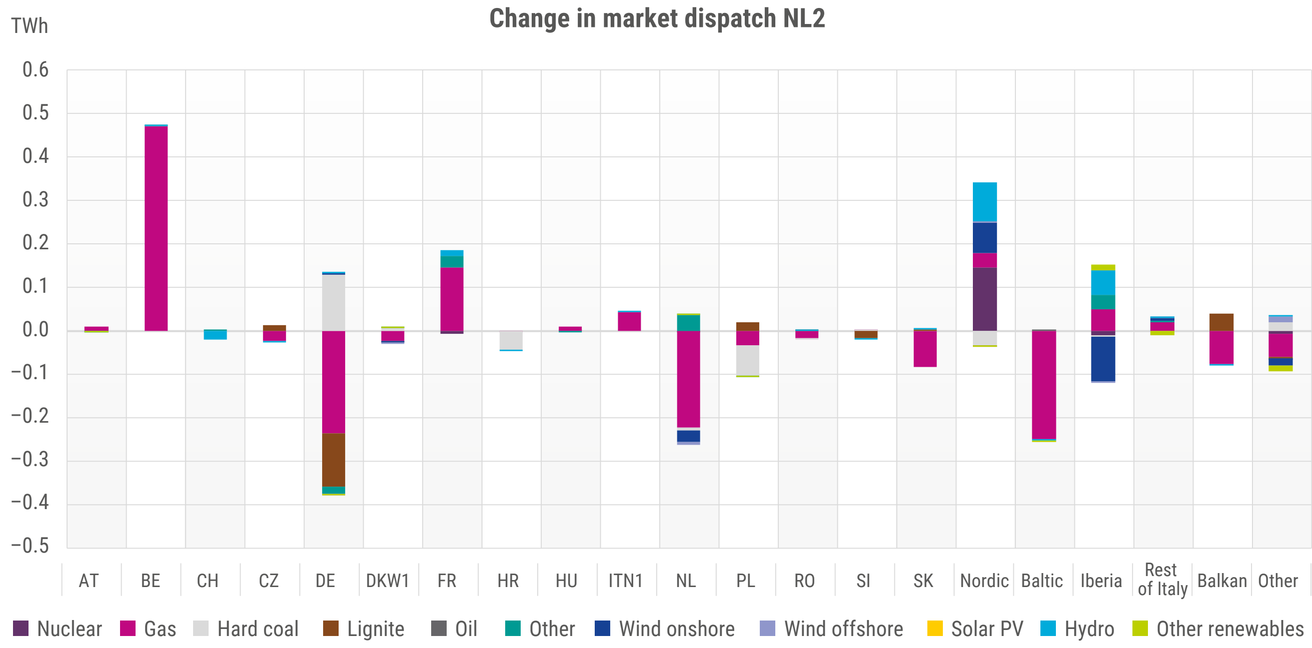


Figure 15: Change in market dispatch in the NL2 configuration relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation, averaged across three climate years

6.1.2.3.2 Market Clearing Prices

Average market clearing prices per Bidding Zone

Figure 16 presents the arithmetic average market clearing prices across all MTUs in the three simulated climate years, for the status quo and alternative configurations.[21] In the status quo, prices gradually increase from west-northwest towards east-southeast CE. The BZ reconfigurations lead to wider changes in the formation of prices, indicated in the configuration graphs with dedicated arrows and respective colours (orange in case prices increase by more than 1 €/MWh, green if prices decrease by more than 1 €/MWh, and blue otherwise). The key conclusions can be summarised as follows:

- **DE/LUX configurations:** The introduction of splits in the DE/LUX bidding zone leads to forming two zones where prices change in opposite directions. Prices increase in the southern German zone(s), Luxembourg, the Czech Republic, Austria, Slovakia, Hungary, Slovenia, Croatia, and Romania. The highest price increases are observed in the Czech Republic, in the range of 3 €/MWh. A decrease in prices in the range of 4 €/MWh is observed for the northern CE zones, namely the northern German zone(s) and Denmark.[22]
- **FR3 configuration:** The split in France mainly affects the price formation in France, with the formation of a zone with increasing prices in the northeast and a zone with decreasing prices in the southeast.
- **IT2 configuration:** The prices in Italy North remain unchanged (slight increase). The main impact is observed in France, with a price reduction mainly due to reduced exports to Italy.
- **NL2 configuration:** No major impact in the price formation in CE is observed.
- **Combinations:** The results of the combinations (DE2/NL2 and DE5/NL2) do not deviate from those of the respective DE split configurations.

21 The resulting average price levels are lower than those currently observed in day-ahead markets. A dedicated sensitivity analysis was performed to assess the impact of higher prices on the configurations.

22 A similar trend is observed for the Nordic BZ based on the results of the all-EU simulation, namely a decrease in prices in the Nordic area due to a reduction in exports towards CE.

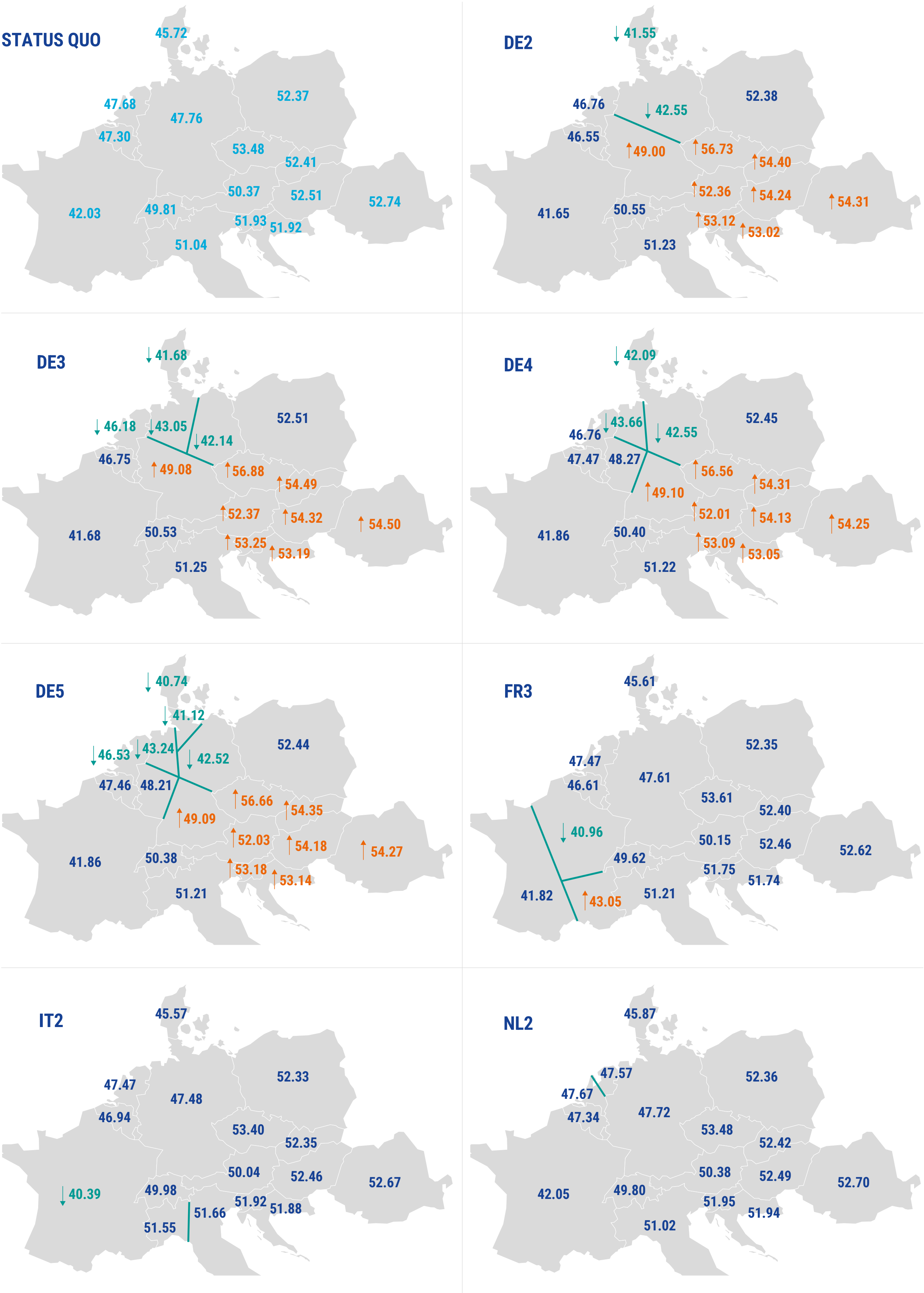
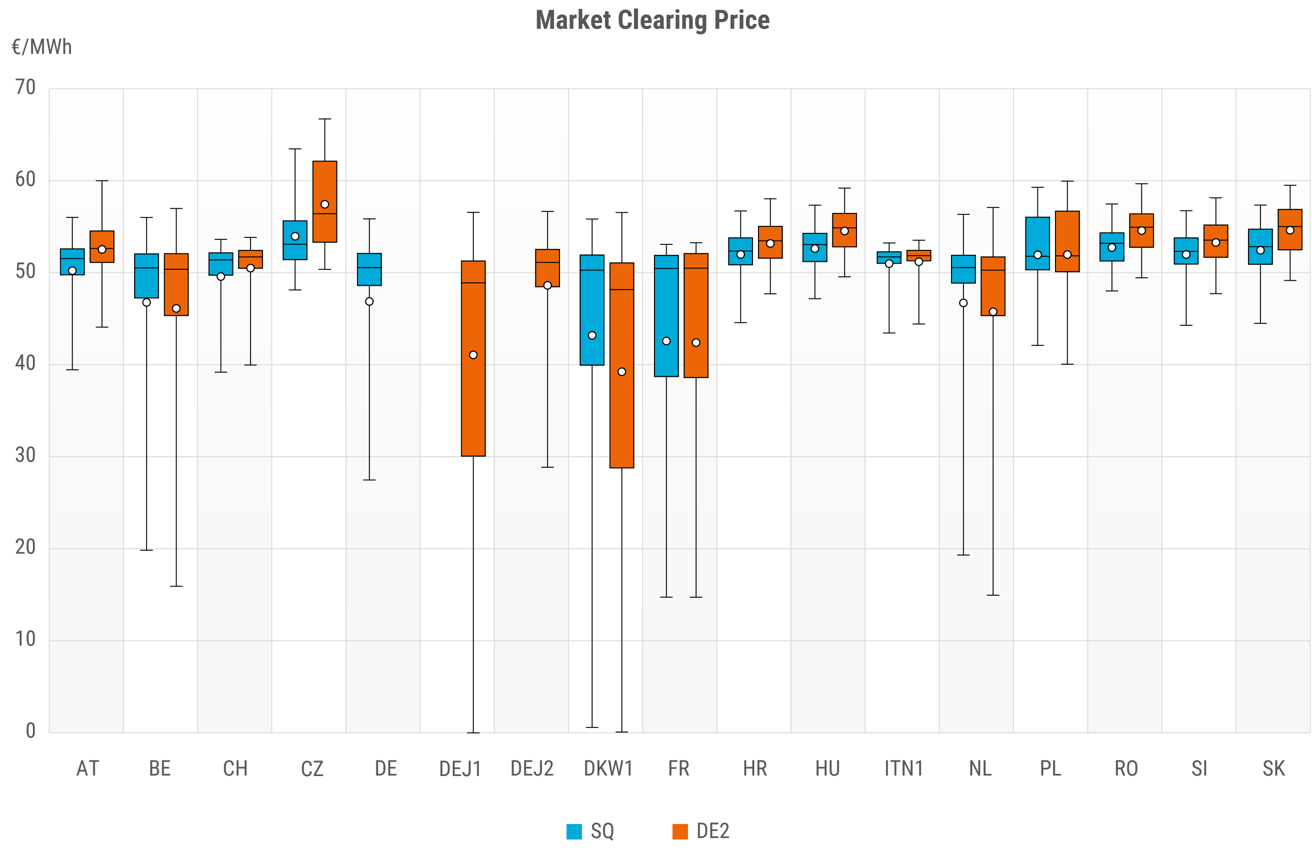


Figure 16: Average market clearing prices in CE for all individual BZ configurations in EUR/MWh (average of three climate years)

Market clearing price distribution

Figure 17 shows the distribution of the hourly market prices for each CE bidding zone in the status quo and DE2 configuration for climate year 1989. Splitting the German–Luxembourgish bidding zone increases the price volatility in northern German zone (DEJ1) and Denmark. This increasing price volatility is mainly attributed to the increasing shares of RES in the northern DE zones, which lead to a reduction of prices in the respective zone, also affecting the price formation in Denmark due to similarities in the RES portfolios (high shares of wind energy).



Note: The whiskers of the boxplots represent the 5th and 95th percentiles. The white dots show the mean.

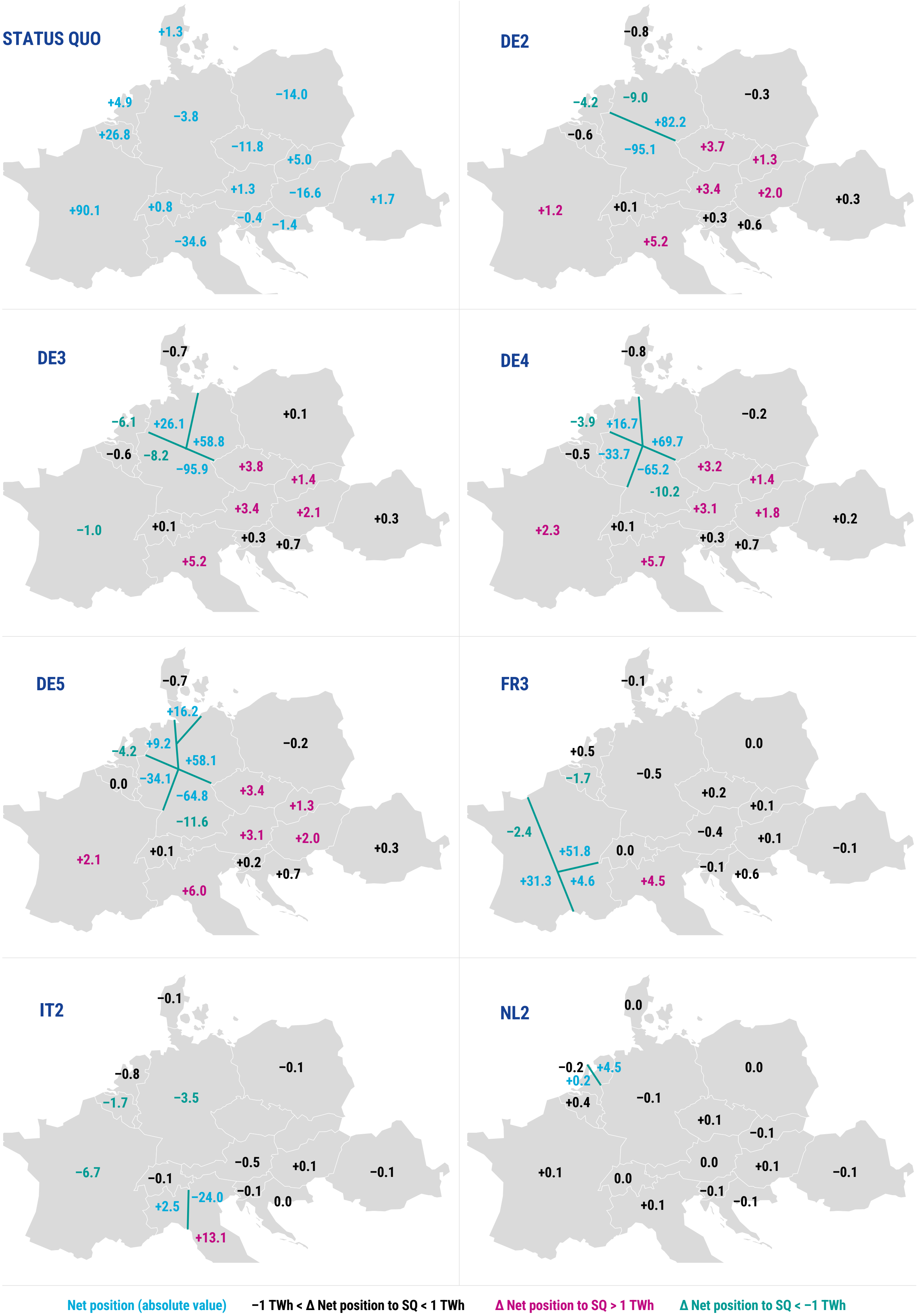
Figure 17: Market clearing prices in CE for the status quo and DE2 configuration in climate year 1989

6.1.2.3.3 Net Positions

Average net position changes per Bidding Zone

Figure 18 presents the average net positions for the status quo and respective changes for all configurations, as the average results for the three simulated climate years. In the status quo, the main exporting zones are formed in the west/northwest and central CE (positive values), with France being the major exporter, followed by Belgium. The highest importer is Italy, followed by Hungary, Poland, and the Czech Republic (negative values). The alternative BZ reconfigurations lead to wider changes in net positions, indicated in the configuration graphs with dedicated signs and respective colours (red in case net positions increase by more than 1 TWh, green if net positions decrease by more than 1 TWh, and black otherwise). For each zone where a split takes place, the new net positions in the internal zones are indicated in blue. The key conclusions are summarised as follows:

- **Germany – Luxembourg configurations:** The introduction of splits in the Germany–Luxembourg BZ leads to forming two zones where net positions change in opposite directions. Net positions increase in the northern German zone(s), the Czech Republic, Austria, Slovakia, Hungary, Italy, and France (for France in all split configurations except the DE3 configuration, where a slight decrease is observed). In Germany, the formation of an exporting zone is observed in the north (due to RES overproduction) and an importing zone in the south. Germany's net position is further reduced by 8 – 12 TWh due to the increased market-based RES curtailment and gas decrease in the northern zones and the subsequent reduction of imports from the Nordics, as discussed in the previous section. Furthermore, a further decrease in net position in the Netherlands is observed, in the range of 4 – 6 TWh due to reduced exports towards the northern DE zones.
- **Combinations:** The results of the combinations (DE2 + NL2, DE4 + NL2 and DE5 + NL2) do not deviate much from those of the respective DE split configurations.
- **FR3 configuration:** The split in France mainly affects the net positions in France, Belgium, and Italy. The split of France leads to reduced exports towards Italy due to the internal capacity limitations in France. This reduction leads to a respective decrease in net positions of France and Belgium (less exports to France) and a respective increase in the net position of Italy as compensation for the reduced imports.
- **IT2 configuration:** The split of northern Italy leads to the formation of two zones due to the better allocation of capacity constraints on the trading, namely a deficit zone in the east where most load is connected and a surplus zone in the west towards France. A reduction in imports from France is observed, leading to an increase in the net position of Italy of 13.1 TWh. This reduction in imports is balanced by a respective reduction in the net position of France, Germany, and Belgium.
- **NL2 configuration:** The split of the Netherlands leads to the formation of an exporting zone in the north of the country, without any major impact in the other CE zones.

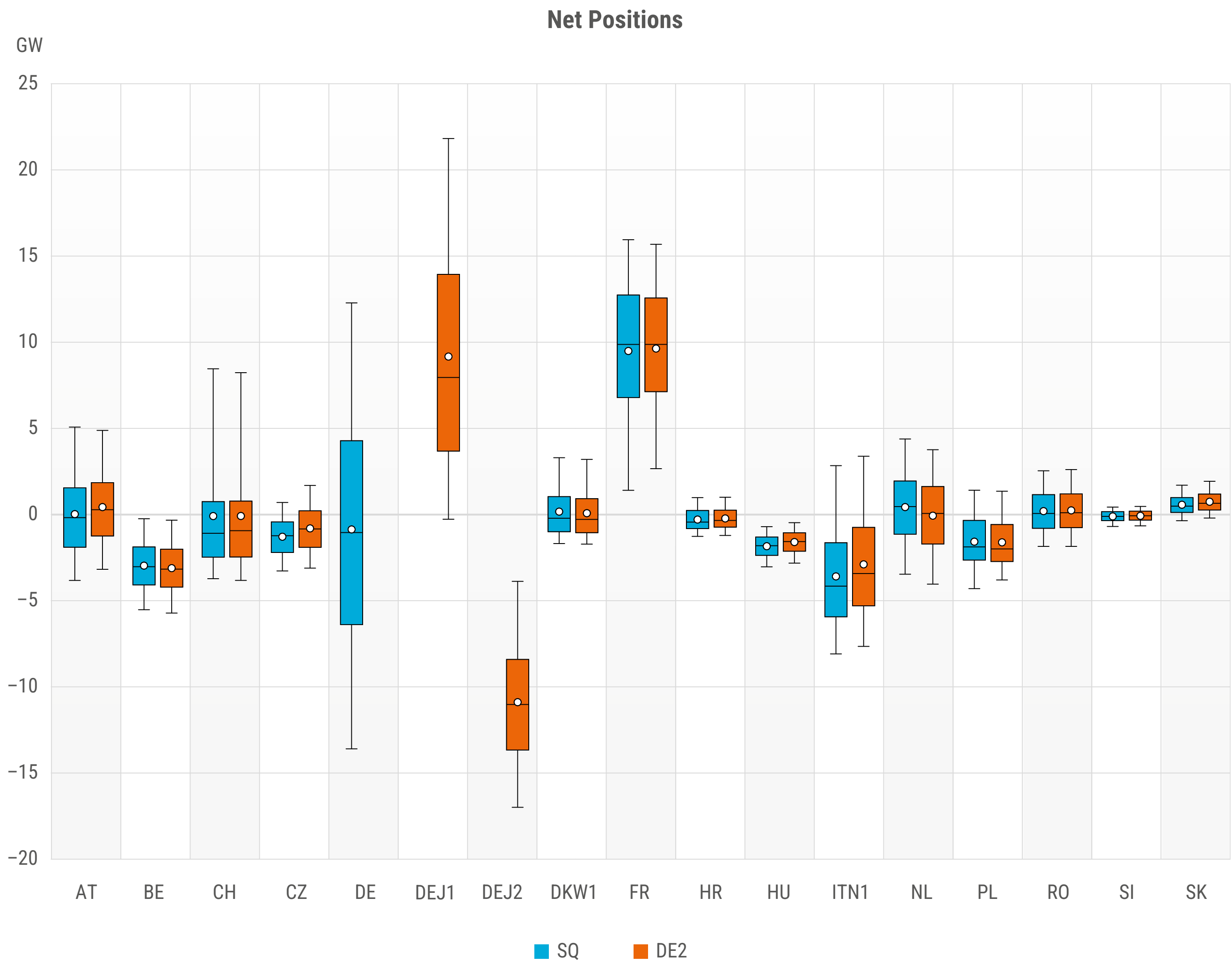


Note: Except for the numbers marked in light blue, which show absolute values, all numbers in the figures show the change in net positions relative to the status quo.

Figure 18: Average net positions in CE for all individual BZ configurations in TWh (average of three climate years)

Net position distribution

Figure 19 shows the distribution of the hourly net positions for each CE bidding zone in the status quo and DE2 configuration for climate year 1989. A split of the German–Luxembourgish bidding zone creates a northern zone (DEJ1) with a positive net position for most of the year due to the high shares of RES, and a southern zone (DEJ2) that is a net importer for over 95 % of the year.



Note: The whiskers of the boxplots represent the 5th and 95th percentiles. The white dots show the mean.

Figure 19: Net positions in CE for the status quo and DE2 for climate year 1989

6.1.2.3.4 Market Welfare

The changes in market dispatch, market clearing prices, and net positions lead to respective changes in the market welfare, being the sum of producer surplus, consumer surplus, and congestion rent changes compared to the status quo configuration.

Consumer surplus

Consumer surplus is calculated as the product of the BZ load multiplied by the difference between the value of loss load (VoLL) and market clearing price. As the load in each zone remains broadly unchanged for alternative configurations (with some minor differences due to demand side response; DSR), the gains / losses in consumer surplus reflect the respective changes in prices in each zone. Lower market prices lead to higher consumer surplus, and higher market prices lead to lower consumer surplus.

Figure 20 shows the change in consumer surplus for the alternative configurations. For most alternative configurations, the consumer surplus increases across all three climate years. To understand this result, it is necessary to assess the impact of zonal price differences presented in Figure 16. In particular, the consumer surplus gains due to price decreases in the northern zones outweigh the respective losses due to price increases in the south / southeast.

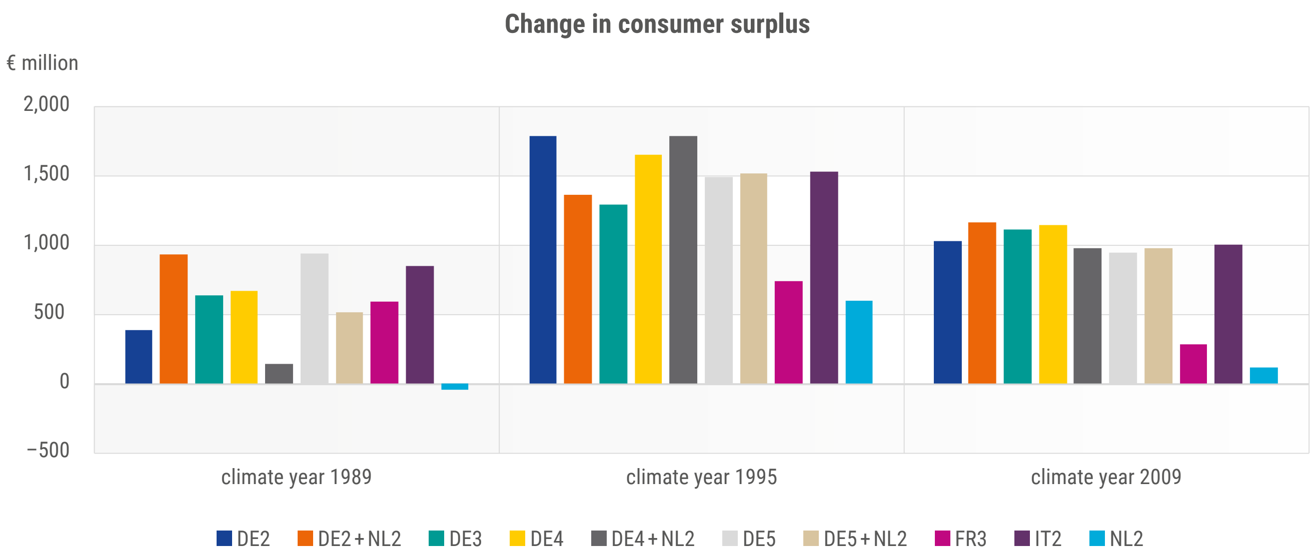


Figure 20: Change in consumer surplus at all EU level in all bidding zones relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation

Producer surplus

Producer Surplus is calculated as the product of the generation of each plant in each BZ and the difference between the market clearing price and the marginal cost of that plant. In this respect, the producer surplus is defined by the changes in prices as reflected in Figure 16, as well as the total energy produced, which can vary depending on each zone's change in net position.

Additionally, the producer surplus also depends on the relative shifts in the merit order due to a change of technology mix dispatched by the market, whereby a renewable producer in the north of Germany can be replaced by a gas producer in the south, whose marginal cost is closer to the market clearing price, resulting in a lower overall surplus.

Figure 21 shows the change in the producer surplus for the alternative configurations. The producer surplus decreases in all configurations. In the case of the German–Luxembourgish split scenarios, this is mainly due to the fact that the reduction in producer surplus in the northern zones (where prices and net positions are reduced) outweighs the increase in producer surplus in the south / southeast (where prices and net positions increase). This is the result of replacing generation that is low in the merit order (RES) in the northern zones with generation that is high in the merit order (gas). In the case of the Italian split scenario, a similar effect occurs, whereby the producer surplus losses in France (mainly nuclear, where prices and net positions are reduced) outweigh the producer surplus gains in Italy (where prices and net positions are increased, but mainly using gas that is marginal). Minor reductions can be observed for FR3 and NL2.

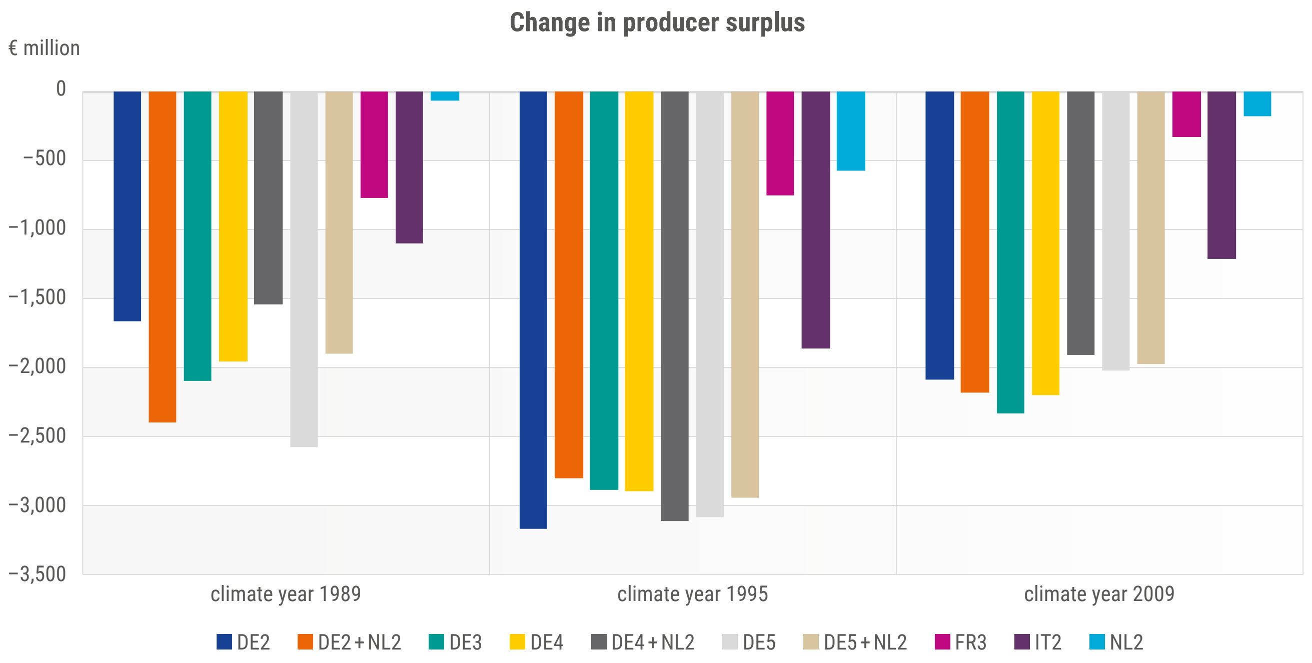


Figure 21: Change in producer surplus in all bidding zones relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation

Congestion rent

A market congestion occurs when the trading capacity between two zones reaches its limit, leading to a price difference (price spread) between the zones. Congestion rent is calculated as the product of price differences across each bidding zone border multiplied by the respective border flow. In this respect, the variation of the congestion rent is determined by the changes in prices between BZs as presented in Figure 16, as well as changes in net positions, as presented in Figure 18. Respectively, the change in congestion rent comes as the sum of the congestion rent for all borders. Therefore, the introduction of additional border also increases the likelihood of higher congestion rents.

Figure 22 shows the change in congestion rent for the alternative configurations. Congestion rents increase in all German–Luxembourgish split scenarios due to the introduction of new borders and the overall increase of price spreads between zones observed in the splits. Market congestion occurs when the exchange capacity between two zones reaches its limit. A positive delta in the German–Luxembourgish splits means that the internal borders introduced are often saturated in the market, limiting the exchange among geographic areas. The change of the congestion rent is negligible for the other individual configurations.

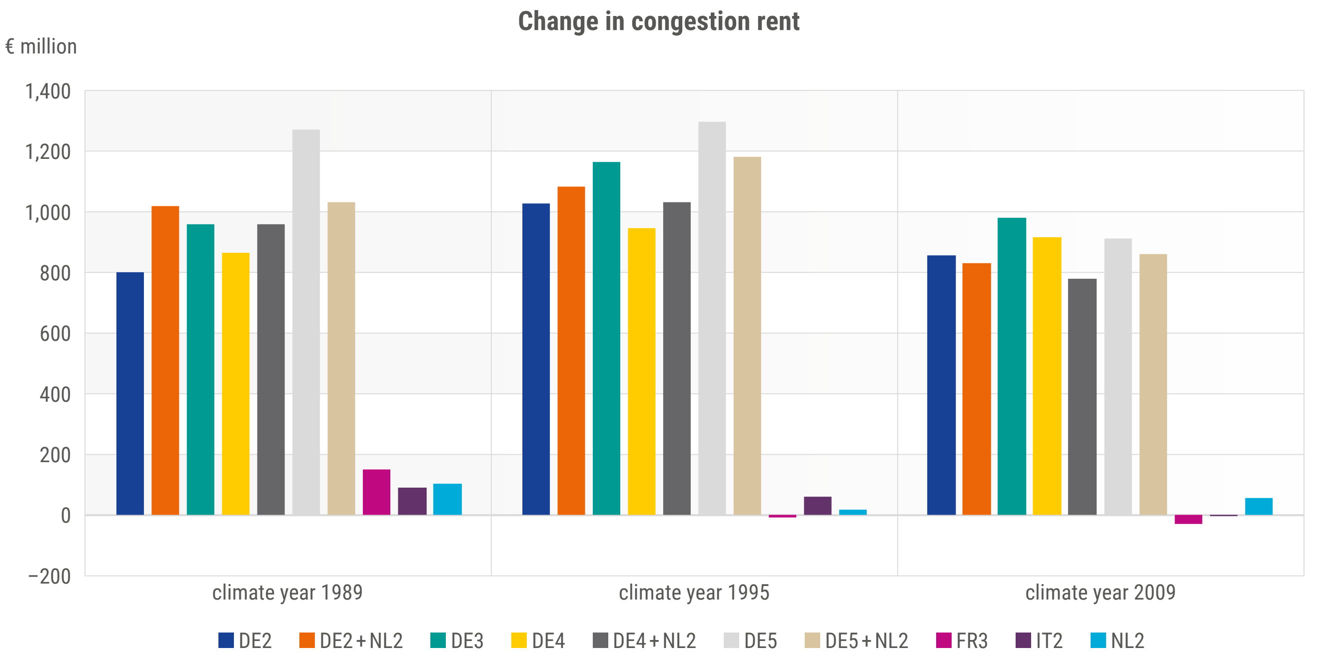


Figure 22: Change in congestion rent in all bidding zones relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation

Market Welfare

Finally, the market welfare – calculated as the sum of the previous three components – presents a decrease in almost every case. This result is expected as introducing a split leads to a restriction of the market and therefore a reduction in overall welfare. An exception is the NL2 split, which shows increased market welfare in climate year 1995. However, this increase is small and could be attributed to the overall numerical accuracy of the modelling chain.

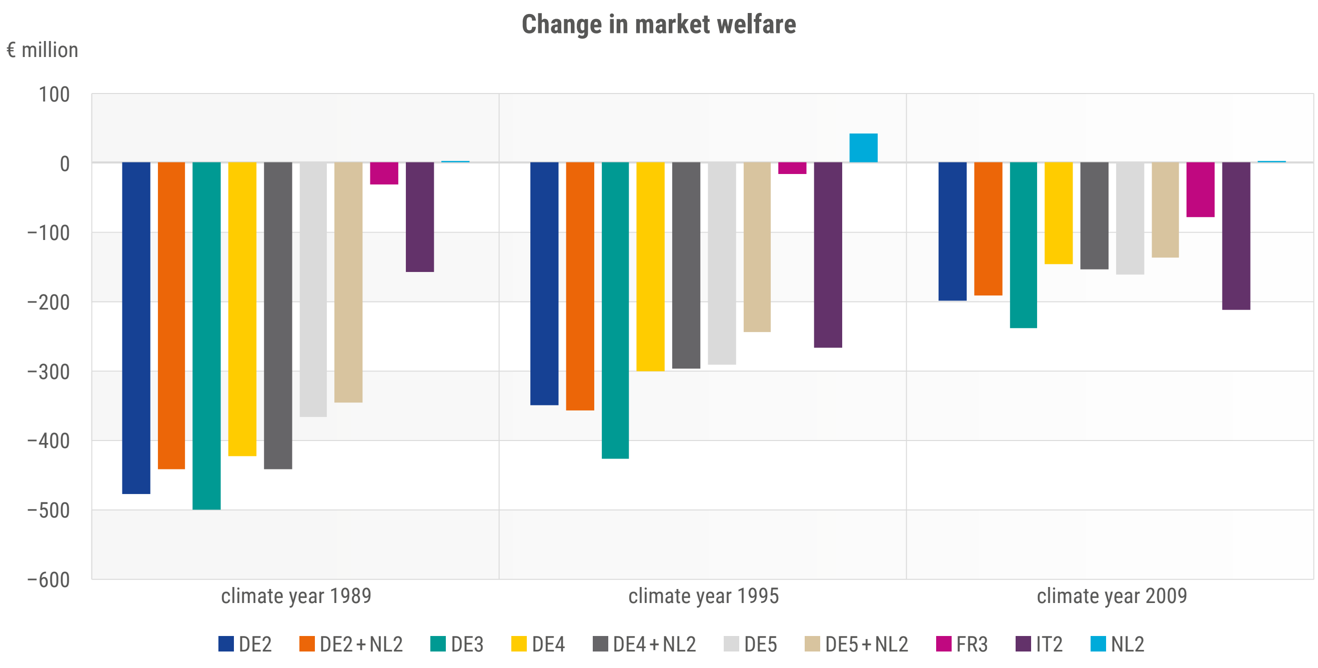


Figure 23: Change in market welfare in all bidding zones relative to the status quo based on the all-EU NTC market simulation and CE FB market simulation

6.1.2.4 Operational Security Analysis and Remedial Actions Optimisation

The operational security analysis (OSA) is conducted to identify operational security violations in the electricity grid resulting from the FBMC simulation outcome. This includes an outage approximation, e. g. the consideration of failures in transmission lines, substations, or control systems that might occur in operational practice (the so-called N-1 principle). The calculations result in load flow information for all network elements, mapping all potential operational security violations for each MTU under all possible combinations of failures of critical elements. In line with the BZR Methodology provisions, the OSA was performed using a DC load flow approach for the full grid in an hourly time resolution.

Based on the OSA results, the RAO focuses on the most cost-efficient strategies to address the identified operational security violations in advance of real time, and thus ensure the security of the grid. These strategies include *non-costly* measures such as flow control actions on high-voltage direct current (HVDC) corridors, control actions on phase-shifting transformers (PSTs), topological remedial actions, and measures that incur costs, such as adjusting the output of available power plants (redispatching) or activating demand-side response (DSR). In line with the BZR Methodology provisions, the RAO is conducted over a period of 50 representative days (1,200 MTUs) obtained by the application of a clustering algorithm,[23] under the assumption of full cross-border coordination.[24] The results obtained from this period are then rescaled to represent a full year based on the representativeness level of each day, i. e. the individual weight that each day obtains in the clustering algorithm. All results presented in this section have been adjusted accordingly to reflect annual values. As part of the result assessment, the following key parameters are assessed:

1. **Congestion volumes:** This is the starting point of the RAO process, the overflows – energy that cannot be transported without violating operational security constraints – on each network element as obtained after the outage approximation (OSA).

2. **Redispatch volumes:** The RAO algorithm is applied, aiming to remove grid congestions under full coordination in CE by prioritising non-costly measures and minimising the necessary operational actions, aiming to reduce the resulting redispatching volumes. The resulting remedial actions take place in the form of balanced upward and downward redispatching actions across different sides of the congestion. The actions per generating unit are aggregated, leading to the total volumes of redispatch needed to alleviate congestions detected in the OSA process. The resulting new net positions after RAO are assessed and compared to the pre-optimisation values, indicating the levels of cross-border redispatching.

3. **Redispatching costs:** Redispatch costs are estimated based on the redispatch volumes, redispatch price, markups, and extra cost items according to the BZR Methodology. These redispatch markups are based on the regulated redispatch markups of Germany in 2019, as explained in Annex II.

4. **Post-RAO dispatch:** The remedial actions lead to the final (post-RAO) system dispatch, which emulates the realtime (physical) system dispatch.

23 The same clustering algorithm was applied as for the selection of representative climate years and weeks (see ENTSO-E Report on the Locational Marginal Pricing Study of the Bidding Zone Review Process). The algorithm provides the 50 most representative days as respective cluster centroids and the level of representativeness for each centroid, which is used as a weighting factor for scaling the results to the full year.

24 Full cross-border coordination refers to the removal of operational security violations through a global optimisation of the system, without prioritising actions per native zone, which is the target RAO model for Core CCR. The decision to apply full cross-border coordination was made in 2020 in accordance with Article 9 (4) (10) of the BZR Methodology, since at that point a full cross-border coordination of redispatching was foreseen to be implemented in the Core CCR for the target year.

6.1.2.4.1 Congestion Volumes

Figure 24 illustrates the volume of overflows on network elements as part of the OSA across various scenarios for the climate years 1989, 1995 and 2009. The status quo scenarios for the three target years present different overflow levels, indicating a good level of representativeness in the selection of climate years. In all climate years, a reduction in operational security violations can be observed when BZs are split.

- **DE/LUX split configurations:** The split of the German–Luxemburgish BZ leads to the highest reduction of overflows. The explanation of this effect lies in a combination of factors related to the impact of imports, the underlying market dispatch, and the integration of variable renewables. In the status quo, high wind generation in the northern regions of Germany and Denmark combined with increased imports from the Nordics leads to operational security violations because the grid cannot transfer the excess energy production in the north to demand regions in the south without overloading network elements (mainly north-south transmission lines). As discussed in the FBMC analysis, splitting Germany into multiple BZs enables the market to take prior action and reduce imports from the Nordics and curtail excess RES energy production at times when congestion between the north and south emerges. Therefore, higher granularity in BZs leads to a reduction of regional imbalances in the FBMC timeframe, reducing network congestion in OSA.
- **Combinations:** The results of the DE2 + NL2 combination are similar to those of the DE2 configuration. Similarly, the results of the DE4 + NL2 combination are similar to the DE4 configuration with only a minor increase in overflows, indicating no major impact of the NL2 split on the formation of overflows. In the case of the DE5 + NL2 combination, a reduction of overflows compared to the DE5 split is observed[25].
- **FR3 configuration:** No major impact on the reduction of overflows compared to the status quo is observed.
- **IT2 configuration:** A minor reduction of overflows is observed compared to the status quo.
- **NL2 configuration:** The NL2 split is the only exception to the general observation of reduced overflows as in climate year 1995, the amount of overflow volume slightly increases. However, this difference is negligible and attributed to the model's overall accuracy.

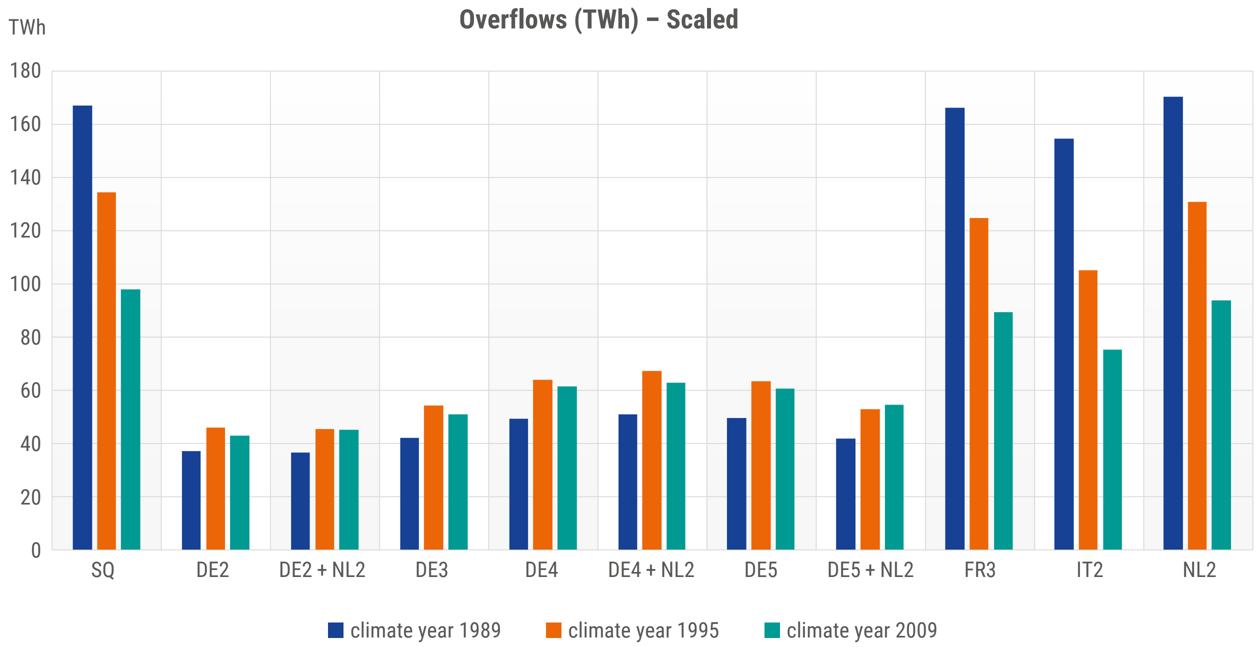


Figure 24: Pre-optimisation volume of overflows in TWh scaled to a year

25 An issue with HVDC scheduling before the RAO calculation was identified, linked to a test update. While it affected some scenarios and slightly increased pre-RAO overflows on the FR – IT border, the impact on RAO redispatch volumes and cost was minimal (~ 1 € million of socio-economic welfare). Consequently, no reruns of other scenarios were conducted due to timing constraints.

6.1.2.4.2 Redispatch Volumes

The analysis of redispatching volumes explains the working of the redispatching process. In essence, the RAO process changes the geographic location of dispatch actions, while the overall volumes of upward and downward redispatch are always balanced. In this section, we start by conducting a detailed analysis of the RAO results for a representative case for all German – Luxembourg configurations, namely comparing the status quo with the DE2 configuration to provide a deeper understanding of the results. In the second part, we present the overall results for all configurations the key observations for each configuration. Further, we present the impact on cross-border redispatching to reflect upon the impact of the assumption of full cross-border coordination.

Deep-dive comparison of redispatch volumes in the status quo and DE2

The maps in Figures 25 and 26 provide a visual representation of the redispatch volumes. The maps present the severity of congestions in OSA – mapped per network element – and the resulting redispatching actions per power plant through the application of RAO. Upward-pointing triangles indicate locations of upward redispatch, while downward-pointing triangles indicate locations of downward redispatch. Technologies and fuel types can be distinguished by the chosen colour palette. The redispatch-inducing bottlenecks in the transmission system are shown in the background, with a respective colour palette indicating congestion severity.

Figure 25 presents the OSA and RAO results for the status quo configuration for the climate year 1989. In the status quo scenario, a high level of congestion and respective remedial actions are observed. Most bottlenecks in the transmission grid are observed on cross-border elements and in the German – Luxembourgish bidding zone. As previously mentioned, the combination of imports from the Nordics with the large concentration of RES (mainly wind energy) in the northern part of CE is a key driver of north-south flows and grid overloads. The resulting high utilisation of corridors is managed in the RAO by downward redispatching actions in the form of: a) the curtailment of wind in the northern area, b) reducing thermal generation (mainly coal power plants) in Denmark and the northern part of Germany, and c) downward redispatching of lignite power plants on the DE / PL / CZ border. Different conventional plants are ramped up to provide upward redispatch to keep the system balanced: a) larger conventional power plants mainly in the southern part of Germany, Italy, and Poland, and b) a large number of smaller plants scattered across the southeastern part of Europe (due to the scale of the visualisation, these ones are not as easily visible).

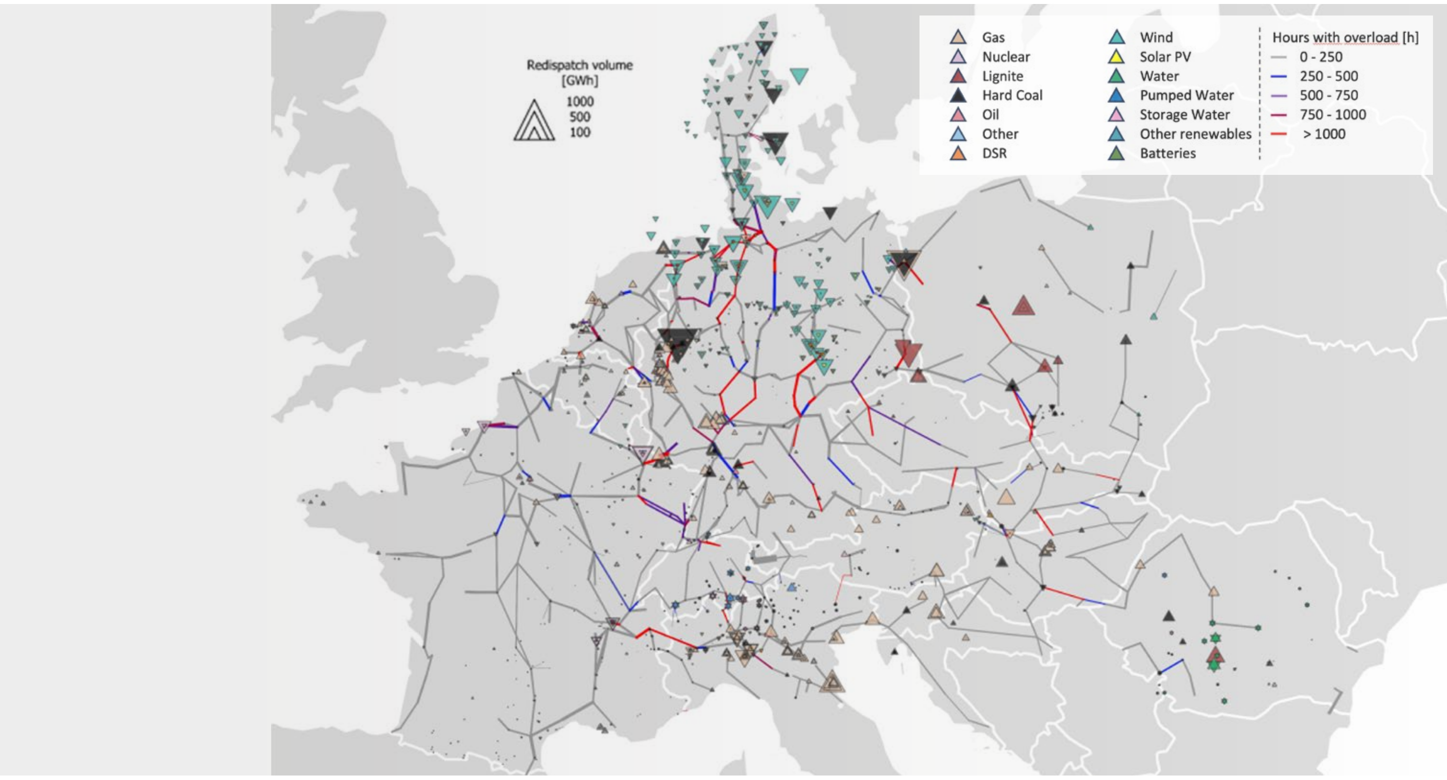


Figure 25: Map of redispatch volumes for the status quo in climate year 1989, scaled to a year

As an example of the impact of a BZ split on the redispatching behaviour of the system, Figure 26 visualises the DE2 split and the resulting redispatch volumes and bottlenecks. In contrast to the status quo, the level of redispatching actions is reduced as most bottlenecks in the grid in Germany do not appear due to the updated market dispatch. Remaining congestions appear in the area around Hamburg and Bremen in the northwestern part of Germany.

This effect can be traced back to high wind infeed in Denmark and Schleswig-Holstein. No significant downward redispatch and RES curtailment are observed in Germany, which – as discussed above – can be attributed to the FBMC market results (see reduced RES utilisation in market simulations, section 6.1.2.3).

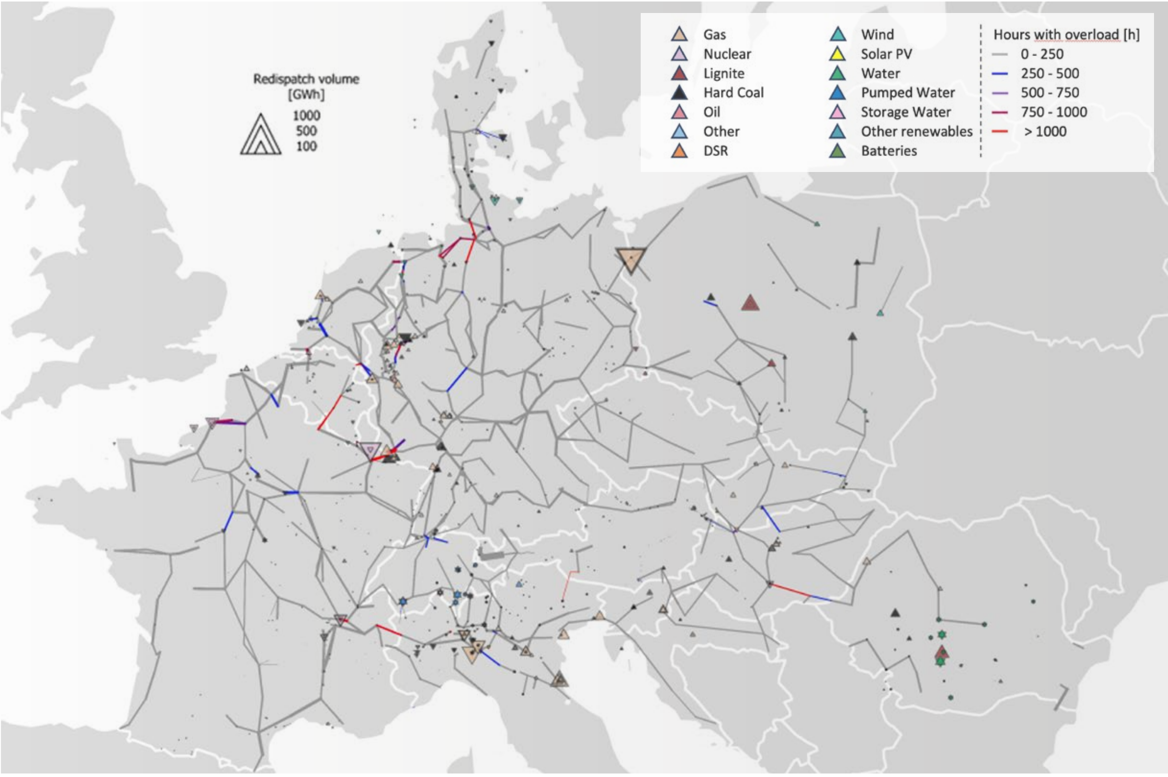


Figure 26: Map of redispatch volumes for DE2 in climate year 1989, scaled to a year

Figures 27 and 28 map the difference in downward and upward redispatching between the status quo and DE2 configuration. A reduction of actions (redispatching volumes) is observed in both graphs, namely fewer downward redispatching actions due to the new dispatch and consequently fewer counter-balancing upward redispatching actions. In accordance with the reduction of overflow energy (see Figure 24), most of the heavily utilised transmission lines in the German – Luxembourgish BZ and a significant number of interconnectors are at least partly relieved (indicated in green).

The downward redispatch reduction is mainly attributed to RES curtailment in Germany and Denmark, and to a lesser extent to hard coal and lignite. The upward redispatch reduction is mainly attributed to the reduction of use of gas and to a lesser extent hard coal and lignite in Germany and southern CE zones.

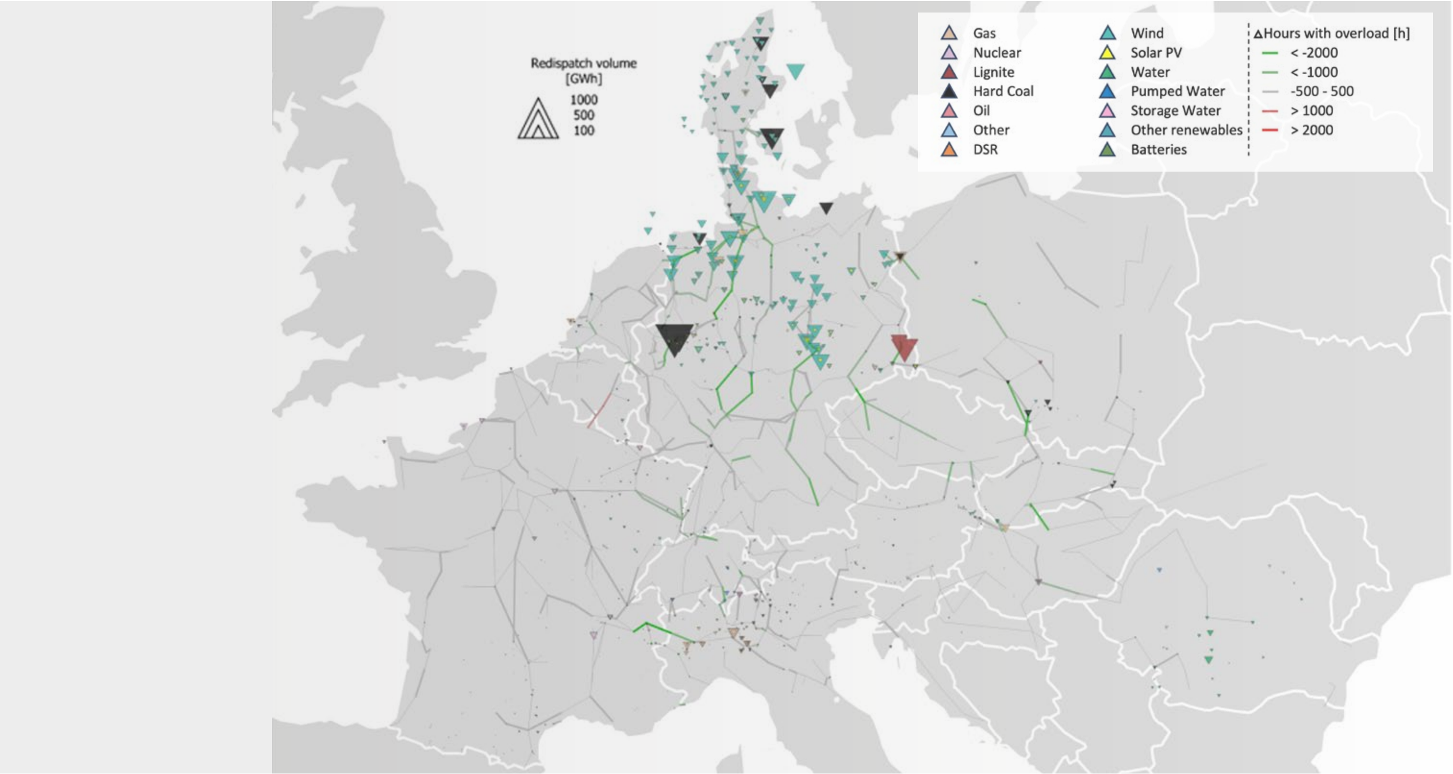


Figure 27: Map of downward redispatch volume change between the DE2 split and status quo, scaled to a year

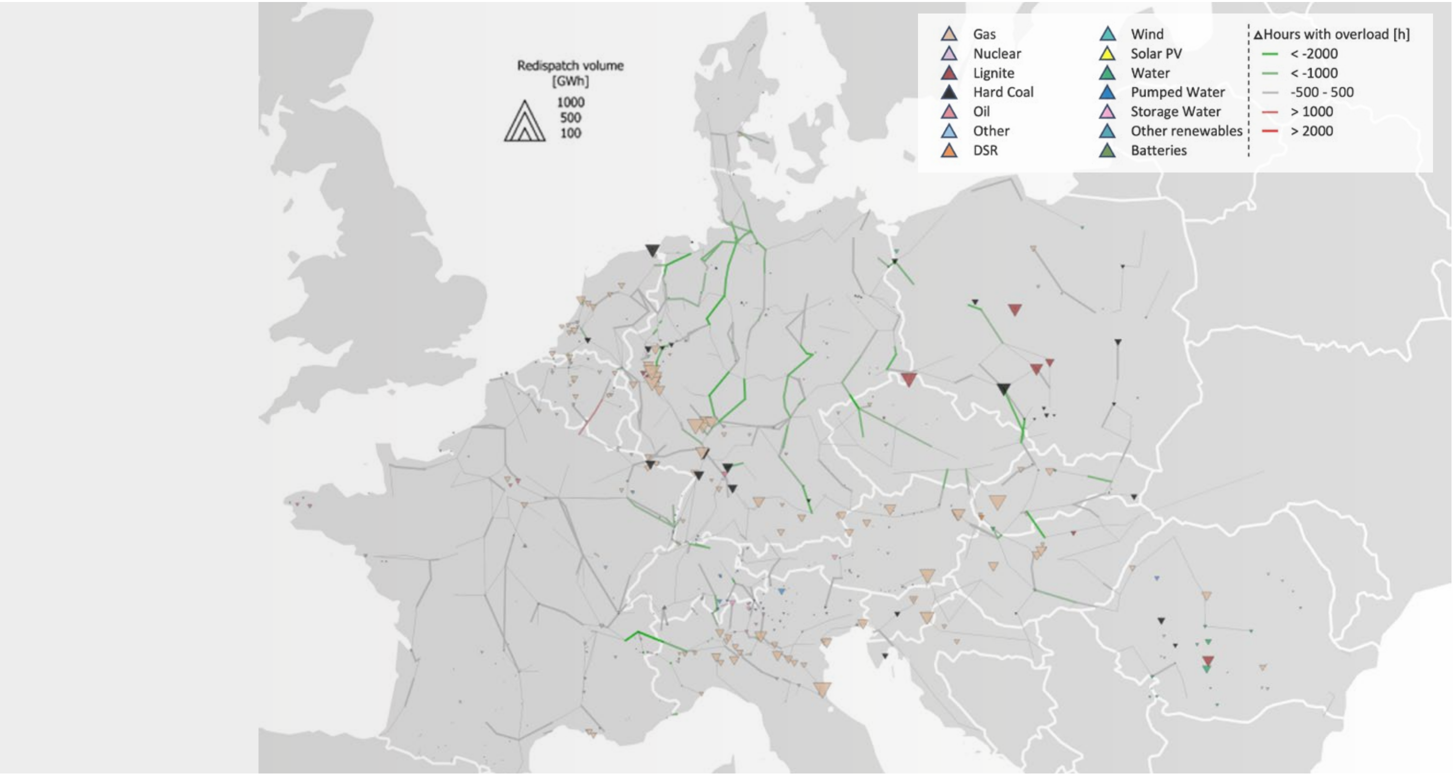


Figure 28: Map of upward redispatch volume change between the DE2 split and status quo, scaled to a year

Overall redispatch volume results for all configurations

Table 7 provides a breakdown of redispatch volumes for each configuration scaled to a full year (the values correspond to one direction, namely up- or downward redispatch, as the volumes are the same in both directions). The largest redispatch volume is observed in climate year 1989, corresponding to a high amount of RES infeed in this climate year and resulting operational security violations.

As expected, looking at the delta in redispatch volumes between the BZ splits and the status quo, an overall decrease in redispatching volumes is observed due to the updated system dispatch.

		SQ	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL5	FR3	IT2	NL2
climate year 1989	*Redispatch Volumes (TWh)*	22.76	8.79	9.06	8.79	9.37	9.58	9.57	9.73	22.54	20.94	22.77
	Delta to SQ (TWh)	0	−13.97	−13.70	−13.97	−13.39	−13.18	−13.19	−13.03	−0.22	−1.82	0.01
climate year 1995	*Redispatch Volumes (TWh)*	20.97	11.35	11.54	11.12	11.31	12.65	10.66	11.72	20.03	17.37	21.28
	Delta to SQ (TWh)	0	−9.62	−9.43	−9.85	−9.66	−8.32	−10.31	−9.25	−0.94	−3.6	0.31
climate year 2009	*Redispatch Volumes (TWh)*	17.35	9.76	10.30	9.44	10.67	11.0	10.72	11.73	15.6	13.7	16.8
	Delta to SQ (TWh)	0	−7.59	−7.05	−7.91	−6.68	−6.35	−6.63	−5.62	−1.75	−3.65	−0.55

Table 7: Redispatch volumes in the study region for different climate years and split scenarios (one direction)

Figure 29 and 30 present a detailed breakdown of the difference in redispatch volumes from the status quo and DE2 for climate year 1989. There is notable upward redispatch of gas and hard coal in southern Germany as a result of the north-south transit within Germany, and a notable upward redispatch of gas in the southern parts of CE. However, this curtailment is reduced in the split configurations, especially in the German–Luxembourgish split. Furthermore, by assessing the maps and bar charts, it can be observed that this reduction in curtailment is balanced by a reduction in the upward redispatch demand (mainly gas generation). This trend can be observed for all climate years.

The general observations per configuration are as follows:

- **DE/LUX configuration:** The most significant reduction of volumes can be observed for the German–Luxembourgish split scenarios. This can be traced back to the reduction of wind curtailment (and imports from the Nordics) in the northern zones and a respective reduction in gas upward redispatching needed for compensation.
- **Combinations:** The results of the DE2 + NL2, DE4 + NL2 and DE5 + NL2 combination are similar to the results of their respective individual German splits, indicating no major impact of the NL2 split to the output of the redispatching process.
- **FR3 configuration:** No major impact on redispatch volumes compared to the status quo is observed.
- **IT2 configuration:** Splitting Italy leads to a reduction of nuclear downward redispatching and a respective reduction of gas upward redispatching.[26]
- **NL2 configuration:** No major impact in redispatch volumes compared to the status quo is observed.

26 The BZR Methodology agreed in the BZR Study for the definition of the redispatching costs does not consider the financial arbitrage that power plants owners in Italy North might display when bidding in the balancing markets, and therefore the cost of redispatch in Italy might be underestimated in this study.

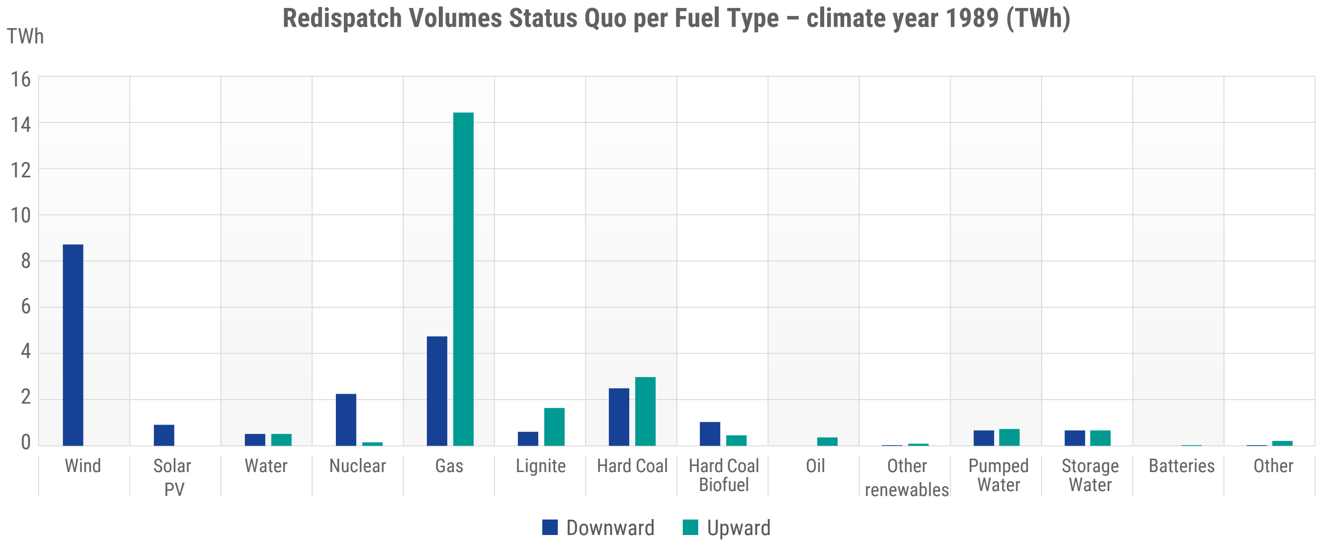


Figure 29: Redispatch volumes per fuel type for the status quo for climate year 1989

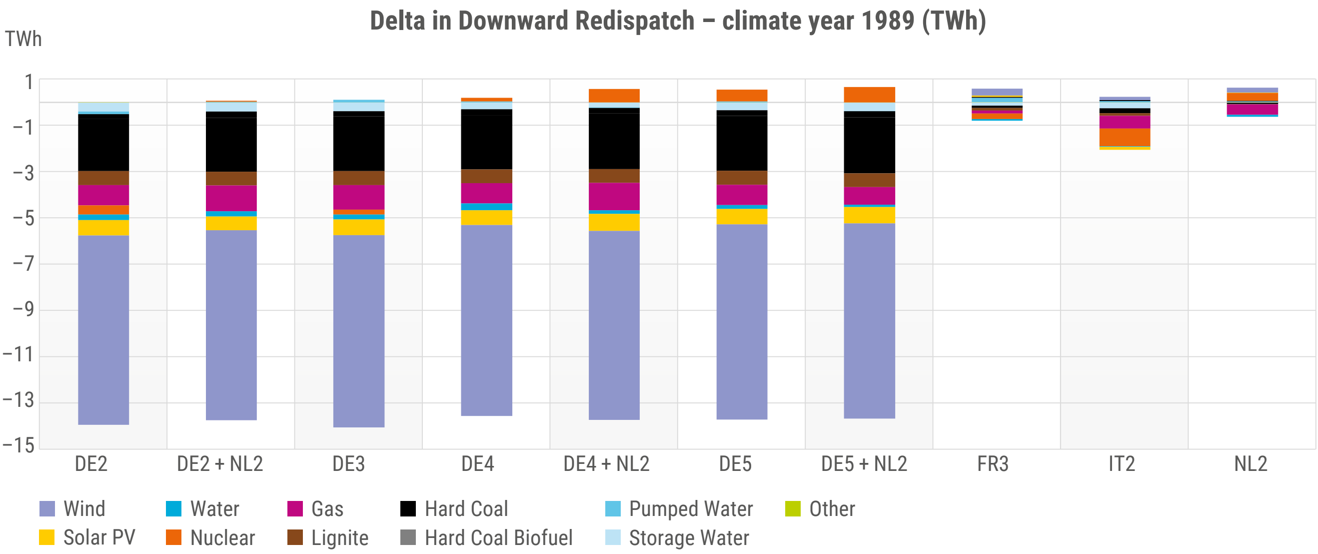


Figure 30: Change in downward redispatch relative to the status quo for climate year 1989

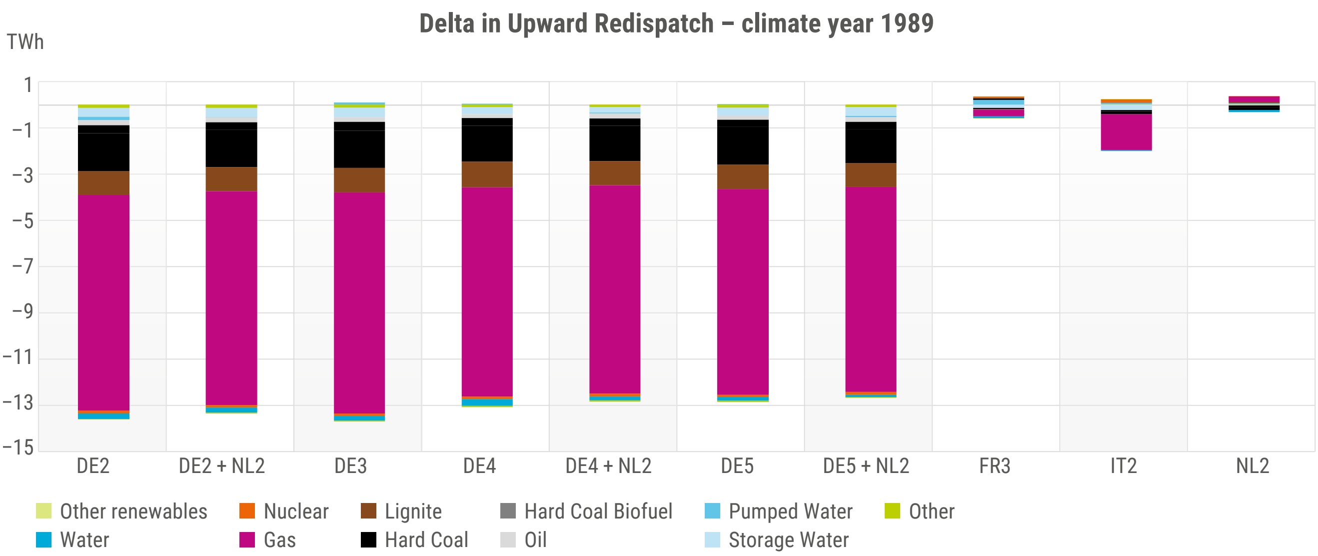


Figure 31: Change in upward redispatch relative to the status quo for climate year 1989

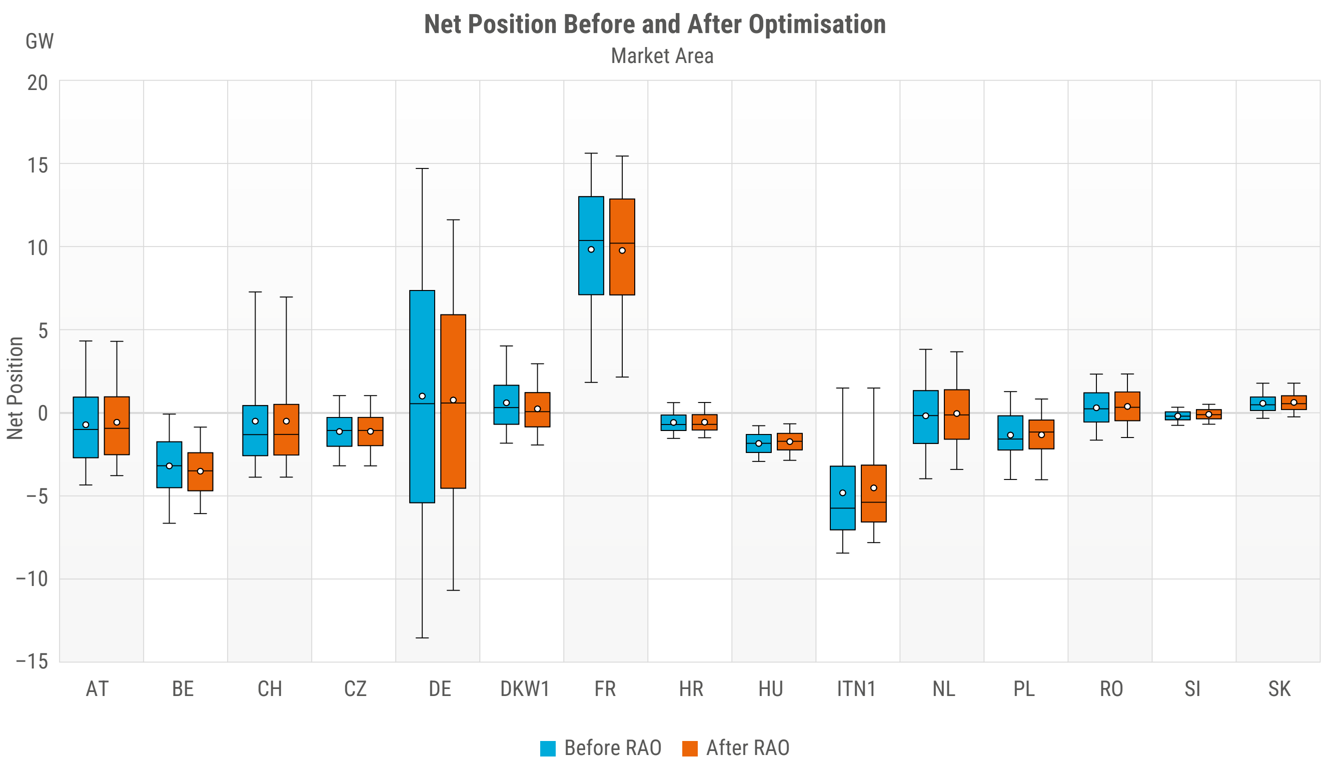
Cross-border redispatch

As previously mentioned, the BZR Methodology assumes a full redispatch coordination between the different CE countries. This means that cross-border redispatch is fully available and subject to no additional costs. This section reflects upon the impact of this assumption.

Figure 32 shows the net positions before and after optimisation for the status quo in climate year 1989. The average net position of the individual BZs before and after redispatch change indicates a cross-border contribution to solving operational security violations in Europe. An increase in the net position can be observed for Austria, Italy, Poland, Romania, and Hungary, and a decrease can be observed for Belgium, Denmark, and France. While Germany shows the highest amount of redispatch need due to grid congestion, the yearly average net position remains the same, although extreme values are smoothed out.

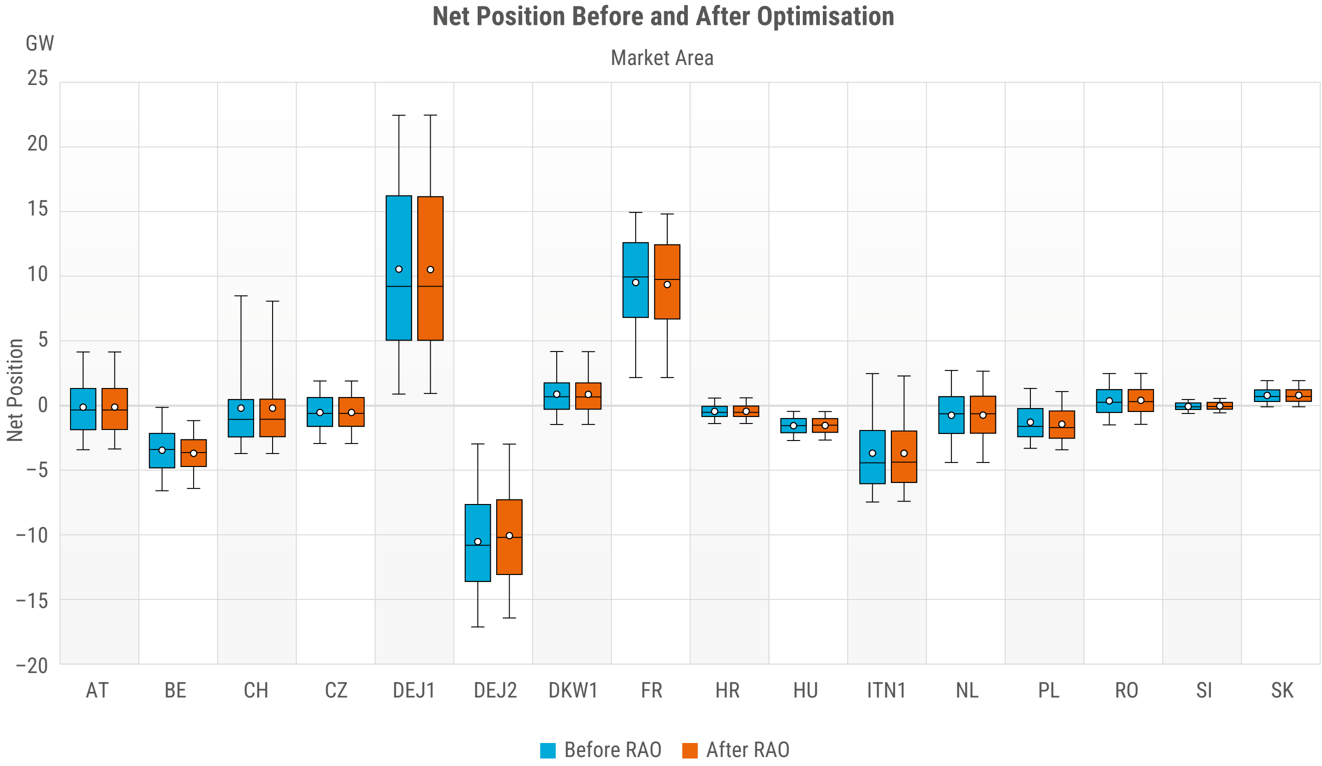
After the optimisation, Poland, Italy, and Hungary import less on average, while France and Denmark export less energy. This effect can be allocated to either the cross-border demand for solving congestion in neighbouring BZ or the fact that interconnectors are highly utilised.

However, this situation is barely present in the German–Luxembourgish split scenarios. Figure 33 shows the German–Luxembourgish two-zone split configuration for the same climate year, where-by the northern zone of Germany has a minimal contribution to the cross-border redispatch. This can be explained by the declining need for remedial actions with the implementation of splits and the reduced utilisation of interconnectors relative to the status quo.



Note: The whiskers of the boxplots represent the 5th and 95th percentiles. The white dots show the mean.

Figure 32: Net positions before and after optimisation for the status quo for climate year 1989



Note: The whiskers of the boxplots represent the 5th and 95th percentiles. The white dots show the mean.

Figure 33: Net positions before and after optimisation for the DE2 split for the climate year 1989

6.1.2.4.3 Redispatching Costs

According to the BZR Methodology, the total redispatch costs are calculated based on the redispatching volumes, considering multiple components. The calculation differentiates between plants that serve as grid reserves – specific to the German region only – and those that do not. Figure 34 presents a breakdown of the key components included in the RAO cost calculation.

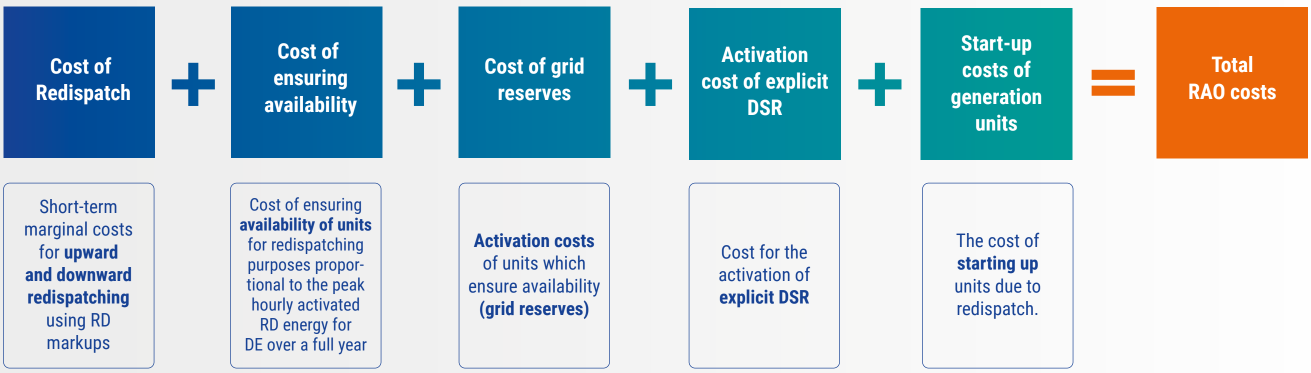


Figure 34: Breakdown of RAO cost calculation

Figure 34 shows the breakdown of redispatch costs for all configurations across the three climate years. The status quo of climate year 1989 configuration incurs the highest RAO costs, which aligns with the RAO results as status quo climate year 1989 showed the largest congestion and redispatch volume, translating into the highest costs.

- The **redispatch cost** is calculated per generation unit by considering both the upward and downward redispatch. This involves determining the redispatch volumes in both directions, scaling the volumes, and multiplying them by the redispatch price along with the upward or downward markup, depending on the direction of redispatch. Across all configurations, the largest component of the RAO costs is associated with upward redispatch, primarily driven by the upward redispatch of gas.
- The **cost of ensuring the availability of units** for redispatching includes the procurement of capacity and any other mechanisms to guarantee that sufficient redispatching reserves are available when needed. The calculation of these costs is proportional to the peak hourly activated redispatching energy over a full year within the respective member states, in accordance with the BZR Methodology (Article 9 (15)). As grid reserves are only available in Germany, this calculation is solely performed for the German market area. The cost of ensuring availability remains relatively consistent across all configurations and climate years.
- The **activation costs of grid reserve units** rely on the redispatch volume of the grid reserves and their redispatch price. The activation costs for grid reserve redispatch are zero in all scenarios because the simulation did not activate grid reserves, resulting in no associated costs. Unlike in reality, power plants in the grid reserve are not activated as other, more cost-optimal redispatch solutions seem to be available at all times in the model, e.g. due to generally lower redispatch volumes or higher redispatch potentials through the assumed cross-border coordination.
- The **activation costs of explicit DSR** are calculated by multiplying the volume of activated DSR by its activation price. The activation cost of explicit DSR is most significant in the status quo of climate year 1989 and reduced in climate year 1995 and climate year 2009. In the German–Luxembourgish split configurations, the cost of DSR is minimal due to the small DSR activation volumes in these configurations.
- Finally, the **cost of startups** is calculated for the plants activated for redispatch. These costs consider the startup-fixed cost and the start up fuel consumption as obtained by the simulation results. These costs are most pronounced in the status quo and FR3, NL2, and IT2 configurations. In the case of the German–Luxembourgish split configurations, this cost is reduced as fewer plants are activated for upward redispatch.

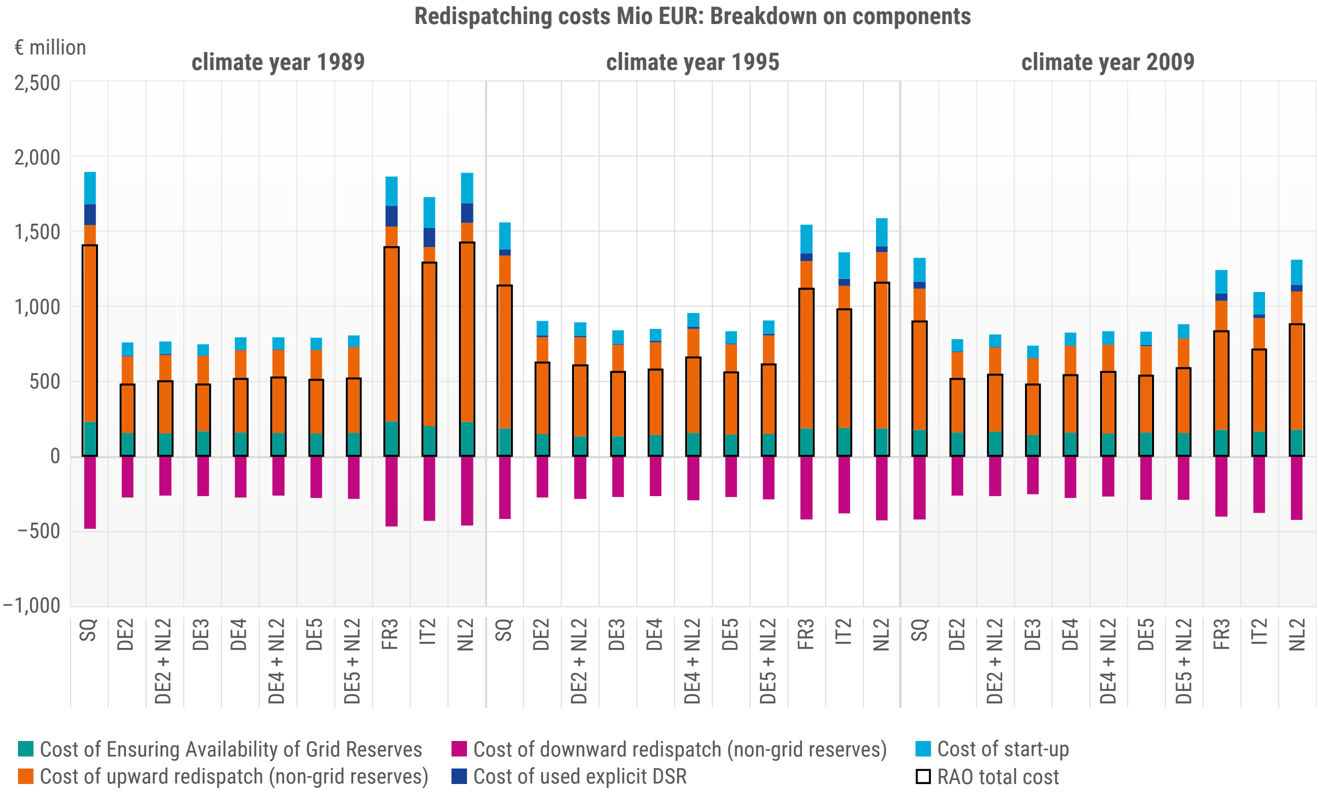


Figure 35: Breakdown of RAO cost for all alternative configurations and climate years

Figure 36 visualises the impact of the splits on the RAO costs, showing cost differences relative to the status quo. The German–Luxembourgish split configuration achieves the largest reduction in RAO costs due to the decrease in redispatch volumes, as observed in section 6.1.2.4.2. For example, in climate year 1989, Figure 31 demonstrates that the German–Luxembourgish splits significantly reduce gas redispatch volumes, with some reduction in hard coal and lignite. These reductions directly reduce the redispatch costs. Additionally, there is a notable reduction in startup costs linked to the reduced use of these fuels.

Costs associated with DSR also decrease under the German–Luxembourgish splits. The cost of ensuring availability decreases as the redispatch peaks in Germany – on which this calculation is based – are reduced in the German–Luxembourgish splits.

In the case of the Italian split configuration, there is a reduction in upward redispatch due to reduced gas redispatch. However, for the FR3 and NL2 configurations, there is no significant change compared to the status quo. This behaviour is consistent across all three climate years.

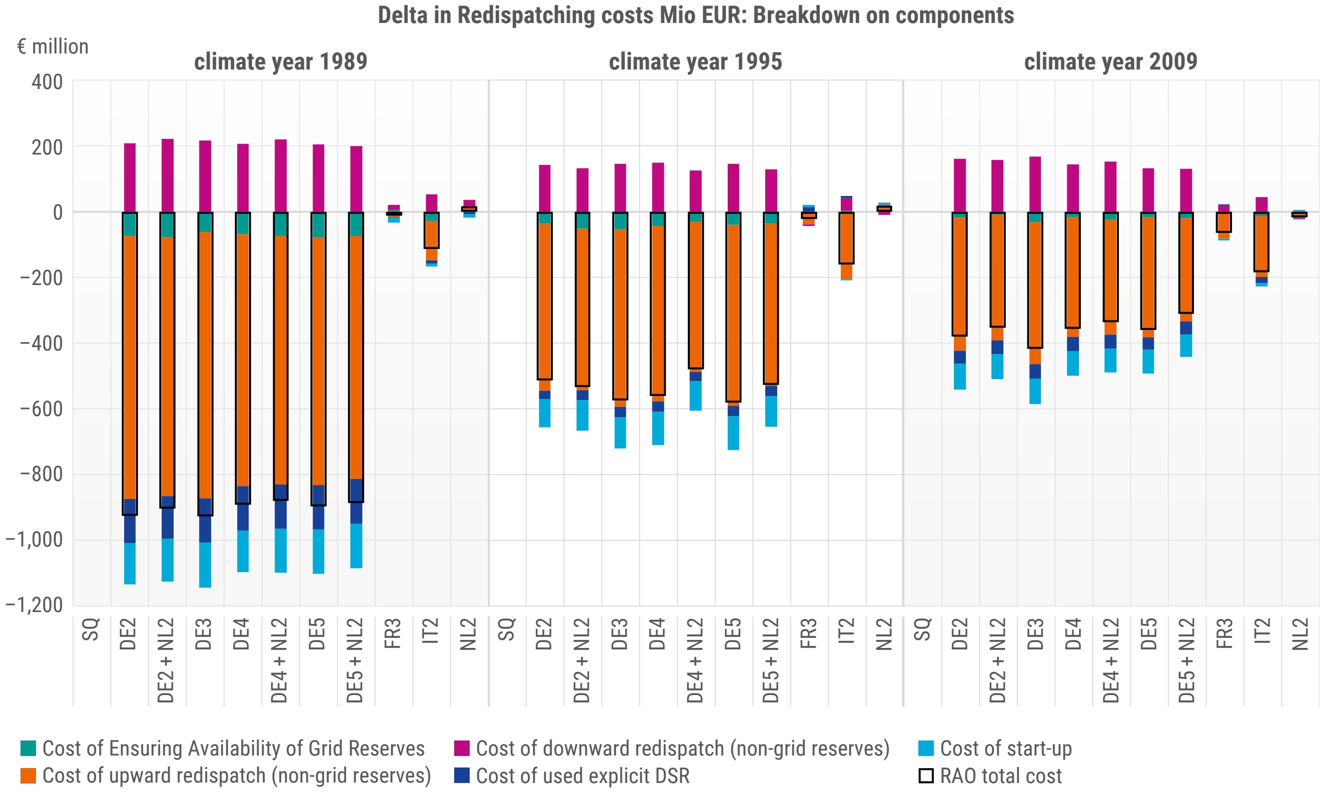


Figure 36: Breakdown of the changes in RAO cost relative to the status quo for all alternative configurations and climate years

6.1.2.4.4 Post-RAO Dispatch Analysis

As post-RAO results, we refer to the final "realtime" physical dispatch of the system, derived as the sum of the actions in the different timeframes, namely the day-ahead FBMC dispatch and the close-to-real-time RAO redispatch actions.

We assess the impact of the different configurations on the post-RAO physical system dispatch by analysing two areas, namely the impact of the total system dispatch in CE and the dispatch variation between timeframes.

Central Europe total system dispatch (fuel utilisation)

Figure 37 shows an analysis using climate year 1989, which shows the final post-RAO system dispatch broken down by fuel type, while Figure 38 presents the dispatch variations with respect to the status quo. Figure 39 zooms in on the distribution of dispatch variations in the different BZs as a representative example of all German–Luxemburgish BZ splits. The general observations regarding the post-RAO system dispatch per configuration are as follows:

- **DE/LUX configuration:** When introducing a split in the German–Luxemburgish BZ, the final system dispatch leads to an overall increase in the RES integration (reduction in RES curtailment) in the northern DE zones and an increase in lignite and coal generation in the same zones. This increase can be attributed to the need for the system to accommodate increased imports from the Nordics in the status quo, which leads to increased curtailment of downward redispatch of conventional units in the northern areas. At the same time, a reduction in gas, other non-RES, other RES, and pumped water is observed in Germany. Furthermore, reductions in gas production are observed in Belgium, the Netherlands, and Poland, as well as a reduction in hard coal biofuel in the Netherlands. These reductions are compensated by gas in Austria, Italy, Hungary, France, Slovakia, and the Czech Republic, and lignite in the Czech Republic.
- **FR3 configuration:** The splitting of France leads to minor changes in the final system dispatch pattern compared to the status quo.
- **IT2 configuration:** Splitting Italy leads to reduced imports from France, prompting a reduction in nuclear and gas production in France. The deficit from reduced imports is compensated by increased gasbased generation in Italy.
- **NL2 configuration:** The NL2 configuration does not lead to significant changes in the overall dispatch pattern or the redispatch volumes.

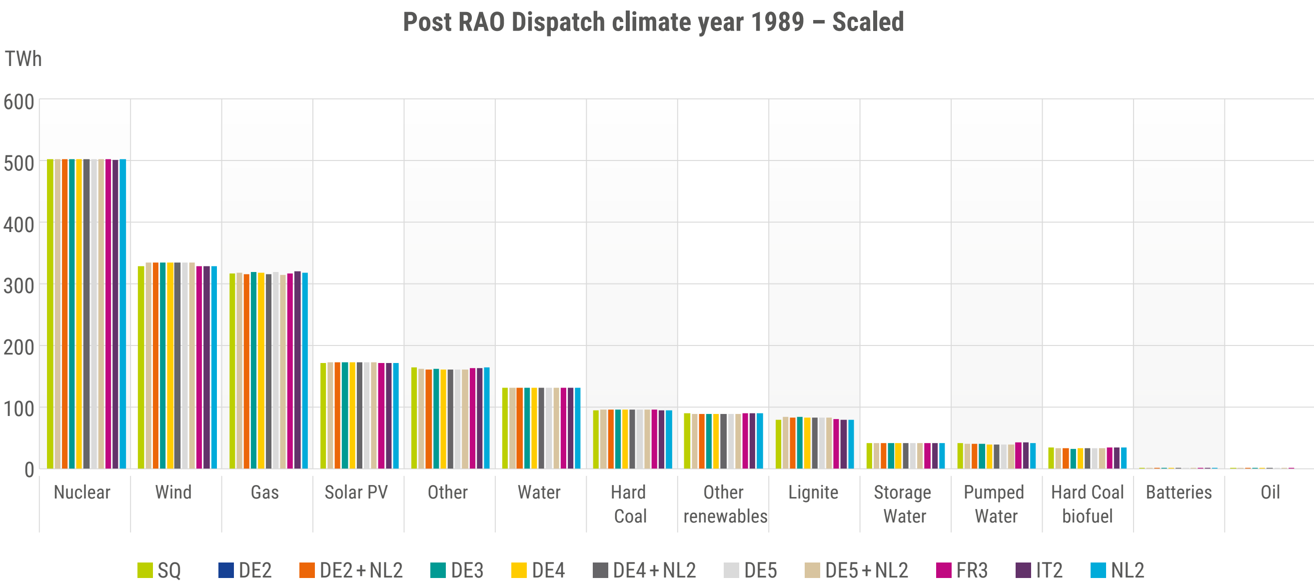


Figure 37: Post-RAO system dispatch per fuel type

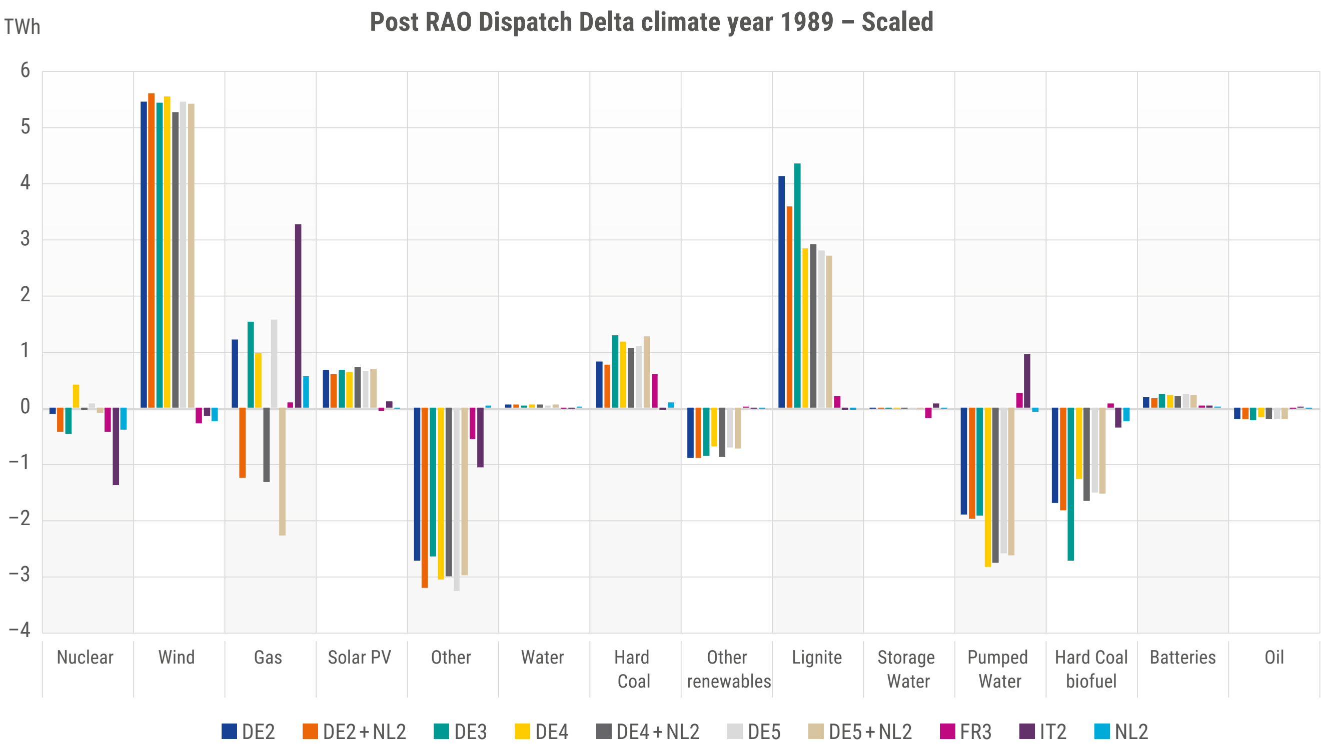


Figure 38: Delta post-RAO system dispatch per fuel type

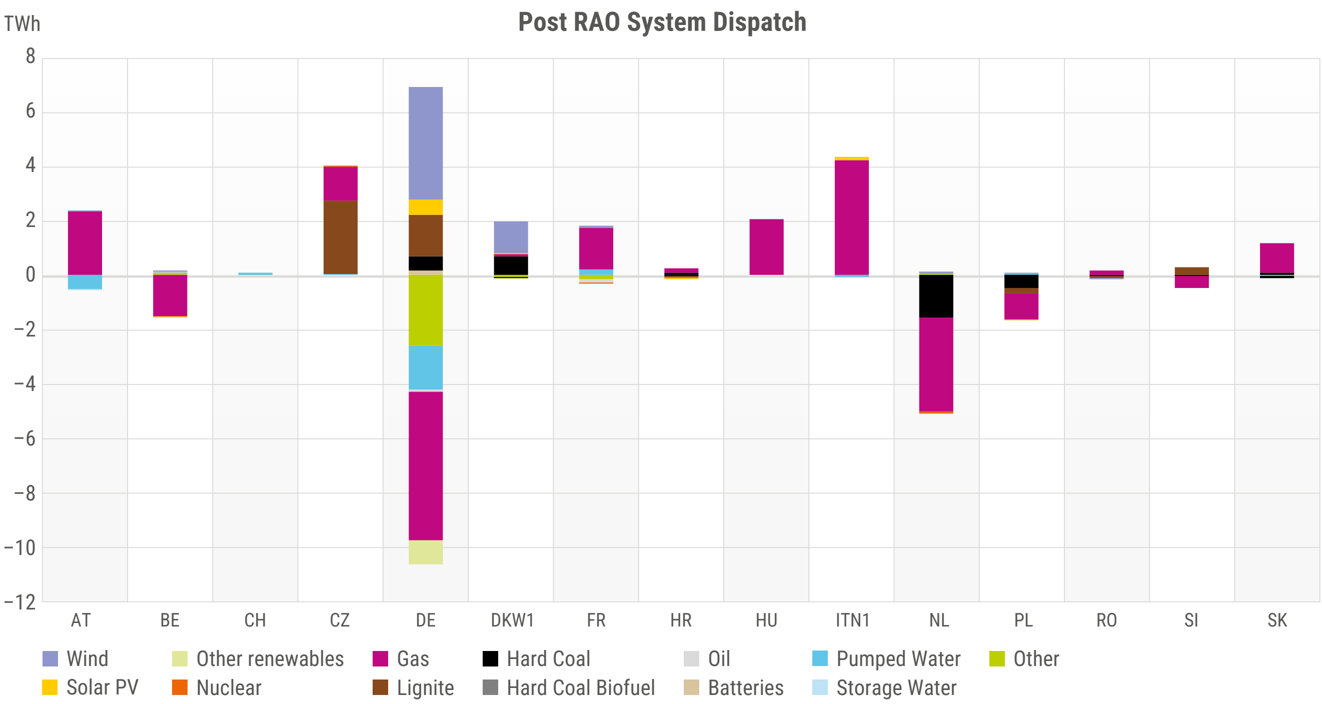


Figure 39: Variation in post-RAO system dispatch between the status quo and DE2 configurations

Generation dispatch variation between timeframes

The post-RAO dispatch analysis reveals that while the final dispatch outcomes remain consistent across different configurations, the processes leading to these outcomes significantly vary. Figure 40 provides a high-level illustration of these processes and their key steps to aid the understanding. In the status quo configuration, the initial dispatch obtained from FBMC requires extensive remedial actions to resolve operational security violations. Introducing a split leads to better geographic allocation in FBMC, reducing the need for such RAO due to better initial alignment of resources within the market, mitigating operational challenges.

The final system dispatch corresponds to a "nodal" solution and the key differences are due to the flexibility of resources participating in RAO. As the load and grid configuration do not significantly change between the status quo and different configurations, the possible differences are attributed to the differences in generation, namely the level of resources is non-dispatchable in RAO. In this respect, the main changes in the final system dispatch are due to imports from external zones (which are not changed in RAO) or due to the commitment of inflexible power plants that cannot change their position when moving to the RAO timeframe.

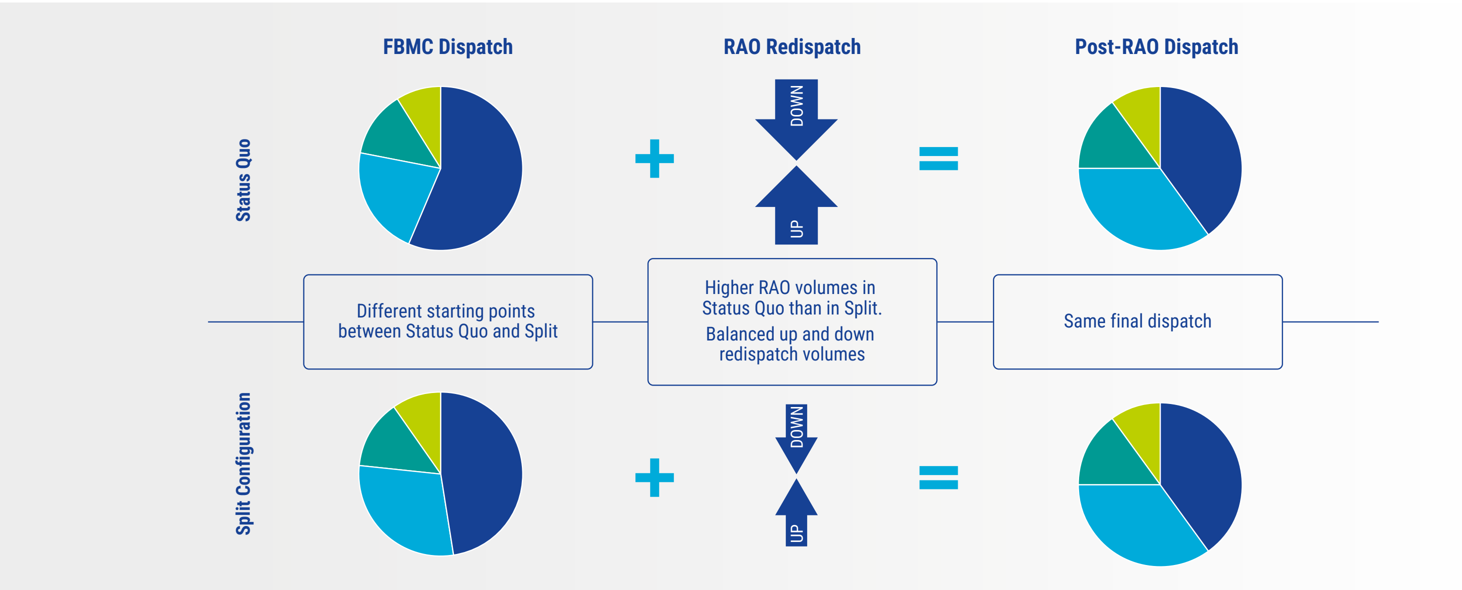


Figure 40: High-level overview of the post-RAO dispatch

6.1.2.4.5 Deep Dive into Counter-intuitive Results on FBMC and RAO

Generally, it is expected that a BZ split has two main effects. First, a reduction in market welfare is expected: where previously unrestricted trade was possible in the single BZ, after the split, this trade is constrained by the available cross-zonal trading capacity. This restriction would lead to a less optimal dispatch of power generation resources and thus a loss of market welfare. Second, a reduction in redispatch volumes and costs is expected. The newly introduced BZ border should ensure that the power flow across this border respects the grid's physical limitations by constraining the cross-zonal trading capacity. By ensuring that the physical limitations of the grid are respected, congestion will be reduced and therefore also the associated redispatch cost.

This effect is directly visible in the simulation results when introducing the two-zone split assessed for the German – Luxemburgish BZ. The results show an average loss of 344 € million in market welfare (CE and non-CE) and simultaneously a reduction in redispatch costs of 607 € million.

However, further splitting the German – Luxembourgish BZ does not see this trend continue. The results show that there is actually a higher market welfare in the DE4 and DE5 configurations compared to the DE2 and DE3 configuration. Furthermore, congestion volumes are observed to increase again, even though the associated redispatch costs largely remain the same. This effect can be observed in the Figure 41, where the difference in congestion between the status quo and DE2 (left graph) is compared with the case between DE3 and DE5 (right graph). Introducing the assessed two-zone split leads to a broad decrease in congestion especially in the north-south direction (indicated in green), while some cases of CNECs can be observed where congestion is increasing. However, when moving to a higher granularity of splits (from DE3 to DE5), this effect is reversed, indicating a majority of CNECs where congestions are increasing. Counter-intuitively, these results point towards increasing cross-zonal trading capacity with a higher granularity of splits of the German – Luxembourgish BZ.

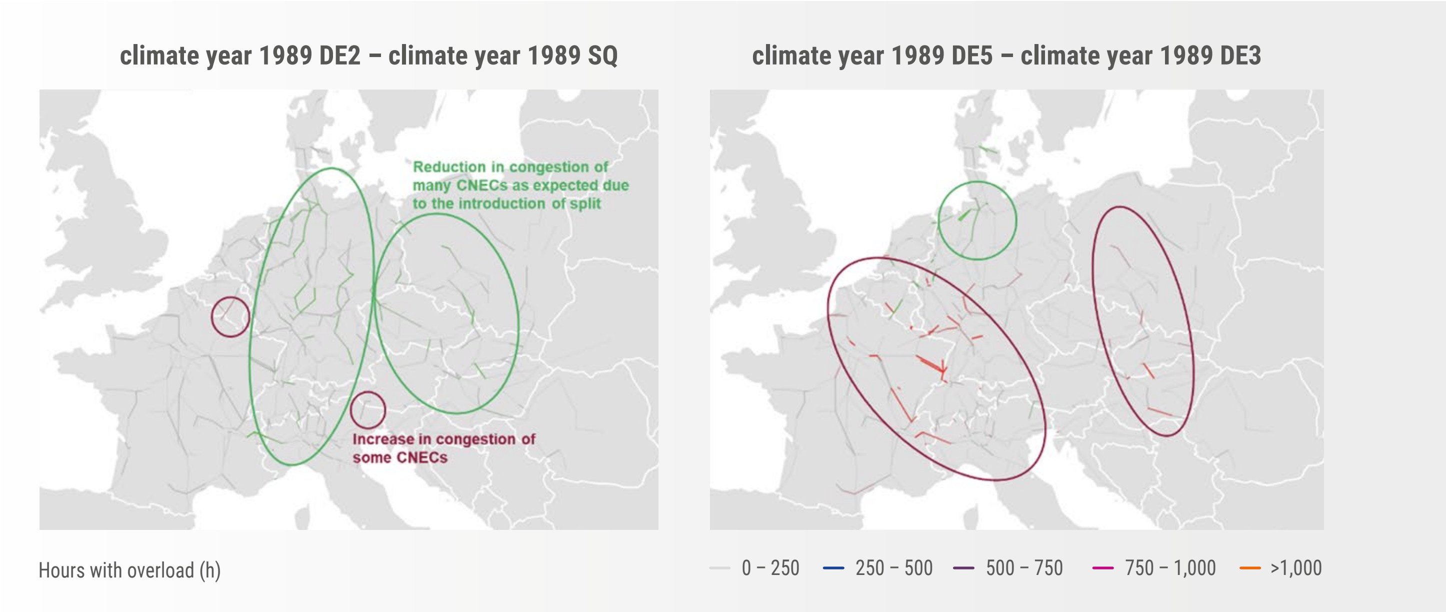


Figure 41: Mapping the change of congestion from the status quo to DE2 (left) and from DE3 to DE5 (right) for climate year 1989

Based on the results from this study, it cannot be concluded to what extent each of these effects discussed below contributes to the counter-intuitive findings, nor can it be definitively concluded whether these effects would be reflected in the Core capacity calculation process in reality.

1. **Increased RAM on limiting CNECs in FBMC:** The reduction of loop flows and internal flows in the flow-based capacity calculation might result in increased European trade flows for more granular splits, thereby increasing the market welfare and resulting in a higher overall level of flows through the grid in OSA (see example below for a numerical explanation).

2. **The use of virtual margin for fulfilling the 70 % rule:** Depending on the optimiser's decision in the FBMC module, more virtual margin might be used in a configuration with more granular splits. This could consequently lead to higher congestion in OSA.

3. **Inconsistent borders across configurations:** It should be noted that various German–Luxembourgish splits do not consecutively build on each other. For example, Schleswig-Holstein is part of the northwestern German zone in the DE3 configuration but part of the north-eastern German zone in the DE4 configuration. The BZBs therefore do not exactly align, which could affect the available cross-zonal capacity resulting from the capacity calculation.

4. **More degrees of freedom in flow-based domains:** Additional BZs within the flow-based region lead to a higher number of dimensions in the flow-based domains. This means that there are more degrees of freedom in the optimisation, constrained by the flow-based domain. This could allow better utilisation of cross-zonal capacity on other borders. Put differently, the limitation on trade within one BZ could allow for more trade across borders to other BZs, leading to an overall better outcome.

5. **Flow-based capacity calculation assumptions:** Overflows in OSA on CNECs in higher granular splits might be caused by specific assumptions in the flow-based capacity calculation such as the GSKs strategy or the selection of market-relevant CNECs, which are dependent on the number and delineation of splits. Furthermore, smaller BZs could improve the accuracy of the GSKs, which are estimated for a smaller geographical area.

Example on the impact of increased RAM on limiting CNECs in FBMC

A BZ reconfiguration affects the base case creation outcome (section 6.1.2.1), which is used as an input for the capacity calculation and therefore the results of the initial load flow calculation within the flow-based capacity calculation process. In particular, the sum of internal flows and loop flows (F0_ALL) and the flows resulting from trading with market areas outside the flow-based region (FUAF) are affected. These flows are relevant for determining the RAM on the CNECs in the capacity calculation.

Figure 42 shows an example from the capacity calculation results for one MTU of an increase in RAM following increasing splits of the German–Luxembourgish BZ. The example shows that the initial loading (F0_ALL) decreases on CNEC2266_b,[27] with the RAM increasing accordingly.

In this example, CNEC2266_b was found to limit the FBMC in this particular MTU across each of the alternative German–Luxembourgish configurations.[28] This means that the increase in RAM increases the trading capacity in the FBMC in a relevant way, therefore affecting the market dispatch and subsequent flows in the operational security analysis (OSA).

While splits of a BZ would generally add more constraints (CNECs) to the FBMC, this example has shown that it can also increase the RAM on other CNECs. During the FBMC, only a few CNECs will be limiting in one MTU. Therefore, the net effect on the FBMC of the BZ split will largely depend on which CNECs end up being limiting.

DE2								
CNEC_ID	F_{max} [MW]	FREF [MW]	**F0_ALL [MW]**	F0_CCR [MW]	FUAF [MW]	FRM [MW]	AMR [MW]	**RAM [MW]**
CNEC2266_b	1,315.70	1,877.45	**94.44**	778.45	684.02	131.57	0.00	**405.68**
DE3								
CNEC_ID	F_{max} [MW]	FREF [MW]	**F0_ALL [MW]**	F0_CCR [MW]	FUAF [MW]	FRM [MW]	AMR [MW]	**RAM [MW]**
CNEC2266_b	1,315.70	1,941.29	**30.25**	727.74	697.49	131.57	0.00	**456.39**
DE4								
CNEC_ID	F_{max} [MW]	FREF [MW]	**F0_ALL [MW]**	F0_CCR [MW]	FUAF [MW]	FRM [MW]	AMR [MW]	**RAM [MW]**
CNEC2266_b	1,315.70	1,916.50	**-1.53**	654.88	656.41	131.57	0.00	**529.25**
DE5								
CNEC_ID	F_{max} [MW]	FREF [MW]	**F0_ALL [MW]**	F0_CCR [MW]	FUAF [MW]	FRM [MW]	AMR [MW]	**RAM [MW]**
CNEC2266_b	1,315.70	1,878.69	**-56.54**	595.93	652.47	131.57	0.00	**588.20**

Figure 42: Effect of a split on F0_ALL and RAM in flow-based capacity calculation process: example for German–Luxembourgish split scenarios in MTU 7773 of climate year 1989

27 This CNEC is the cross-border network element between Belgium (ACHÈNE) and France (Lonny). The label _b means that a positive value is associated with a flow in backward direction.

28 Please note that in this MTU for climate year 1989 not only CNEC2266_b but several CNECs are limiting the FB-domain. This holds true for all German–Luxembourgish split scenarios.

6.1.2.5 Loop Flow Analysis

Loop flow analyses are conducted after FBMC to identify adverse effects of internal transactions on other BZs (see criterion 14). The following section describes how the simulations have been executed, describing the general results and explaining the counter-intuitive effects observed.

6.1.2.5.1 General Information

For the simulations, the TNA software was used with the power flow colouring (PFC) method to identify and analyse loop flows and their compositions.

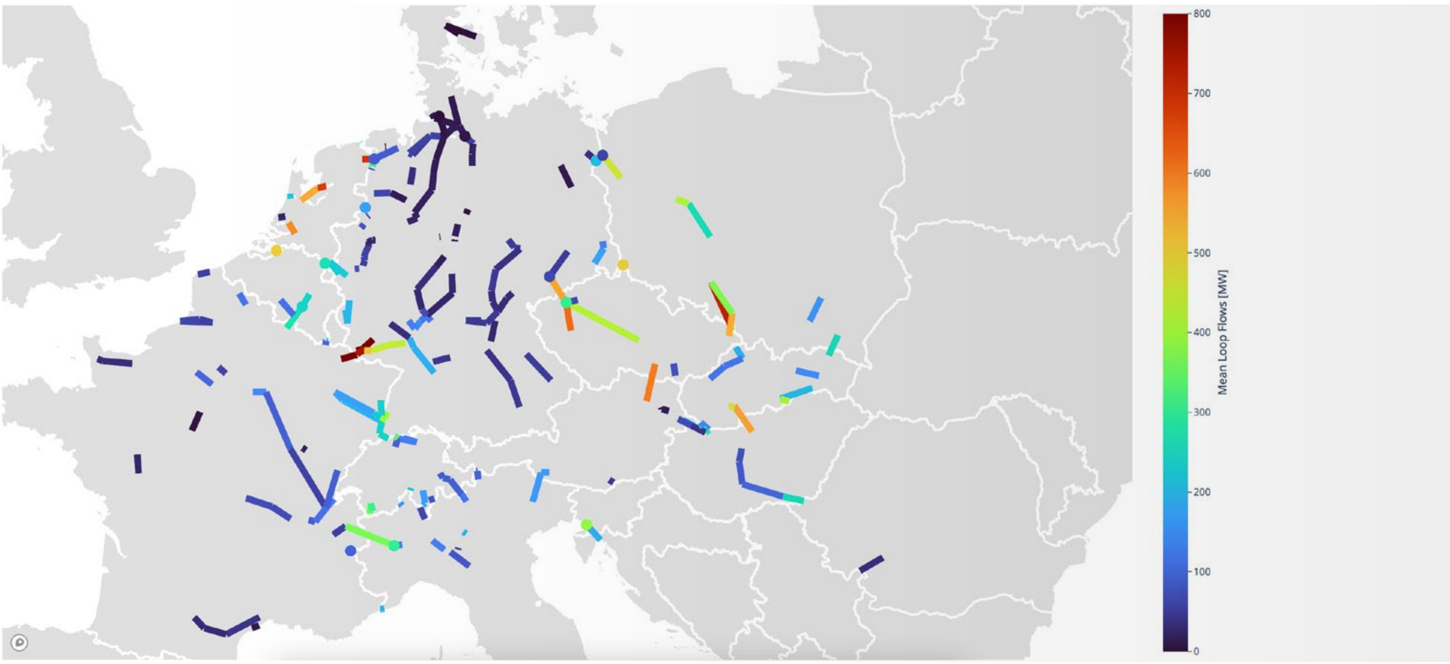
The analysis is confined to a period of 50 days to manage the calculation duration effectively, equating to 1,200 MTUs following the same selection process as in the RAO module and presented in section 6.1.2.4.

The CNECs are determined based on Article 10 of the BZR Methodology. CNECs with a shadow price greater than zero – as identified from FBMC – are included as market congestions. Additionally, CNECs are selected based on their utilisation as per RAO results for physical congestions. This results in a static CNEC list, incorporating CNECs across all climate years and configurations that have either a market congestion or a physical congestion for more than 1 % of the time. This list includes 866 CNECs that meet the defined constraints and standards, covering a broader spectrum of fifteen market areas in the status quo configuration. This approach was necessary to reduce the simulation runtimes.

The PFC is computed for each MTU. The calculation utilises the GSKs and the static CNEC list for each MTU, as well as generated grid models for each MTU based on FBMC results. This calculation approach results in comprehensive PFC outcomes for each MTU across the evaluated scenarios, providing insights into the loop flows per CNEC. In case there are multiple contingencies congested for a CNE on a specific MTU, the CNEC with the highest loop flow is presented below and used for assessing the indicator.

6.1.2.5.2 Comparative Analysis of Loop Flows

In the following example, the simulation results are analysed by comparing the status quo scenario and the scenario splitting Germany into two BZs (DE2) to investigate differences in loop flows due to this split. Based on this, the geographical distributions between the two scenarios are analysed. Additionally, CNECs were analysed to identify those that exhibited different behaviours, such as significantly increasing or decreasing loop flows, or not appearing at all. This comparative approach provides a deeper understanding of how the BZ configurations affect the loop flow simulations across the network.

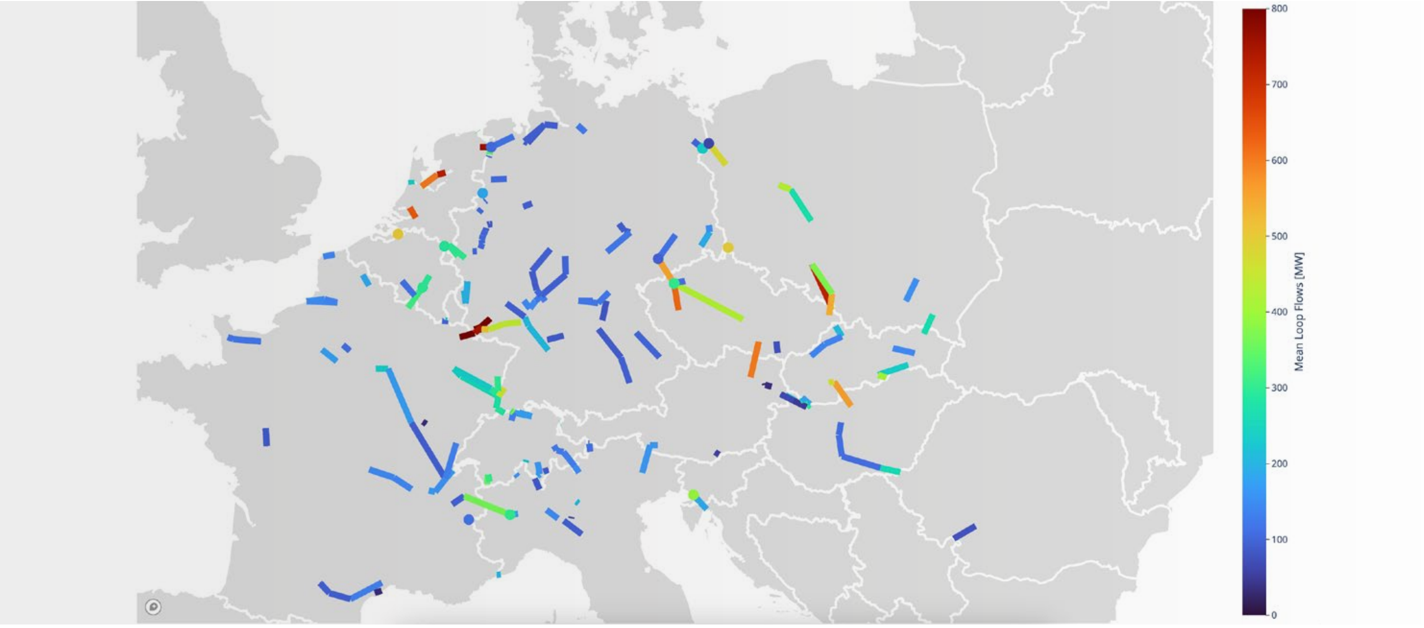


Note: Lines represent power lines and dots represent transformers.

Figure 43: Average loop flow across all MTUs considered on the CNECs considered in the status quo for climate year 1989

Figure 43 depicts the distribution of loop flows on CNECs across CE for the status quo in climate year 1989. Because loop flows are only calculated for congested elements, it is not possible to observe the entire route that a loop flow takes. Furthermore, many CNECs show relatively small loop flows.

To refine the analysis, a 5 % threshold of the maximum utilisation F_{max} is applied – i.e. CNECs with a loop flow smaller that 5 % of their F_{max} are filtered out – as depicted in Figure 44. This threshold effectively filters out CNECs with minimal loop flows, highlighting those with more significant loop flows.

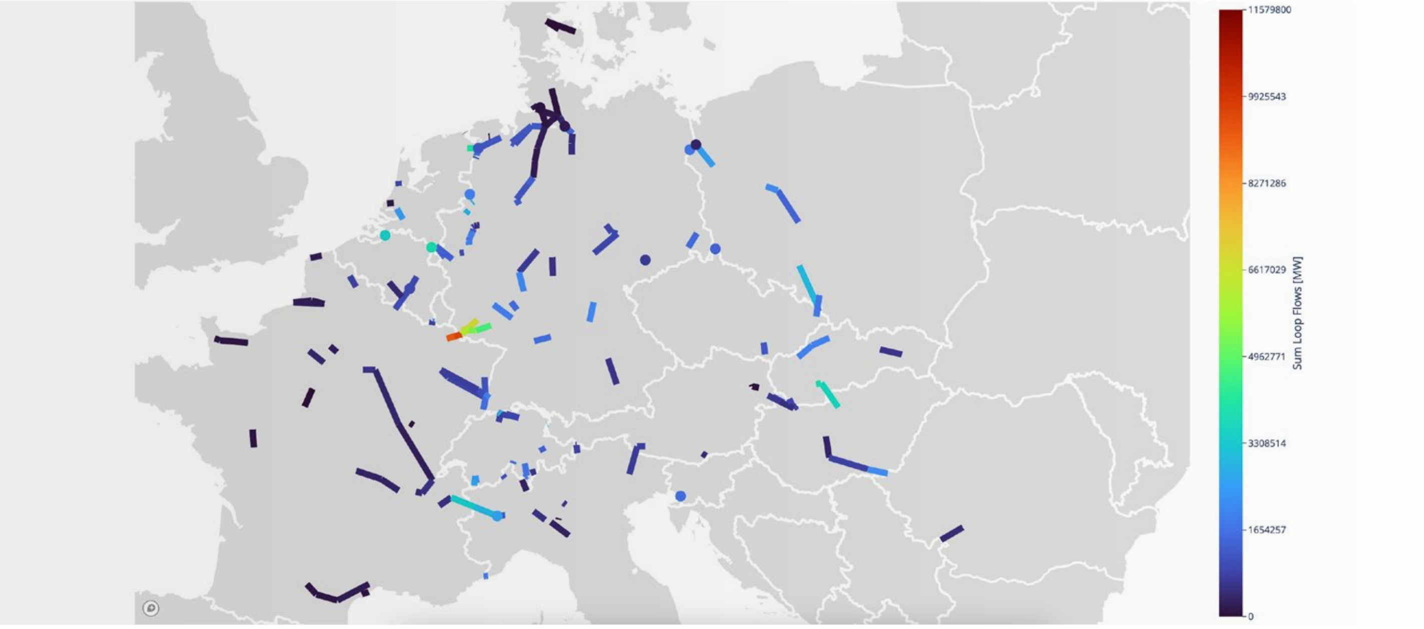


Note: Lines represent power lines and dots represent transformers.

Figure 44: Average loop flows across all MTUs considered with a 5 % threshold of the maximum utilisation F_{max} on the CNECs considered in the status quo for climate year 1989

In Figure 44, the highest loop flows can be identified occurring in areas such as the Netherlands, Belgium, France, and the western border of Germany. Additionally, comparatively large loop flows are also noted in Poland, Czech Republic, Austria, and on the eastern border of Germany.

Following this, Figure 45 below shows the average loop flows across all MTUs for the DE2 alternative configuration in which the German–Luxemburgish BZ is split into DEJ1 and DEJ2.

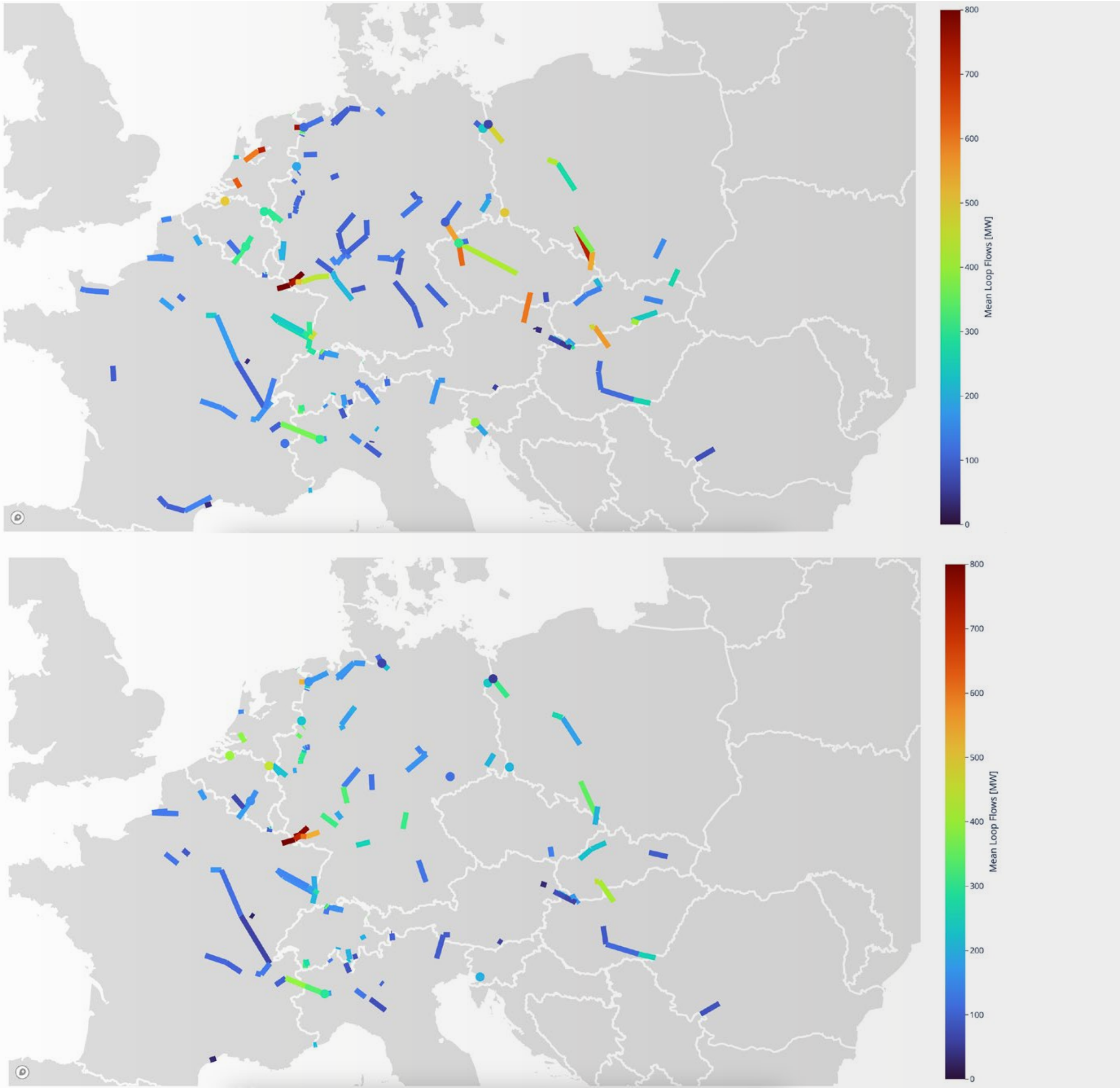


Note: Lines represent power lines and dots represent transformers.

Figure 45: Average loop flows across all MTUs considered on the CNECs considered for the DE2 split in climate year 1989

Subsequently, the same alternative configuration is presented with a 5 % threshold applied on F_{max} over the CNECs, allowing for a clearer analysis by filtering out less impactful loop flows.

To enable an easier comparison, Figure 46 depicts the status quo with a 5 % threshold and DE2 with a 5 % threshold on top of each other.

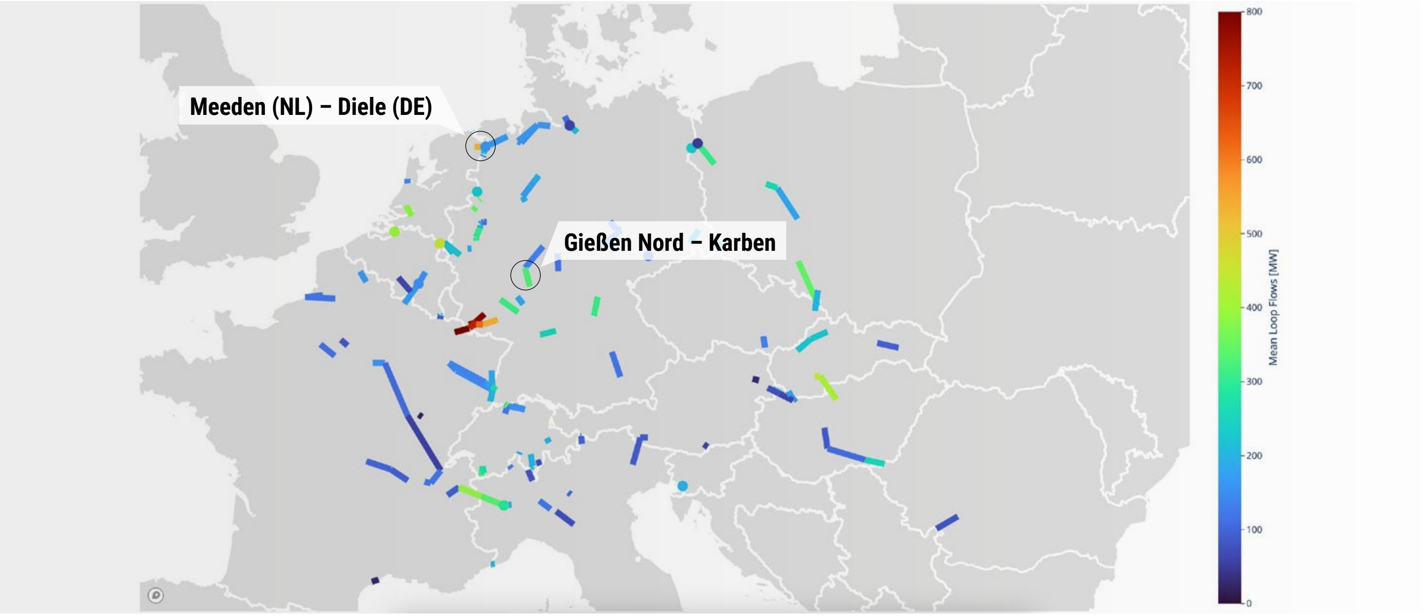


Note: Lines represent power lines and dots represent transformers.

Figure 46: Average loop flows across all considered MTUs with a 5 % threshold of the maximum utilisation F_{max} on the CNECs considered in the status quo (upper) and DE2 (lower) for climate year 1989

Comparing CNEC elements in the status quo and DE2, it is evident that the split affects the magnitude in loop flows. It can be seen that in DE2 several CNECs in countries such as the Czech Republic, Netherlands, Belgium, and France no longer have loop flows, or they have loop flows lower than 5 % of F_{max}.

Additionally, some CNECs show less loop flows in Poland, Slovakia, France, Belgium, and the Netherlands. When examining the results for the German–Luxemburgish BZ, some CNECs show higher loop flows in the DE2 split scenario compared to the status quo, as seen in the colouring of CNECs. This finding leads to an indepth analysis of the composition of flows on specific CNECs.



Note: Lines represent power lines and dots represent transformers.

Figure 47: Average loop flows across all considered MTUs with a 5 % threshold of the maximum utilisation F_{max} on the CNECs considered in DE2 for climate year 1989 highlighting a CNEC connecting Meeden (NL) to Diele (DE) and a CNEC connecting Gießen Nord to Karben above Frankfurt (DE)

For this analysis, two CNECs are selected to further illustrate the loop flow results and different patterns observed.

Reduction of loop flows in the DE2 alternative configuration compared to the status quo configuration

Overall, it can be observed that the DE2 split results in reduced loop flows compared to the status quo scenario on CNECs outside of Germany. This is illustrated by the cross-border CNEC from Meeden (NL) to Diele (DE), which sees its average share of loop flows reduced from 803 MW to 502 MW.

Figure 48 shows a reduction in loop flows when comparing the loop flows from the status quo to DE2 on this specific grid element. In the status quo, the loop flows regularly exceed 2,000 MW, taking up nearly the full line capacity (F_{max}). In the DE2 configuration, these loop flows are significantly reduced, in several MTUs by approximately 50 %. This indicates more opportunities for cross-zonal trade due to the DE2 split.

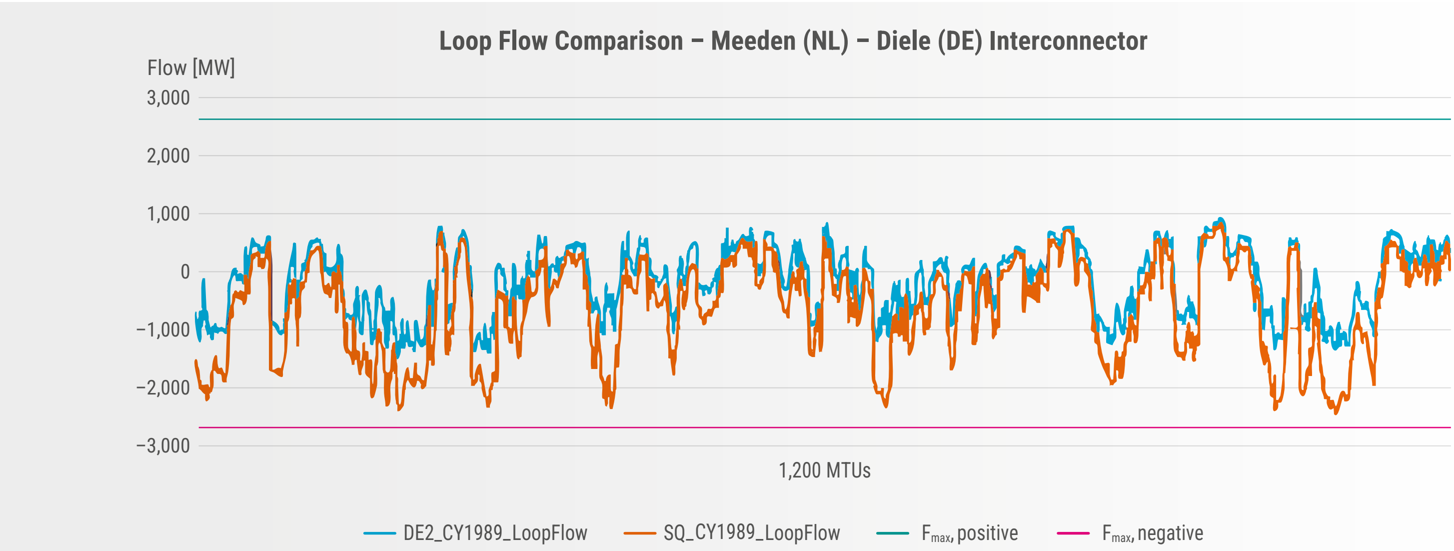


Figure 48: Comparison of loop flows between the status quo and DE2 on the Meeden (NL)–Diele (DE) interconnector

Increase in loop flows between the DE2 alternative configuration and the status quo configuration

In order to illustrate this effect, an analysis is presented for the CNEC connecting Gießen Nord to Karben located just north of Frankfurt (DE), as shown in Figure 47. In this instance, the average loop flow for this CNEC shows significantly increased average loop flows from 90 MW in the status quo to 330 MW in the DE2 split.

By zooming in on the relevant CNEC, Figure 49 shows the internal flow and loop flow for both the status quo and DE2. This graph demonstrates the increase in loop flow over all MTUs. The increase can be explained by the fact that a high share of internal flows in the status quo is redirected to loop flows in the newly split BZs.

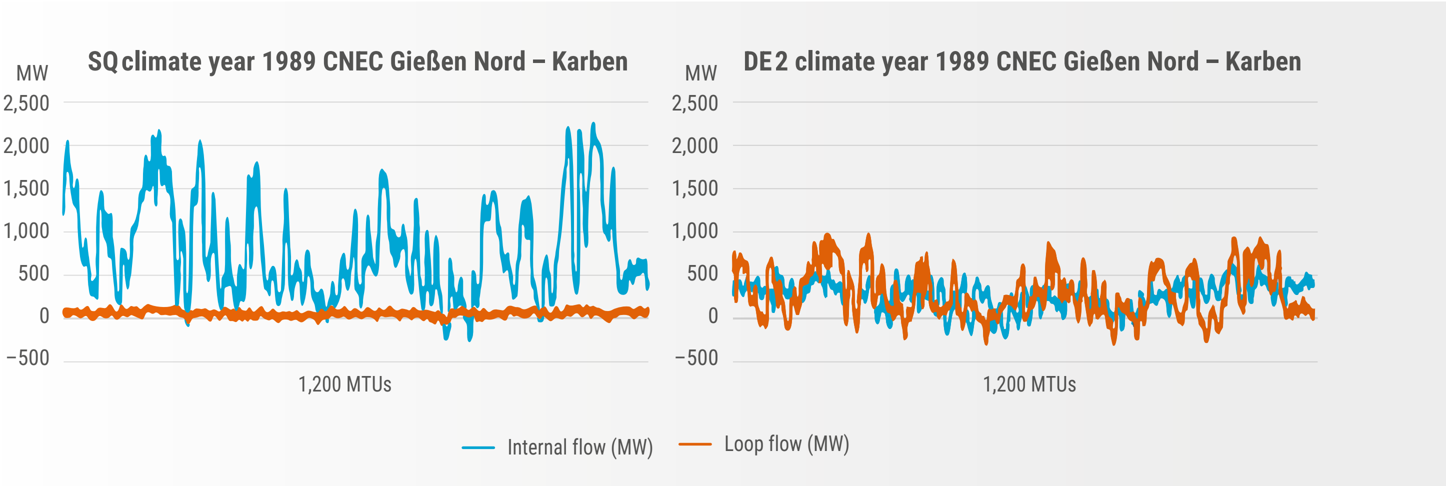


Figure 49: Comparative analysis of loop flows and internal flow in status quo (left) and DE2 (right) for climate year 1989 for 1,200 MTUs on one internal German CNEC considered (Gießen Nord–Karben)

Diving into the different components of the loop flow for one MTU, we can observe that it mainly originates from DEJ1, e.g. the northern German–Luxembourgish BZ, as well as minor contributions from surrounding market areas.

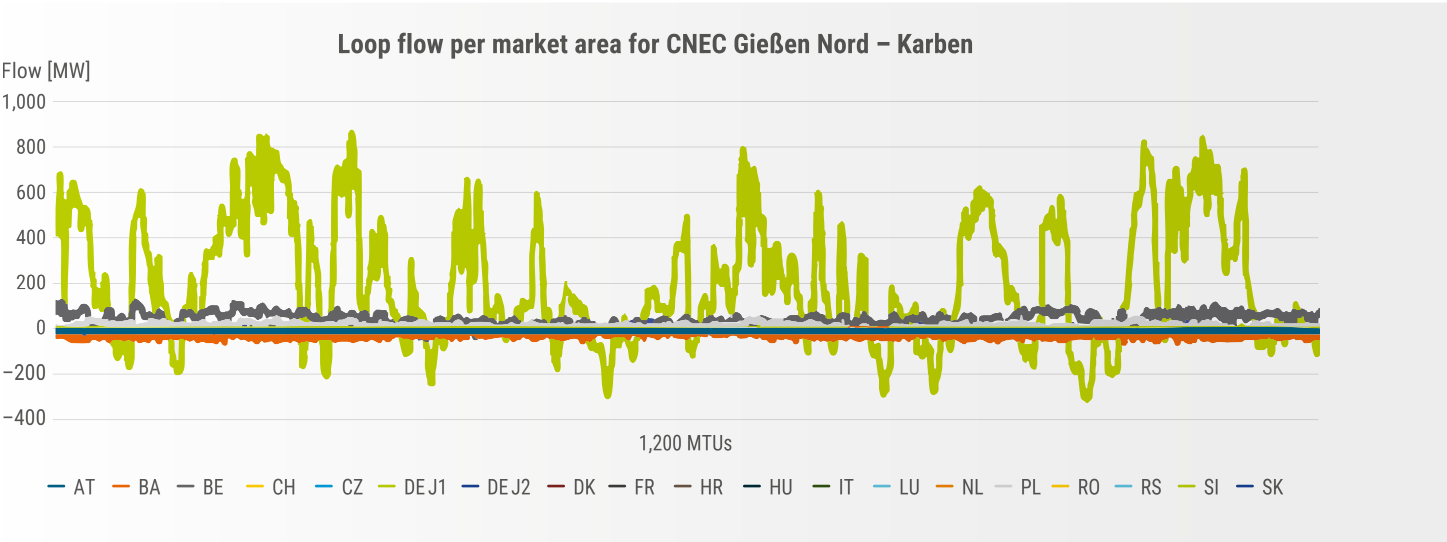


Figure 50: Market area composition of loop flows across the Gießen Nord–Karben CNEC

A second effect observed in the graph is that the contributions to the loop flow comprise many market areas with minor effects – often referred to as noise – and only a few main contributors, such as DEJ1 in this case. To further illustrate this, Figure 51 shows the composition of the CNEC in one MTU, highlighting the significant contributors to the loop flow and distinguishing them from the minor, less impactful contributions. This detailed breakdown helps in understanding the primary sources of loop flows and their relative impact on the network.

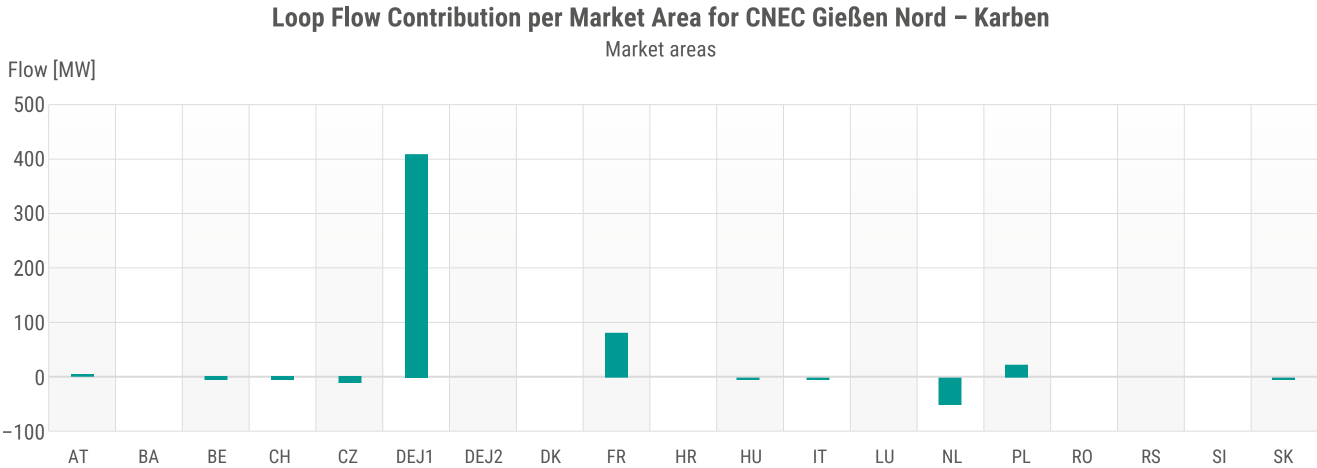


Figure 51: Contribution per market area for the Gießen Nord–Karben CNEC for MTU 1016

In Figure 51, it can be seen that the main contributor to the loop flow is DEJ1 in this example, with the French BZ ranking second. However, there are also numerous other market areas contributing small loop flows, such as the Slovakian BZ with 5 MW in this MTU. This illustrates the effect of applying a 5 % threshold in the analysis to filter out CNECs with very small loop flows. Please note that this 5 % threshold was applied to facilitate further analysis in the examples above but was not applied for the assessment of the criteria in step 2.

In conclusion, the analysis reveals that because loop flows were only calculated for congested elements, the complete loop flow trajectories are not visible in these simulation results. Furthermore, there is only a relatively small loop flow on many congested elements.

To better understand the loop flow simulation results, an indepth analysis is performed comparing the DE2 split with the status quo configuration. This exemplary analysis shows that a split of the German – Luxemburgish BZ generally results in reductions in loop flows compared to the status quo outside of Germany, thereby enabling increased cross-border trade in the simulations. This is because part of the exchanges within the German – Luxembourgish bidding zone that give rise to loop flows in the status quo become potentially exchanges between the newly formed BZBs in a split configuration and therefore need to compete for the allocation of cross-zonal capacity. The flows resulting from such exchanges are labelled market flows instead of loop flows. In summary, splitting a BZ would lead to reduced opportunities for internal trades, while it is likely to reduce loop flows and give more room for cross-border trades and internal flows in other BZs.

However, there are instances where counter-intuitive results – such as increased loop flows – can be observed when splitting. In the exemplary analysis described above, these anomalies can be explained by the reallocation of internal flows to loop flows due to the splitting of market areas where north to south flows within Germany are marked as internal flows in the status quo but become – by definition – loop flows in a split German – Luxembourgish BZ. Additionally, the network's complexity is highlighted by the presence of noise, where small loop flows from various countries accumulate, with only some major contributors. This dual effect underscores the intricate impact of BZ configurations on loop flows within the network.

6.1.2.5.3 Counter-intuitive Results when Assessing Criterion 14 Based on Loop Flows

It is important to note that the assessment performed in line with the BZR Methodology does not present a full picture on loop flows in the system because the loop flows were only post-processed after the actual simulations for a subset of elements displaying either a market or physical congestion depending on the configuration. Elements without a congestion might still have a significant loop flow but are not included in this analysis, while congestion might be primarily determined by a trade flow but is included in the analysis.

The static CNEC list is based on the CNECs congested most often across all configurations and climate years to comply with the BZR Methodology to only include congested CNECs while keeping the total set of CNECs the same across the configurations, thus enabling the same basis for comparison. Applying the same rule per configuration would have led to different CNECs for every configuration and climate year. The end result is a set of 866 CNECs – among more than 7,000 in total – that are analysed in detail, including 700 internal CNECs and 166 cross-border CNECs. A high share of CNECs is situated in or connected to the German–Luxembourgish BZ.

	Internal CNECS		Cross-border CNECs	
	Count	% share	Count	% share
AT	46	7%	13	8%
BA	0	0%	1	1%
BE	39	6%	4	2%
CH	70	10%	2	1%
CZ	35	5%	14	8%
DE	297	42%	64	39%
DKW1	4	1%	0	0%
FR	81	12%	50	30%
HR	13	2%	3	2%
RS	0	0%	1	1%
HU	31	4%	8	5%
ITN1	19	3%	2	1%
NL	20	3%	2	1%
PL	16	2%	0	0%
RO	1	0%	2	1%
SI	8	1%	0	0%
SK	20	3%	0	0%
Total	700	100%	166	100%

Table 8: Breakdown of the CNECs used in loop flow analysis per bidding zone in internal and cross-border elements

Continuing with this subset of CNECs, an average loop flow is determined in accordance with the BZR Methodology. It is important to note that using only this average to evaluate the performance does not show the full picture.

This can be illustrated by the following numerical example visible in Figure 52, where the average loop flow is calculated. The end result is a higher average loop flow after the split even though the loop flows on all elements have decreased.

This is caused by CNEC 1 in the example no longer being congested and therefore not included in calculating the average loop flow. In the simulation results, it can also be seen that the average loop flow calculation for the German split scenarios include fewer CNECs compared to the status quo, as visible in Figure 53.

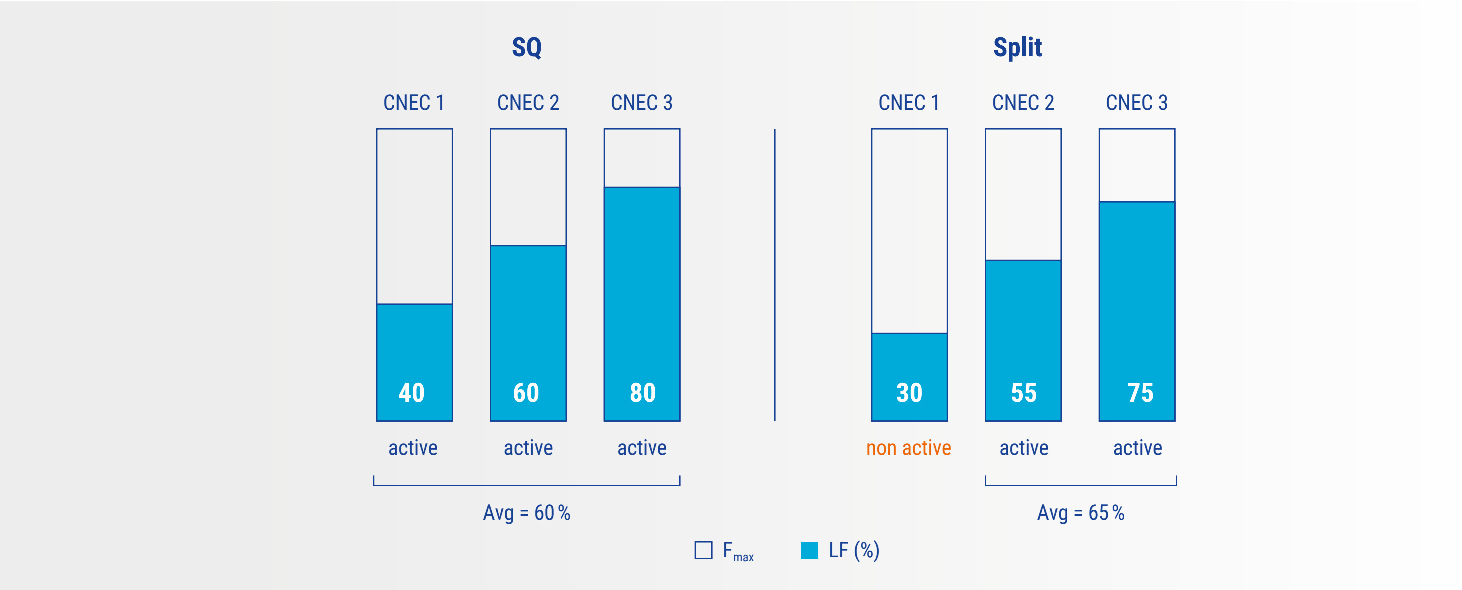


Figure 52: Illustrative example of how a decrease in loop flows can lead to higher average loop flows on congested CNECs

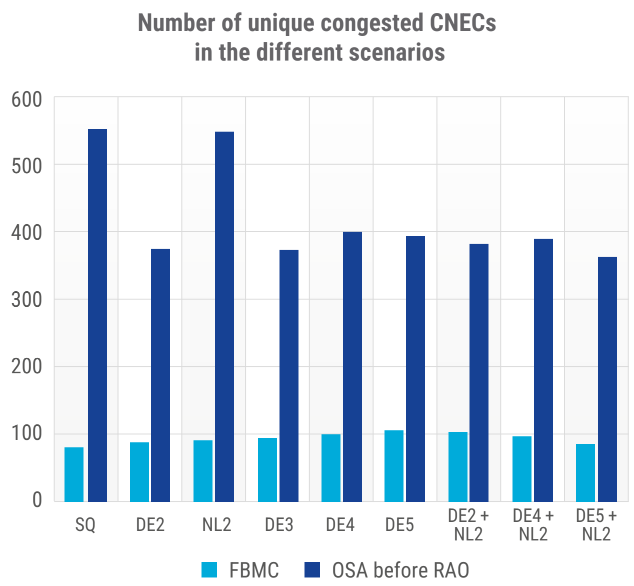


Figure 53: Number of unique congested CNECs in the different scenarios

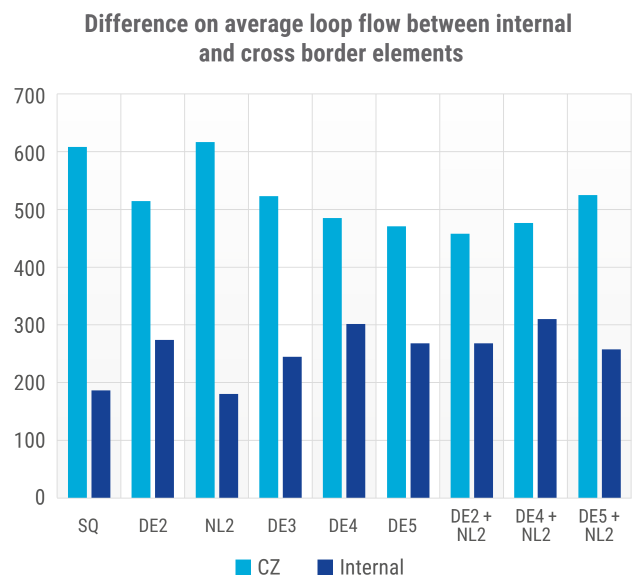


Figure 54: Difference in average loop flow between internal and cross-border elements

As will be observed when evaluating the loop flows as part of criterion 14 (adverse effects of internal transactions on other BZs), following the BZR Methodology can lead to non-intuitive assessments of the performance of the configurations. Additionally, there is an interesting difference between internal and cross-border elements, as explained in the previous section. For cross-border elements, the average loop flow seems to decrease overall, while for the internal elements this is less pronounced or even increasing in most German split scenarios.

6.2 Step 1: Monetised Benefits (Assessment of Criterion 4: Economic Efficiency)

As set forth in Article 13 of the BZR Methodology, the first step in the bidding zone review is to assess the monetised benefits. This shall be achieved by assessing criterion 4 (economic efficiency), which is the only monetised criterion considered for the CE BZRR.

6.2.1 Economic Efficiency for the Alternative Bidding Zone Configurations of Individual Countries

Economic efficiency is assessed according to Article 15(4) of the BZR Methodology. It is evaluated for the 2025 target year as the difference of:

a) the average change (over all climate years) in the socio-economic welfare coming from the market dispatch (calculated at the European level) and

b) the average change (over all climate years) in total additional costs derived from the RAO at the CE BZRR level,

for each alternative BZ configuration assessed compared to the status quo.

Economic efficiency is calculated as the change in socio-economic welfare with respect to the status quo configuration where:

- the change is calculated as the difference between the welfare respectively cost components for each alternative configuration and the welfare respectively cost components for the status quo configuration;
- the change in welfare coming from the market dispatch (market welfare) is calculated as the sum of the changes in consumer surplus, producer surplus, and congestion rent;
- economic efficiency is calculated as the change in socio-economic welfare, i.e. the difference between the change in market welfare and the change in additional costs from redispatch.

Table 9 presents an overview of the economic efficiency for each alternative configuration of individual countries in the CE BZRR. To put into perspective, this value is less than 1 % of the simulated system costs[29] in the CE region.

	Average change over all climate years with respect to status quo					
	Market dispatch (CE + non-CE)				RAO (CE)	Economic Efficiency
Configuration compared to status quo	Market welfare [€ million]	Consumer surplus [€ million]	Producer surplus [€ million]	Overall congestion revenue [€ million]	Additional costs from redispatch [€ million]	Socio-economic welfare (criterion 4) [€ million]
DE2	−344	1,072	−2,312	897	−607	264
DE3	−390	1,017	−2,445	1,038	−641	251
DE4	−291	1,159	−2,361	912	−603	312
DE5	−274	1,128	−2,566	1,165	−613	339
FR3	−42	541	-620	37	-33	−9
IT2	−214	1,132	−1,394	48	−154	−60
NL2	14	228	−272	59	5	9

Table 9: Average change in socio-economic welfare over all climate years

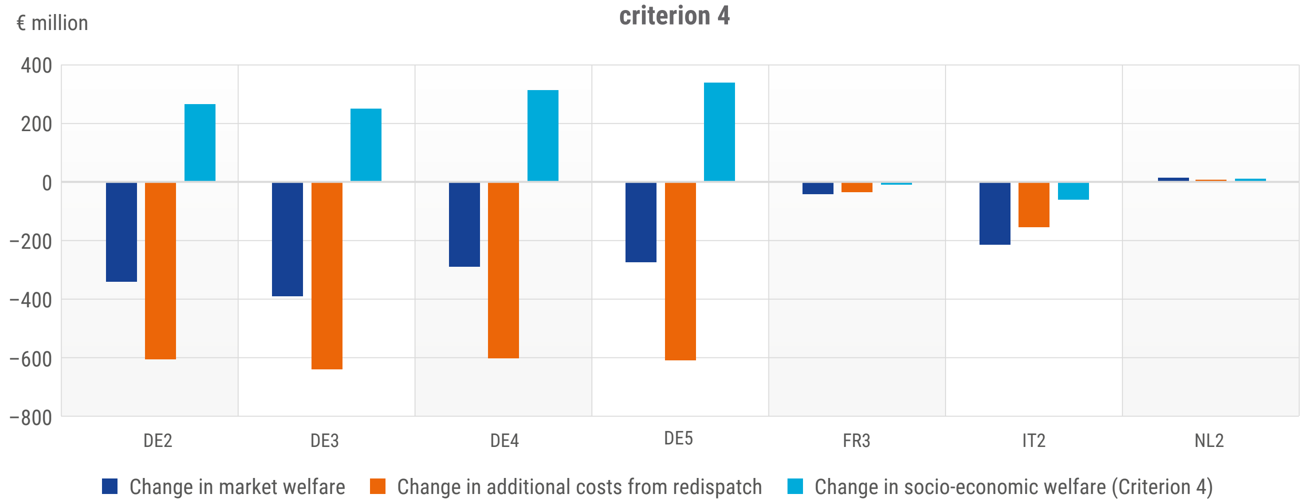


Figure 55: Average change in socio-economic welfare over all climate years

As requested by Article 15 (4) (a) (iii) of the BZR Methodology, Annex VII provides a breakdown per member state of the components of the market welfare for the CE BZRR.

29 System cost is defined as the sum of the operational producer costs and the DSR costs, i. e. the total cost to meet the demand while considering the constraints in the FBMC simulations.

6.2.2 Rejection of Alternative Bidding Zone Configurations

Table 9 shows that the economic efficiencies of FR3 and IT2, respectively, are negative. In accordance with Article 13 (1) (a) (iii). 1. a. of the BZR Methodology, TSOs therefore decided to reject these two alternative BZ configurations, thereby not proceeding with the next steps for FR3 and IT2.

6.2.3 Combinations

According to Annex I of ACER decision 11-2022 on alternative configurations, TSOs shall consider two additional configurations combining two individual alternative BZ configurations that comprise only two member states and with the highest sum of the individual positive monetised benefit. Table 10 shows the sum of the individual positive monetised benefits, i. e. adding the welfare benefits of the respective German–Luxembourgish individual alternative configurations to welfare benefits of the Dutch alternative configuration.

Individual configurations added	Sum of change in socio-economic welfare coming from the simulation of individual configurations [€ million]	Ranking
DE2 and NL2	272	3
DE3 and NL2	259	4
DE4 and NL2	321	2
DE5 and NL2	348	1

Table 10: Sum of individual positive monetised benefits of the remaining individual alternative BZ configurations and ranking

Table 10 shows the sum of individual positive monetised benefits and the ranking of the combinations according to this sum. The combinations leading to the highest sum of individual monetised benefits are a combination of DE5 and NL2 (identified as DE5 + NL2 in the following) on the one hand and DE4 and NL2 (identified as DE4 + NL2 in the following) on the other hand. Following the BZR Methodology, TSOs have therefore subsequently assessed those two combinations.

Additionally, TSOs assessed a combination of DE2 and NL2 (identified as DE2 + NL2 in the following). This allows to evaluate the effects of combining a split of the Netherlands with a relatively modest split of Germany (DE2), thereby enlarging the spectrum of analysis.

Finally, in Table 11, an overview of the economic efficiency is presented for DE5 + NL2, DE4 + NL2 and DE2 + NL2 where both the change in market welfare and the change in additional cost from redispatch are included.

Average change over all climate years						
	Market dispatch (CE + non-CE)				RAO (CE)	Economic Efficiency
Configuration compared to status quo	Market welfare [€ million]	Consumer surplus [€ million]	Producer surplus [€ million]	Overall congestion revenue [€ million]	Additional costs from redispatch [€ million]	Socio-economic welfare (criterion 4) [€ million]
DE2 + NL2	–331	1,156	–2,469	981	–598	266
DE4 + NL2	–298	971	–2,195	925	–566	268
DE5 + NL2	–243	1,008	–2,278	1,027	–576	332

Table 11: Average change in socio-economic welfare over all climate years for the combinations

The economic efficiencies of the combinations (DE5 + NL2, DE4 + NL2 and DE2 + NL2) are very close to the underlying individual German–Luxembourgish splits, in line with expectations given the negligible welfare benefits of the Dutch split.

As a summary, the results for criterion 4 are presented in Figure 56 below. They are subsequently used in step 4 of the assessment as presented in section 6.5.1.

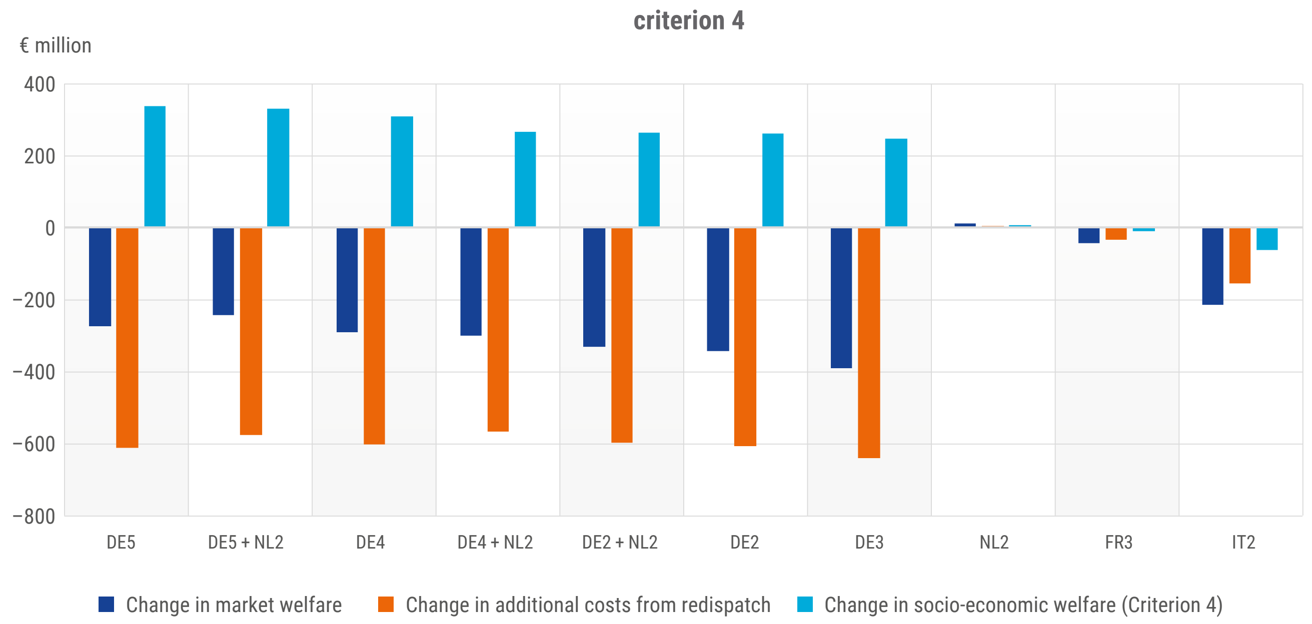


Figure 56: Average change in socio-economic welfare over all climate years for all alternative configurations including combinations

6.3 Step 2: Assessment of all other Criteria

As set forth in Article 13 of the BZR Methodology, the second step in the BZR is to assess all other criteria, i.e. those not considered in step 1 (economic efficiency) for all remaining alternative configurations. Hence, in the following, TSOs assess the remaining criteria for all alternative configurations except for the French and Italian alternative configurations that were rejected under step 1.

6.3.1 Criterion 1: Operational Security

Operational security is assessed through a DC load flow calculation performed after the flow-based market dispatch. All physical flows and operational security violations in N and N-1[30] situations are determined by the OSA / RAO module. Two indicators are derived from the results to assess the criterion: (i) the aggregated number of N and N-1 operational security violations before remedial actions and (ii) the physical congestion index.

The first indicator is assessed by the number of occurrences where the CNEs (defined in the status quo) were congested for N violations.

Moreover, for N-1 violations, a number of occurrences where the CNE in N-1 were congested is assessed (in case of several contingencies leading to the same congestion in one specific MTU, this congestion is accounted for only once).

Figure 57 shows the aggregated number of N and N-1 operational security violations before the application of remedial actions per type of violation (N or N-1) overall, and Table 12 presents the change with respect to the status quo:

30 N refers to critical network elements without a contingency (CNEs). N-1 refers to CNECs.

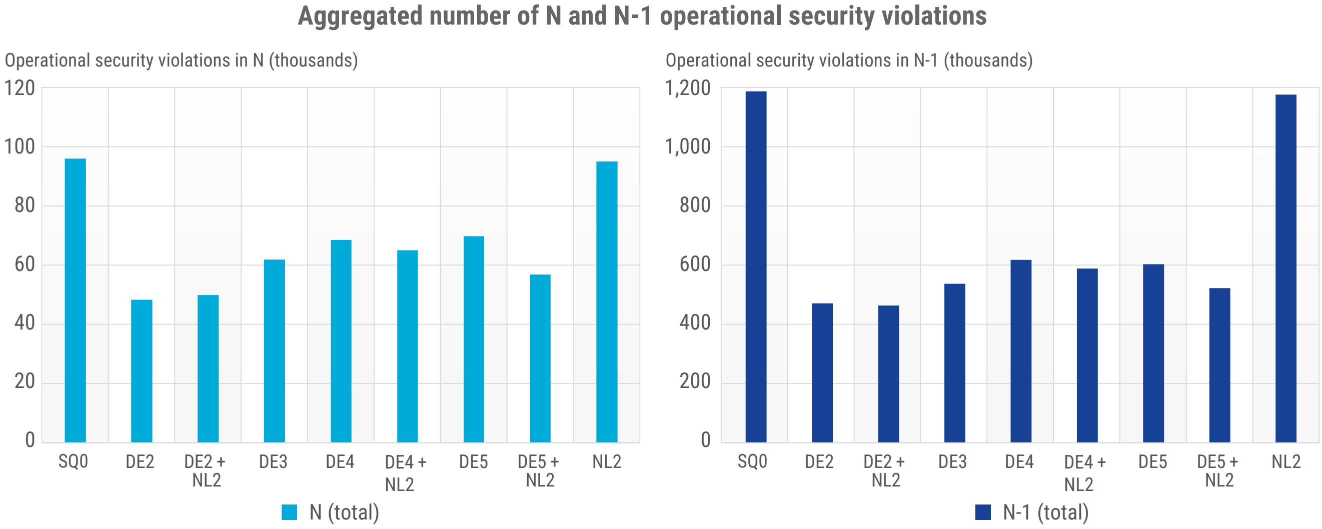


Figure 57: Aggregated number of N and N-1 operational security violations

	SQ	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
N (total in thousands)	96	48	50	62	69	65	70	57	95
N (% change)	–	−49.9	−48.1	−35.4	−28.5	−32,1	−27.3	−40.7	−0.9
N-1 (total in thousands)	1,191	472	466	538	618	589	606	525	1,181
N-1 (% change)	–	−60.3	−60.8	−54.8	−48.1	−50,5	−49.1	−55.9	−0.9

Table 12: Percentage change in the number of N and N-1 operational security violations compared to the status quo

The second indicator – physical congestion index – is defined by the sum of physical overloads on all network elements for all MTUs. In case of several contingencies for the same CNE, the one leading to the highest physical overload is accounted for. The results of physical congestion index are presented in Figure 58 and the change regarding status quo is shown in Table 13.[31]

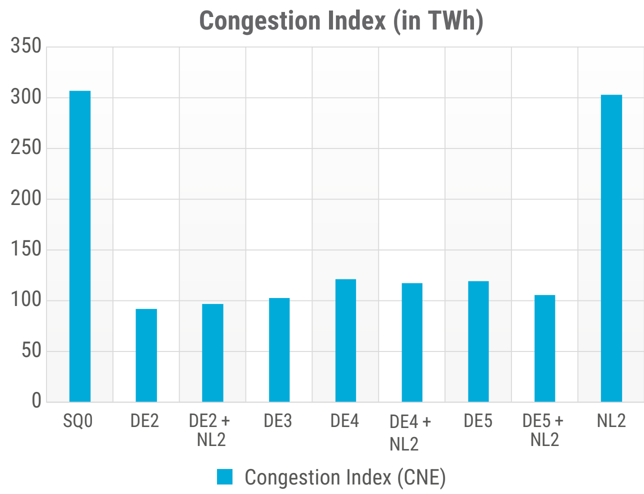


Figure 58: Congestion index

	SQ	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
Aggregated index (in TWh)	307	93	97	103	121	118	119	106	303
Change (%)	–	−69.8	−68.5	−66.4	−60.4	−61.5	−61.1	−65.6	−1.1

Table 13: Congestion index

31 Another way of calculating the congestion index is to consider physical congestion as every congestion of a given critical network element (CNE) plus contingency. This approach leads to very similar results and confirms the final assessment of this indicator.

Finally, Table 14 provides the final assessment for the "operational security" criterion of each alternative configuration compared to the status quo. For this criterion, the changes in the Dutch alternative configuration do not appear to be significant considering the model accuracy. Therefore, in this case, the criterion is assessed as performing the same as the status quo configuration.

	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
Security violations	Better	Better	Better	Better	Better	Better	Better	Same
Congestion index	Better	Better	Better	Better	Better	Better	Better	Same
Assessment	Better	Better	Better	Better	Better	Better	Better	Same

Table 14: Final assessment for the "operational security" criterion

6.3.2 Criterion 2: Security of Supply

Estimating security of supply is a complex task that ENTSO-E performs in dedicated resource adequacy studies such as the Seasonal Outlook and the European Resource Adequacy Assessment (ERAA). In order to evaluate the required probabilistic indicators of Loss of Load Expectation (LOLE; predicted hours with unmet demand per year) and Expected Energy Not Served (EENS; expected energy / demand not served per year) and monetise the "security of supply" criterion within the context of a BZ Study, a significant model extension and additional data collection would have been necessary.

Performing simulations as complex as the ERAA for all configurations – on top of the existing modelling complexity – was not feasible in the scope of this BZ Study. Thus, TSOs decided not to perform this complex assessment, and – according to the Article 15(2)(c)(ii) of the BZR Methodology – instead consider all alternative BZ configurations as performing the same as the status quo regarding the "security of supply" criterion.

6.3.3 Criterion 3: Degree of Uncertainty in Cross-zonal Capacity Calculation

In accordance with Article 15(3) of the BZR Methodology, the "degree of uncertainty in cross-zonal capacity" criterion is not assessed since it shall be considered as implicitly monetised and included in all other monetised criteria.

6.3.4 Criterion 5: Firmness Cost

The "firmness cost" criterion is connected to the "economic efficiency" criterion as one of the monetised indicators, and the methodology explicitly states that the assessment of firmness costs is to be considered as implicitly monetised in the economic efficiency criterion. There, the firmness costs are quantitatively estimated in the remedial action simulation only.

6.3.5 Criterion 6: Market Liquidity and Transaction Costs

Liquidity and Transaction Costs Study and Assessment of Criterion 6

The "market liquidity and transaction costs" criterion was evaluated through a study performed jointly for the CE and Nordic BZRRs in accordance with Article 15(6) of the BZR Methodology. This study aimed to assess the expected evolution of market liquidity and its impact on transaction costs for the long- and short-term timeframes for all alternative BZ configurations in the CE and Nordic BZRRs. It was conducted by Compass Lexecon, consulted as part of the public consultation foreseen in Article 17(4) of the BZR Methodology, and can be found in Annex IV. The conclusions derived from this study lead to the following assessment of criterion 6.

Alternative Configuration	Assessment on changes to liquidity metrics of short-term markets	Assessment of changes to liquidity metrics of the long-term markets	Performance with respect to criterion 6 market liquidity and transaction costs
DE2	Same	Worse	Worse
DE2 + NL2	Same	Worse	Worse
DE3	Same	Worse	Worse
DE4	Same	Worse	Worse
DE4 + NL2	Same	Worse	Worse
DE5	Same	Worse	Worse
DE5 + NL2	Same	Worse	Worse
NL2	Worse	Worse	Worse

Table 15: Conclusion of assessment for criterion 6

Assessment of Mitigation Measures

The BZR Methodology foresees a public consultation on the possible measures to mitigate negative impacts of specific alternative BZ configurations regarding the "market liquidity and transaction costs" criterion. In the following, TSOs reflect upon the feedback on liquidity and transaction costs received in the public consultation. A detailed summary of all responses received during the public consultation can be found in Appendix B of the liquidity and transaction costs study in Annex IV. In general, the public consultation showed that measures to address the negative impact of a possible alternative BZ configurations are seldom sufficiently mature to deliver (ex-ante) proof that negative impacts on liquidity could be mitigated. Furthermore, ENTSO-E expects that any mitigation measure will come at additional costs, whose magnitude and allocation are for policymakers to decide.

Some stakeholders proposed easing the collateral requirements to attract liquidity in forward markets. Determining the collateral requirements for exchange-traded products is at the discretion of power exchanges; collateral requirements for financial transmission rights (FTRs) are set by TSOs' harmonised allocation rules. Easing collateral requirements might facilitate trading such products but it neglects the need to mitigate the counterparty risk.

Stakeholders mentioned "market making" to boost liquidity in forward markets. We understand market making as an artificial way of increasing liquidity in a trading venue that comes at a cost. TSOs observe that market making is already undertaken by some nominated electricity market operators (NEMOs) today. We are unaware of the magnitude of costs associated with market making and thus cannot assess its efficiency, effectiveness, and feasibility.

Several stakeholders highlighted the need to improve hedging possibilities to mitigate price risks. The natural approach to cover price risk is trading in forward (derivative) markets. We observe that these stakeholders fear losing a derivative market to cover price risks in the event of a BZ split. The Compass Lexecon study on liquidity and transaction costs concludes that liquidity metrics of long-term markets tend to be impaired by splits of the current BZ configurations, mainly due to the decreases in market size.

Stakeholders also highlighted the need to improve cross-border hedging opportunities. Market participants who have no liquid "domestic" forward market need to engage in proxy hedging in "foreign" forward markets to hedge price risks. FTRs issued by the Joint Allocation Office (JAO) on behalf of TSOs provide an opportunity to hedge the cross-border price risk (which is relevant in the case of proxy hedging). However, in the absence of a liquid proxy market, such TSO products (even in an improved auction design) are no longer useful to market participants.

If the German–Luxembourgish BZ no longer resembles a natural hub for trading forward contracts, it might become more difficult for market participants to hedge price risks. Depending on the alternative configuration, the Germany–Luxembourgish BZs might still be significant in size. If liquidity declines, the BZs could still possess a sufficient liquidity level and thus could be used for proxy hedging. In case of very low liquidity in new German–Luxembourgish BZs, it will be natural for the market to develop alternatives without TSO involvement.

In a policy paper from February 2023, ACER concluded that zone-to-hub FTRs can be "expected to attract and gather liquidity of national forward markets into regional hubs".[32] This would require introducing regional virtual hubs, which is subject to an ongoing impact assessment of the European Commission following the latest electricity market design reform. In the public consultation, several stakeholders picked up the concept of regional virtual hubs and raised doubts about its effectiveness.

In a paper from July 2024, ENTSO-E analysed this concept in depth and concluded that there is insufficient evidence for a virtual hub to mitigate the negative impacts of the alternative BZ configurations.[33] Therefore, ENTSO-E proposed a range of less disruptive improvements to the design and auctioning of FTRs. ENTSO-E is convinced that these improvements will provide benefits to cross-border trading under today's BZ configuration and in the case of an alternative BZ configuration. We strongly recommend safeguarding or even increasing liquidity in today's forward markets to maintain sufficient hedging opportunities for market participants.

The main risk of introducing a regional hub is that the forward trading will not move to the hub, creating a liquidity split between hub and the larger liquid zones, while harming the efficiency of all hedging products. A lack of liquidity in the virtual hub will result in making the "zone-to-hub FTRs" trading de facto illiquid.

A hub needs to have strong and stable correlations with single BZs over time to attract sufficient liquidity. Determining a suitable geographical composition is one of the major challenges of designing a hub. However, some essential design elements of a virtual hub (e. g. geographical scope, price definition methodology) are not yet determined. First, analyses conducted within ENTSO-E have not led to a clear solution. Moreover, a study performed by Compass Lexecon on behalf of Energy Traders Europe, Eurelectric, and Europex stressed the difficulties related to implementing regional virtual hubs.[34] Based on experience from the Nordics, it is very challenging – if not impossible – to create a hub price with these characteristics. Due to changing market conditions, it is necessary to regularly re-assess the composition of the hub price.

The benefits of the virtual hub might be observed in the absence of a natural physical hub. It is expected that market actors will gravitate towards existing zonal hubs rather than a virtual hub since there is no proof-of-concept for such an approach. In case of a BZ reconfiguration, one of the "new" BZs would most likely take over as the zonal reference hub. In the worst case, the disruption of established zonal hubs due to an alternative BZ configuration could reduce forward trading across all hubs.

To conclude, stakeholders suggested several potential mitigation measures in the public consultation. While they might help to improve liquidity, it is not possible for TSOs to conclude ex-ante that they will be sufficient to mitigate the expected negative effect of a BZ reconfiguration on liquidity and transaction costs. Therefore, the assessment as presented in the previous paragraph remains unchanged.

6.3.6 Criterion 7: Market Concentration and Market Power

Market concentration refers to the number of companies and their respective shares of the total market, and hence the degree of competition. Market power refers to the capability of certain parties to profitably manipulate market prices in their favour, which is a greater risk in less competitive (i. e. more concentrated) markets. The level of market concentration can vary in space – e. g. if redispatch is required at a certain location in the grid and the only plants that can provide effective redispatch are owned by the same company – or time, e. g. the majority of online plants are owned by the same company.

As per the BZR Methodology Article 15 (7), the "market concentration and market power criterion" shall be split into the sub-criteria of (i) "market concentration and market power in the wholesale markets (from long-term to short-term markets)" and (ii) "market concentration and market power in the TSOs' mechanisms to resolve physical congestions".

For the evaluation of the criterion, at a minimum, either the Herfindahl-Hirschman-Index (HHI) or the RSI – which can be simplified into a PSI – shall be calculated. The CE BZRR TSOs decided to use the RSI / PSI to evaluate criterion 7.

32 ACER (2023): Policy Paper on the Further Development of the EU Electricity Forward Market. Retrieved from: https://acer.europa.eu/sites/default/files/documents/Position%20Papers/Electricity_Forward_Market_PolicyPaper.pdf

33 ENTSO-E (2024): Advocacy Note on Forward Markets. Retrieved from: https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Network%20codes%20documents/NC%20FCA/publications/240703_EE_advocacy_note_forward_markets.pdf

34 Compass Lexecon (2024): Assessment of potential impacts of regional virtual hubs on the forward markets. Retrieved from: https://cms.energytraderseurope.org/storage/uploads/media/compass-lexecon-report-on-virtual-hubs-eurelectric-energy-traders-europe-europex.pdf

The hourly RSI for the largest market party *L* in *BZ* is calculated as follows:

$$RSI^{mtu}_{BZ,L} = \frac{\text{Generation capacity}^{mtu}_{BZ} + \text{Import capacity}^{mtu}_{BZ} - \text{Generation capacity}^{mtu}_{L}}{\text{Demand}^{mtu}_{BZ} + \text{Reserves}^{mtu}_{BZ}}$$

where $\text{Generation capacity}^{mtu}_{BZ}$ is the total available generation capacity within the BZ. For hydro and thermal plants, the available generation capacity is the same as the installed capacity. For solar and wind generators, the available capacity is the potential generation per MTU based on the weather conditions; $\text{Generation capacity}^{mtu}_{L}$ is the available generation capacity of market party *L*, determined in the same way as for the available generation capacity of the bidding zone; Demand^{mtu}_{BZ} is the total demand within the BZ; and $\text{Reserves}^{mtu}_{BZ}$ is the total reserves requirement for the bidding zone.

The import capacity is determined as follows:

$$\text{Import capacity}^{mtu}_{BZ} = \sum_{\text{NTC borders}} NTC^{mtu}_{BZ,\text{NTC border}} + cf \times \text{FB minimum net positon}^{mtu}_{BZ}$$

where $NTC^{mtu}_{BZ,\text{NTC border}}$ is the NTC import capacity on an NTC border of the BZ, based on a cNTC calculation where applicable; $\text{FB minimum net positon}^{mtu}_{BZ}$ is the minimum net position of the BZ, when it is part of a flow-based CCR; and cf a correction factor to account for a reasonable import capacity as considering the entire minimum net position of a BZ would result in unlikely scenarios in which the exchanges across all BZ would be optimised for BZ under investigation and thereby overestimate the reasonably to expect import capacity. For their RSI / PSI calculations, CE TSOs used correction factors of 25 %, 50 % and 75 % of the minimum net position and show the results for all correction factors in this report for full transparency.

Based on the hourly RSI, the yearly RSI is calculated as follows:

$$RSI^{y}_{BZ,L} = \frac{\sum_{mtus} RSI^{mtu}_{BZ,L}}{8{,}760}$$

The indicators are calculated for the status quo configuration, each alternative BZ configuration, and each climate year. Based on the indicators calculated for each BZ and climate year, it shall be concluded for each alternative configuration whether higher (respectively lower) levels of market concentration and – potentially – scope for market power can be expected in the wholesale markets compared to the status quo configuration. The BZR Methodology focuses on studying structural concentration indicators and assumes that market power is structural, namely that it does not depend on BZs, but that BZs determine the timeframe where market power arises. It assumes that in case of a BZ reconfiguration, whereby some of the congestions previously managed by redispatch mechanisms are internalised in the wholesale markets, higher market concentration in wholesale markets is associated with less scope for market power in RD mechanisms, and vice versa. While this does not properly reflect the notion that redispatch mechanisms significantly vary across Europe and might include other effective mechanisms to prevent market power in this timeframe, TSOs adhere to the prescription of the methodology and assess this indicator in the way that if market concentration increases in wholesale markets, it decreases in TSOs' mechanisms to resolve physical congestions markets, and vice versa.

The aggregated market concentration indicator for the entire BZRR, RSI_{BZRR} is calculated as the weighted average results for the individual BZs, where the total demand in the BZs is used as a weighting factor. When the aggregated indicators in an alternative configuration are lower than for the status quo configuration, this indicates a negative impact on market concentration and stronger potential scope for exerting market power in wholesale markets and conversely for congestion management market, and vice versa for higher values for the RSI. However, the average indicator can conceal a deterioration of market concentration in some BZs, while the situation improves for the entire region. Therefore, TSOs use an additional indication which counts the total number of MTUs per climate year and BZ where the RSI is lower than 1, indicating that a single supplier is pivotal to cover the load in a certain BZ (Pivotal Supplier Index counted – PSIC). An aggregated indicator for the entire BZRR – $PSIC_{BZRR}$ – can then be calculated as the sum of the indicator across all BZs.[35] It thus counts the total number of MTUs across all BZs in which the RSI is lower than 1. When the aggregated indicator is higher in an alternative configuration than the status quo, this might indicate a negative impact on market concentration and stronger potential scope for exerting market power in wholesale markets, even if the average RSI_{BZRR} might improve.

35 To improve the readability of the PSI, especially for the following tables showing PSI values per BZ, TSOs display the counted PSI values in the report, denoted as PSIC. The relative PSI per BZ can be obtained by dividing the PSIC values by the number of MTUs (8,760).

Table 16 shows the simulated RSI_{BZRR} values and Table 17 shows the simulated $PSIC_{BZRR}$ values averaged across all climate years for the different correction factors as described above.

cf [share of min net position]	SQ	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
25 %	1.610	1.599	1.605	1.606	1.615	1.623	1.620	1.631	1.615
50 %	1.705	1.715	1.727	1.730	1.760	1.775	1.772	1.791	1.716
75 %	1.800	1.830	1.848	1.854	1.904	1.926	1.924	1.950	1.816

Table 16: RSI_{BZRR} values

cf [share of min net position]	SQ	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
25 %	13,440	14,004	14,050	13,941	15,382	15,106	15,297	14,967	13,425
50 %	5,509	5,775	5,741	5,713	5,769	5,567	5,739	5,554	5,496
75 %	2,602	2,561	2,535	2,519	2,316	2,292	2,319	2,285	2,593

Table 17: $PSIC_{BZRR}$ values (#RSI < 1 summed up across all CE bidding zones)

The results in Table 16 show that for most alternative configurations, the RSI_{BZRR} tends to increase compared to the status quo, which would indicate a decrease in market concentration on the wholesale markets, whereby the pattern is mostly independent of the magnitude of the correction factor. Thus, the results indicate that due to a BZ reconfiguration in most cases the import capacities to other adjacent BZs increase, which offsets the previously unlimited internal exchanges of the status quo configuration. However, it should be duly noted that this can be inherently caused by the way in which the indicator is calculated as the overall import capabilities increase with additional BZ borders and the situation in newly formed BZs can look significantly different than at the regional level. Hence, in the following, TSOs reflect upon this trend for each alternative configuration under investigation.

DE2

For the case of the German–Luxembourgish split into two BZs, it can be observed that the RSI_{BZRR} slightly decreases compared with the status quo for a correction factor of 25%, whereas it slightly increases for stronger correction factors at the regional level, as shown in Table 16. In terms of the $PSIC_{BZRR}$, the correction factors of 25% and 50% indicate an increased market concentration, whereas the correction factor of 75% indicates a decrease (cf Table 17).

Within Germany, a mixed picture on the respective RSI can be observed. While the RSI increases in the northern DEJ1 BZ, it decreases in the southern DEJ2 BZ across all correction factors, as visible in Table 18. In the southern DEJ2 BZ, the largest supplier becomes pivotal more often.

The analyses reveal that there is no uniform trend in the indicators on BZRR and bidding zone level. It is important to note that positive impacts of less concentrated markets in some BZs might not outweigh the negative impacts of stronger market concentration elsewhere, especially if the market in these bidding zones is already dominated by a few players. Being aware of this mixed picture, TSOs conclude that the risk of market concentration and market power in wholesale markets tends to increase for the DE2 configuration. Consequently, as prescribed in the BZR Methodology, TSOs conclude that the risk of market concentration and market power in mechanisms to resolve physical congestion tends to decrease.

Correction factor [% Min net position]	Configuration – BZ	RSI	PSIC (#RSI < 1)
25 %	SQ – DE00	1.71	1.33
	DE2 – DEJ1	2.47	0.00
	DE2 – DEJ2	1.32	263.00
50 %	SQ – DE00	1.77	0.00
	DE2 – DEJ1	2.62	0.00
	DE2 – DEJ2	1.45	2.67
75 %	SQ – DE	1.84	0.00
	DE2 – DEJ1	2.77	0.00
	DE2 – DEJ2	1.58	0.00

Table 18: RSI and PSI values at the bidding-zone level for the DE2 alternative configuration averaged across climate years

DE2 + NL2

For the combination of the German–Luxembourgish and Dutch two-zone split, it can be observed that the RSI_{BZRR} slightly decreases compared to the status quo for a correction factor of 25 %, whereas it slightly increases for stronger correction factors at the regional level, as shown in Table 16. In terms of the $PSIC_{BZRR}$, the correction factors of 25 % and 50 % indicate an increased market concentration, whereas the correction factor of 75 % indicates a decrease.

While the zone-specific RSI increases in the northern German DEJ1 BZ and in both Dutch BZs, it decreases in the southern DEJ2 BZ across all correction factors, as shown in Table 19. In the southern DEJ2 BZ, the largest supplier becomes pivotal more often.

The analyses reveal that there is no uniform trend in the indicators on BZRR and bidding zone level. It is important to note that positive impacts of less concentrated markets in some BZs might not outweigh the negative impacts of stronger market concentration elsewhere, especially if the market in these bidding zones is already dominated by a few players. Being aware of this mixed picture, TSOs conclude that the risk of market concentration and market power in wholesale markets tends to increase for the DE2 + NL2 combination. Consequently, as prescribed in the BZR Methodology, TSOs conclude that the risk of market concentration and market power in mechanisms to resolve physical congestion tends to decrease.

Correction factor [% Min net position]	Configuration – BZ	RSI	PSIC (#RSI < 1)
25 %	SQ – DE00	1.71	1.33
	SQ – NL00	1.75	0.00
	DE2 + NL2 – DEJ1	2.47	0.00
	DE2 + NL2 – DEJ2	1.32	230.33
	DE2 + NL2 – NLN1	1.78	0.00
	DE2 + NL2 – NLN2	2.11	0.00
50 %	SQ – DE00	1.77	0.00
	SQ – NL00	1.88	0.00
	DE2 + NL2 – DEJ1	2.62	0.00
	DE2 + NL2 – DEJ2	1.46	2.33
	DE2 + NL2 – NLN1	1.97	0.00
	DE2 + NL2 – NLN2	2.52	0.00
75 %	SQ – DE00	1.84	0.00
	SQ – NL00	2.02	0.00
	DE2 + NL2 – DEJ1	2.78	0.00
	DE2 + NL2 – DEJ2	1.59	0.00
	DE2 + NL2 – NLN1	2.16	0.00
	DE2 + NL2 – NLN2	2.93	0.00

Table 19: RSI and PSI values at the bidding-zone level for the DE2 + NL2 combination averaged across climate years

DE3

For the case of the German–Luxembourgish split into three BZs, it can be observed that the RSI_{BZRR} decreases compared to the status quo for a correction factor of 25 %, whereas it increases for stronger correction factors at the regional level. In terms of the $PSIC_{BZRR}$, the correction factors of 25 % and 50 % show a higher dependence on pivotal suppliers, whereas the opposite case applies for a correction factor of 75 %.

Within Germany, a mixed picture on the respective RSI can be observed. While the RSI increases in the northern DEJ1 and DEJ2 BZs, it decreases in the southern DEJ3 bidding zone across all correction factors, as shown in Table 20. In the southern DEJ3 BZ, the largest supplier becomes pivotal more often.

The analyses reveal that there is no uniform trend in the indicators on BZRR and bidding zone level. It is important to note that positive impacts of less concentrated markets in some BZs might not outweigh the negative impacts of stronger market concentration elsewhere, especially if the market in these bidding zones is already dominated by a few players. Being aware of this mixed picture, TSOs conclude that the risk of market concentration and market power in wholesale markets tends to increase for the DE3 configuration. Consequently, as prescribed in the BZR Methodology, TSOs establish that the risk of market concentration and market power in mechanisms to resolve physical congestion tends to decrease.

Correction factor [% Min net position]	Configuration – BZ	RSI	PSIC (#RSI < 1)
25 %	SQ – DE00	1.71	1.33
	DE3 – DEJ1	2.25	0.00
	DE3 – DEJ2	2.86	0.00
	DE3 – DEJ3	1.32	236.67
50 %	SQ – DE00	1.77	0.00
	DE3 – DEJ1	2.46	0.00
	DE3 – DEJ2	3.14	0.00
	DE3 – DEJ3	1.45	2.33
75 %	SQ – DE00	1.84	0.00
	DE3 – DEJ1	2.68	0.00
	DE3 – DEJ2	3.42	0.00
	DE3 – DEJ3	1.59	0.00

Table 20: RSI and PSI values at the bidding-zone level for the DE3 alternative configuration averaged across climate years

DE4

For the case of the German–Luxembourgish split into four BZs, it can be observed that the RSI_{BZRR} increases compared to the status quo across all correction factors at the regional level. In terms of the $PSIC_{BZRR}$, the correction factors of 25% and 50% show a stronger dependence on pivotal suppliers, whereas the opposite case applies for a correction factor of 75%.

Within Germany, a mixed picture on the respective RSI can be observed. While the RSI increases in the northern DEJ1 and DEJ3 BZs, it decreases in the southern DEJ2 BZ across all correction factors. For DEJ4, the development depends on the correction factor, as shown in Table 21. Particularly in the southern DEJ2 BZ, the largest supplier becomes pivotal more often. With a correction factor of 25%, the largest supplier also becomes pivotal in DEJ1 in some MTUs.

Correction factor [% Min net position]	Configuration – BZ	RSI	PSIC (#RSI < 1)
25%	SQ – DE00	1.71	1.33
	DE4 – DEJ1	1.86	39.00
	DE4 – DEJ2	1.19	1,701.33
	DE4 – DEJ3	2.97	0.00
	DE4 – DEJ4	1.51	0.00
50%	SQ – DE00	1.77	0.00
	DE4 – DEJ1	2.19	0.00
	DE4 – DEJ2	1.39	195.67
	DE4 – DEJ3	3.18	0.00
	DE4 – DEJ4	1.75	0.00
75%	SQ – DE00	1.84	0.00
	DE4 – DEJ1	2.53	0.00
	DE4 – DEJ2	1.59	0.00
	DE4 – DEJ3	3.39	0.00
	DE4 – DEJ4	1.98	0.00

Table 21: RSI and PSI values at the bidding-zone level for the DE4 alternative configuration averaged across climate years

The analyses reveal that there is no uniform trend in the indicators on BZRR and bidding zone level. It is important to note that positive impacts of less concentrated markets in some BZs might not outweigh the negative impacts of stronger market concentration elsewhere, especially if the market in these bidding zones is already dominated by a few players. Being aware of this mixed picture, TSOs conclude that the risk of market concentration and market power in wholesale markets tends to increase for the DE4 configuration. Consequently, as prescribed in the BZR Methodology, TSOs conclude that the risk of market concentration and market power in mechanisms to resolve physical congestion tends to decrease.

DE4 + NL2

For the combination of the German–Luxembourgish split into four zones and the Dutch split into two zones, it can be observed that the RSI_{BZRR} increases compared to the status quo across all correction factors at the regional level. In terms of the $PSIC_{BZRR}$, the correction factors of 25% and 50% show a stronger dependence on pivotal suppliers, whereas the opposite is the case for a correction factor of 75%.

While the zone-specific RSI increases in the northern German DEJ1 and DEJ3 and in both Dutch BZs, it decreases in most cases in the southern DEJ2 and DEJ4 BZs, as shown in Table 22. In the south-western DEJ2 BZ, the largest supplier becomes pivotal more often.

Correction factor [% Min net position]	Configuration – BZ	RSI	PSIC (#RSI < 1)
25%	SQ – DE00	1.71	1.33
	SQ – NL00	1.75	0.00
	DE5 + NL2 – DEJ1	1.86	31.33
	DE5 + NL2 – DEJ2	1.21	1,365.67
	DE5 + NL2 – DEJ3	2.97	0.00
	DE5 + NL2 – DEJ4	1.51	0.00
	DE5 + NL2 – NLN1	1.79	0.00
	DE5 + NL2 – NLN2	2.12	0.00
50%	SQ – DE00	1.77	0.00
	SQ – NL00	1.88	0.00
	DE5 + NL2 – DEJ1	2.21	0.00
	DE5 + NL2 – DEJ2	1.43	35.00
	DE5 + NL2 – DEJ3	3.18	0.00
	DE5 + NL2 – DEJ4	1.75	0.00
	DE5 + NL2 – NLN1	1.98	0.00
	DE5 + NL2 – NLN2	2.53	0.00
75%	SQ – DE00	1.84	0.00
	SQ – NL00	2.02	0.00
	DE5 + NL2 – DEJ1	2.55	0.00
	DE5 + NL2 – DEJ2	1.65	0.00
	DE5 + NL2 – DEJ3	3.39	0.00
	DE5 + NL2 – DEJ4	1.98	0.00
	DE5 + NL2 – NLN1	2.17	0.00
	DE5 + NL2 – NLN2	2.95	0.00

Table 22: RSI and PSI values at the bidding-zone level for the DE4 + NL2 combination averaged across climate years

The analyses reveal that there is no uniform trend in the indicators on BZRR and bidding zone level. It is important to note that positive impacts of less concentrated markets in some BZs might not outweigh the negative impacts of stronger market concentration elsewhere, especially if the market in these bidding zones is already dominated by a few players. Being aware of this mixed picture, TSOs conclude that the risk of market concentration and market power in wholesale markets tends to increase for the DE4 + NL2 combination. Consequently, as prescribed in the BZR Methodology, TSOs conclude that the risk of market concentration and market power in mechanisms to resolve physical congestion tends to decrease.

DE5

For the case of the German–Luxembourgish split into five BZs, it can be observed that the RSI_{BZRR} increases compared to the status quo across all correction factors at the regional level. In terms of the $PSIC_{BZRR}$, the correction factors of 25 % and 50 % show a stronger dependence on pivotal suppliers, whereas the opposite case applies for a correction factor of 75 %.

Within Germany, a mixed picture on the respective RSI can be observed. While the RSI increases in the northern DEJ1, DEJ3, and DEJ 5 BZs, it decreases in most cases in the southern DEJ2 and DEJ4 BZs, as shown in Table 23. In the southern DEJ2 BZ, the largest supplier becomes pivotal more often.

The analyses reveal that there is no uniform trend in the indicators on BZRR and bidding zone level. It is important to note that positive impacts of less concentrated markets in some BZs might not outweigh the negative impacts of stronger market concentration elsewhere, especially if the market in these bidding zones is already dominated by a few players. Being aware of this mixed picture, TSOs conclude that the risk of market concentration and market power in wholesale markets tends to increase for the DE5 configuration. Consequently, as prescribed in the BZR Methodology, TSOs conclude that the risk of market concentration and market power in mechanisms to resolve physical congestion tends to decrease.

Correction factor [% Min net position]	Configuration – BZ	RSI	PSIC (#RSI < 1)
25 %	SQ – DE00	1.71	1.33
	DE5 – DEJ1	1.84	24.67
	DE5 – DEJ2	1.19	1,646.00
	DE5 – DEJ3	2.88	0.00
	DE5 – DEJ4	1.51	0.00
	DE5 – DEJ5	4.62	0.00
50 %	SQ – DE00	1.77	0.00
	DE5 – DEJ1	2.23	0.00
	DE5 – DEJ2	1.40	171.00
	DE5 – DEJ3	3.19	0.00
	DE5 – DEJ4	1.74	0.00
	DE5 – DEJ5	5.01	0.00
75 %	SQ – DE00	1.84	0.00
	DE5 – DEJ1	2.63	0.00
	DE5 – DEJ2	1.60	0.00
	DE5 – DEJ3	3.49	0.00
	DE5 – DEJ4	1.97	0.00
	DE5 – DEJ5	5.40	0.00

Table 23: RSI and PSI values at the bidding-zone level for the DE5 alternative configuration averaged across climate years

DE5 + NL2

For the combination of the German–Luxembourgish split into five zones and the Dutch split into two zones, it can be observed that the RSI_{BZRR} increases compared to the status quo across all correction factors at the regional level. In terms of the $PSIC_{BZRR}$, the correction factors of 25% and 50% show a stronger dependence on pivotal suppliers, whereas the opposite is the case for a correction factor of 75%.

While the zone-specific RSI increases in the northern German DEJ1, DEJ3, and DEJ5 BZs and both Dutch BZs, it decreases in most cases in the southern DEJ2 and DEJ4 BZs, as shown in Table 24. In the southern-western DEJ2 BZ, the largest supplier becomes pivotal more often.

Correction factor [% Min net position]	Configuration – BZ	RSI	PSIC (#RSI < 1)
25%	SQ – DE00	1.71	1.33
	SQ – NL00	1.75	0.00
	DE5 + NL2 – DEJ1	1.84	14.00
	DE5 + NL2 – DEJ2	1.22	1,301.33
	DE5 + NL2 – DEJ3	2.89	0.00
	DE5 + NL2 – DEJ4	1.51	0.00
	DE5 + NL2 – DEJ5	4.67	0.00
	DE5 + NL2 – NLN1	1.79	0.00
	DE5 + NL2 – NLN2	2.12	0.00
50%	SQ – DE00	1.77	0.00
	SQ – NL00	1.88	0.00
	DE5 + NL2 – DEJ1	2.24	0.00
	DE5 + NL2 – DEJ2	1.45	34.33
	DE5 + NL2 – DEJ3	3.19	0.00
	DE5 + NL2 – DEJ4	1.74	0.00
	DE5 + NL2 – DEJ5	5.06	0.00
	DE5 + NL2 – NLN1	1.98	0.00
	DE5 + NL2 – NLN2	2.53	0.00
75%	SQ – DE00	1.84	0.00
	SQ – NL00	2.02	0.00
	DE5 + NL2 – DEJ1	2.65	0.00
	DE5 + NL2 – DEJ2	1.67	0.00
	DE5 + NL2 – DEJ3	3.49	0.00
	DE5 + NL2 – DEJ4	1.97	0.00
	DE5 + NL2 – DEJ5	5.44	0.00
	DE5 + NL2 – NLN1	2.17	0.00
	DE5 + NL2 – NLN2	2.95	0.00

Table 24: RSI and PSI values at the bidding-zone level for the DE5 + NL2 combination averaged across climate years

The analyses reveal that there is no uniform trend in the indicators on BZRR and bidding zone level. It is important to note that positive impacts of less concentrated markets in some BZs might not outweigh the negative impacts of stronger market concentration elsewhere, especially if the market in these bidding zones is already dominated by a few players. Being aware of this mixed picture, TSOs conclude that the risk of market concentration and market power in wholesale markets tends to increase for the DE5 + NL2 combination. Consequently, as prescribed in the BZR Methodology, TSOs conclude that the risk of market concentration and market power in mechanisms to resolve physical congestion tends to decrease.

NL2

For the Dutch alternative configuration, it can be observed that the RSI_{BZRR} increases compared to the status quo across all correction factors.The $PSIC_{BZRR}$ slightly decreases across all correction factors, as visible in Table 17.

Considering the Dutch alternative BZs investigated, it can be observed that the RSI increases in both Dutch BZs and that there are no MTUs where a supplier was identified as being pivotal, as shown visible in Table 25.

Correction factor [% Min net position]	Configuration – BZ	RSI	PSIC (#RSI < 1)
25%	SQ – NL00	1.75	0
	NL2 – NLN1	1.77	0
	NL2 – NLN2	2.10	0
50%	SQ – NL00	1.88	0
	NL2 – NLN1	1.95	0
	NL2 – NLN2	2.50	0
75%	SQ – NL00	2.02	0
	NL2 – NLN1	2.13	0
	NL2 – NLN2	2.89	0

Table 25: RSI and PSI values at the bidding-zone level for the NL2 alternative configuration averaged across climate years

Based on these findings, CE TSOs conclude that the market concentration and market power in the wholesale markets tends to decrease for the NL2 configuration and – as prescribed by the BZR Methodology – market concentration and market power in the TSOs' mechanisms to resolve physical congestions tends to increase for this alternative configuration.

Table 26 shows the evaluation of the two sub-criteria if all sub-criteria are equally weighted. According to the BZR Methodology, the sub-criteria are considered separately for the consolidation under step 4 in section 6.5.

Alternative Configuration	Performance with respect to sub-criterion 7i "Market concentration and market power in the wholesale markets (from long- to short-term markets)"	Performance with respect to sub-criterion 7ii "Market concentration and market power in the TSOs' mechanisms to resolve physical congestion"	Performance with respect to indicator 7 "Market concentration and market power"
DE2	Worse	Better	Same
DE2 + NL2	Worse	Better	Same
DE3	Worse	Better	Same
DE4	Worse	Better	Same
DE4 + NL2	Worse	Better	Same
DE5	Worse	Better	Same
DE5 + NL2	Worse	Better	Same
NL2	Better	Worse	Same

Table 26: Conclusions for criterion 7

While TSOs devote effort to estimating and interpreting RSI/PSI values in accordance with the BZR Methodology, the results have to be seen in the context of some shortcomings, particularly with respect to limited information available on ownership data and the available import capacities and the BZR Methodology's assumption that market power is structural, resulting in a shift in market power from TSOs mechanisms to resolve physical congestions to wholesale markets. This does not take into account the fact that market power might not decrease in countries that have other effective mechanisms in place to prevent market power in the redispatch timeframe, especially in case of regulated redispatch regimes such as Germany. Overall, the conclusions for this criterion entail significant uncertainties and further limitations are elaborated upon in section 6.6.4.6.

6.3.7 Criterion 8: Facilitation of Effective Competition

As per the BZR Methodology Article 15(8), the "facilitation of effective competition" criterion shall be split into the following three different sub-criteria, which shall be separately assessed:

- Short-term competition
- Long-term competition
- Competition for cross-zonal capacity

In accordance with the BZR Methodology, the assessment of the short- and long-term competition sub-criteria are only assessed based on two other criteria of the BZ review.

For both sub-criteria, an alternative configuration performs better (respectively worse) than the status quo configuration if the analysis of the two other criteria on which they are based performs better (respectively worse) than the status quo, or if one of the criteria performs better (respectively worse) while the other one performs the same as the status quo configuration. In any other case, it shall be expected to perform the same as the status quo configuration.

Sub-criterion 8i – short-term competition – is assessed based on criterion 6 (market liquidity and transaction costs) and criterion 7 (market concentration and market power). Table 27 shows the results of these criteria for the alternative BZ configurations and draws a conclusion for sub-criterion 8i.

Alternative Configuration	Performance with respect to criterion 6 "Market liquidity and transaction costs"	Performance with respect to criterion 7 "Market concentration and market power"	Performance with respect to sub-criterion 8i "Short-term competition"
DE2	Worse	Same	Worse
DE2 + NL2	Worse	Same	Worse
DE3	Worse	Same	Worse
DE4	Worse	Same	Worse
DE4 + NL2	Worse	Same	Worse
DE5	Worse	Same	Worse
DE5 + NL2	Worse	Same	Worse
NL2	Worse	Same	Worse

Table 27: Conclusions for sub-criterion 8i (short-term competition)

Sub-criterion 8ii – long-term competition – is assessed based on criterion 9 (price signals for building infrastructure) and criterion 10 (accuracy and robustness of price signals).

Table 28 shows the results for these criteria for the alternative BZ configurations and draws a conclusion for sub-criterion 8ii.

Alternative Configuration	Performance with respect to criterion 9 "Price signals for building infrastructure"	Performance with respect to criterion 10 "Accuracy and robustness of price signals"	Performance with respect to sub-criterion 8ii "Long-term competition"
DE2	Same	Same	Same
DE2 + NL2	Same	Same	Same
DE3	Same	Same	Same
DE4	Same	Same	Same
DE4 + NL2	Same	Same	Same
DE5	Same	Same	Same
DE5 + NL2	Same	Same	Same
NL2	Same	Same	Same

Table 28: Conclusions for sub-criterion 8ii (long-term competition)

As criterion 10 (accuracy and robustness of prices signals) and criterion 9 (price signals for building infrastructure) perform the same for all alternative configurations, sub-criterion 8ii – long-term competition – is evaluated to perform the same as the status quo for all alternative configurations.

The assessment of sub-criterion 8iii – competition for cross-zonal capacity – shall aim to analyse whether structural differences in zonal PTDFs might lead to competitive disadvantages for certain BZs. In order to perform the analysis, TSOs shall compare the standard deviation of the mean –averaged across all timestamps – zone-to-zone PTDFs between the alternative configuration and the status quo:

$$\sigma\left[\mu\left|PTDF_{BZ_i-BZ_j}\right|\right]$$

where σ is the standard deviation over all pairs of BZs within the CCR; μ is the arithmetic average over all CNECs considered in capacity calculation within a CCR for a given pair of BZs; $\left|PTDF_{BZ_i-BZ_j}\right|$ is the absolute value of the zone-to-zone PTDF for two given BZs *i* and *j* and for a given CNEC; and *i* and *j* are a pair of BZs within a CCR.

According to the BZR Methodology, a given alternative configuration performs better (respectively worse) than the status quo configuration regarding the "competition for cross-zonal capacity" sub-criterion when the above-described formula shows a lower (respectively higher) value for the configuration than for the status quo configuration. Table 29 shows the results for the status quo and all alternative configurations averaged across all climate years and draws conclusions for sub-criterion 8iii.

Configuration	Standard deviation of all mean zone-to-zone PTDFs	Relative difference compared to the status quo layout	Performance with respect to sub-criterion 8iii “Competition for cross-zonal capacity”
SQ	0.009136		–
DE2	0.008571	−6.2 %	Better
DE2 + NL2	0.008977	−1.7 %	Same
DE3	0.008229	−9.9 %	Better
DE4	0.007861	−14.0 %	Better
DE4 + NL2	0.008225	−10.0 %	Better
DE5	0.008022	−12.2 %	Better
DE5 + NL2	0.008245	−9.8 %	Better
NL2	0.009520	+4.2 %	Worse

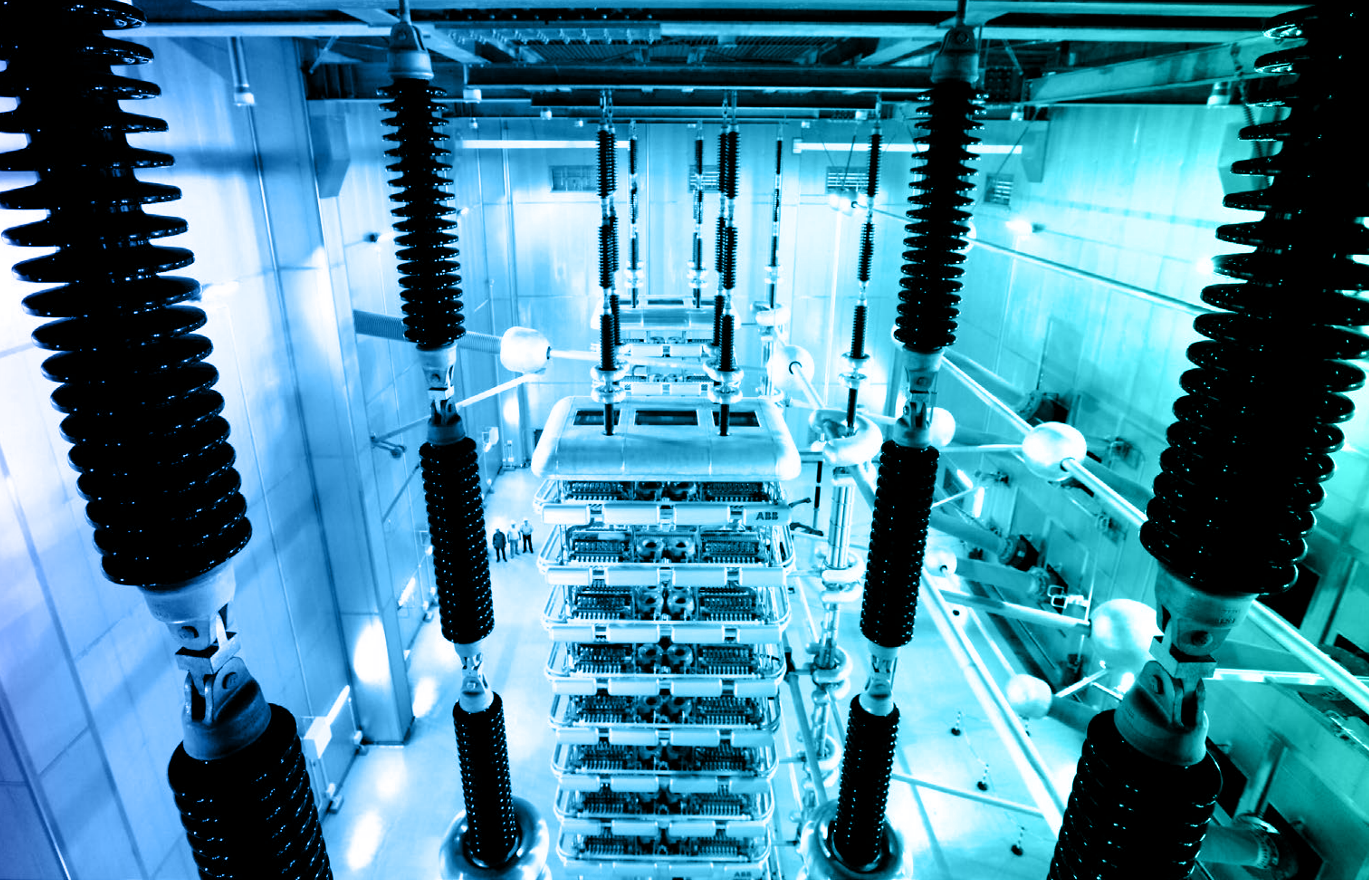
Table 29: Conclusions for sub-criterion 8iii (competition for cross-zonal capacity)

The results show that the standard deviation of the mean zone-to-zone PTDFs decreases for all German–Luxembourgish splits, whereas it increases for the Dutch split. For the German–Luxembourgish splits, the standard deviation further decreases with the number of splits in Germany, except for the configuration where the German–Luxembourgish BZ is split in five zones. In this case, the standard deviation is higher than for the DE4 alternative configuration. In case of all investigated combinations, the value decreases compared to the status quo, albeit not to the same extent as for the individual German–Luxembourgish alternative configurations. Overall, this sub-criterion is assessed to perform better for all German–Luxembourgish alternative configurations and the combinations DE4 + NL2 and DE5 + NL2 and worse for the Dutch alternative configuration. For the combination DE2 + NL2, the change is minimal and therefore this configuration is assessed to perform the same as the status quo.

Table 30 shows the evaluation of the three sub-criteria and draws conclusions for criterion 8 overall, if all sub-criteria are equally weighted. According to the BZR Methodology, the sub-criteria are considered separately for the consolidation under step 4 in section 6.5.

Alternative Configuration	Performance with respect to sub-criterion 8i “Short-term competition”	Performance with respect to sub-criterion 8ii “Long-term competition”	Performance with respect to sub-criterion 8iii “Competition for cross-zonal capacity”	Performance with respect to criterion 8 “Facilitation of effective competition”
DE2	Worse	Same	Better	Same
DE2 + NL2	Worse	Same	Same	Same
DE3	Worse	Same	Better	Same
DE4	Worse	Same	Better	Same
DE4 + NL2	Worse	Same	Better	Same
DE5	Worse	Same	Better	Same
DE5 + NL2	Worse	Same	Better	Same
DE4 + NL2	Worse	Same	Better	Same
NL2	Worse	Same	Worse	Worse

Table 30: Conclusions for criterion 8



6.3.8 Criterion 9: Price Signals for Building Infrastructure

According to Article 15(9) of the BZR Methodology, the "price signals for building infrastructure" criterion shall consider network infrastructures, generation, and demand assets.

Moreover, the BZR Methodology states the following:

- In order for prices to give relevant signals to build generation and demand assets in a cost-efficient manner, prices shall be accurate and robust. Therefore, the ability of prices to promote efficient investments in generation and demand assets shall be based on the results of the "accuracy and robustness of price signals" criterion.
- In order for prices to give relevant signals to build networks, physical congestion should be preferably dealt within the market. This shall be evaluated by using the indicator of the percentage of time when the physical congestion was not previously detected in the day-ahead market, i.e. the percentage of time when physical congestion (or no remaining physical capacity) was detected in a given network element, following the OSA pursuant to Article 8 of the BZR Methodology, while market congestion for the said network element was not identified following the day-ahead market dispatch pursuant to Article 7 of the BZR Methodology.

"Market congestion" refers to Article 2(17) of the CACM Regulation, i.e. to market time units when there is at least one constraint, with a shadow price, which actively limits cross-zonal exchanges during capacity allocation. Such a constraint may be a cross-zonal or internal line, or an allocation constraint, based on the day-ahead market simulations, pursuant to Article 7 of the BZR Methodology.

In order to conclude on this criterion, the results of the "accuracy and robustness of price signals" criterion and the indicator of the percentage of time when the physical congestion was not previously detected in the day-ahead market shall be considered.

The analysis of this criterion comprises two steps. The first step compares the shares of MTUs when the physical congestion was not previously detected in the day-ahead market (indicator 9(c)). A given BZ configuration shall be expected to perform better (respectively worse) regarding indicator 9 (c) when the indicator shows a lower (respectively higher) value for the configuration than for the status quo one.

The second step combines the results obtained in the previous step and the results of the "accuracy and robustness of price signals" criterion. A BZ configuration shall be expected to perform better (respectively worse) than the status quo configuration regarding the "price signals for building infrastructure" criterion when it performs better (respectively worse) regarding both aforementioned aspects or that at least it performs better (respectively worse) regarding one of the aspects while the performance of the other aspect remains the same as for the status quo configuration.

In any other case, it shall be expected to perform the same as the status quo configuration.

Results of Indicator 9(c): Physical Congestion not Detected in the Day-ahead (DA) Market

Configuration	SQ	DE2	DE2 + NL 2	DE3	DE4	DE4+NL2	DE5	DE5+NL2	NL2
Share of hours with congestion on at least one CNE/CNEC in OSA but not in DA (%)	100	100	100	100	100	100	100	100	100
Performance	–	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**

Table 31: Percentage of hours in which there is at least one CNEC with physical congestion that does not show up as a market congestion

Table 31 shows the percentage of hours in which there is at least one CNEC with a physical congestion that does not show up as a market congestion, showing that this is the case for 100 % of the MTUs, regardless of the BZ configuration. This result is not unexpected given that the market results will generally only produce a small set of market congestions, or CNECs with a non-zero shadow price. This number is mathematically limited by the dimension of the flow-based domains, although it will generally be lower than that. In this study, the flow-based domains have thirteen or fourteen dimensions (twelve hubs and one or two HVDCs). At the same time, the OSA finds between 50 and 150 physical congestions per MTU on average, as also shown under criterion 1. Therefore, it can be expected that there will always be physical congestion that does not appear as market congestion.

Based on these results, all configurations perform the same regarding indicator 9 (c).

Overall Results for Criterion 9: Price Signals for Building Infrastructure

Criterion / Indicator	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
Physical congestion not detected in DA (9c)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**
Accuracy and robustness of price signals (10)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**
Performance in total (9)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**

Table 32: Overall results for criterion 9

Table 32 shows the overall results for criterion 9, in which the results from indicator 9 (c) are combined with those from criterion 10.

For both indicator 9 (c) and criterion 10, all configurations were found to perform the same. Therefore, it is concluded that for criterion 9 all configurations also perform the same.

6.3.9 Criterion 10: Accuracy and Robustness of Price Signals

Prices are accurate and robust when a majority of market participants – i.e. participating in DA markets and/or using the DA price as the main price reference – perceive the benefits of reacting to the actual needs of the system at the precise location and point in time.

Article 15(10) of the BZR Methodology describes in detail how the "accuracy and robustness of price signals" criterion shall be evaluated. For each BZ configuration, the correlation between a zone's volume-weighted average nodal prices and the zonal DA market prices shall be compared to the correlation for the same zone in the status quo.[36] This approach is illustrated in Figure 59.

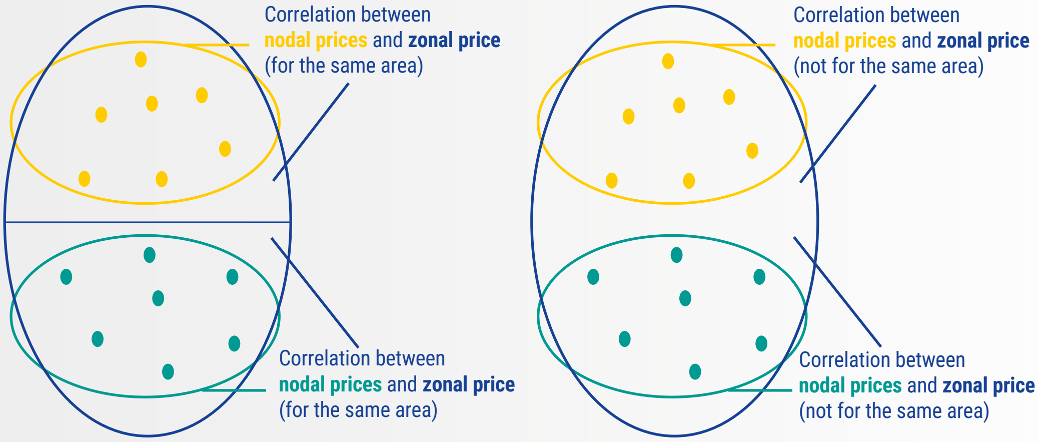


Figure 59: Calculation of correlation in the split configuration (left) and the status quo (right)

A BZ configuration shall be expected to perform better (respectively worse) than the status quo configuration regarding the "accuracy and robustness of price signals" criterion when the correlation described above shows a higher (respectively lower) value for the configuration than for the status quo one. In any other case, it shall be expected to perform the same as the status quo configuration.

Please note that for the assessment of this criterion, the different regions were volume-weighted according to their share of the total generation and demand in the CE region in the respective configuration, averaged over the three climate years.

Configuration	CE-wide weighted correlation	CE-wide weighted correlation in SQ	Absolute difference to SQ	Relative change to SQ	Evaluation
DE2	0.697	0.692	0.005	0.7%	**Same**
DE2 + NL2	0.700	0.691	0.009	1.3%	**Same**
DE3	0.698	0.691	0.007	1.0%	**Same**
DE4	0.699	0.690	0.009	1.3%	**Same**
DE4 + NL2	0.700	0.689	0.011	1.6%	**Same**
DE5	0.698	0.690	0.008	1.2%	**Same**
DE5 + NL2	0.701	0.689	0.012	1.7%	**Same**
NL2	0.692	0.693	−0.001	−0.1%	**Same**

Table 33: CE-wide weighted correlations for each configuration compared to the status quo

36 The results of criterion 10 might also be affected by the shortcomings identified ex-post on the nodal price calculations. For instance, the French nuclear power plants availability was assumed too high in the LMP Study (as mentioned in Annex II), leading to excess exports that could influence the final correlation.

When comparing the CE-wide weighted correlations for the different configurations with the respective correlations in the status quo, the results shown in Table 33 suggest that the "accuracy and robustness of price signals" criterion does not show a significant change in performance, neither in the German–Luxembourgish and Dutch split cases nor the combination configurations. This is because the increase in performance in some BZs is outweighed by the decrease in performance in other BZs. For example, the performance in the German–Luxembourgish zones significantly increases in the German–Luxembourgish split scenarios, while other countries are negatively affected.

According to the BZR Methodology, for the "accuracy and robustness of price signals" criterion all split scenarios considered perform the same as the status quo configuration. However, the methodology focuses the criterion very narrowly on the accuracy of price signals, while the robustness of prices signals is omitted. The completeness and value of this criterion should thus be improved in future assessments.

6.3.10 Criterion 11: Transition Costs

Assessment of Criterion 11

The transition costs to a new BZ configuration are one-off costs that have been evaluated through a study performed jointly for the CE and Nordic BZRRs in accordance with Article 15(11) of the BZR Methodology. This study aims to identify and estimate the transition costs for all alternative BZ configurations in the CE and Nordic BZRRs. It was conducted by Compass Lexecon, consulted as part of the public consultation foreseen in Article 17(4) of the BZR Methodology, and can be found in Annex V. As set forth in Article 15(11)(b) of the BZR Methodology, the estimated transition costs shall be used to calculate the minimum lifetime of an alternative BZ configuration that would be needed to pay back the transition costs in light of the monetised benefits compared to the status quo, and considering a discount rate. In line with ACER's position paper towards greater consistency of costs benefit analysis methodologies,[37] a discount rate of 4% has been considered for calculating the minimum lifetimes.

The minimum lifetime of an alternative BZ configuration is calculated according to the following formula:

$$\text{NPV} = \frac{\text{cash flow}}{(1+i)^t} - \text{initial investment}$$

Where the transition costs are taken as initial investment, the cash flow is the total socio-economic welfare in € million/year, i is the discount rate of 4%, and t is the calculated minimum lifetime.

Table 34 provides an overview of the monetised benefits for the 2025 target year, transition costs (for a three-year lead time), and the corresponding minimum lifetime of each alternative configuration for the CE BZRR.

BZ configuration	Monetised benefits [€ million]	Transition costs [€ million] *			Minimum lifetime [years]		
		min	med	max	min	med	max
DE2	264	1,186	1538	1,540	5.1	6.8	6.8
DE2 + NL2	266	1,233	1,785	1969	5.2	8.0	9.0
DE3	251	1,191	1,542	1,566	5.4	7.2	7.3
DE4	312	1,263	1,616	2,266	4.5	5.9	8.7
DE4 + NL2	268	1,310	1,863	2,695	5.5	8.3	13.1
DE5	339	1,269	1,621	2,378	4.1	5.4	8.4
DE5 + NL2	332	1,316	1,868	2,807	4.4	6.5	10.5
NL2	9	47	247	429	6.2	270.3	1,240.0

* Estimates of the transition costs for individual split configurations were evaluated in the transition costs study. For the combinations, they were calculated as the sum of the estimates of the transition costs of the individual split configurations.
Note: The "min" costs are based on the scaled cost of the relatively lowest cost estimate, "med" costs are based on the scaled costs of the median cost estimate, and "max" costs are the scaled costs of the relatively highest cost estimate.

Table 34: Transition costs estimates and minimum lifetime of a change in BZ configuration

37 https://www.acer.europa.eu/sites/default/files/documents/Position%20Papers/ACER_Consistency%20of%20CBA%20methodologies.pdf

Assessment of Mitigation Measures

The BZR Methodology foresees a public consultation on the possible measures to mitigate negative impacts of specific alternative BZ configurations regarding the "transition costs" criterion. This public consultation was held in the summer of 2024, and in the following section TSOs reflect upon the main feedback received from stakeholders on mitigation measures related to transition costs. A detailed summary of all responses received during the public consultation can be found in Appendix A of Annex V.

Most feedback received relates to the necessary increase in transparency and regulatory certainty. In particular, market participants highlight the need to be sufficiently informed in advance of a change to have sufficient time to adapt their systems to a potential new BZ configuration. This particular concern was also voiced by TSOs while answering the transition costs questionnaires. The complexity of the IT systems and processes (in particular for a reconfiguration of the German–Luxembourgish BZ) should not be underestimated. Having an adequate lead time (a lead of three years was considered as unrealistic by the German TSOs in case of a German–Luxembourgish split configuration) would allow for a higher cost efficiency when planning and implementing these changes.

6.3.11 Criterion 12: Infrastructure Cost

According to Article 15(12) of the BZR Methodology, the "infrastructure cost" criterion should preferably be estimated by modelling the effect of BZ configurations on investment decisions, e.g. generation or demand assets and the need to build – or not – network infrastructure to address congestion in a cost-efficient manner.

In the absence of a modelling tool that is able to robustly assess the aforementioned aspects, the BZR Methodology provides the possibility of evaluating the "infrastructure cost" criterion based on the comparison of the results of two other criteria:

- Accuracy and robustness of price signals
- Price signals for building infrastructure

TSOs had no modelling tool available for this study that could robustly model the effect of BZ configurations on possible investment decisions in generation, demand, or transmission assets. Thus, the assessment of the "infrastructure cost" criterion was based on the evaluation of the other two criteria mentioned above.

Table 35 below shows the results of the "infrastructure cost" criterion assessed according to these two criteria.

Criterion	DE2	DE2+NL2	DE3	DE4	DE4+NL2	DE5	DE5+NL2	NL2
Price signals for building infrastructure (9)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**
Accuracy and robustness of the price signals (10)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**
Performance in total (12)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**

Table 35: Results of the "infrastructure cost" criterion

According to the BZR Methodology, all alternative configurations are assessed as performing the same as the status quo.

6.3.12 Criterion 13: Market Outcomes in Comparison to Corrective Measures

As set forth in Article 15(13) of the BZR Methodology, the evaluation of the "market outcomes in comparison to corrective measures" criterion shall be performed by calculating the total remedial action costs as envisaged in Article 9 of the BZR Methodology and shall be evaluated together with the socio-economic welfare derived from the market dispatch as envisaged in Article 7 of the BZR Methodology. This joint evaluation corresponds to the assessment of the "economic efficiency criterion", as described in section 6.2.1.

6.3.13 Criterion 14: Adverse Effects of Internal Transactions on other Bidding Zones

The evaluation of the "adverse effects of internal transactions on other BZs" criterion according to Article 15(14) of the BZR Methodology should consider two indicators:

1. **Average share of loop flows on network elements,** with either a market congestion following the DA market dispatch, or with physical congestion during the OSA following the DA market dispatch pursuant to Article 7.

2. **Number of occurrences (hours) with loop flows – on all network elements – higher than a given threshold,** expressed as a percentage of F_{max}, and agreed upon by all TSOs of a CCR.

A BZ configuration shall be expected to perform better (respectively worse) than the status quo configuration regarding adverse effects of internal transactions on other BZs when either the two above-described indicators show a lower (respectively higher) value for the said configuration than for the status quo one, or at least one of the two indicators shows a lower (respectively higher) value for the said BZ configuration, while the other is the same as for the status quo configuration. In any other case, it shall be expected to perform the same as the status quo configuration.

For both indicators, the starting point for the simulations of loop flows is the static CNEC list with the most frequently occurring congestions as described in the section 6.1.2.5. The detailed loop flow analysis based on power flow colouring (PFC) is available for 866 CNECs for all configurations. A detailed loop flow analysis including all 7,000 + CNECs defined for this study was not computationally feasible.

Average Share of Loop Flows on Network Elements

The first indicator – average share of loop flows on network elements – was calculated based on CNECs that showed market congestion or physical congestion, respectively, in at least one MTU for a given BZ configuration as prescribed by the BZR Methodology. Additionally, per MTU, for all CNECs related to the same CNE, only the CNEC with the highest loop flow is considered in calculating the overall average. This approach results in a different set of CNECs that are considered for different BZ configurations. For instance, when we could observe lower flows in a split configuration for a given CNEC that has a physical congestion in the status quo, this CNEC might no longer have a physical congestion in the split configuration and is thus not used for calculating the average loop flow for the split configuration while it was used for the average in the status quo. Thus, by following the BZR Methodology we see limited comparability between BZ configurations in this indicator, as also illustrated in Figure 52 (section 6.1.2.5.3).

The differences between the status quo and alternative BZ configurations are presented in the charts and tables below for the average share of loop flows and average change in FBMC (Figure 60 and Table 36) and the share and change in OSA before RAO (Figures 61 and 37). All configurations perform better than the status quo after the FBMC phase. In this calculation, only a limited number of CNECs are included as only a few have market congestion.

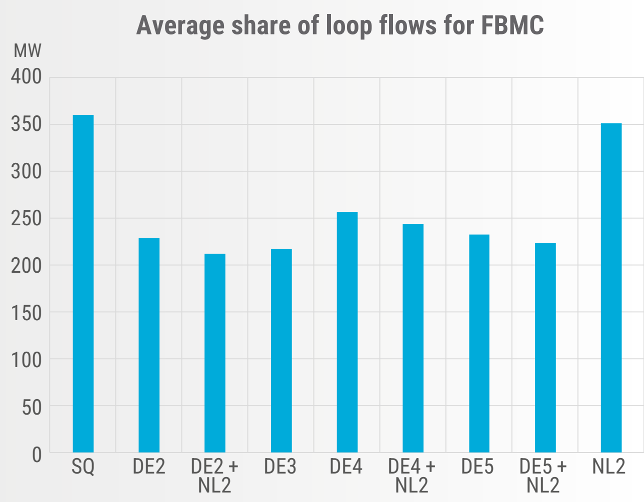


Figure 60: Average share of loop flows for FBMC

Configuration	Average share of loop flows (MW)	Absolute difference to SQ (MW)	Relative change to SQ
SQ	359	N/A	0.0 %
DE2	228	–132	–36.7 %
DE2 + NL2	211	–148	–41.2 %
DE3	216	–143	–39.8 %
DE4	257	–103	–28.6 %
DE4 + NL2	244	–116	–32.2 %
DE5	231	–128	–35.6 %
DE5 + NL2	223	–137	–38.0 %
NL2	351	–8	–2.3 %

Table 36: Change in average share of loop flows for FBMC

Figure 61 and Table 37 show that all German split configurations and combinations perform worse than the status quo for OSA before RAO. The NL2 configuration performs the same as the status quo.

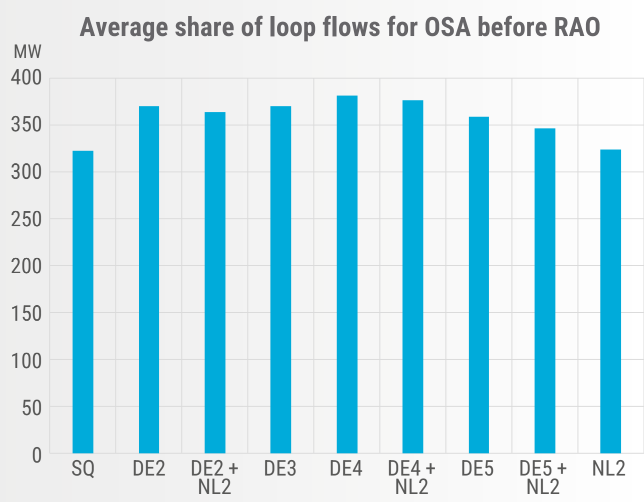


Figure 61: Average share of loop flows for OSA before RAO

Configuration	Average share of loop flows (MW)	Absolute difference to SQ (MW)	Relative change to SQ
SQ	323	N/A	N/A
DE2	371	48	14.8 %
DE2 + NL2	365	42	13.1 %
DE3	370	48	14.8 %
DE4	383	60	18.6 %
DE4 + NL2	377	55	17.0 %
DE5	360	37	11.5 %
DE5 + NL2	347	25	7.6 %
NL2	324	1	0.4 %

Table 37: Average change in share of loop flows for OSA before RAO

The results of the average share of loop flows on network elements indicator can be seen in Table 38 below. According to the BZR Methodology, besides NL2 – which performs better – all alternative configurations perform the same as the status quo.

1. Average share of loop flows on network elements	Configuration	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
	FBMC	Better	Better	Better	Better	Better	Better	Better	Better
	OSA before RAO	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Same
	Performance Results	Same	Same	Same	Same	Same	Same	Same	Better

Table 38: Performance results for average share of loop flows on network element indicator

Number of Occurrences (hours) with Loop Flows, on all Network Elements, Higher than a Given Threshold

The second indicator – number of occurrences (hours) with loop flows, on all network elements, higher than a given threshold – is calculated based on counting the occurrences with loop flows on network elements higher than a given threshold. For each hour, a 10 % threshold is used for internal CNECs and 20 % for cross-border CNECs. Per MTU, only the CNECs included in the capacity calculation process are used. The results of the number of occurrences (hours) with loop flows on all network elements higher than a given threshold indicator can be seen in Figure 62 and Table 39. According to the BZR Methodology, DE2, DE3 and DE2 + NL2 are assessed as performing better than the status quo, while DE4, DE5, NL2 and DE5 + NL2 are assessed as performing worse. However, these results can be caused by external reasons such as having a different number of CNECs depending on the configuration.

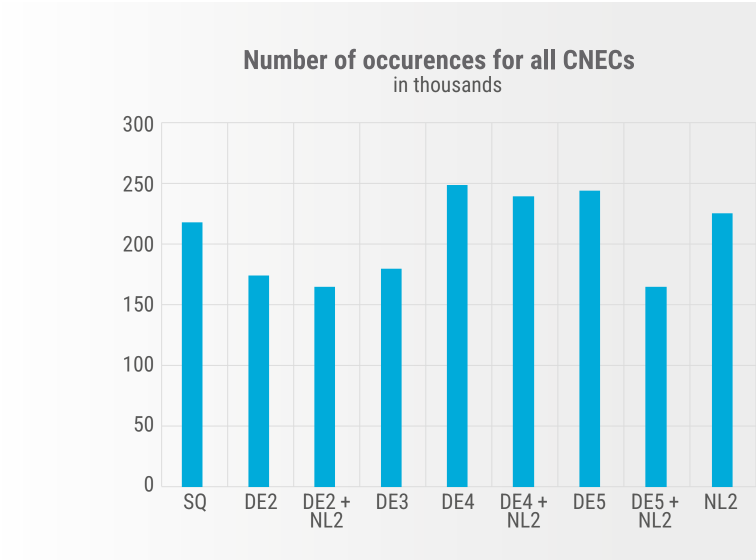


Figure 62: Number of occurrences (hours) with loop flows on network elements higher than a given threshold

Configuration	Number of occurrences for all CNECs	Absolute difference to SQ	Relative change to SQ
SQ	217,821	N/A	N/A
DE2	174,306	−43,515	−20.0 %
DE2 + NL2	165,405	−52,416	−24.1 %
DE3	180,321	−37,500	−17.2 %
DE4	248,408	30,587	14.0 %
DE4 + NL2	239,608	21,787	10.0 %
DE5	243,946	26,125	12.0 %
DE5 + NL2	165,405	−52,416	−24.1 %
NL2	225,184	7,363	3.4 %

Table 39: Average change in number of occurrences (hours) with loop flows on all network elements higher than a given threshold

2. Number of occurrences (hours) with loop flows, on all network elements, higher than a given threshold	Configuration	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
	Performance results	Better	Better	Better	Worse	Worse	Worse	Worse	Worse

Table 40: Number of occurrences (hours) with loop flows on all network elements higher than a given threshold

Taking into account the two aforementioned indicators, we receive an overall result for criterion 14 based on the sum of the respective indicators results. The overall results for the "adverse effects of internal transactions on other BZs" criterion can be seen in Table 41 below. According to the BZR Methodology, DE2, DE3, and DE2 + NL2 are assessed as performing better than the status quo, while DE4, DE5, as well as the combinations DE4 + NL2 and DE5 + NL2 are assessed as performing worse. There are no impacts from inaccurate price signals that should be considered as both criteria 10 (accuracy and robustness of price signals) and 9 (price signals for building infrastructure) are assessed as performing the same for every alternative configuration.

However, the indicators prescribed by the BZR Methodology do not give a full picture on the effects of loop flows as explained in the general section on loop flow results. The results for DE4, DE5, and DE5 + NL2 configurations seem to be non-intuitive and might result from the aforementioned aspect of having a different subset of CNECs depending on the configuration.

Criterion 14 Overall results	Configuration	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
	Results	Better	Better	Better	Worse	Worse	Worse	Worse	Same

Table 41: Overall results of criterion 14 "Adverse effects of internal transactions on other BZs"

6.3.14 Criterion 15: Impact on the Operation and Efficiency of the Balancing Mechanisms and Imbalance Settlement Processes

As set forth in Article 15(15) of the BZR Methodology, the impact of the operation and efficiency of the balancing mechanisms and imbalance settlement processes shall be split into two difference sub-criteria, which shall be assessed separately:

1. Operation and efficiency of the balancing mechanisms
2. Imbalance settlement processes

Sub-criterion 15.1: Operation and Efficiency of the Balancing Mechanisms

As the BZ Study cannot address the impact of co-optimisation and the cost of imbalance energy activation, the alternative BZ configurations may be considered to perform the same as the status quo configuration regarding the "operation and efficiency of the balancing mechanisms" sub-criterion.

Notwithstanding these methodological prescriptions, the TSOs of the Germany–Luxembourg BZ wish to highlight the challenges for the balancing market in Germany and Luxembourg in case of a reconfiguration of the German–Luxembourgish BZ in a qualitative way.

The German–Luxembourgish BZ applies a self-dispatching market arrangement, with an intraday gate closure of 30 minutes before delivery for trades across different load frequency control (LFC) areas of the BZ. Trades within the same LFC area are possible until close before real time. Under such an arrangement, balance responsible parties (BRPs) are able to and responsible for balancing their position by trading until close to real time. In 2022, approximately 62 TWh were traded in the continuous intraday market until shortly before real time due to the need to integrate a high share of RES. In case the German–Luxembourgish BZ were divided and thus became smaller, market participants would have fewer opportunities to execute such trading to balance their position. Additionally, limited inner-German–Luxembourgish intraday trading possibilities might also lead to limited possibilities for German TSOs to support each other and their neighbouring TSOs in critical situations (e.g. with mutual energy assistance services; MEAS) and lead to higher associated costs. The recent developments of RES and the related operational challenges visible in daily operation – especially in 2023 and 2024 – underline this need.

Less individual trading opportunities might result in more imbalanced positions. Consequently, TSOs would have to contract and activate a higher overall volume of reserves. This self-dispatch arrangement is fundamentally different from central dispatch systems such as Italy, where individual trading is put on hold with significant more lead time before real time. This enables central dispatchers (TSOs) to adjust the generation (load) pattern with sufficient lead time, thereby balancing supply and demand and resolving congestions, which can be achieved independently of BZBs. Therefore, BZ splits have a weaker impact on reserve capacity requirements in central dispatch systems compared to self-dispatch arrangements.

The LFC DE/LU/DKW block (and especially the DE/LU BZ) dimensions its reserve capacity beyond the minimum criteria set in Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (SOGL). This leads to the ability to mostly balance occurring imbalances avoiding demands for balancing energy beyond the available reserves and thus a negative impact on system frequency in the Central Europe Synchronous Area (CE SA). This is even more remarkable regarding the significant amount of renewables being installed in the DE/LU/DKW LFC block and the high loads connected. Thus, the LFC DE/LU/DKW block takes responsibility resulting from the fact that it is the largest LFC block in CE SA. Therefore, the issue of sufficient reserve capacity cannot be discussed with the limited scope on the LFC DE/LU/DKW block and procurement costs. System security and power frequency quality must not be neglected.

For the LFC DE/LU/DKW block, it is current practice to set dimensioning requirements for reserve capacity at the BZ level based on reference incidents and historical imbalances, whereby each BZ within the LFC DE/LU/DKW block is able to fulfil the SOGL requirements. Consequently, the LFC block itself fulfils the SOGL requirements at all times. Assuming that this principle would also apply to a situation in which the German–Luxembourgish single BZ would be split up in several BZs, the dimensioning of the total balancing reserve capacity would increase as each BZ has its own reference incident and historical imbalances to be covered by sufficient reserve capacity. This dimensioning requirement is independent from measures that might be taken to reduce the overall amount of reserve capacity to be procured in the DE/LU/DKW LFC block, but which are dependent on CZC available between the new BZs.

The ability to reliably allocate CZC for balancing purposes might indeed reduce the balancing capacity to be procured and is the desired way forward in case of a BZ reconfiguration. However, this firm reservation of CZC for balancing purposes would result in reduced CZC for the exchange of energy through the wholesale electricity markets in all other timeframes. Hence, from German and Luxembourgish TSOs'

perspective, the BZ Study needs to reflect either the increase of balancing capacity requirements or the reduction of CZC for the wholesale electricity markets (or a combination of both) to accurately simulate the expected developments.

Against this background, on 22 December 2022, the TSOs of the CE BZRR informed ACER on their approach to consider increased balancing capacity requirements for the German–Luxembourgish BZ splits in the BZR simulations.

However, on 27 July 2023, ACER and the chair of the Board of Regulators addressed an escalation letter to ENTSO-E in which they explicitly requested the German and Luxembourgish TSOs to assume a constant volume of balancing reserves for the German–Luxembourgish area in all alternative BZ configurations to be investigated in the BZ Study and reserve the right to follow up with enforcement actions. German and Luxembourgish TSOs have therefore decided to comply with ACER's and NRAs' request and implement the assumption of constant balancing capacity in the German–Luxembourgish area while not reducing the cross-zonal capacity for the wholesale electricity markets to proceed with the BZR. However, based on their operational practice and experience, given the relevant legal and regulatory framework and anticipating an increased need for reserve capacity or the need for reserving CZC for balancing purposes in case of BZ splits, German and Luxembourgish TSOs are convinced that this assumption is incorrect. In case of a BZ split, it would be necessary to re-evaluate the impact on reserve capacity, operational processes, and in particular the volume changes.

Major parts of prequalified reserve-providing groups and units active in frequency restoration reserves (FRRs) in the German–Luxembourgish BZ are located in the south. To reduce cost for reserves, the German–Luxembourgish BZ has applied a common dimensioning of reserve capacity and procurement of balancing capacity since 2010.

Not including CZC into the common dimensioning of split German–Luxembourgish BZ and not allocating CZC for the procurement of balancing capacity could potentially lead to a physical shortage of balancing capacity in certain new BZs due to the current geographical distribution, e g. resulting from pumped hydro being dependent of certain geographical conditions. The combination of higher need for reserve capacity and a shortage of supply in certain BZs is likely to result in higher costs for society.

Additionally, the balancing market in Germany is already dominated by few BSPs today. As those large BSPs originate from former energy monopolies in different regions of Germany, a BZ split would lead to a scenario where only one or two major players dominate the balancing market in each BZ. German and Luxembourgish TSOs are concerned that further regional fragmentation of the balancing market without firm exchange possibilities might significantly increase the risk of market manipulation and market power abuse.

Overall, German and Luxembourgish TSOs emphasise that in case of a BZ reconfiguration, an operational balancing concept – including allocation of CZCA – would need to be developed, assessed, and implemented. The BZR alone cannot address all remaining challenges for the national balancing markets nor forecast any developments that might occur in the reserve markets. Considering current and foreseen operational practices, the balancing costs for multiple German–Luxembourgish BZs would exceed the balancing costs for a single German–Luxembourgish BZ. This effect is not considered in the BZR and would reduce the overall welfare impact of the German–Luxembourgish split scenarios.

Sub-criterion 15.2: Imbalance Settlement Processes

With respect to the "imbalance settlement processes" sub-criterion, a given BZ configuration is expected to perform better (worse, or the same) than the status quo configuration when it performs better (respectively worse or the same) regarding the "accuracy and robustness of price signals" criterion assessed in section 6.3.9. Therefore, according to the BZR Methodology, for this sub-criterion all split scenarios considered perform the same as the status quo configuration.

However, it should be noted that the "accuracy and robustness of price signals" criterion is based on simulated market prices that do not sufficiently represent the imbalance price, whose effect is supposed to be assessed here. Additionally, the imbalance settlement process is a very complex process that is hardly captured by simply the imbalance price. The adequacy of this sub-criterion can therefore be questioned.

Assessment of criterion 15

Table 42 shows the evaluation of the two sub-criteria and draws conclusions for criterion 15 overall considering that all sub-criteria are equally weighted.

According to the BZR Methodology, the sub-criteria are considered separately for the consolidation under step 4 in section 6.5.

Alternative configuration	Performance with respect to sub-criterion 15.1 "Operation and efficiency of the balancing mechanisms"	Performance with respect to sub-criterion 15.2 "Imbalance settlement processes"	Performance with respect to criterion 15
DE2	**Same**	**Same**	**Same**
DE2 + NL2	**Same**	**Same**	**Same**
DE3	**Same**	**Same**	**Same**
DE4	**Same**	**Same**	**Same**
DE4 + NL2	**Same**	**Same**	**Same**
DE5	**Same**	**Same**	**Same**
DE5 + NL2	**Same**	**Same**	**Same**
NL2	**Same**	**Same**	**Same**

Table 42: Conclusions for criterion 15

6.3.15 Criterion 16: Stability and Robustness of Bidding Zones over Time

Quantitative Assessment of Atability and Robustness of Bidding Zones over Time

As set forth in Article 15(16) of the BZR Methodology, the assessment of the "stability and robustness of BZs" over time criterion shall be based on at least the evaluation of the "economic efficiency" criterion for each of the sensitivity analyses pursuant to Article 4(10), indicating that TSOs shall at least perform one sensitivity analysis. The sensitivities performed shall reflect appropriate and foreseeable variations in any of the input data or grid infrastructure of the scenario defined pursuant to paragraph 1 of the BZR Methodology.

CE BZRR TSOs decided to ultimately perform one sensitivity analysis considering an increase in fuel and CO_2 prices (including adapted redispatch markups).

Criteria Evaluation

The impacts for the alternative BZ configurations are not assessed on a stand-alone basis, but always in comparison to the status quo configuration. As set forth in Article 15(16) of the BZR Methodology, a given BZ configuration shall be expected to perform better (respectively worse) than the status quo configuration regarding the "stability and robustness of BZs over time" criterion when the evaluation of the "economic efficiency" criterion leads to a positive (respectively negative) change in overall welfare compared to the status quo configuration for the majority of sensitivities considered or having analysed all criteria TSOs conclude that the BZ configuration performs better (respectively worse) than the status quo configuration for the majority of sensitivities considered.

In line with the BZR Methodology, CE BZRR TSOs have chosen to assess the 'stability and robustness of BZs over time' criterion by analysing exclusively the "economic efficiency" criterion for the sensitivity analysis performed in the BZ Study. Moreover, in order to allow for a timely delivery of the results, TSOs have decided to assess this criterion for only one climate year. Accordingly, climate year 1989 has been chosen because the input data in terms of renewable generations and load for this climate year are in a relatively average range compared to the other climate years.

Some further explanation of the results of the sensitivity analysis is available in Annex VIII.

Table 43 provides an overview of the changes in socio-economic welfare for all alternative configurations for the sensitivity analysis considered for climate year 1989.

Average change with respect to status quo for the sensitivity analysis (climate year 1989)						
	Market dispatch (CE + non-CE)				RAO (CE)	Economic Efficiency
Configuration compared to status quo	Market welfare [€ million]	Consumer surplus [€ million]	Producer surplus [€ million]	Overall congestion revenue [€ million]	Additional costs from redispatch [€ million]	Socio-economic welfare (criterion 4) [€ million]
DE2	−1,197	1,087	−3,899	1,615	−1,666	468
DE2 + NL2	−1,188	1,640	−4,843	2,014	−1,636	447
DE3	−1,270	1,190	−4,346	1,885	−1,732	462
DE4	−1,257	1,344	−4,156	1,555	−1,701	444
DE4 + NL2	−1,298	461	−3,501	1,742	−1,619	321
DE5	−1,053	1,931	−5,352	2,368	−1,607	554
DE5 + NL2	−1,037	796	−3,671	1,839	−1,565	528
NL2	2	−521	401	122	42	−40

Table 43: Average change in socio-economic welfare[38] for the sensitivity analysis for climate year 1989

Based on these results, criterion 16 can be assessed as presented in Table 44.

Criterion 16	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
Stability and robustness of bidding zones over time	Better	Better	Better	Better	Better	Better	Better	Worse

Table 44: Assessment of criterion 16

38 Calculated as presented in section 6.2.1

6.3.16 Criterion 17: Consistency Across Capacity Calculation Timeframes

As set forth in Article 15(17) of the BZR Methodology, the impact of alternative BZ configurations on this criterion shall not be considered as dependent on the BZ configuration since the consistency across capacity calculation timeframes is a regulatory requirement. Alternative BZ configurations shall thus perform the same as the status quo configuration regarding this criterion.

6.3.17 Criterion 18: Assignment of Generation and Load Units to Bidding Zones

The unique and unambiguous assignment of nodes to BZs is one of the CACM criteria to assess alternative configurations (CACM Article 33(1)(c)(iii)) and is a prerequisite for the alternative configurations according to Article 15(18) of the BZR Methodology. In this respect, the unique and unambiguous assignment of generation and load units to a BZ should be addressed when proposing alternative BZ configurations to be assessed in the BZ Study. In order to confirm that all alternative BZ configurations meet this prerequisite, the fulfilment of this criterion shall be assessed during the BZ Study. In case this prerequisite is not met, then the alternative BZ configuration can be "rejected" as part of step 1 of the assessment, pursuant to Article 13(1)(a)(iii)(4) of the BZR Methodology; otherwise, an alternative BZ configuration shall be considered to perform the same as the status quo configuration regarding this criterion. However, when the BZR Methodology was written, it was assumed that there would be more clarity regarding the assignment of nodes to zones when determining the alternative configurations. To avoid having to reject several alternative configurations, the following solution was found.

Possibility to opt for the so-called Fallback Configurations for Germany

The ACER decision 11/2022 on alternative configurations defines four default configurations and three fallback configurations for Germany (Figure 63) because German TSOs had already highlighted issues with some of the default configurations during the consultation process regarding the unique and unambiguous assignment of generation and load units to BZs. According to Annex I Article 2 of the ACER decision 11/2022 on alternative configurations, TSOs should assess the node-to-zone assignment for the default configurations. If a unique and unambiguous assignment cannot be achieved, then TSOs must replace the concerned configuration(s) with the corresponding fallback configurations, as shown in Figure 63.

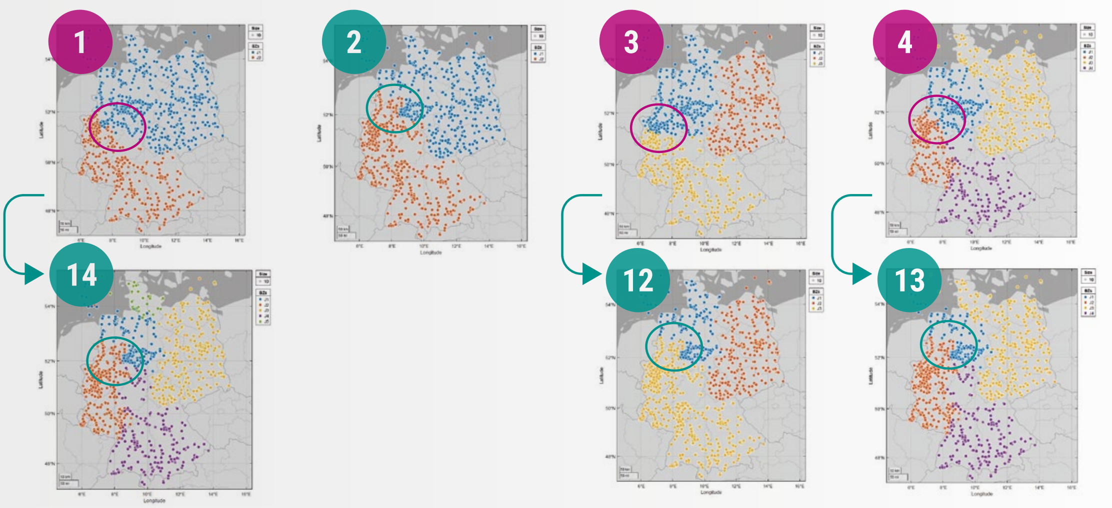


Figure 63: Default (upper graphs) and fallback (lower graphs) configurations for Germany

The assessment of the node-to-zone assignment is complicated by the fact that the 110 kV grid does not belong to the German TSOs. Instead, there are around 900 distribution system operators (DSOs) operating the lower voltage levels in Germany. Therefore, not all information needed for the assessment was available to the German TSOs when the decision on the alternative configurations had to be taken.

In the official communication between German TSOs and ACER on possible options, the TSOs highlighted that a detailed analysis as described by ACER with clear assignment of the nodes to a zone would require both obtaining the necessary data from the 110 kV grid operators and an analysis of this data. They also highlighted that such analyses would require a considerable amount of time.

Since this analysis must precede the evaluation process, it would have delayed the entire review project.

Against this background, the TSOs asked ACER whether they shall opt for the analysis as described in ACER's decision 11/2022 before concluding which configurations to evaluate in the review with the consequences on the planning mentioned above. Alternatively, they asked whether a more simplified analysis might provide sufficient insights to determine which configurations should be evaluated in the BZ Study. ACER acknowledged the difficulty and accepted the simplified approach suggested by the TSOs.

Outcome of the Simplified Analysis for the Amprion Grid and Decision to Assess the Fallback Configurations

In default configurations 1, 3, and 4, the 110 kV network is split in several instances. From a practical standpoint, the unique and unambiguous node-to-zone assignment is not always possible: even if generation and load units were assigned to one zone in theory according to a particular arbitrarily chosen criterion (e.g. lowest electrical distance), in practice generation units would still feed into both zones. While this is generally undesired for measurement technological reasons, on such a large scale it would pose a real problem for keeping track of flows for balancing and settlement purposes and integrating them into the market coupling. Opening breakers could help to mitigate the problem of measuring flows, although not all 110 kV lines have breakers. Furthermore, opening breakers for the sole purpose of assigning generation/load to particular BZs is questionable.

Additional practical concerns include the fact that setting up the necessary meters in the low-voltage level on such a large scale requires time (initially estimated at a minimum of six years) and effort. Long delivery times could prolong the implementation time. The question of whether 110 kV lines have to be considered as critical network elements in the market coupling has not been assessed but also needs to be discussed since this could potentially lead to more issues. These concerns can be mitigated by not splitting through the Ruhr area but along the northern Amprion LFC area, i.e. choosing to evaluate the fallback configurations in the BZR.

According to Article 2 of Annex I of the ACER decision 11/2022 on alternative configurations, TSOs shall replace the default with the fallback configurations in case the unique assignment of generation and load units to BZs cannot be achieved for the default configurations. The only criterion to consider when determining the alternative configurations to be evaluated in the BZ Study is the unique assignment of nodes to zones. Regarding the practical implementability, a simplified study has revealed issues with the node-to-zone assignment of the default splits 1, 3, and 4. In particular, a cut through the highly-meshed Ruhr area would lead to major challenges. Assigning 110 kV nodes to BZs would add to those challenges since it would also require assigning the associated injections/withdrawals to zones for balancing and settlement purposes and integrating them into the market coupling. Therefore, CE TSOs chose the application of the fallback configurations in the BZ Study.

Conclusion on the Criterion

As the fallback configurations mostly align with the control areas of the German TSOs, the risk of ambiguous assignment of generation and load units should generally be lower than for the default configurations. However, it cannot fully be ruled out that in some cases – and especially for small-scale generation and load units – units are connected to more than one substation in the distribution grid that are eventually further connected to different transmission nodes that belong to different alternative BZ configurations. This might even depend on the switching state of the underlying DSOs.

However, CE BZRR TSOs decided not to reject any of the assessed alternative configurations based on the unique assignment of generation and load units to a BZ under step 1. Consequently, according to Article 15(18) of the BZR Methodology, this criterion shall be assessed as performing the same for the alternative configuration as for the status quo configuration.

CE BZRR TSOs would like to highlight that they cannot take any responsibility for ensuring the fulfilment of this criterion and that in case a BZ split was implemented, a clear delineation should be provided by the political decisionmakers.

6.3.18 Criterion 19: Location and Frequency of Congestion (Market and Grid)

As set forth in Article 15(19) of the BZR Methodology, the "location and frequency of congestion" criterion is assessed using the following two indicators:

i. An indicator of the percentage of time when the physical congestion was not previously detected in the DA market.
ii. The share of market congestions which occurred on cross-zonal network elements over the total market congestions on internal and cross-zonal elements.

The first indicator is already within the analysis of the "price signals for building infrastructure" criterion in section 6.3.8 and performs the same for all alternative configurations. The second indicator is expected to perform better (respective worse) if the value for the share of market congestion on cross-zonal network elements presents a higher (respective lower) value. Moreover, the assessment is provided in Table 45 by accounting the highest congestion of a given CNE among all contingencies.[39]

39 Another way to calculate the share of congestion on BZBs is to consider physical congestion as every congestion of given CNE plus contingency. This approach leads to very similar results and confirms the final assessment of this indicator.

	SQ	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
Total number of market congestions on cross-zonal lines counting only on CNE for all climate yearss (in thousands)	64	64	64	64	70	70	70	71	64
Total number of market congestions counting only on CNE for all climate years (in thousands)	94	111	115	116	123	127	126	131	97
share	0.68	0.57	0.56	0.55	0.57	0.56	0.56	0.55	0.67
Relative change (%)		–14.9	–17.9	–18.3	–16.2	–18.3	–18.1	–20. 1	–1.9

Table 45: Share of market congestions which occurred on cross-zonal elements indicator

The assumed expectation from the methodology regarding this indicator is that the increase of the share of market congestions in cross-border elements would be a positive effect of splitting a BZ. Intuitively, the split would solve internal market congestions by transferring them to new cross-border elements, thus increasing the share of market congestions on all cross-border elements. However, simulation results show the opposite behaviour, whereby the share of cross-border market congestion decreases in all splits.

This can be explained due to specificities of the flow-based system. More BZs add more dimensions in the flow-based domains, which could lead to more limiting CNECs at a time. Irrespective of the number of CNECs, there is a higher likelihood that more CNECs could limit the domain, explaining why more market congestions are present in higher splits. By analysing both cross-border market congestions and total number of market congestions (Figure 64), it is possible to confirm that the increase of total market congestion with the higher number of splits is driving down the share of congestion on cross-border elements.

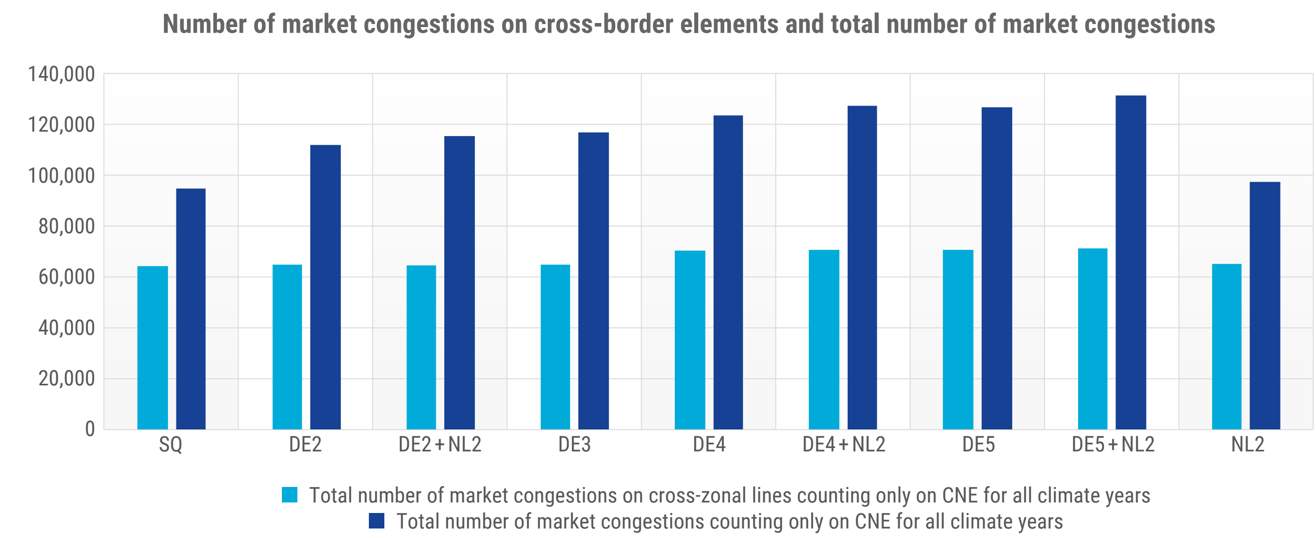


Figure 64: Number of market congestions on cross-border elements and total number of market congestions

Finally, Table 46 provides the final assessment for the "location and frequency of congestion" criterion for each alternative configuration compared to the status quo. The results shall be interpreted as better for a given BZ configuration if the two indicators perform better, or at least one indicator performs better while the other remains the same regarding the status quo.

	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
Physical congested not detected on DA	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**
Share on cross-zonal elements	**Worse**	**Worse**	**Worse**	**Worse**	**Worse**	**Worse**	**Worse**	**Same**
Assessment	**Worse**	**Worse**	**Worse**	**Worse**	**Worse**	**Worse**	**Worse**	**Same**

Table 46: Final assessment for the "location and frequency of congestion" criterion

6.3.19 Criterion 20: Short-term Effects on CO_2 Emissions

As set forth in Article 15(20) of the BZR Methodology, the overall volume of CO_2 emissions after optimisation of remedial actions for each configuration shall be evaluated to assess the "short-term effects on CO_2 emissions" criterion. For each of the BZ configurations under investigation and the status quo configuration, the total volume of CO_2 emissions should be determined as the sum of CO_2 emissions from each generation unit in each MTU.

A given BZ configuration is expected to perform better (or worse) than the status quo configuration in terms of the "short-term effects on CO_2 emissions" criterion when the overall volume of CO_2 emissions for the said BZ configuration is lower (or higher) than for the status quo. If the total volume of CO_2 emissions remains the same as in the status quo configuration, the configuration is regarded as performing the same. This criterion is assessed based on all-EU (CE + non-CE region) results. The results of the "short-term effects on CO_2 emissions" criterion are shown in Table 47 below.

Configuration	Overall volume of CO_2 emissions after RA [million tonnes]	Difference between the given configuration and status quo configuration [million tonnes]	Relative change compared to Status Quo [%]
SQ	436.79	0	0%
DE2	437.85	1.07	+0.2%
DE2 + NL2	437.90	1.11	+0.3%
DE3	438.29	1.50	+0.3%
DE4	437.47	0.69	+0.2%
DE4 + NL2	437.74	0.95	+0.2%
DE5	438.03	1.24	+0.3%
DE5 + NL2	437.93	1.14	+0.3%
NL2	437.04	0.25	+0.1%

Table 47: Short-term effects on CO_2 emissions

Table 48 below summarises the results for the "short-term effects on CO_2 emissions" criterion where each configuration is compared to the status quo. There is no significant change between the different configurations and the status quo configuration. As a result, all configurations perform the same for the "short-term effects on CO_2 emissions" criterion.

Configuration	Performance of the "short-term effects on CO_2 emissions" criterion
DE2	**Same**
DE2 + NL2	**Same**
DE3	**Same**
DE4	**Same**
DE4 + NL2	**Same**
DE5	**Same**
DE5 + NL2	**Same**
NL2	**Same**

Table 48: Final assessment for "short-term effects on CO_2 emissions" criterion

6.3.20 Criterion 21: Short-term Effects on RES Integration

According to Article 15(21) of the BZR Methodology, the impact of alternative BZ configurations on this criterion shall be assessed based on the total amount of simulated fed-in energy from RES after optimising remedial actions. For each of the alternative configurations under investigation and the status quo configuration, the total amount of simulated fed-in energy from RES should be determined as the sum of fed-in energy from each renewable generation unit in each MTU.

Regarding this criterion, a given BZ configuration is expected to perform better (respectively worse) than the status quo configuration when the total amount of simulated fed-in energy quantities from RES for the said BZ configuration is higher (respectively lower) than for the status quo one. If the fed-in energy quantities from RES are the same as in the status quo configuration, the said configuration shall be considered to perform the same as the status quo configuration. This criterion is assessed based on all-EU (CE + non-CE region) results.

The results for the status quo and the different configurations can be found in Table 49.

Configuration	Total amount of simulated fed-in energy from RES after RA [TWh]	Difference between the given configuration and status quo configuration [TWh]	Relative change compared to status quo [%]
Status quo	1,462.3	0	0
DE2	1,464.7	2.4	+0.2
DE2 + NL2	1,464.9	2.6	+0.2
DE3	1,464.5	2.2	+0.2
DE4	1,465.2	2.9	+0.2
DE4 + NL2	1,464.6	2.3	+0.2
DE5	1,464.7	2.4	+0.2
DE5 + NL2	1,465.1	2.8	+0.2
NL2	1,462.4	0.0	0

Table 49: Short-term effects on RES integration

Table 50 presents the conclusions drawn based on the results shown in the table and graphs in the previous sections. When comparing the different configurations for criterion 21, there is no significant change compared to the status quo configuration. Based on this, all alternative configurations perform the same as the status quo regarding this criterion.

Configuration	Performance with respect to short-term effects on RES integration criterion
Status quo	**Same**
DE2	**Same**
DE2 + NL2	**Same**
DE3	**Same**
DE4	**Same**
DE4 + NL2	**Same**
DE5	**Same**
DE5 + NL2	**Same**
NL2	**Same**

Table 50: Final assessment for short-term effects on RES integration criterion

6.3.21 Criterion 22: Long-term Effects on Low-carbon Investments

According to Article 15(22) of the BZR Methodology, the assessment of the "long-term effects on low-carbon investments" criterion shall be based on the comparison of the results of two other criteria:

i. Accuracy and robustness of price signals (assessed in section 6.3.9)

ii. Price signals for building infrastructure (assessed in section 6.3.8)

Table 51 shows the results of the "long-term effects on low-carbon investments" criterion.

Criterion	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5 + NL2	NL2
Price signals for building infrastructure (9)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**
Accuracy and robustness of the price signals (10)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**
Performance in total (22)	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**	**Same**

Table 51: Final assessment for the "long-term effects on low-carbon investments" criterion

According to the BZR Methodology, all alternative configurations perform the same as the status quo. However, this criterion is overly simplified as it does not consider important aspects influencing investment decisions on low-carbon technologies, e.g. the effect of a price decrease in some zones on the business case of RES. The adequacy of the assessment of this criterion can therefore be questioned.

6.4 Step 3: Acceptability Assessment of the Alternative Configurations

According to Article 13 (1) (c) of the BZR Methodology, TSOs shall perform an acceptability assessment for each alternative configuration that performs worse than the status quo configuration for at least one criterion under step 2. The results of the criteria assessments conducted in step 2 can be summarised in the following Table 52:

	Configuration								
Criterion	DE2	DE2 + NL2	DE3	DE4	DE4 + NL2	DE5	DE5+NL2	NL2	Remarks
1 – Operational security	Better	Better	Better	Better	Better	Better	Better	Same	
2 – Security of supply	Same	Same	Same	Same	Same	Same	Same	Same	Detailed assessment could not be performed, performance assumed the same as the status quo
3 – Degree of uncertainty in cross-zonal capacity calculation	Implicit assessment through criterion 4 (economic efficiency)								
5 – Firmness costs	Implicit assessment through criterion 4 (economic efficiency)								
6 – Market liquidity and transaction costs	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	
7 – Market concentration and market power	Same	Same	Same	Same	Same	Same	Same	Same	See section 6.3.6 for assessment of the sub-criteria
8 – Facilitation of effective competition	Same	Same	Same	Same	Same	Same	Same	Worse	See section 6.3.7 for assessment of the sub-criteria
9 – Price signals for building infrastructure	Same	Same	Same	Same	Same	Same	Same	Same	
10 – Accuracy and robustness of price signals	Same	Same	Same	Same	Same	Same	Same	Same	
11 – Transition costs (ranges in € mn)	[1,186; 1,540]	[1,233; 1,969]	[1,191; 1,566]	[1,263; 2,266]	[1,863; 2,695]	[1,269; 2,378]	[1,316; 2,807]	[47;429]	Used to calculate the minimum lifetime of a bidding zone
12 – Infrastructure costs	Same	Same	Same	Same	Same	Same	Same	Same	Assessed as criterion 9 and 10
13 – Market outcomes in comparison to corrective measures	Implicit assessment through criterion 4 (economic efficiency)								
14 – Adverse effects of internal transaction on other bidding zones	Better	Better	Better	Worse	Worse	Worse	Worse	Same	
15 – Impact on the operation and efficiency of the balancing mechanisms and imbalance settlement processes	Same	Same	Same	Same	Same	Same	Same	Same	See section 6.3.14 for assessment of the sub-criteria For sub-criterion 15.1, monetised assessment could not be performed For sub-criterion 15.2, assessed as criterion 10
16 – Stability and robustness of bidding zone over time	Better	Better	Better	Better	Better	Better	Better	Worse	
17 – Consistency across capacity calculation time frames	Same	Same	Same	Same	Same	Same	Same	Same	Assessment set upfront in the BZR Methodology
18 – Assignment of generation and load units to BZs	Same	Same	Same	Same	Same	Same	Same	Same	Assessment set upfront in the BZR Methodology
19 – Location and frequency of congestion	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Same	
20 – Short-term effects on CO_2 emissions	Same	Same	Same	Same	Same	Same	Same	Same	
21 – Short-term effects on RES integration	Same	Same	Same	Same	Same	Same	Same	Same	
22 – Long-term effects on low-carbon investments	Same	Same	Same	Same	Same	Same	Same	Same	Assessed as criterion 9 and 10
Evaluation	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	

Table 52: Acceptability assessment of the criteria

TSOs concluded that even though some alternative configurations might perform worse on some criteria, when considering the relative performance of these criteria and the need to consider all criteria assessed in steps 1 and 2, taken together, rather than considering each criterion individually all remaining configurations perform as "acceptable".

Therefore, as a final result of step 3, the list of potentially unacceptable configurations based on this assessment is empty and no consultation with the relevant authorities was necessary. All remaining configurations are included in step 4.

6.5 Step 4: Consolidation of Results

6.5.1 Ranking and Acceptability of Alternative Bidding Zone Configurations

Ranking	BZ configuration	Monetised benefits for 2025 target year [€ mn]	Transition costs [€ million]			Minimum lifetime [years]			Accepted/ rejected	Justification
			min	med	max	min	med	max		
1	DE5	339	1,269	1,621	2,378	4.1	5.4	8.4	Accepted	Positive monetised benefit
2	DE5 + NL2	332	1,316	1,868	2,807	4.4	6.5	10.5	Accepted	Positive monetised benefit
3	DE4	312	1,263	1,616	2,266	4.5	5.9	8.7	Accepted	Positive monetised benefit
4	DE4 + NL2	268	1,310	1,862	2,695	5.5	8.3	13.1	Accepted	Positive monetised benefit
5	DE2 + NL2	266	1,233	1,785	1,969	5.2	8.0	9.0	Accepted	Positive monetised benefit
6	DE2	264	1,186	1,538	1,540	5.1	6.8	6.8	Accepted	Positive monetised benefit
7	DE3	251	1,191	1,542	1,566	5.4	7.2	7.3	Accepted	Positive monetised benefit
8	NL2	9	47	247	429	6.2	270.3	1,240.0	Accepted	Positive monetised benefit
9	FR3	–9	415	469	478	N/A	N/A	N/A	Rejected	Negative monetised benefit
10	IT2	–60	45	–	237	N/A	N/A	N/A	Rejected	Negative monetised benefit

Table 53: Ranking and Acceptability of Alternative Bidding Zone Configurations

6.5.2 Short-term Effects of Alternative Bidding Zone Configurations

Criterion / BZ configuration	Operational security	Market liquidity and transaction costs	Market concentration and market power (from long-term to short-term markets)	Market concentration and market power (redispatching mechanism)
	Performance	Performance	Performance	Performance
DE2	Better	Worse	Worse	Better
DE2 + NL2	Better	Worse	Worse	Better
DE3	Better	Worse	Worse	Better
DE4	Better	Worse	Worse	Better
DE4 + NL2	Better	Worse	Worse	Better
DE5	Better	Worse	Worse	Better
DE5 + NL2	Better	Worse	Worse	Better
NL2	Same	Worse	Better	Worse

Table 54: Short-term Effects of Alternative Bidding Zone Configurations

Criterion / BZ configuration	Facilitation of effective competition (short-term)	Adverse effects of internal transactions on other BZs	Short-term effects on CO_2 emissions	Short-term effects on RES integration
	Performance	Performance	Performance	Performance
DE2	Worse	Better	Same	Same
DE2 + NL2	Worse	Better	Same	Same
DE3	Worse	Better	Same	Same
DE4	Worse	Worse	Same	Same
DE4 + NL2	Worse	Worse	Same	Same
DE5	Worse	Worse	Same	Same
DE5 + NL2	Worse	Worse	Same	Same
NL2	Worse	Same	Same	Same

Table 55: Short-term Effects of Alternative Bidding Zone Configurations II

6.5.3 Long-term Effects of Alternative Bidding Zone Configurations

Criterion / BZ configuration	Facilitation of effective competition (long-term)	Facilitation of effective competition (relative access to cross-zonal capacity)	Price signals for building infrastructure	Accuracy and robustness of price signals
	Performance	Performance	Performance	Performance
DE2	Same	Better	Same	Same
DE2 + NL2	Same	Better	Same	Same
DE3	Same	Better	Same	Same
DE4	Same	Better	Same	Same
DE4 + NL2	Same	Better	Same	Same
DE5	Same	Better	Same	Same
DE5 + NL2	Same	Same	Same	Same
NL2	Same	Worse	Same	Same

Table 56: Long-term Effects of Alternative Bidding Zone Configurations

Criterion / BZ configuration	Infrastructure cost	Impact on the imbalance settlement processes	Stability and robustness of BZs over time	Location and frequency of congestion (market and grid)	Long-term effects on low-carbon investments
	Performance	Performance	Performance	Performance	Performance
DE2	Same	Same	Better	Worse	Same
DE2 + NL2	Same	Same	Better	Worse	Same
DE3	Same	Same	Better	Worse	Same
DE4	Same	Same	Better	Worse	Same
DE4 + NL2	Same	Same	Better	Worse	Same
DE5	Same	Same	Better	Worse	Same
DE5 + NL2	Same	Same	Better	Worse	Same
NL2	Same	Same	Worse	Same	Same

Table 57: Long-term Effects of Alternative Bidding Zone Configurations II

6.6 Limitations of the Bidding Zone Review in Central Europe

Analysing the performance of potential alternative BZ configurations for the future is a challenging task. The BZR Methodology outlines 22 criteria that should be evaluated by TSOs, more than half of which need to be quantified based on detailed hourly simulations of the future European electricity market. With these simulations, TSOs use an electricity market model to simulate – among others – the potential dispatch of thousands of individual power plants, possible exchanges between BZs, and the physical flows that these exchanges might induce through thousands of grid elements. The level of technical complexity in performing these calculations should not be underestimated.

At the same time, it is also important to highlight that models – regardless how detailed – will never be a perfect reflection of reality. The results of the BZ Study should thus be seen in the context of the necessary simplifications and methodological assumptions of the underlying component models, the uncertainties in the input data and assumptions, and the scope of the overall assessment methodology. For example, the modelling chain focuses on simulating a proxy of the future DA market, and required remedial actions to ensure safe grid operation. However, energy trading is possible far ahead of actual delivery until close to real time, although such effects lie beyond the study scope. Nevertheless, the fact that the BZ Study is a "delta study" in which the differences versus the status quo configuration form the basis of the evaluation – rather than the absolute results – increases the robustness of the results against most assumptions and methodological simplifications, as these are applied across all configurations.

The following sections reflect on some of the main limitations and caveats of this BZ Study, which should be taken into consideration by policymakers along with the recommendations provided in section 6.7.

6.6.1 Uncertainty in Input Data and Assumptions

The scenario input data and assumptions serving as a basis for this BZ Study for the 2025 target year were collected from TSOs in 2019 for ENTSO-E's MAF 2020 and TYNDP 2020.[40] Since then, the European electricity market has faced an unprecedented period of volatility resulting from the COVID-19 pandemic in 2020 and the EU Energy Crisis of 2021-2022. These developments could not have been foreseen back in 2019. At the same time, additional policy programmes have been implemented at the EU and national level to enhance energy efficiency and accelerate the deployment of renewable energy sources such as *REPowerEU* and *Fit for 55*. Moreover, given the decision by ACER in the BZR Methodology to request TSOs to first perform the LMP simulations to support them in defining the alternative BZ configurations, the complex technical requirements of the BZR Methodology, the modelling tools that needed to be built, and re-runs required to ensure quality results, TSOs submitted this final report significantly later than the extremely challenging – if not completely unrealistic – timeline had originally foreseen. Due to the market and policy developments and delays encountered in the overall BZR process, some of the scenario assumptions made in the MAF 2020 for the 2025 target year might not fully reflect the current market situation in 2025. For example, the deployment of renewable energy sources has accelerated faster than expected in several member states (but slower in others), and fuel and carbon prices will likely be higher in 2025 than originally expected. TSOs had planned to perform several sensitivity analyses on multiple dimensions as part of the study to capture and quantify some of these uncertainties, including higher fuel and carbon emission prices, deployment of renewables, electricity demand, and additional grid expansion projects, as explained in Annex II. Due to the challenges explained in Annex VIII, unfortunately it was ultimately only possible to conduct the fuel and carbon price sensitivity analysis. Although the results showed that the ranking of the alternative configurations would remain unchanged in a situation with higher fuel and carbon prices, even a sensitivity analysis has its limitations in quantifying uncertainty. For example, natural gas (TTF) was trading at a price of roughly 15 €/MWh in November 2019, reached a high point of over 300 €/MWh during the peak of the energy crisis in August 2022, and as of early November 2024 was trading at 40 €/MWh. Carbon emission allowances were trading at roughly 25 €/t in December 2019, exceeded 100 €/t in March 2022, but were trading at roughly 70 €/t in November 2024. Thus, uncertainties cannot be fully captured even in a sensitivity analysis, and in a complex multi-year study such as the BZ Study it is highly improbable that the assumptions made at the start of the study will fully reflect real-world conditions.

Despite these uncertain market developments, the original input assumptions, market data, and grid models derived from MAF 2020 and TYNDP 2020 for the 2025 target year were not updated in the course of the study to ensure the required consistency with the LMP simulations – which served as the basis for ACER to identify the proposed alternative configurations – and transparency on the data used for the BZ Study.

40 The MAF was the predecessor to the European Resource Adequacy Assessment (ERAA).

6.6.2 Misalignment Between the Target and Implementation Year and Limited Temporal Horizon

Two limitations regarding the temporal scope of the BZ Study are important to highlight. First, there is a discrepancy between the target year of the BZ Study (2025) and the year of implementing a potential change in BZ configurations in Europe (around 2030). Second, by only considering a single target year, the robustness of an alternative BZ configuration cannot be verified for a longer time horizon. These two limitations are further discussed below.

According to the current timeline of the BZR and the deadlines set in Regulation (EU) 2019/943, a decision by member state(s) on a potential change in the configuration of the BZs in Europe is not expected before end of 2025. Realistically, an adjustment of the BZs would not be operational before around 2030, which is not in line with the analysed target year of 2025. In the expected implementation year, the grid developments – in particular in Germany – will be considerably more progressed than considered in the BZ Study and will continue to increase until 2035.[41] Against this background, the north-south congestion might be noticeably reduced by the higher transmission capacity at the point in time when a BZ split becomes operational. This is supported by different German analyses (Bedarfsanalyse and Langfristanalyse, scenario with inner-German HVDCs). While the Bedarfsanalyse predicts redispatch volumes of 25 TWh (one-sided) in Germany in 2025, this scenario of the Langfristanalyse predicts redispatch volumes of 15.5 TWh (one-sided) in 2030, corresponding to a decrease in redispatch volumes of roughly 40%.

Furthermore, given that the expected implementation time of a BZ reconfiguration is three to five years, and the minimum payback time for a BZ reconfiguration is at least four years starting from the potential implementation date (see section 6.5), this BZ Study further highlights that a BZR needs to be sufficiently forward-looking to draw the most robust conclusions and recommendations. In the context of this particular BZ Study, this would mean looking not only at the 2025 target year but also out to at least 2030 (i.e. Y+5) and even 2035 (i.e. Y+10). The "current stability and robustness of BZs over time" criterion based on sensitivity analysis varying only a limited number of dimensions is not fit for this purpose. However, an assessment of multiple target years under the same complexity level as the one required by the BZR Methodology would exceed the current exercise and require a significantly longer timeframe than the one year currently provided for in the IEM Regulation.

6.6.3 Modelling Simplifications

Due to the complexity of the modelling chain, several simplifications were necessary to ensure a stable modelling process with reasonable simulation times. While these simplifications were all within the scope of the BZR Methodology – and in some cases necessary to ensure that the models would run at all – they nevertheless could have affected the results. The main simplifications applied are summarised below.

- **The capacity calculation step required certain assumptions and simplifications** either due to a lack of available operational data or to reduce computational burden. These simplifications are in line with the BZR Methodology and/or were consistent with expected operational practice when the modelling chain was finalised. These are summarised below:
  - While non-costly remedial actions (e.g. PST tap changes, HVDC flows, and topological remedial actions) were included as part of the OSA after the market coupling, non-costly remedial actions were not used to maximise the flow-based domain in the capacity calculation step. This was due to computational limitations, as it was found during testing that including these parameters led to unacceptably long computational times.[42]
  - A fixed flow reliability margin (FRM) of 10% of the F_{max} was applied for all CNECs (as per Art 6.10(b)).
  - A fixed average zone-to-zone PTDF threshold of 10% for the selection of market-relevant CNECs (as per Article 6(8)).
  - No individual validation step was performed to analyse whether virtual margins given on CNECs were feasible from an OSA perspective (as performed in operational practice).
  - An NTC approach is applied to estimate available trading capacities to the Nordic region. However, currently foreseen from 2025 onwards, the Nordic and the Core CCRs will apply a joint advanced hybrid coupling approach.
  - An NTC approach is applied to estimate available trading capacities from the Core CCR to Italy North CCR and Switzerland. However, currently foreseen from 2027, these regions will be part of the newly created CE CCR and therefore part of a common flow-based region.

41 Germany plans to have 8 GW of HVDC capacities installed by 2028 (6 GW more than considered in the model) and up to 18 GW by 2033 according to the Netzentwicklungsplan 2023.

42 Article 6(18) states that "Non-costly remedial actions *may* be taken into account to increase the size of the initial flow-based domain in the directions which are likely to be valuable for the market"

- **Balancing reserve capacity requirements were assumed to remain the same in all alternative configurations.** This was a simplification due to the challenges in estimating future balancing capacity requirements. The background and implications of this assumption – in particular for the splits of the German–Luxembourgish BZ – are further explained in sections 6.3.14 and 6.6.4.2.
- **The RAO step also required certain assumptions and simplifications**, which are in line with the BZR Methodology and / or were consistent with expected operational practice when the modelling chain was finalised. These are summarised below:

  - **The RAO was performed on representative subset of 50 days, rather than for all hours of the year.** This followed a robust clustering algorithm, was consistent with the BZR Methodology (Art. 9 (12)), and was necessary to ensure feasible simulation times. Nevertheless, it does mean that not all potential grid conditions were considered.

  - **The redispatch markups applied in all countries were based on the regulated markups for Germany.** As explained in Annex II, this assumption was necessary due to limited data availability on historical redispatch markups. In particular, it was not possible to collect separate costs for countries relying on market- and non-market-based (i.e. regulated) redispatching of sufficient quality in a way that was consistent with the methodology. Thus, the regulated markups for Germany were applied to all countries as per BZR Methodology Article 9 (4) (b) (iii).

  - **Full cross-border coordination on remedial actions was assumed in the redispatch timeframe.** This assumption was made for two reasons. First, at the time when the modelling chain was developed, the ambition for the methodology for regional operational security coordination (ROSC) in the Core CCR was to have implemented full cross-border coordination in remedial actions by 2025. Due to challenges and operational delays, this goal is unlikely to be achieved by 2025. Second, the BZ Study is the first time TSOs have performed cross-border redispatch simulations at such scale, as the few TSOs that simulate cross-border redispatch in national studies do so in a simplified way. Thus, there was no tried-and-tested methodology for simulating partly-coordinated cross-border redispatch that could be applied. The assumption of full cross-border coordination might contribute to the significantly lower redispatch volumes of approximately 20 TWh (one-sided) for the status quo configuration across the entire CE BZRR compared to what has been observed in reality in recent years.

For some of the aforementioned uncertainties, assumptions, and modelling simplifications, it is possible to make a rough assessment of the potential impact on the results of certain parts of the study when these factors are considered in isolation. For example, in terms of input assumptions, higher fuel and carbon prices will lead to higher electricity prices, higher price differences between (split) zones, and higher redispatch costs, as seen in the sensitivity analysis results. While not assessed in this study, higher deployment of RES is likely to lead to lower electricity prices in their native (and nearby) BZs, and higher redispatch volumes and costs, depending on where they are deployed in the grid. On the other hand, the higher transmission capacity offered by additional grid expansion projects would lead to less congestion, less redispatch, and better price convergence. In terms of simplifications, assuming full cross-border coordination of remedial actions is likely to have led to lower redispatch costs than if imperfect coordination of remedial actions had been assumed. However, for most other aspects, it is very difficult to assess their potential impact on the results on the individual market coupling and RAO steps, and their impact on the overall results, especially when considered altogether.

6.6.4 Limitations in Assessed Criteria

Due to the complex technical requirements of the BZR Methodology, it was not feasible to robustly quantify several criteria within the BZ Study due to data, model, or time limitations. In these cases, all alternative configurations were assumed to perform the same as the status quo configuration with respect to these specific criteria, as prescribed by the BZR Methodology. However, the fact that these criteria could not be assessed as part of this BZ review does not mean that they are unimportant. These criteria include:

- Security of supply
- Impact on the operation and efficiency of the balancing mechanisms and imbalance settlement processes

In addition, some criteria were assessed according to the requirements of BZR Methodology but detailed analysis was limited in scope or highlighted limitations in how these criteria were defined in the methodology. These criteria include:

- Operational security
- Transition costs
- Market liquidity and transaction costs
- Market concentration and market power
- Adverse effects of internal transactions on other BZs
- Price signals for building infrastructure
- Accuracy and robustness of price signals
- Long-term effects on low-carbon investments

The main limitations regarding these criteria are discussed in the following sections.

6.6.4.1 Limitations Regarding Security of Supply

As explained in section 6.3.2, it was not possible to assess security of supply with a robust ERAA-style analysis of probabilistic indicators such as energy not served (ENS) and LOLE. Thus, all configurations were evaluated to perform the same as the status quo for this criterion. However, ensuring security of supply is one of the fundamental objectives of electricity market design. Given that a BZ reconfiguration does not change the actual physical location of demand, supply, and transmission assets in the grid, one could argue that in theory a change in BZ configuration should not have any impact on security of supply. However, the potential for a BZ split to affect factors such as short-term balancing reserve requirements and long-term investments in demand- and supply-side capacity resources do not preclude the possibility of an impact on security of supply.

6.6.4.2 Limitations Regarding Impact on the Operation and Efficiency of the Balancing Mechanisms and Imbalance Settlement Processes

Article 4 (3) (a) of the BZR Methodology requires that dimensioning of reserve products "shall reflect reserve needs to cover imbalances in line with Articles 153, 157 and 160 of SO Regulation". However, dimensioning of reserve capacity is a complex process, typically relying on historical data on imbalances. In the case of the potential BZ splits analysed in this study, TSOs did not have historical data available to rely on. In the absence of historical data, TSOs needed to make assumptions on how much balancing capacity would be necessary in the newly formed zones for each alternative configuration. Ultimately, ACER and NRAs requested TSOs to assume that the volume of balancing reserves would remain the same for all market areas after a split in the BZ Study, and all configurations were assessed the same as the status quo for this criterion. However, this assumption is a simplification ignoring the fact that a split of the German–Luxembourgish BZ will ultimately lead to an increasing requirement for balancing capacity according to German and Luxembourgish TSO experts. Either higher balancing requirements would need to be reflected in the model, or cross-zonal capacity between the new zones would need to be reduced to account for reserve sharing (or a combination). In case a higher balancing capacity demand for the German–Luxembourgish BZ would be needed, higher balancing capacity costs are to be expected (see additional explanations in section 6.3.14).

6.6.4.3 Limitations Regarding Operational Security

The "operational security" criterion only scratches the surface of the multidimensional facets of a secure and stable operation of the electricity system. A BZ configuration that relies on frequent and deep interventions by TSOs to correct market results in order to maintain a secure and stable system is highly dependent on well-functioning systems, processes, sufficient resources for remedial actions as well as human factors. In some countries, there is already a significant number of manual or semiautomatic interventions needed to maintain a secure electricity supply. Against this background, it is crucial to consider that market design options can have a significant impact on the challenges in system operation and should set correct price signals to incentivise a system-friendly behaviour of market participants. Beyond all economic considerations for or against a BZ split the operability of the system itself in a fast-paced transition should have the highest priority in any evaluation of the BZ configuration.

6.6.4.4 Limitations Regarding Transition Costs

A separate study on transition costs (see Annex V) was conducted to evaluate this criterion. While the methodology applied to estimate total transition costs provides valuable insights, there were several limitations that should be considered when interpreting the results. For example, despite efforts to enhance data quality and coverage, a relatively limited number of responses from market parties and stakeholders were received. Additionally, the definition of transition costs as set forth in the BZR Methodology did not capture all potential costs, such as changes in asset value or regulatory risks, which some stakeholders may consider relevant. Those limitations are detailed in Annex V and affect the evaluation of the minimum lifetime of a BZ configuration, as presented in section 6.3.10.

6.6.4.5 Limitations Regarding Market Liquidity and Transaction Costs

A separate pan-EU study on market liquidity and transaction costs (see Annex IV) was also conducted to evaluate this criterion by assessing potential market liquidity and transaction costs impacts for both short- and long-term timeframes. While following the BZR Methodology, the study highlighted certain limitations in both the approach and the available data, which should be considered when interpreting the results:

- The simulations provide dispatch model results but do not differentiate between the market places through which electricity is traded, including differences between short-term and long-term products. For this reason, the analysis of liquidity could only be done indirectly, through the relationships between the key market characteristics and liquidity metrics based on historical data, and under specific market design conditions, which may not remain valid in the future.
- The analysis focuses on each BZ individually and does not account for potential cross-border effects or include data for intraday-OTC markets and Power Purchase Agreements (PPAs).
- The analysis of market liquidity and transaction costs focuses on liquidity for the subset of BZs where alternative configurations have been proposed by in ACER decision 11-2022. The BZ reconfigurations assessed in the study may lead to spill-over effects affecting liquidity in BZs, not directly affected by the reconfiguration. These spill-over effects are not considered in the analysis.

Despite these limitations, the conclusions drawn provide important insights on the effects of a change in BZ configurations on liquidity and transaction costs.

6.6.4.6 Limitations Regarding Market Concentration and Market Power

As explained in section 6.3.6, the assessment of the "market concentration and market power" criterion is based on a questionable assumption on the structure of market power and uncertainties in the calculation of the RSI / PSI values.

First, the methodology assumes that market power is structural, i.e. that higher market power in wholesale markets is associated with lower market power in TSOs' mechanisms to resolve physical congestions. This assumption is questionable as TSOs' mechanisms to resolve physical congestion significantly vary across Europe and might entail other effective measures and regulated instruments that prevent that market power from being exercised. Under this assumption, the overall criterion comprising the sub-criteria for wholesale markets and TSOs mechanisms to resolve physical congestions inevitably performs the same for all alternative configurations.

Second, a main challenge for calculating the RSI / PSI lies in defining the regional scope of the market areas under investigations and the extent to which imports can be realised in case a powerful market player within a certain BZ would withhold its capacity. One possibility discussed is to define the relevant market area per MTU as the area in which price convergence is created in the model (i.e. the notion that cross-zonal capacity is not limiting) as further cross-zonal exchanges could be realised. However, it cannot be guaranteed that this price convergence (i.e. having sufficient cross-zonal capacity) would have been created in the situation where market power was exercised. Given that the RSI / PSI aim to specifically assess these situations, the price convergence area would hardly be applicable. Instead, the expected import capacities of BZs under investigation were considered. Whereas import capacity is relatively straightforward to define with NTC-based market coupling, this is not the case with FBMC as flow-based capacities consider that the import capacity of one BZ depends on the net positions of other BZs. Without knowing the net positions of the other BZs up front, the import capacity cannot be known. Hence, a proxy for the import capacity in a flow-based region was calculated based on the minimum net position. This is a common indicator for a flow-based domain, reflecting the theoretical maximum import capacity of a BZ if the net positions of all BZs were optimised for this. However, when using this proxy, it should be considered that this theoretical maximum will be an overestimation and should be corrected downwards. Therefore, TSOs applied three correction factors (25 %, 50 %, and 75 % of the minimum net position) to create full transparency on the dependence of the RSI / PSI on assumed import capabilities. As these correction factors always apply to the status quo and the alternative BZ configurations, the conclusions were found to be rather independent of the correction factors as the trend of the RSI/PSI values in alternative configurations compared with the status quo mostly remain the same.

Third, only limited ownership data of generation units was available to TSOs and the data entails significant gaps, particularly for distributed RES. While for calculating the RSI/PSI only the largest player within a certain BZ holds relevance, the impact of missing ownership data for small-scale units is assumed to have a limited impact on the results, although it could be more pronounced for BZs dominated by small-scale RES that generally show particularly high RSI values, i.e. an overall lower level of market concentration.

Overall, the conclusions for this indicator shall be regarded with caution and especially the absolute values of the RSI/PSI values must be seen in the context of the aforementioned limitations.

6.6.4.7 Limitations Regarding Adverse Effects of Internal Transactions on Other BZS

Sections 6.1.2.5 and 6.3.13 describe the general loop flow results and evaluation of the related criterion, respectively. In general, the evaluation of loop flows is challenging mainly due to the following reasons:

- A limited number of CNECs could be considered due to computational limitations, as detailed loop flow analysis – i.e. PFC – for every CNEC, configuration, and climate year requires high computational resources.
- There is no single metric available to compare the performance of a certain configuration in terms of loop flows. Loop flows are an inevitable part of meshed AC grids in a zonal market design and there is no unambiguous definition of a disproportionate loop flow. A loop flow can be burdening but also relieving and a relatively low loop flow in one location can have stronger consequences than a relatively high one somewhere else.

Regarding the assessment of criterion 14 ("adverse effects of internal transactions on other BZs"), it is important to note that the assessment performed does not present a full picture of all loop flows in the system. This is the case because according to the methodology, the loop flows have only been post-processed after the actual simulations for a subset of elements, based on the criterion of whether either market or physical congestion was present depending on the configuration. Based on the limitations described above, this confirms suspicions that 1) looking only at a subset of CNECs – depending on the configuration – might lead to a result that is not representative for the whole system and 2) the metric used for the evaluation might not be as straightforward to interpret. Furthermore, the different effects playing in market coupling – as elaborated in section 6.1.2.4.5 on the counter-intuitive FBMC results – will affect the loop flow results.

6.6.4.8 Limitations Regarding Price Signals for Building Infrastructure

As explained in section 6.3.8, the assessment for the "price signals for building infrastructure" criterion found that 100% of the time there is physical congestion that is not detected as market congestion. The reason for this was that market results will generally only produce a small set of congestion, as opposed to the OSA, where considerably more physical congestion appears on average. This leads to the result that there is always physical congestion that does not appear as market congestion. TSOs thus believe this criterion should be better formulated in any future BZR Methodology, and its interdependency with other criteria should be reconsidered.

6.6.4.9 Limitations Regarding "Accuracy and Robustness of Price Signals"

As explained in section 6.3.9, the methodology focuses the criterion rather narrowly on the accuracy of price signals, while the robustness of prices signals is omitted. The completeness and value of this criterion should thus be improved in future assessments.

6.6.4.10 Limitations Regarding "Long-term Effects on Low-carbon Investments"

As explained in section 6.3.21, this criterion is overly simplified as it does not consider important aspects influencing investment decisions on low-carbon technologies, e.g. effect of a price drop in some zones on the business case of RES. This particular concern was voiced during the public consultation and is not reflected in the BZR Methodology. The adequacy of the assessment of this criterion can therefore be questioned.

6.6.4.11 Consequences Beyond the Scope of the BZR Methodology

Aside from the aforementioned criteria that could not be (fully) assessed in the scope of this BZ Study, a BZ reconfiguration can potentially influence and interact with other aspects of (national) market design and system operation. These factors might be very country-specific and beyond the scope of a pan-EU BZR to assess. Some examples are highlighted below:

› **Interaction with national market design elements and subsidies, such as RES subsidy schemes:** A BZ reconfiguration will lead to zones with lower prices, and zones with a higher price than in the status quo. In newly formed zones with a higher share of generation from RES, lower prices will benefit consumers but also affect the business case of RES producers located in that zone. If existing producers receive government subsidies such as a feed-in premium with a guaranteed minimum price, the required subsidy payments from the government might increase. The business case for new investments will also be affected, and higher subsidy levels might be required to incentivise additional deployment of RES in that zone. On the other hand, a BZ split will potentially increase the incentive for RES investments in newly formed higher-priced zones and reduce the volume of subsidies required. Regarding the RES business case, it is worth mentioning that a BZ split would create obstacles for (industrial) consumers in accessing (renewable) electricity in newly created BZs where they are not located, i. e. PPAs.

› **Uncertainty in the energy sector:** A BZ reconfiguration introduces uncertainty in the electricity market, with varied impacts across countries, neighbouring markets, and consumer groups. While some regions might experience a balance between higher local electricity prices and increased revenues for energy producers, others might face predominantly negative impacts. The distributional effects of a split could result in differing electricity prices across consumer groups, potentially benefiting some with lower costs but imposing significant burdens on others. For industries that are strongly reliant on affordable energy, higher electricity costs could risk closures, leading to broader economic repercussions.

6.7 Central Europe Bidding Zone Review Region Proposal[43]

As per Article 13 (1) (d) (iii) (2) of the BZR Methodology defined by ACER, the TSOs shall make a recommendation on whether to maintain or amend the BZs based on the insights of the BZ Study, and specifically the analysis for the 2025 target year. The BZR Methodology envisages that based on the BZ Study performed, the TSOs recommend the BZ configuration with the highest monetised benefits compared to the status quo OR, an alternative BZ configuration that is among the "acceptable" ones but different from the one with the highest monetised benefits compared to the status quo, if they can duly justify the recommendation. Alternatively, the TSOs may recommend maintaining the status quo configuration, if they can duly justify that this is a better option than any of the "acceptable" alternative BZ configurations.

Based on the BZ Study, and by strictly applying the BZR Methodology and data requirements defined by ACER without any additional considerations, the results of the BZ Study indicate that the configuration with the highest positive monetised benefit compared to the status quo would be the split of Germany/Luxembourg into 5 bidding zones (DE5).

Strictly applying the BZR Methodology, this configuration results in an estimated positive monetised benefit of 339 € million for the 2025 target year, with the value being the sum of positive and negative effects of welfare change in different countries. Put in perspective: this value is less than 1 % of the simulated system costs in the CE region.

This result does not take important additional aspects into account and therefore should not be seen in isolation but rather in combination with certain considerations, which are key for the eventual decision by the relevant Member States on the future BZ configuration. These key considerations should be applied to the decision on (1) whether a change in BZ configuration should be implemented or not and (2), as the case may be, which potential alternative configuration should be implemented.

In addition to the outcomes of the BZ Study, the following considerations should be thoroughly assessed prior to the eventual decision of the relevant Member State(s) affected by a split.

43 The CE proposal was approved by the participating TSOs of the CE BZRR.

Considerations related to the BZR Methodology:

- **Consideration 1:** The target year assumed for the study and the simulation is 2025. A potential implementation of a revised BZ configuration would require a lead time of at least 3 – 5 years. Therefore, the conditional proposal of splitting the bidding zone should be verified and confirmed by assessing the impact of the change of key influencing factors between 2025 and a potential implementation date around 2030. These factors include in particular the envisaged grid expansions in Germany.
- **Consideration 2:** It is an unfortunate reality that the input data used in the BZR is outdated. The majority of the input data was created in 2019 for the 2025 target year. To meet the methodological requirements on data consistency throughout the process, the data set could not be updated by TSOs. Therefore, before taking any decision on changing a BZ configuration, the robustness of the outcome with regard to more up-to-date input data should be reevaluated.
- **Consideration 3:** The robustness of the results should be assessed for a number of years beyond the year of implementation corresponding to the payback period of the bidding zone split. Considering the implementation time of 3 to 5 years and assuming a payback time of 4 to 9 years, the breakeven point would be reached by mid-2030 at the earliest. It should be ensured that the benefits actually materialise and breakeven points are reached within a reasonable timeframe to grant the required robustness over time.
- **Consideration 4:** It should be assessed and ensured that the negative implications related to market liquidity and transaction costs, which could affect markets and participants throughout Europe, do not exceed the potential welfare gain computed in this study.
- **Consideration 5:** The BZR has not thoroughly assessed the impact on balancing markets in case of a BZ split. It should be ensured that a potential BZ split does not have negative impacts on balancing markets (e. g. higher prices, excessive volume requirements) that are substantially reducing the potential welfare gain computed in this study or placing undue strain on the TSOs or market participants in the region.

Further considerations beyond the application of the methodology:

Conclusions solely based on simulation results are not suitable for decision-making when seen in isolation. The BZR Methodology focuses on a quantitative assessment of the various criteria, which is largely based on simulation results and leaves insufficient room for interpretation or consideration of an expert assessment. Simulation results can only offer an indication of a future situation and they should always be carefully evaluated against the background of qualitative considerations, including:

- **Consideration 6:** The distributional effects of a potential BZ split will lead to different electricity prices and hence costs for certain consumer groups. While several consumers across Europe may benefit from lower electricity prices, it should be ensured that higher electricity prices for other consumers do not have excessive overarching negative economic implications that extend beyond the electricity market. For example, higher prices for price-sensitive industrial customers should not lead to the closure of industrial production. While the overall impact of the split might balance out for certain countries, others are likely to experience predominantly negative effects on their industries without any clearly identifiable benefits.
- **Consideration 7:** A potential BZ split will create obstacles for (industrial) consumers in accessing (renewable) electricity in newly created BZs where they are not located, i. e. power purchase agreements. When reconfiguring BZs, it should be ensured that such existing and future access arrangements are not undermined.
- **Consideration 8:** The simulations show that market-based revenues for RES in lower price zones substantially decline. Against this background, a potential BZ split will have negative implications for certain types of renewable electricity producers/RES that are not flexible regarding their location (i. e. offshore wind). It should be ensured that there are no negative implications for the investment decisions of those electricity producers leading to substantial deferrals or withdrawals of investment decisions in renewable electricity generation.
- **Consideration 9:** The annual support costs for RES already amount to many billions of euros. Existing renewable electricity producers located in lower priced BZs with guaranteed feed-in tariffs will have to receive even higher compensation for their electricity generation. It should be ensured that this is accepted by Members States / electricity consumers having to pay these higher subsidies.

The arguments and considerations outlined above could have a considerable impact on the interpretation and the outcomes of the BZ Study performed by the TSOs.[44]

Therefore, the TSOs recommend taking the above considerations into account for the final decision by the relevant Member States.

44 For information on the limitations of the Study please refer to section 6.6.

7 Results in the Nordic Bidding Zone Review Region

The following chapter presents the results from the Nordic BZ Study. First, the four alternative configurations assessed in the study are described in general, and from an operational perspective. Thereafter, the four steps in the modelling chain are explained. General simulation results are presented in a next step, including results from the DA market dispatch, the OSA and RAO. Thereafter, the results for the monetised benefits and the economic efficiency criterion are presented. Finally, the limitations of the Nordic BZ Study are discussed, and the Nordic recommendation is presented.

7.1 Introduction

In the Nordic BZ Study, the performances of four alternative configurations have been compared to the status quo. Two out of the four analysed configurations (Config 8 and 10) were proposed by ACER based on the results from the nodal simulations conducted in the LMP study[45]. The additional two configurations (Config 9 and 11) were modifications of the ACER proposals based on operational experience and suggested by the Swedish TSO, Svenska kraftnät.

The methodology used by ACER to identify proposed configurations resulted in alternative BZ delineations only for Sweden within the Nordic area. This is in line with the results from the LMP Study where no major structural congestion was identified in eastern Denmark nor in Finland. Assessing alternative BZs for Norway were not part of the study.[46] Table 58 provides more information regarding the configurations and the reasoning behind the modifications are provided.

Config	Source (algorithm of ACER / TSO modification)	Number of BZs	Reason for modification of ACER's proposed configurations
8	ACER	3	N/A
9	Modified version of Config 8 following remarks provided by Svenska kraftnät	3	Forsmark nuclear power plants and the connection of the Fenno-Skan interconnectors included in the central east area to allow Svenska kraftnät to manage the network in a more coherent manner, considering the fact that the area around Stockholm is operated by a DSO with different operational principles.
10	ACER	4	N/A
11	Modified version of Config 10 following remarks provided by Svenska kraftnät	4	Forsmark nuclear power plants and the connection of the Fenno-Skan interconnector included in the central east area (See Config 9). The border between the current BZs of SE1 and SE2 remains at the current location to – among other reasons – limit the number of BZ changes.

Note: Fenno-Skan is the name of the two cables connecting Finland and the current SE3 bidding zone.

Table 58: Origin of the configurations analysed in the Nordic BZ Study

45 ENTSO-E Report on the Locational Marginal Pricing Study of the Bidding Zone Review Process (eepublicdown-loads.blob.core.windows.net)
46 Since Regulation (EU) 2019/943 has not been incorporated into the EEA agreement, alternative BZs in Norway are not considered in this review.

Figure 65 presents the status quo and the four alternative configurations schematically and are further described in the following.

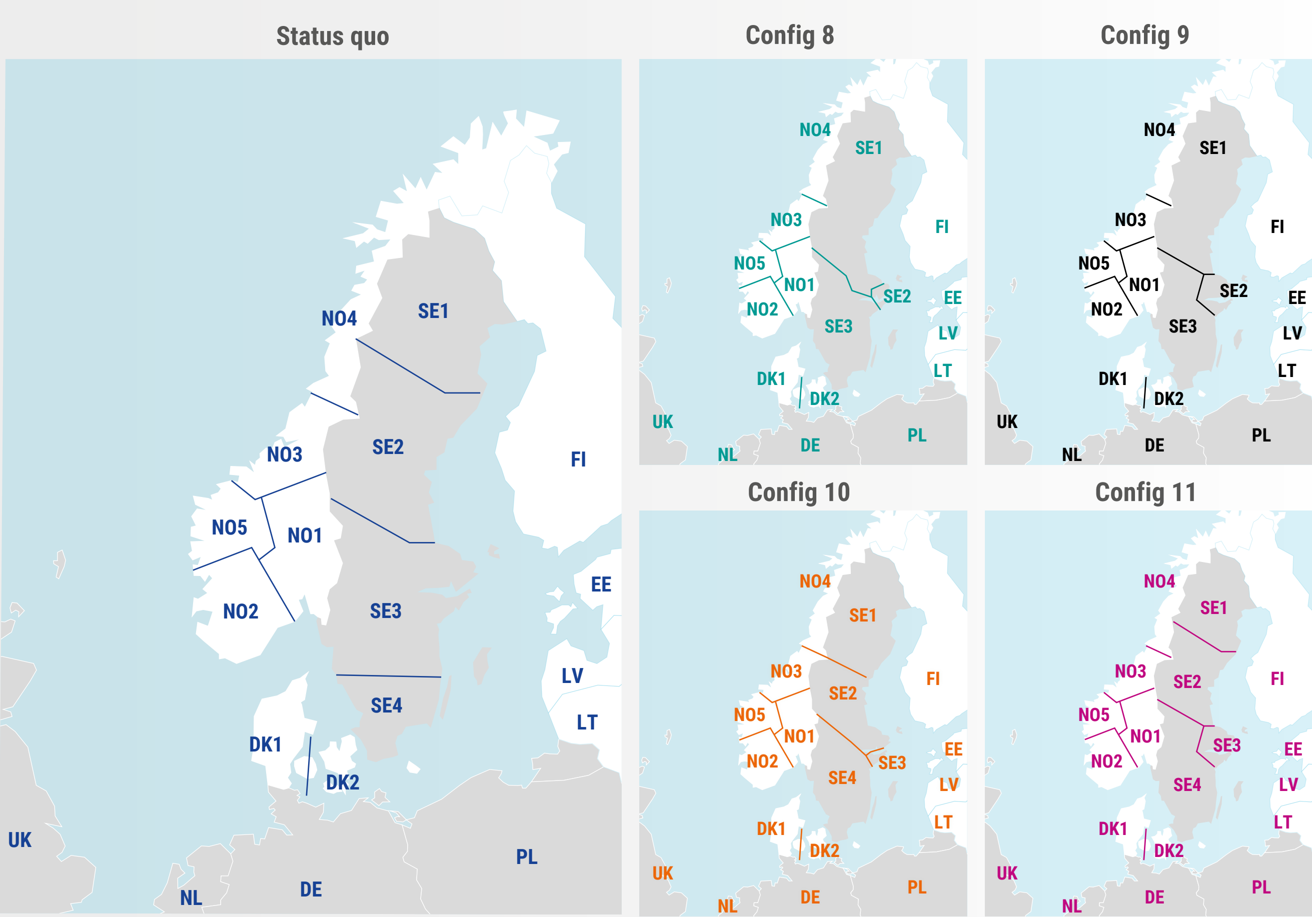


Figure 65: Schematic representation of the status quo and the four alternative configurations analysed in the Nordic BZ Study

The border between the current BZs of SE1 and SE2 is maintained in Config 11, moved towards the south in Config 10, and removed in Config 8 and 9.

Common to all configurations is the border between the current BZs SE2 and SE3, corresponding to the limited grid capacity for north-south flows that commonly occurs in today's operations and the simulations, although the exact location of this border differs between the configurations.

In all configurations, a new BZ is introduced, hereafter referred to as the "central east area". The purpose of this area is to capture the internal limitations within today's BZ SE3, mainly due to flows in east–west direction in case of imports from Finland and exports to Denmark and Norway.

The size and setup of the central east area differ between the configurations; for example, regarding the placement of the Forsmark nuclear reactors and the connection of the Fenno-Skan HVDC cables. As the setup of the BZ is important from an operational perspective regarding – for example – balancing (see further section 7.1.1), it is described more in detail in Table 59.

The border between current BZs SE3 and SE4 in the alternative configurations is removed as the congestion was foreseen to be handled by other borders in the alternative configurations.

	Config 8	Config 9	Config 10	Config 11
Fenno-Skan connection	Not incl.	Incl.	Not incl.	Incl.
Forsmark nuclear reactors	F1 and F2 (F3 in northern area)	Incl.	Not incl.	Incl.
Production (TWh/y)	17.8	31.7	1.1	31.7
Consumption (TWh/y)	21.9	32.3	16.2	32.3
Net position (TWh/y)	−4.2	−0.6	−15.0	−0.6
Production capacity (MW)	3,141	5,877	637	5,877
– Nuclear	2,104	3,271	0	3,271
– CHP, etc.	463	697	257	697
– Hydro	0	505	0	505
– Solar	491	620	380	620
– Wind	83	783	0	783

Note: Forsmark nuclear power plant comprises three reactors (F1, F2 and F3) and the table lists whether or not these are included in the new area.

Table 59: Setup of the new "central east area" BZ

7.1.1 Review of the Configuration from an Operational Practice Perspective

From an operational practice perspective, the configurations have various characteristics that are described in the following.

Config 8 lacks the current border between BZs SE1 and SE2. This BZB enables managing frequently occurring limitations due to the dynamic stability (rotor angle stability and voltage stability). The configuration also includes a small central east area (new SE2) where one of the reactors of Forsmark nuclear power plant (F3) and the connection of the Fenno-Skan cables will be situated in the northern area (new SE1). The limited production in this setup for the central east area has a limited volume of resources for balancing. Furthermore, it is desirable to create equal conditions for the different reactors of the Forsmark nuclear power plant as this is important to ensure an efficient dispatch. Another potential problem with the placement of F3 is that in case of a fault or maintenance on one of the connecting transmission lines, in-feed will only be possible to the central east area despite the reactor not being part of that area.

Config 9 also lacks the aforementioned border between BZs SE1 and SE2 and will thus have the same related issues as Config 8. Compared to Config 8, this configuration has a more balanced central east area where all three reactors of Forsmark nuclear power plant and the connection of the Fenno-Skan cables are part of the BZ. It creates a better balance between production and consumption. The central east area in this configuration is also placed so that east-west flows – in case of imports from Finland and exports to Denmark and Norway – can be managed in a more efficient manner.

Config 10 has a border between BZs SE1 and SE2, similar to the border in the status quo, although located more to the south. Nevertheless, this creates better conditions to operate the system compared to Config 8 and 9. However, Config 10 has the smallest central east area and includes neither the reactors of Forsmark nuclear power plant nor the connection of the Fenno-Skan cables. Similar to Config 8, the very limited production capacity of the area will make it very difficult to ensure sufficient resources for balancing.

Config 11 has a border between BZs SE1 and SE2 – as in the status quo – and a larger and more balanced central east area. As for Config 9, the central east area in this configuration is set up to create a better balance between production and consumption and to ensure that the east–west flows can be managed in an efficient manner. From an operational practice point of perspective, Config 11 would be the most promising alternative.

7.1.2 Modelling Chain

AFRY's BID3 power market model was used for the simulations in the Nordic BZ Study. For the purpose of conducting these studies, the BID3 model has undergone substantial development including the implementation of completely new functions. The 2025 target year was assessed under each of three climate years[47] (1989, 1995, and 2009) governing renewable resources, hydro inflows, and demand patterns. The geographical scope of the simulations covered the entirety of Europe.[48] Nevertheless, FB modelling was only carried out for the capacity calculation within the Nordic CCR and cross-border capacities between other BZs were approximated by the NTC approach. HVDC links in the Nordic system were handled with the advanced hybrid coupling approach in FB modelling.

The modelling chain comprises four steps: the capacity calculation, the DA market dispatch, the OSA, and the RAO. Figure 66 presents the different steps with a brief description in the two following sections. The modelling chain is described in further detail in the Annex III.

Figure 66: Overview of modelling chain used in the Nordic BZ Study

7.1.2.1 Capacity Calculation and Day-ahead Market Dispatch

The capacity calculation was performed using the FB approach for the Nordic CCR. It comprises several parts, such as calculating the GSKs, PTDFs, and RAMs and identifying network elements as constraints to the DA market dispatch. In the following sections, the different parts and parameters in the capacity calculation and the DA market dispatch are briefly described.

The nodal PTDF (i.e. node-to-slack PTDF) is the starting point for the capacity calculation and describes how an increase in each node's net position would influence the flow on all network elements. The nodal PTDF is calculated from the grid topology and the line reactance. In a similar way, the zonal PTDF (i.e. zone-to-slack PTDF) is a matrix describing the linear relation between an increase in the BZs' net positions and the corresponding flows on the network elements. The zonal PTDF is obtained from the nodal PTDF through multiplication by a GSK matrix. The GSK matrix aims to translate how generation and demand in nodes within a BZ would change during an increase of the BZ's net position. In other words, the GSK is a weighting of the nodes within each BZ.

The algorithm for determining the GSK is known as the GSK strategy. The chosen GSK strategy for the Nordic BZs uses the resulting generation and/or demand from the DA market dispatch. Using the resulting generation and/or demand – as opposed to using available capacity as GSK (which is independent of the market outcome), for example – requires an iterative approach. This is the case because the GSK affects the dispatch pattern and hence the GSK calculation through its impact on the PTDF and the flows.

Figure 67 schematically presents the iterative approach. A starting point for each simulated day is provided by a base case, containing an expectation of the grid topology and net positions used to estimate the GSK and the RAM (i.e. the "FB parameters"). During step 6 in the figure, the FB parameters from the previous simulated week are used to solve an initial

47 The selection of climate years was based on identifying the three years that best represented a 30-year study period. To assess this, the residual load was used to capture the spatial and temporal variability of renewable energy resource across the continent. The three climate years with the lowest mean deviation from the overall mean and closest standard deviation was preferred. These years do not represent the full spread of variability for the Nordic system but the advantage of using the same climate years for all BZR regions was considered more important and is a requirement of the BZR Methodology. For more details on the climate year chosen, please see the LMP Report Annex 1: ENTSO-E Report on the Locational Marginal Pricing Study of the Bidding Zone Review Process (eepublicdownloads.blob.core.windows.net)

48 Apart from the Nordics, the following countries are simulated in the Nordic BZR: Albania, Austria, Belgium, Bosnia, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Montenegro, the Netherlands, North Macedonia, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Switzerland, Turkey, Ukraine, and the United Kingdom.

DA market outcome using all relevant inputs for the current week e. g., hydro inflows, renewable resources, and demand. The result of this initial optimisation is used as a new base case, providing updated GSK and RAM (step 7). The updated FB parameters are used in the final DA dispatch optimisation (step 8). This means that the capacity calculation and the DA market dispatch are undertaken in sequence week by week. The GSK and RAM are thereafter recalculated again using the final dispatch outcome, providing the base case for the upcoming week (step 9).

Given that the first simulated week lacks a predecessor, an NTC base case is assumed (step 1) where the NTC is approximated by the sum of thermal limits ("F_{max}") of all transmission lines between each pair of neighbouring BZs.

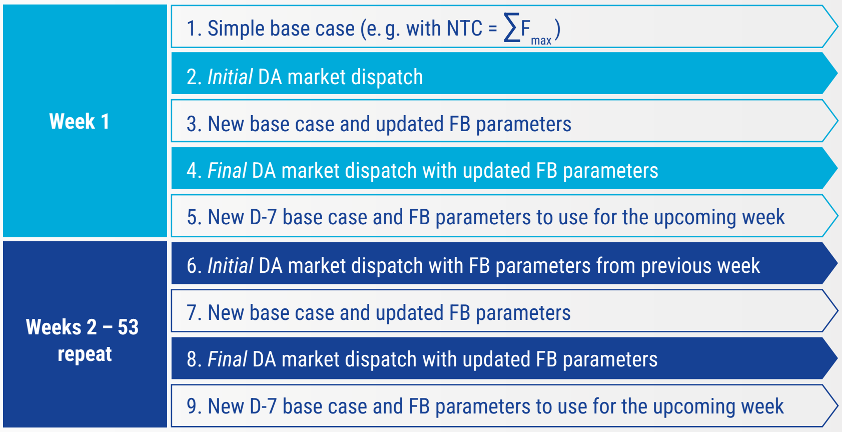


Figure 67: Schematic presentation of the iterative approach used in the capacity calculation and the day-ahead market dispatch

The zonal PTDF is defined for all network elements and a subset is applied as constraints in the DA market dispatch. Elements that satisfy either of the following two conditions are used to define individual FB constraints:

- Grid elements that connect two different BZs.
- Grid elements that are important for cross-zonal transmission but do not directly cross a BZB. This is achieved by identifying those whose maximum absolute zone-to-zone PTDF is above a threshold of 10 %.[49]

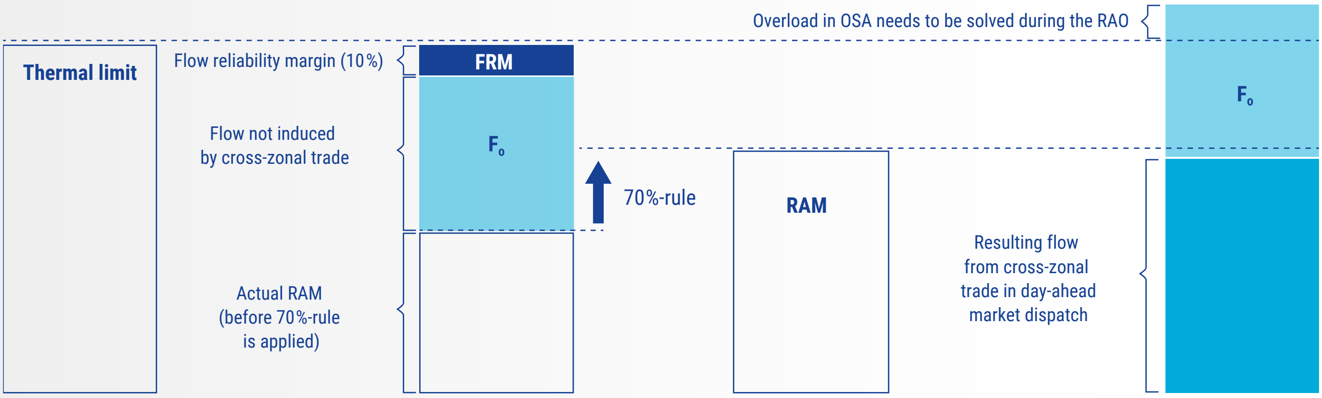
As described in the previous section, the RAM is calculated alongside the GSK as part of the iterative approach. The RAM is the transmission capacity available for the DA market dispatch. The RAM of a given grid element is calculated from adjustments of its thermal limit, undertaken in the following steps:

- Adjustment for FRM set to be 10 % of the thermal limit of each network element.
- Leave headroom for the flows not induced by cross-zonal trade[50] (F0), as these are not seen by the DA market optimisation.
- As required by the BZR Methodology, at least 70 % of the thermal limit should always be available for cross-zonal trade in the DA market dispatch (referred to as the "70 % rule").

This means that even if the first two bullet points make up to more than 30 % of the thermal limit of a network element, the RAM will still be set to 70 %. Depending on the market outcome for cross-zonal trade, this could result in an overload during the OSA that needs to be solved by activating remedial actions in the RAO (see section 7.1.2.2). Figure 68 schematically presents an example of this.

49 The zone-to-zone PTDF for grid element I is obtained by taking the row in the zonal PTDF (i. e. zone-to-slack PTDF) corresponding to grid element I, and calculating the maximum difference between any two elements. The absolute value of this difference is compared against the threshold. If the difference is above the threshold, the grid element will have an associated constraint for that hour, otherwise it will be ignored for the day-ahead market dispatch simulations..

50 The calculation of flows not induced by cross-zonal trade is further described in Nordic BZRR Annex III.



Note: In this example, RAM is set according to the 70% rule as the FRM and flow not induced by cross-zonal trade exceed 30% of the network element's thermal limit. The resulting flow from cross-zonal trade is within the RAM so the network element will not constrain the day-ahead market dispatch. However, as the total flow (adding the non-cross-zonal flow and the cross-zonal flow together) exceeds the thermal limit, an overload on the network element will be detected in the OSA, which needs to be solved during the RAO.

Figure 68: Schematic example of how setting available transmission capacity (RAM) via the 70% rule could result in the network element being overloaded

For the DA market simulation, least cost dispatch was modelled (equivalent to maximising socio-economic welfare) at an hourly resolution, optimising the behaviour of thermal, hydro, and renewable plants and storage units alongside transmission, DSR, and co-optimisation of generation with reserve procurement.

For the Nordic hydro power, water value curves[51] were calculated in advance of the capacity calculation and the DA market dispatch. Hydro optimisation outside of the Nordics was simulated using a simplified perfect foresight approach.[52] As previously mentioned, the DA market dispatch used the FB parameters obtained in the capacity calculation.

7.1.2.2 Operational Security Analysis and Remedial Action Optimisation

After the completion of the capacity calculation and the DA market dispatch, a nodal DC load flow analysis was carried out, referred to as the OSA. The production and consumption at each network node were computed and resulting flows were determined using power flow equations. In this section of the modelling chain, the flows on HVDC cables were kept fixed to the optimised values from the DA market simulations. The resulting flows on the alternating current (AC) network were compared against the thermal limits of each network element to determine the number and frequency of overloads induced on the system.

In the RAO, the DA market dispatch was resolved with an additional layer of constraints, namely the transmission constraints, together with a cost applied to up- and down-regulate the production. The purpose of the RAO was to solve the overloads detected during the OSA and ensure that no new overloads occurred, at a minimal cost for the system. The RAO was carried out only for the Nordic CCR, fixing interconnector flows to external BZs to the results of the DA market simulations (see also section 7.3.5.1).

The transmission constraints applied in the RAO contain two parts, namely the physical grid using the DC optimal power flow approximation and the FB constraints obtained from the capacity calculation/DA market dispatch. The latter ensured that remedial actions solely resolve the physical grid constraints. Removing the FB constraints from the RAO can enable an overall lower system cost if the FB constraints are more binding than the physical grid constraints (for example, due to an inaccurate GSK strategy).

The dominance of hydro in the Nordics requires reservoirs to be given sufficient flexibility during the RAO. During constrained periods, it can become necessary to reduce hydro output in one region and increase output in another. In order to capture this flexibility, excess water from the DA market dispatch can be banked for use in the future, or conversely water can be borrowed if it is the cheapest – or sometimes only – way of covering demand. While the BZR Methodology (Article 9(8)(c)) stipulates that banking and borrowing can only occur within the same day, this constraint has been softened in the Nordic BZ Study to allow for banking and borrowing between different days, albeit at a cost. The overall

51 In hydro-dominated areas such the Nordic region, it is critical to use such a technique as the uncertainty of future inflows strongly affects the pricing of electricity on the day-ahead market. The optimal decision is found by solving a stochastic optimisation problem, where the marginal expected value of dispatching today equals the marginal expected value of keeping hydro in the reservoir today and dispatching in the future.

52 In central Europe, where hydro plays a less important role, using the simpler approach with perfect foresight optimisation is preferable. All inflow for the coming year is known, and hydro dispatch during the year is then co-optimised with dispatch from other technologies to find a least costly way of reaching a certain reservoir level at the end of the year.

borrowing cost is 1.25 times the water value, although the total banking is represented as a cost-saving (as less water is used) of 0.8 times the water value. These values have been found to offer sufficient flexibility to hydro to resolve constraints effectively, while encouraging a final dispatch close to the solution of the DA market simulation. The penalty costs of hydro banking and borrowing are not directly included in the redispatch costs or welfare outputs.

The OSA and the RAO were carried out for the full target year of 2025.

7.1.3 General Simulation Results

This section presents the annual general results from the simulations. First, in section 7.1.3.1, results from the DA market dispatch are presented, focusing on the generation, demand, net positions, prices, and flows. Subsequently, in section 7.1.3.5, results from the OSA and the RAO are presented. Unless otherwise mentioned, the results presented are the average for the three simulated climate years.

The scenario data used is further described in the LMP Report[53] and in the Nordic BZRR Annex III. Detailed output data according to Annex Ia of the BZR Methodology can be found on the ENTSO-E homepage at the latest one month after the publication of this report.

7.1.3.1 Results from the Day-ahead Market Dispatch

In the following sections, annual results are presented following the simulation of the DA market dispatch.

7.1.3.2 Generation, Demand, and Net Positions

Figure 69 presents the yearly generation, demand, and net positions for the Nordic countries following the DA market dispatch for the status quo. Table 59 lists the changes compared to the status quo for each configuration, also presenting the differences in generation, demand, and net positions for the rest of Europe.

The general results are as follows:

- For Config 8, Norway produces more hydro power compared to the status quo, leading to a higher net position for the Nordics. Thermal production is reduced in Europe.
- The opposite is true for Config 9, where less hydro power is produced in the Nordics, which is compensated for with increased thermal power production in Europe.
- For Configs 10 and 11, there are only small changes in production compared to the status quo.

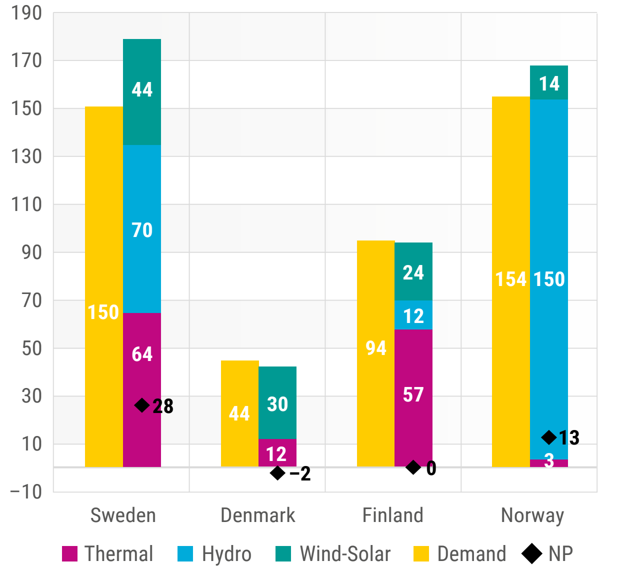


Figure 69: Simulated demand, production, and resulting net position for the status quo presented for the Nordic countries

53 ENTSO-E Report on the Locational Marginal Pricing Study of the Bidding Zone Review Process (eepublicdown-loads.blob.core.windows.net)

	Country	Thermal	Hydro	Wind + Solar	Demand	NP
Config 8	**Tot Nordics**	42.4	471.2	49.8	4.3	559.1
	Sweden	2.4	−373.4	304.3	3.9	−70.7
	Denmark	17.3	0	−21.1	0	−3.8
	Finland	24.8	−108.5	−220.1	0.3	−304.2
	Norway	−2.1	953.1	−13.2	0.1	937.8
	Rest of Europe	−674.5	138.1	−12.4	−0.9	−547.9
	Tot	−632.1	609.3	37.4	3.4	11.2

	Country	Thermal	Hydro	Wind + Solar	Demand	NP
Config 9	**Tot Nordics**	99.5	−1,483.2	−44.0	−3.4	−1,424.2
	Sweden	38.1	−796.0	97.4	−3.6	−656.8
	Denmark	52.4	0	4.4	0	56.9
	Finland	9.4	−112.2	−134.9	0.0	−237.7
	Norway	−0.4	−575.1	−11.0	0.2	−586.6
	Rest of Europe	1,324.8	91.9	−4.9	−1.2	1,413.0
	Tot	1,424.3	−1,391.3	−48.9	−4.7	−11.2

	Country	Thermal	Hydro	Wind + Solar	Demand	NP
Config 10	**Tot Nordics**	25.7	−89.7	89.2	−3.7	28.8
	Sweden	27.1	−110.4	15.6	−4.1	−63.5
	Denmark	−0.2	0.0	−0.6	0.0	−0.9
	Finland	2.1	35.9	82.5	0.3	120.2
	Norway	−3.3	−15.3	−8.3	0.2	−27.1
	Rest of Europe	22.5	−57.0	9.7	0.3	−25.2
	Tot	48.1	−146.8	98.9	−3.4	3.6

	Country	Thermal	Hydro	Wind + Solar	Demand	NP
Config 11	**Tot Nordics**	17.1	−9.2	−14.0	−3.0	−3.1
	Sweden	31.0	0.4	−6.6	−3.5	28.3
	Denmark	−1.4	0.0	4.1	0.0	2.8
	Finland	−12.6	6.8	−13.5	0.6	−19.9
	Norway	0.0	−16.4	2.0	−0.1	−14.3
	Rest of Europe	12.1	−19.7	9.0	−0.1	1.6
	Tot	29.2	−28.9	−5.0	−3.1	−1.5

Note: A darker blue/red colour corresponds to a larger positive/negative value, and the opposite is valid for lighter colours. In Config 8, the Nordic net position increases compared to the status quo, while the opposite is true for Config 9. Configs 10 and 11 show similar results as the status quo.

Table 60: Change in yearly production, demand, and net position for the configurations compared to the status quo in GWh

The hydro power production deviates in different directions for Configs 8 and 9 compared to the status quo but is about the same in Configs 10 and 11. However, the differences between the configurations of around 0.5 to 1.5 TWh are minor compared to the total Nordic reservoir storage, which amounts to approximately 87 TWh in Norway, for example. Analyses indicate that the differences are due to variations in water values and shares in GSKs when reconfiguring the BZs. The GSKs influence the zonal PTDF, which can lead to differences depending on configurations; for example, whether or not an internal grid element constrains the market outcome. Moreover, the setup for the climate years affects the results. The impact of the simulated climate years and water value calculations are further described in section 7.3.4.

The differences in hydro power production between the configurations will result in different end reservoir levels. For example, Config 8 will end up with a lower Nordic end reservoir level compared to the status quo, while Config 9 will have a higher end level. As the water in storage represents a value to the producers, it should be considered when calculating the socio-economic welfare. The reservoir delta estimates this value by multiplying the change in annual hydro production by the weighted average water value as a numerical integral of the water value curve between the start and end reservoir level. The reservoir delta value is added to the producer surplus when calculating the market welfare (see section 7.2.2).

7.1.3.3 Power Prices

Figure 70 presents the annual average power prices per BZ. The general results are as follows:

- For Configs 8 and 9, prices mainly increase in the northern BZs in Norway and Sweden as well as in Finland and the Baltics.
- For Config 10, BZ SE2 has a higher price compared to the status quo (although not exactly the same geographical area).
- The central east area has a lower price compared to BZ SE3 in the status quo in all configurations.
- The prices in the southern Swedish BZs increase in all configurations to levels comparable to those of SE4 in status quo. As a result, an increase can be seen in the former SE3 BZ.

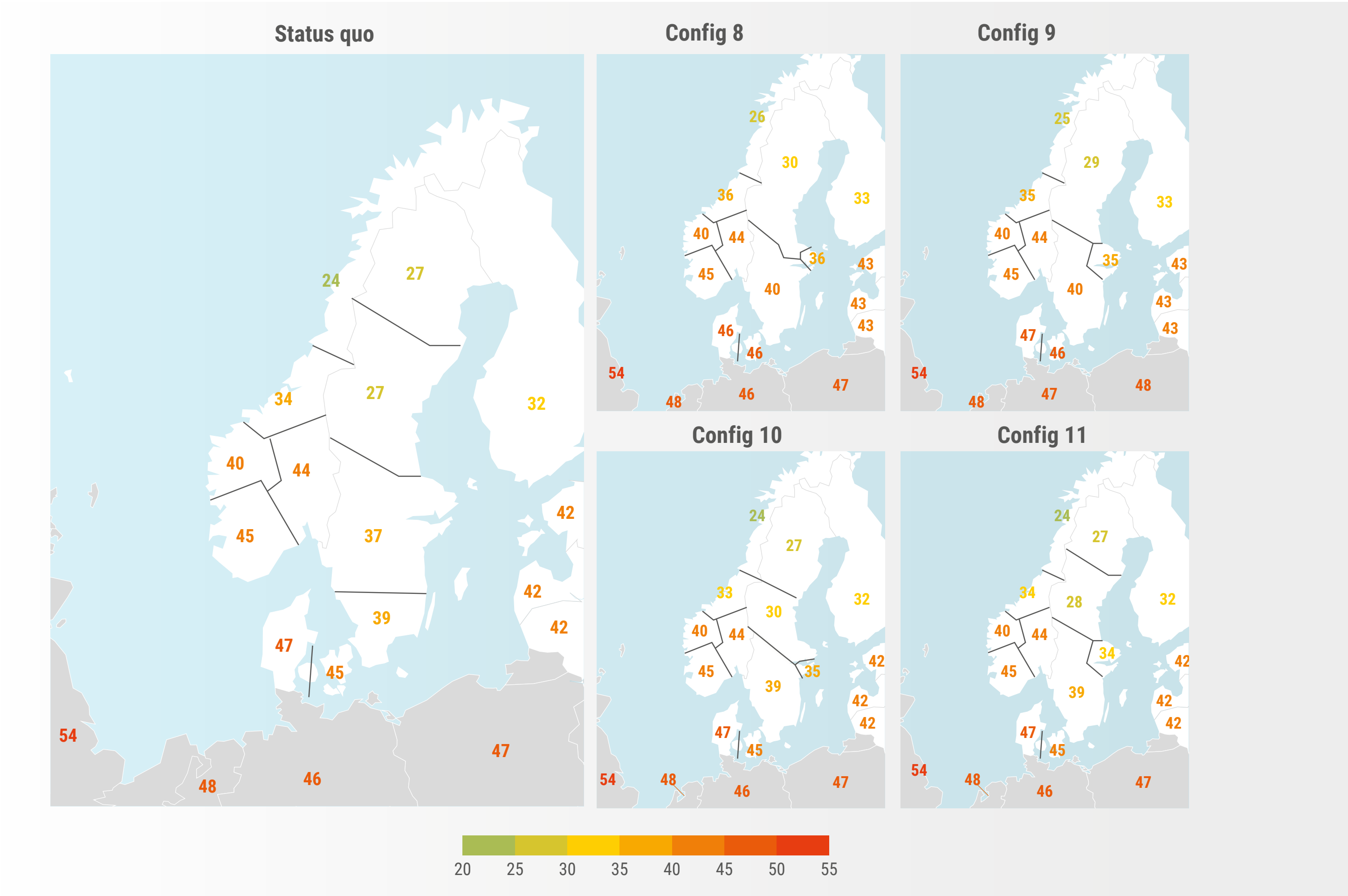


Figure 70: Average annual power prices in € / MWh

7.1.3.4 Flows

Table 60 presents the annual flows between BZs. The general results are as follows:

- For Configs 9 and 11, power is transferred through the central east area from the north to the south of Sweden. This can be seen through the fact that the imports to the central east area are almost the same as the exports from the same area.
- As the deficit for the central east area is higher for Configs 8 and 10 (see the net positions in Table 58), imports from northern Sweden are higher than the exports from the central east area.
- For Config 8, flows seem to go from northern Sweden to Finland and back again to Sweden via the Fenno-Skan cables to a greater extent.
- For Config 11, more power is imported from northern Norway to Sweden compared to the other alternative configurations, and the flows are similar to the status quo.
- For Config 8, Norway exports more power to UK, DK1, DE, and NL compared to the other configurations and the status quo.

TWh/y Location	Border (as in status quo)	Status quo			Config 8			Config 9			Config 10			Config 11		
		Export	Import	Net flow	Export	Import	Net flow	Export	Import	Net flow	Export	Import	Net flow	Export	Import	Net flow
SE	SE1 → SE2	11.4	−0.5	10.9	N/A	N/A	N/A	N/A	N/A	N/A	38.7	−5.7	33.0	11.4	−0.5	10.8
	SE2 → SE3	51.8	−0.1	51.6	36.9	−0.2	36.7	31.8	0.0	31.7	46.6	−0.3	46.3	32.6	0.0	32.5
	SE3 → SE4	32.6	−0.3	32.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	North SE → Central east area	N/A	N/A	N/A	18.8	−0.4	18.4	18.6	−0.1	18.5	20.1	−0.1	20.0	19.2	−0.1	19.0
	Central east area → South SE	N/A	N/A	N/A	14.3	0.0	14.3	18.7	−0.2	18.5	5.0	−0.1	5.0	19.2	−0.2	19.0
SE-FI	SE1 → FI	6.8	−1.5	5.3	7.3	−1.2	6.0	7.1	−1.4	5.7	6.8	−1.5	5.3	6.9	−1.4	5.4
	SE3 → FI (Fenno-Skan)	3.5	−4.0	−0.5	3.1	−4.2	−1.1	3.4	−4.1	−0.65	3.3	−3.9	−0.59	3.5	−4.0	−0.57
SE-DK	SE3 → DK1 (Konti-Skan)	4.8	−1.0	3.8	4.8	−1.0	3.8	4.8	−1.0	3.8	4.8	−0.9	3.9	4.8	−1.0	3.9
	SE4 → DK2	7.1	−1.1	6.0	7.1	−1.2	5.9	7.0	−1.2	5.8	7.1	−1.1	5.9	7.1	−1.1	6.0
NO-SE	SE1 → NO4	0.8	−3.6	−2.9	1.2	−3.7	−2.5	1.2	−3.7	−2.4	1.1	−3.7	−2.6	0.8	−3.6	−2.8
	SE2 → NO4	0.3	−0.5	−0.3										0.3	−0.5	−0.3
	SE2 → NO3	1.5	−1.0	0.5	1.5	−1.1	0.3	1.5	−1.2	0.2	1.3	−1.0	0.3	1.5	−0.9	0.5
	SE3 → NO1	8.0	−1.1	6.9	8.3	−1.6	6.7	7.6	−1.3	6.3	7.8	−1.0	6.8	7.9	−1.1	6.8
NO	NO3 → NO4	0.0	−6.2	−6.1	0.0	−6.4	−6.4	0.0	−6.5	−6.4	0.0	−6.7	−6.7	0.0	−6.2	−6.2
	NO3 → NO5	2.2	−0.7	1.4	2.2	−0.8	1.4	2.2	−0.8	1.4	2.3	−0.7	1.6	2.2	−0.7	1.5
	NO3 → NO1	3.9	0.0	3.9	3.9	0.0	3.9	4.0	0.0	3.9	4.1	0.0	4.1	4.0	0.0	4.0
	NO1 → NO2	5.5	−5.2	0.3	5.7	−5.3	0.5	5.3	−5.5	−0.2	5.4	−5.0	0.4	5.5	−5.2	0.3
	NO1 → NO5	0.3	−12.1	−11.9	0.3	−12.4	−12.1	0.3	−12.2	−11.9	0.2	−12.1	−11.9	0.3	−12.2	−11.9
	NO2 → NO5	0.6	−3.5	−2.8	0.6	−3.6	−3.0	0.6	−3.4	−2.8	0.6	−3.5	−2.9	0.6	−3.5	−2.9
DK	DK1 → DK2	0.9	−3.0	−2.0	0.9	−2.8	−1.9	0.9	−2.9	−1.9	0.9	−2.9	−2.0	0.9	−2.9	−2.0
From Nordic	SE4 → DE	3.4	−0.5	2.9	3.3	−0.6	2.7	3.3	−0.6	2.7	3.4	−0.6	2.8	3.4	−0.5	2.9
	SE4 → PL	4.0	−0.8	3.3	4.0	−0.8	3.1	3.9	−0.9	3.1	4.0	−0.8	3.2	4.0	−0.8	3.3
	SE4 → LT	4.0	−0.6	3.4	4.0	−0.5	3.5	3.9	−0.6	3.3	3.9	−0.6	3.3	4.0	−0.6	3.4
	NO2 → UK	9.9	−1.2	8.8	10.1	−1.1	9.0	9.9	−1.2	8.7	10.0	−1.2	8.8	9.9	−1.2	8.8
	NO2 → DK1	7.8	−4.2	3.7	8.0	−4.1	4.0	7.6	−4.3	3.5	7.9	−4.2	3.8	7.8	−4.2	3.7
	NO2 → DE	5.8	−3.4	2.5	6.1	−3.2	3.0	5.6	−3.5	2.3	5.8	−3.3	2.6	5.8	−3.4	2.5
	NO2 → NL	3.8	−1.3	2.5	3.9	−1.3	2.7	3.7	−1.4	2.4	3.8	−1.3	2.6	3.8	−1.3	2.5
	DK1 → NL	3.9	−0.3	3.6	3.9	−0.3	3.6	3.9	−0.3	3.6	3.9	−0.3	3.6	3.9	−0.3	3.6
	FI → RU	0.0	−3.1	−3.1	0.0	−3.1	−3.1	0.0	−3.1	−3.1	0.0	−3.1	−3.1	0.0	−3.1	−3.1
	FI → EE	8.2	0.0	8.1	8.0	−0.1	7.9	8.1	0.0	8.1	8.1	0.0	8.1	8.2	0.0	8.2
	DK1 → UK	9.0	−0.2	8.8	9.0	−0.2	8.8	9.0	−0.2	8.8	9.0	−0.2	8.8	9.0	−0.2	8.8

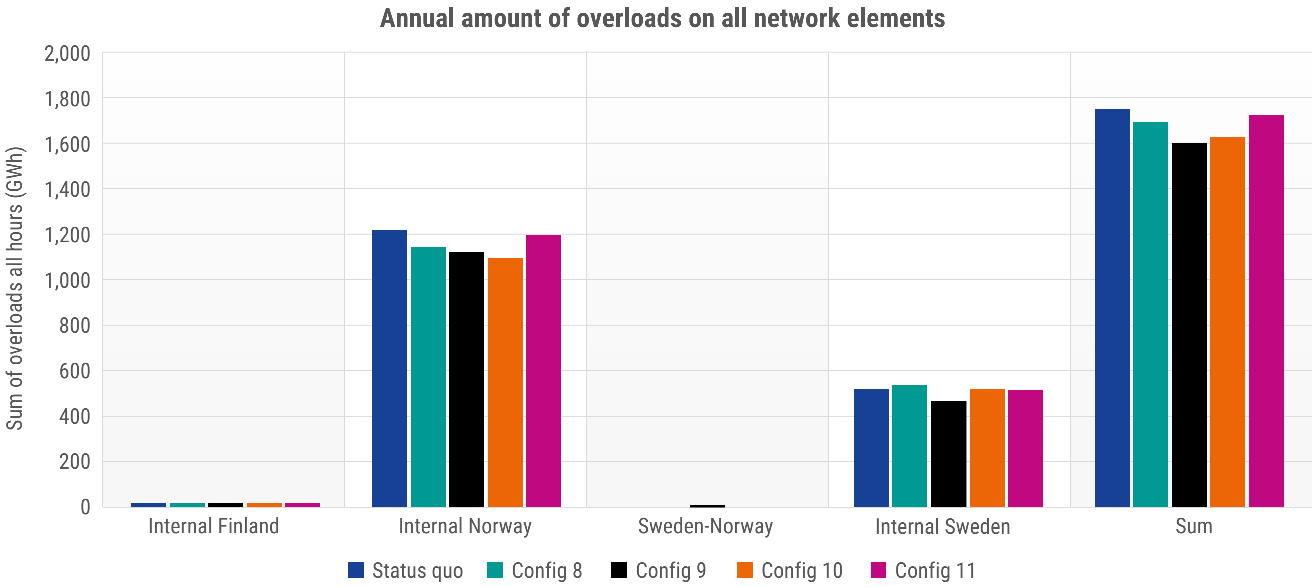
Note: For example, a positive flow means that the average annual flow is in the direction from SE1 to SE2 regarding the SE1 » SE2 border, etc. A negative flow means that the average annual flow is in the direction from NO4 to SE1 regarding the SE1 » NO4 border. A darker blue/red colour corresponds to a larger positive/negative value, and the opposite applies for lighter colours.

Table 61: Annual net, export, and import flows on Nordic borders in TWh/y

7.1.3.5 Results from the Operational Security Analysis and the Remedial Action Optimisation

An OSA was performed following the DA market dispatch simulation. Thereafter, a RAO was conducted to solve any operational security violations detected in the OSA. Only the BZs within the Nordic CCR were included in the RAO, thus keeping flows on the HVDC links connected to the region fixed to the DA market dispatch outcome (see also section 7.3.5.1). The sum of violations – or overloads – detected in the OSA ranges between 1.5 TWh and 1.9 TWh annually, depending on the configuration and climate year.

On average, the majority of the overloads (around 70 %) were detected on internal network elements in Norway, and around 30 % on internal network elements in Sweden. Only minor overloads could be observed in Finland and between Norway and Sweden (< 1 %). No overloaded elements were found in Denmark. Figure 71 presents the sum of overloads for all hours.

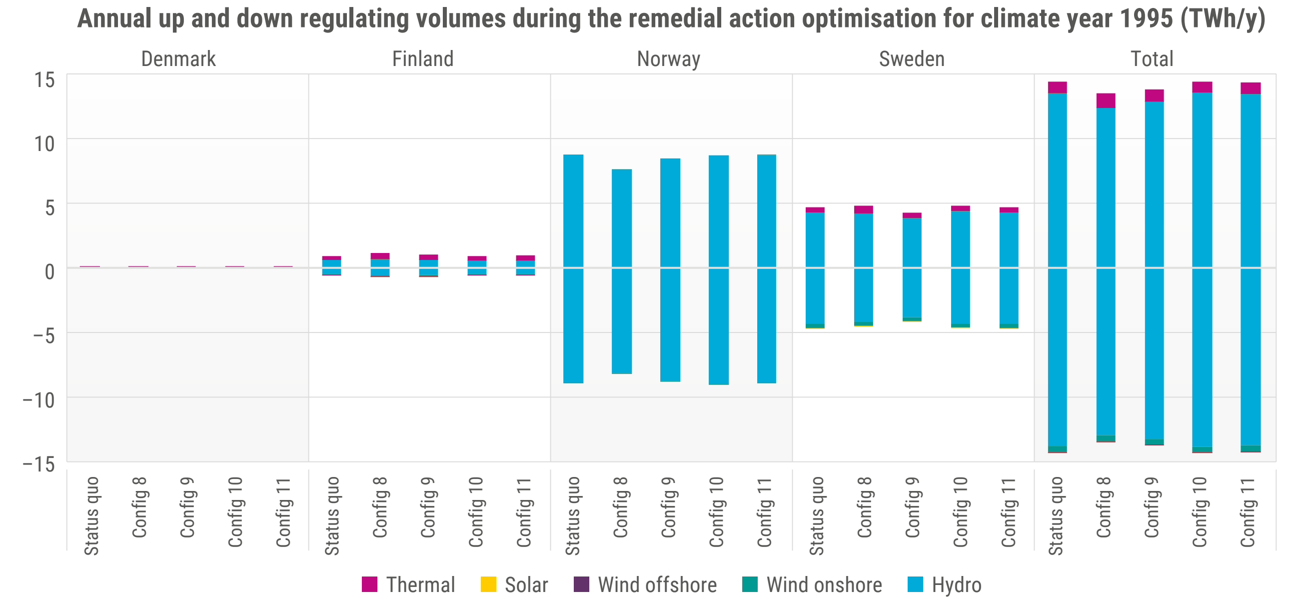


Note: The majority of overloads occurs on grid elements located internally in Norway and in Sweden.

Figure 71: Sum and location of all violations / overloads in GWh / y

The magnitude of the overloads detected is high compared to the current operational practice, largely driven by the implementation of the 70 % rule according to the BZR Methodology. The rule stipulates that at least 70 % of the capacity of each grid element should be available in the model for cross-zonal trade (see also section 7.1.2.1 and Figure 68). A test simulation without the minimum requirement of 70 % capacity for cross-zonal trade reduced the overloads from 1.85 TWh to 0.19 TWh annually for the status quo and climate year 1995, corresponding to a reduction of overloads by 90 %. As might be expected, the simulation setting also has a significant impact on power prices, flows, and production, as well as socio-economic welfare. In other words, the implementation of the 70 % rule has a substantial impact on the DA market optimisation and results in high overloads that have to be solved via the RAO.

Figure 72 presents the up- and downregulating volumes per generation type and country following the RAO for the climate year 1995. Similar results can be seen for all three climate years. The figure shows that the overloads were mainly solved by up- and downregulating the hydro power production from the DA market dispatch, especially in Norway and Sweden. In Norway, the hydro power plants upregulate production compared to the DA market solution by around 7.5 – 8.5 TWh annually. This volume is about seven times higher than the internal overloads in Norway. The regulating volumes should indeed be higher than the overloads as there is not a 1:1 ratio between a power plant's production and mitigating an overload due to the grid being meshed, although the model also needs to ensure that no new overloads occur. The redispatch module might also be re-optimising the DA market dispatch solution, although several measures have been implemented to suppress re-optimisation, and the impact is deemed minor.

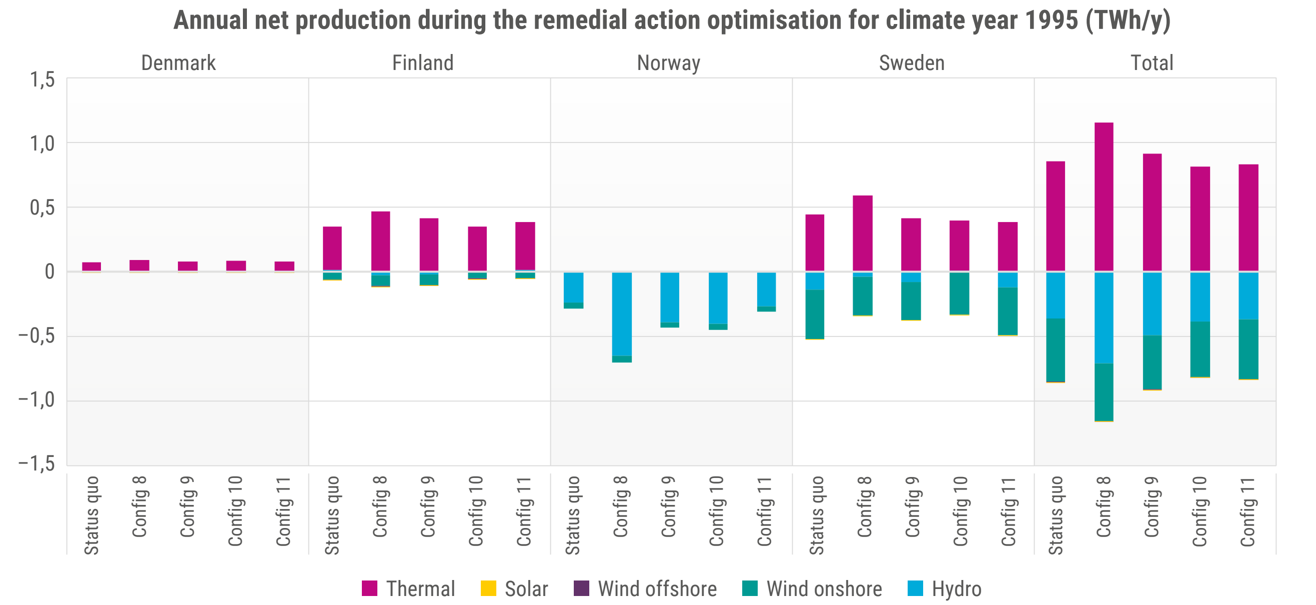


Note: Similar results can be seen for all three climate years.

Figure 72: Annual volumes used for up- and downregulation in the RAO per generation type and country in TWh/y for climate year 1995

Figure 73 presents the netted volumes from Figure 72 used during the RAO for climate year 1995. At a net level, hydro and wind power production volumes decreased during the RAO compared to the DA market dispatch, while thermal production increased.

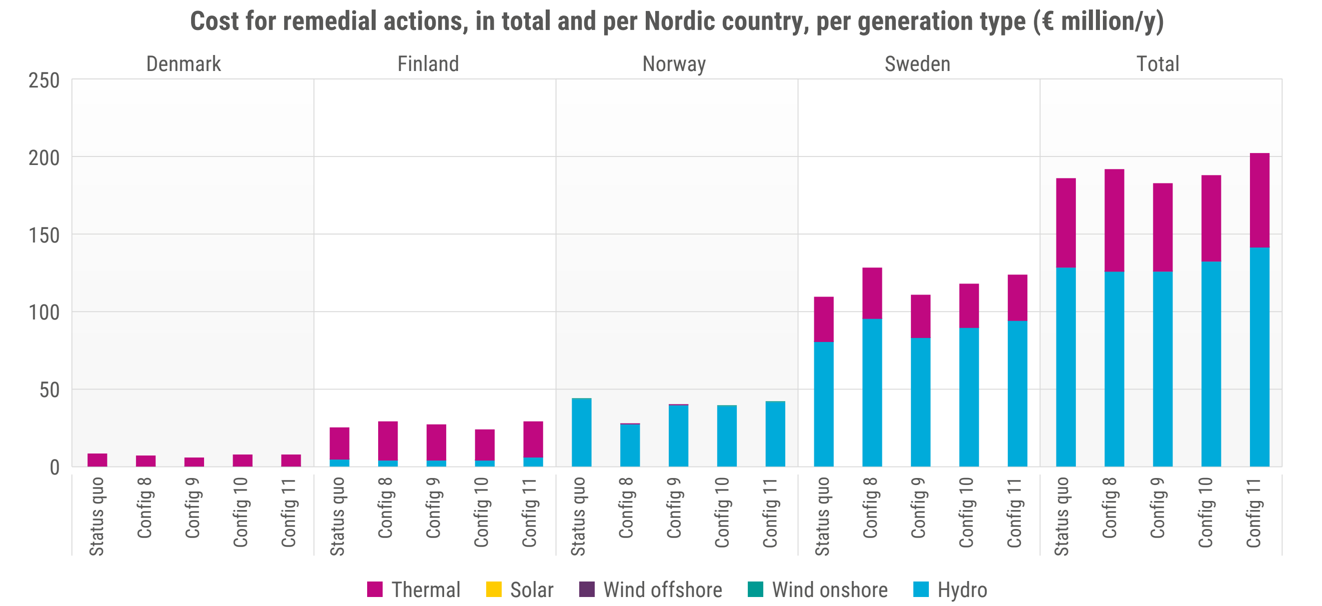
Due to the 70 % rule, more low-cost production can be transferred from surplus BZs in the Nordic, although as these flows lead to some grid elements being overloaded the production is then downregulated in the RAO.



Note: Similar results can be seen for all three climate years.

Figure 73: Annual netted volumes (i. e. upregulating volumes minus downregulating volumes) used in the RAO per generation type and country in TWh/y for climate year 1995

Figure 74 presents the costs for solving the overloads during the RAO per generation type and Nordic country. The simulated costs are around four times higher than the costs for remedial actions during 2023 in the Nordics, although the practice during 2023 was very different to the simulation setup in the BZ Study, e. g. FBMC instead of NTC and how the 70 % rule is applied. As previously mentioned in this chapter, overloads are also much higher than seen historically.



Note: The costs are also shown per generation type.

Figure 74: Annual average costs for remedial actions overall and per Nordic country in € million

7.2 Step 1: Monetised Benefits

As described in Bidding Zone Methodology and Assumptions, the first step in the BZR – according to the BZR Methodology – is to assess the monetised benefits for each configuration and compare them with the status quo. In the Nordic BZ Study, this is undertaken via criterion 4 (economic efficiency), described in section 7.2.2. If the comparison shows a positive value for any of the configurations, meaning that the configuration has a higher monetised benefit than the status quo, this configuration will move forward to the next assessment step. If none of the configurations shows a higher monetised benefit compared to the status quo, the process will stop and there will be no change in the assessed country's BZ configuration.

7.2.1 Ranking and Acceptability of Bidding Zone Configurations

Table 62 presents the economic efficiency for the Nordic BZ Study for all configurations compared to the status quo. All four configurations show negative monetised benefits and therefore are rejected. As a result, the Nordic BZ Study will stop after the first step and not proceed with the next steps of the overall process.

BZ configuration	Economic efficiency [€ million/year]	Accepted/rejected	Justification
8	-7.0	Rejected	Monetised benefits compared to status quo are negative
9	-34.8	Rejected	
10	-2.2	Rejected	
11	-15.9	Rejected	

Table 62: Economic efficiency for the different configurations compared to the status quo together with their acceptance or rejection in the BZR process

7.2.2 Economic Efficiency

Economic efficiency is evaluated based on the change in socio-economic welfare (SEW) calculated by the market welfare for the DA market dispatch and the cost of remedial actions for RAO, assessed for each of the four BZ configurations and compared to the status quo. Calculation of market welfare includes the modelled Europe and the additional costs from the RAO is obtained for the Nordic synchronous area (Sweden, Norway, Finland, and DK2). The reservoir delta value (see section 7.1.3.2) is accounted for as a surplus/deficit to the producer surplus.

Figure 75 presents an overview of the change in economic efficiency for each proposed alternative configuration including both the market welfare and the cost from RAO. The results show that economic efficiency is lower compared to the status quo for Configs 8, 9, 10 and 11.

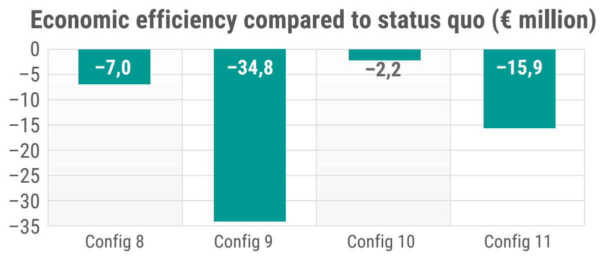


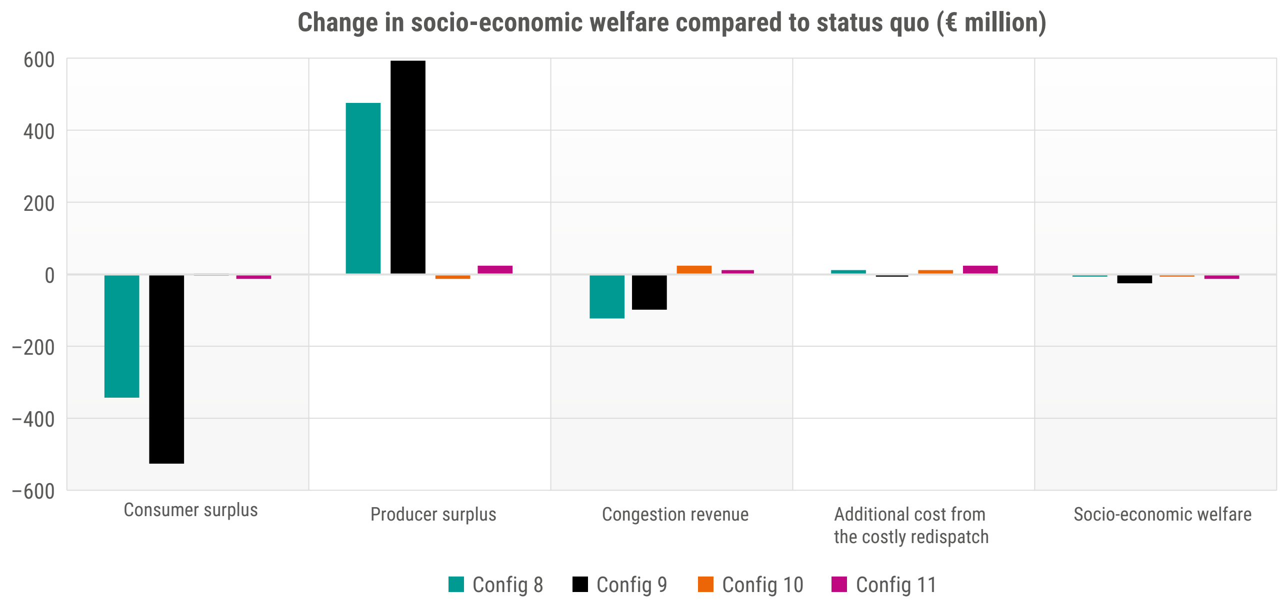
Figure 75: Economic efficiency for Configs 8, 9, 10, and 11 compared to the status quo

Looking at the economic efficiency and the change in SEW results in further detail, the consumer surplus for Configs 8 and 9 is lower compared to the status quo and the producer surplus is higher (Table 63 and Figure 76). This is related to the power price in general being higher in these configurations (for more details, see section 7.1.3.3). Configs 10 and 11 have minor changes in SEW compared to the status quo.

	Average change over all climate years with respect to status quo					
	DA market dispatch				RAO	Economic efficiency
Configuration compared to Status quo	Total market welfare [€ million]	Consumer surplus [€ million]	Producer surplus [€ million]	Congestion revenue [€ million]	Additional cost from redispatch [€ million]	Socio-economic welfare (criterion 4) [€ million]
Config 8	−1.5	−349.6	472.7	−124.6	5.5	−7.0
Config 9	−38.4	−529.7	594.1	−102.8	−3.6	−34.8
Config 10	−0.6	−5.2	−19.3	23.9	1.6	−2.2
Config 11	−0.2	−14.3	14.0	0.2	15.7	−15.9

Note: Reservoir delta is included in the producer surplus.

Table 63: Average change in socio-economic welfare over all climate years compared to the status quo per section



Note: Reservoir delta is included in the producer surplus.

Figure 76: Change in socio-economic welfare per section and configuration

7.3 Limitations of the Nordic Bidding Zone Review

Both the LMP Study and the BZ Study represent new methods for simulating the power system for the Nordic TSOs. For the purpose of conducting these studies, the BID3 model has been undergoing substantial development and close collaboration between the Nordic TSOs and AFRY (the provider of the BID3 model used) has been necessary.

Considering the model's development while conducting the studies alongside the high complexity of the simulations, it is not unexpected that simplifications are necessary and issues brought to light that – to some extent – have limited the outcome of the studies. In this section, the main limitations of the BZ Study for the Nordics are presented.

7.3.1 Potential Improvements in the LMP Simulations

During the course of the BZ Study, potential improvements were discovered in the data used during the LMP Study. Most issues would have had a minor impact on the proposal for alternative BZ delineations, although the impact is deemed substantial for two inaccuracies, presented in Table 64. The full list of improvements since the LMP Study can be found in Annex III.

Issue	Description
Incorrect reactance	The BID3 model interpreted reactance per grid element but the reactance was inputted per km. Correcting this error in the BZ Study has considerably reduced overloads and led to large changes in the market welfare results. It is difficult to tell the exact consequences of the error in LMP, although correct reactance would have led to other results, which could have resulted in different proposals for BZ configurations.* As this error has been fixed in the BZ Study, the assessments of the configurations studied remain valid. Two out of four configurations (Config 9 and 11) are also modifications of the LMP result-based ones (i. e. Config 8 and 10), where current operational practices and flow patterns have been accounted for in the proposal of these BZs.
Incorrect capacity of CNEC in Stockholm	In the Stockholm metropolitan region, the LMP results showed one 220 kV CNEC causing very high shadow prices for a limited number of hours. In the BZ Study, the capacity of this CNEC has been increased (setting F_{max} very high) as it is more aligned with operational practices. This has resulted in reduced overloads and no longer occurrences of loss of load that were previously present in the BZ Study simulations. In the LMP Study, the limiting CNEC in Stockholm gave rise to high prices in nearby nodes, which could have affects the BZ suggestions for Configs 8 and 10.

* No new nodal simulations, comparable to the ones done in the LMP Study, have been conducted to confirm the actual impact on the result.

Table 64: Two major issues found in the LMP data

7.3.2 Scenario Data

Based on agreement concerning how to interpret the BZR Methodology, the scenario data used for the 2025 target year in the BZ Study and the LMP Study was based on the Pan-European Market Modelling Database (PEMMDB) according to the scenario used in the MAF 2020 – National Trends 2025. The data were originally collected by TSOs and delivered to ENTSO-E during 2019. Some adjustments were made to the Nordic data during the LMP Study, i. e. consumption and wind power capacity were updated to reflect the most recent Nordic TSO forecasts at the time.

Due to various factors, several key assumptions made in the BZ Study for the 2025 target year might no longer be valid. Especially growth in the renewable energy sector has generally been faster than expected and input data for the LMP Study and the BZ Study is out of date in this case.

The fuel and CO_2 price levels in the BZ Study are also lower than the markets are currently expecting for the 2025 target year. Another related aspect is that the Nordic TSOs will be unable to implement a potential new BZ configuration until 2027/2028 due to Svenska kraftnät switching operational monitoring system. As the energy system is set to significantly change along with the green transition, the results from an already – in some regards – outdated 2025 scenario will be even more outdated after 2027, which undermines the validity and robustness of the results. Several grid reinforcements are planned after 2025, which would also impact the need and setup of new BZ configurations.

7.3.3 Grid Capacity

The same operational security limits for the network elements were used for all simulated hours. In real operational conditions, the operational security limits are dependent on the ambient temperature. Furthermore, the majority of the maintenance work and planned outages due to investments in the grid are conducted during the summer, when the cross-border capacity is often limited in the Nordic power system. Neither temperature nor seasonal-dependent capacities were considered in the BZ Study.

7.3.4 Climate Years in Parallel and Water Value Calculations

In the LMP Study and BZ Study, the three climate years have been simulated in parallel, meaning that all three climate years start from the same data points, e.g. with the same reservoir levels (set to 70%). The common approach in the Nordics when evaluating – for example – new transmission lines in electricity market models is to simulate a number of climate years (>30) in sequence, whereby the end reservoir level for the first climate year will be the starting reservoir level for the second climate year, etc. This simulation setup is deemed important as the Nordic power system is strongly dependent on the hydro production conditions. The sequential simulation enables the TSO to capture these various conditions coherently; for example, periods with dry weather for two years in a row, etc. The longer simulation period also helps "calibrating" the water usage in the model so that different simulations – for example, with and without a transmission line – use very similar amounts of hydro energy on average over the climate years modelled.

The simulations in the BZ Study are much more complicated than the common usage of models in the Nordics and in practice a full run takes about three weeks (approximately two weeks for capacity calculation, DA market dispatch, and OSA, and one week for RAO). Running the three climate years in sequence in the Nordic BZ Study would triple the time needed to run through the simulation to about nine weeks. Therefore, running >30 climate years in sequence would not be manageable. Nonetheless, the setup with "only" three climate years in parallel is a limitation of the study results. The end reservoir level between the different BZ configurations is relatively high, meaning that the approximation of the reservoir delta value (see section 7.1.3.2) plays a more important role in the overall results compared to ordinary studies in the Nordic region. The fact that the Nordic hydro production is higher in Config 8 compared to the status quo but lower in Config 9 might to some extent result from the water usage not being calibrated correctly, i.e. without sequential climate years, the hydro power production results are less robust. For future studies, it might be important to soften some of the input restrictions to make the simulation less complicated to be able to run more climate years and/or run them in sequence.

The fact that the water value calculation is based on an NTC representation of the network reflects another aspect regarding the hydro power optimisation that affected the results. Thus, the water values and costs for hydro power differ between the different configurations as the BZBs are not the same.

7.3.5 Remedial Action Optimisation

The setup of the RAO according to the BZR Methodology required a major development of the BID3 model. However, several simplifications were necessary to provide realistic results in a reasonable amount of time. The most important ones are described in the following sections.

7.3.5.1 Optimisation of Remedial Actions Only for the Nordic Capacity Calculation Region

One simplification was to include only the BZs within the Nordic CCR in the RAO, thus keeping flows on the HVDC links connected to the region fixed to the DA market dispatch outcome. Attempts were made to include all of Europe in the redispatch simulation, although it proved difficult regarding the quality of the results and the necessary simulation time. By limiting the simulation to the Nordic CCR, the same optimisation horizon could be used as in the DA market dispatch and the whole year could be simulated in one sequence.

In current operational practice, the remedial actions used are mainly from sources within the Nordics, although the Nordic TSOs are working towards joining the European platforms for trading balancing resources (MARI and PICASSO) in 2026, which will enable enhanced trade of remedial actions from outside of the Nordics. However, even with the European platform, it is anticipated that the majority of the redispatch volumes will be from resources within the Nordic CCR. One reason is that the HVDC capacity between the Nordics and the continental Europe might be restricted for remedial actions due to technical reasons, such as the rate of power changes and number of pole reversals of HVDC cables.

7.3.5.2 No Optimisation of Explicit Demand-side Response

Another simplification made in the RAO was that explicit DSR was kept at the resulting levels from the DA market dispatch, thus not taking part in the optimisation of remedial actions. As presented in the LMP Study, the cost for explicit DSR – i. e. industrial load – was modelled with a high price threshold (between 200 € / MWh and 500 € / MWh), which is rarely reached in the simulation results. Therefore, it was concluded that excluding explicit DSR from RAO would not affect the results and the necessary development to include DSR in RAO could be deprioritised.

7.3.5.3 Non-costly Remedial Action not Considered

The BZR Methodology states that the RAO shall also optimise "non-costly remedial actions", reflecting the expected operational practices of TSOs for the target year. Non-costly remedial actions shall be assumed to lead to no cost. In the Nordics, the non-costly remedial action involves topology changes in the grid undertaken by the TSO depending on the operating situation.

As an example, Svenska kraftnät has the possibility to bypass the series compensators on the 400 kV lines between current SE2 and SE3 BZs. This action is – for example – taken during flow patterns from east to west in the SE3 BZ, when the lines where the series compensators are located could otherwise be limiting the market outcome. By bypassing some of the series compensators during these situations, increased east–west flows could be managed. Another example is the possibility to take limiting parallel lower voltage transmission lines out of operation to increase the capacity to the market during certain operational conditions.

Modelling and optimising the non-costly remedial actions described in the previous section were deemed too complex for the simulation setup and the tool used. Identifying operational situations where either one of the topological interventions would be suitable and changing the network model for these hours would have required vast development. It would also have led to a substantial increase in simulation time as recalculation of nodal PTDF would have been necessary, for instance. Nonetheless, several of these topological measures play an important role in operating the Nordic power system in a cost-effective manner and not including them in the simulation is a limitation to the study results. The optimisation of the grid topology would have enabled more trade in the DA market dispatch and led to fewer constraints.

7.4 Nordic BZRR Proposal[54]

Based on the results presented in chapter 7.2.1 in general and table 62 specifically, **the recommendation for the Nordic BZ Study is to maintain the status quo.**

7.5 Next Steps in the Nordic Region

In the Nordic BZ Study, four configurations (Configs 8, 9, 10, and 11) have been compared to the status quo based on economic efficiency. The results showed that none of the configurations assessed perform better than the status quo, and therefore the recommendation is to maintain the current BZ configuration.

New developments have been implemented to adhere to the BZR Methodology to assess the different configurations. These new developments were carried out alongside with the BZ Study, which led to a longer study period than if no new development had been needed. Although the study year of the BZR was set to 2025, due to the study period length and the rapid changes in the European power system, some data is already outdated in the study. Furthermore, there were two erroneous critical parameters in the LMP study, which – if inputted correctly – could have affected the optimal configurations proposed by ACER (Configs 8 and 10). The proposed configurations from Svenska kraftnät (Configs 9 and 11) were partly based on empirical knowledge and therefore not equally sensitive to the error.

Based on the aforementioned critical aspects, **Svenska kraftnät will continue to investigate whether there is a need for a new assessment of BZ configurations in Sweden. The model development and the knowledge built up during the study are valuable aspects to include in future studies.**

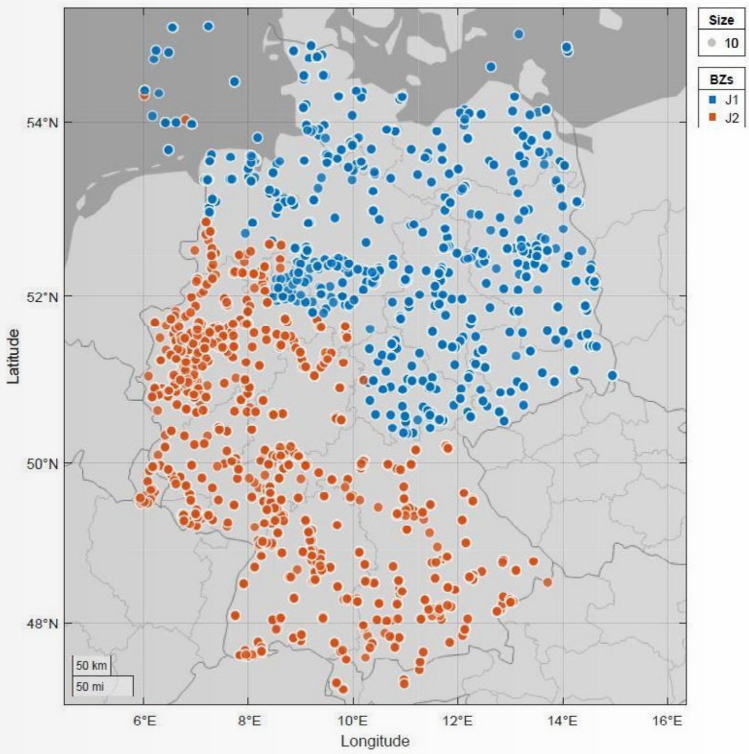
54 Nordic Proposal has been approved by the participating TSOs of the Nordic BZRR.

Annex I: Description of the Alternative Configurations Assessed in the Bidding Zone Study

The alternative configurations are described in detail in Annex I of ACER decision ACER 11-2022. The following configurations are assessed in the BZ Study.

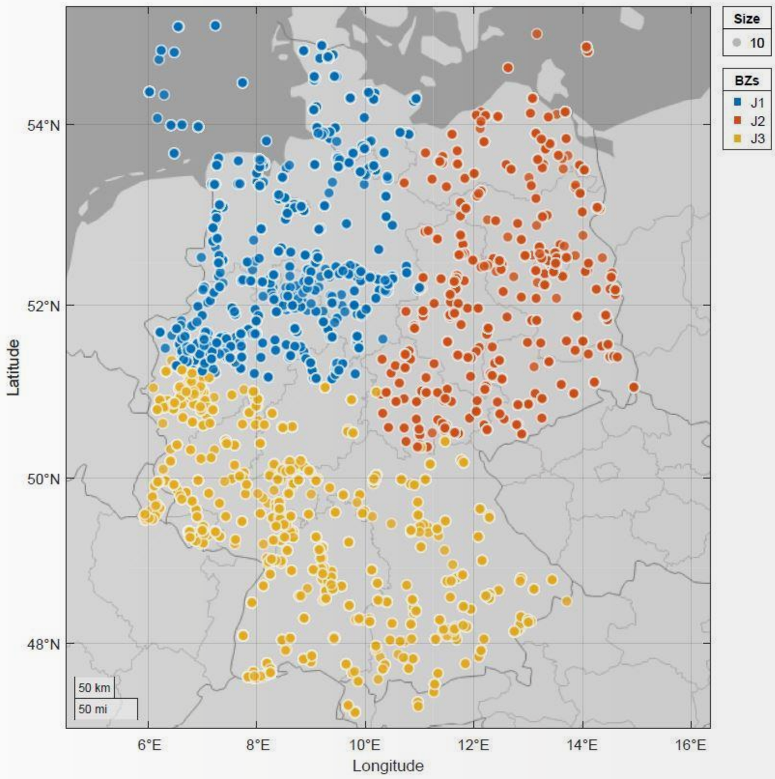
CE BZRR

DE2 – ACER ID 2 (modified version of Spectral P1 following remarks provided by the German TSOs)



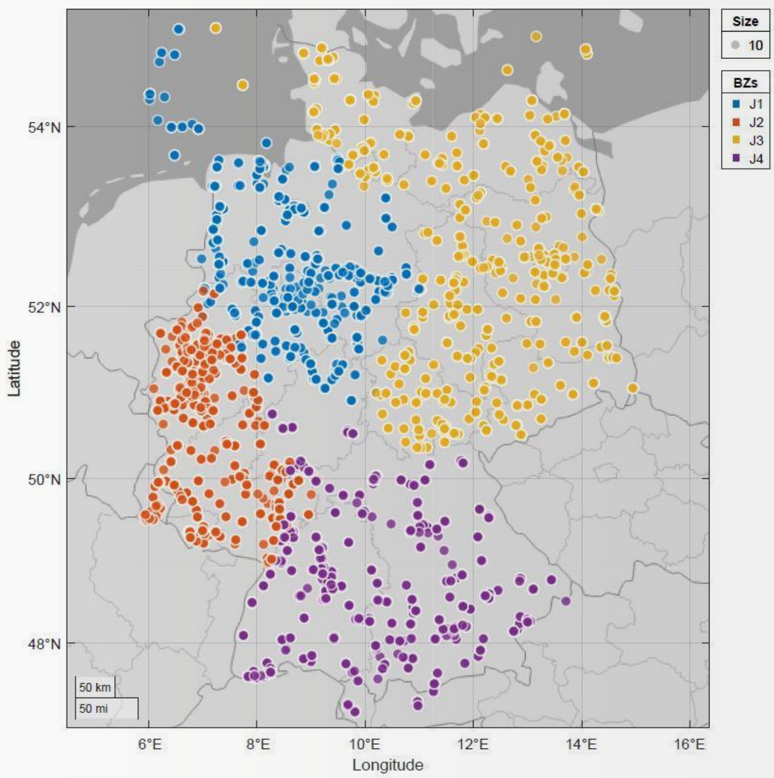
Note: J¹ and J² are the two newly-defined German-Luxembourgish bidding zones.

DE3 – ACER ID 12 (modified version of configuration 3 to align with Amprion's control area borders)



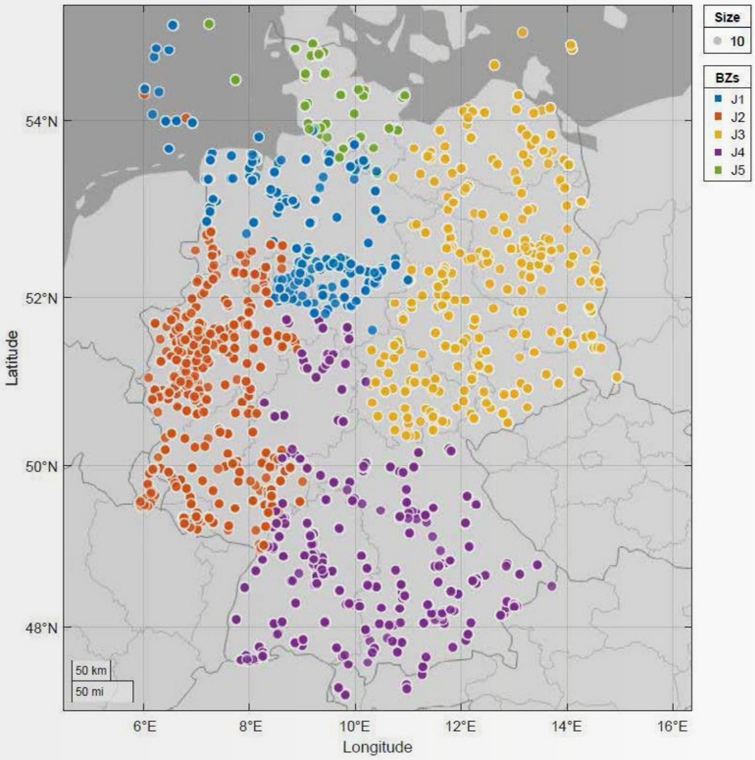
Note: J¹, J² and J³ are the three newly-defined German-Luxembourgish bidding zones.

DE4 – ACER ID 13 (modified version of configuration 4 to align with Amprion's control area borders)

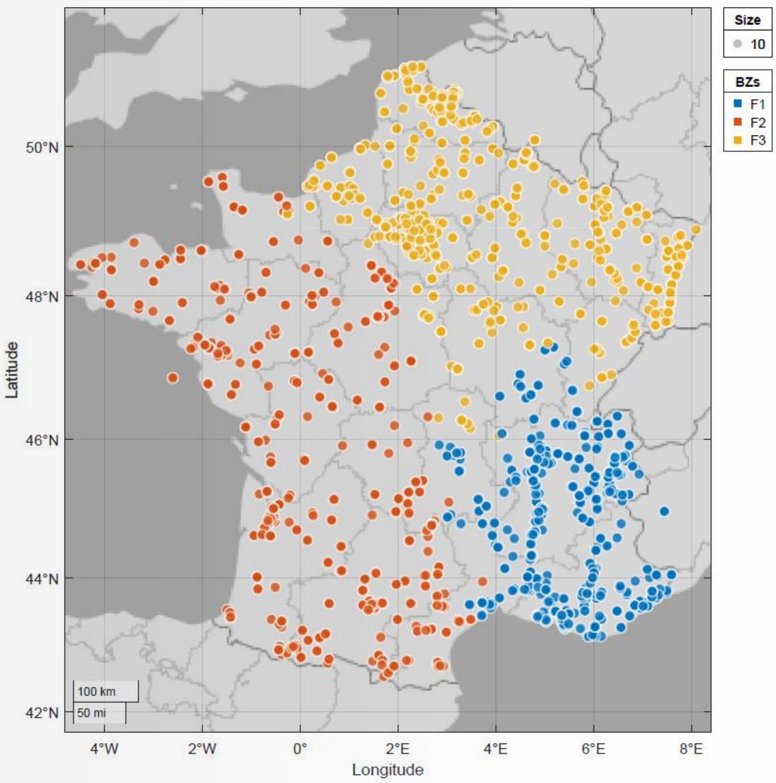


Note: J¹, J², J³ and J⁴ are the four newly-defined German-Luxembourgish bidding zones.

DE5 – ACER ID 14 (modified version of configuration 13 including a new bidding zone in Schleswig-Holstein)

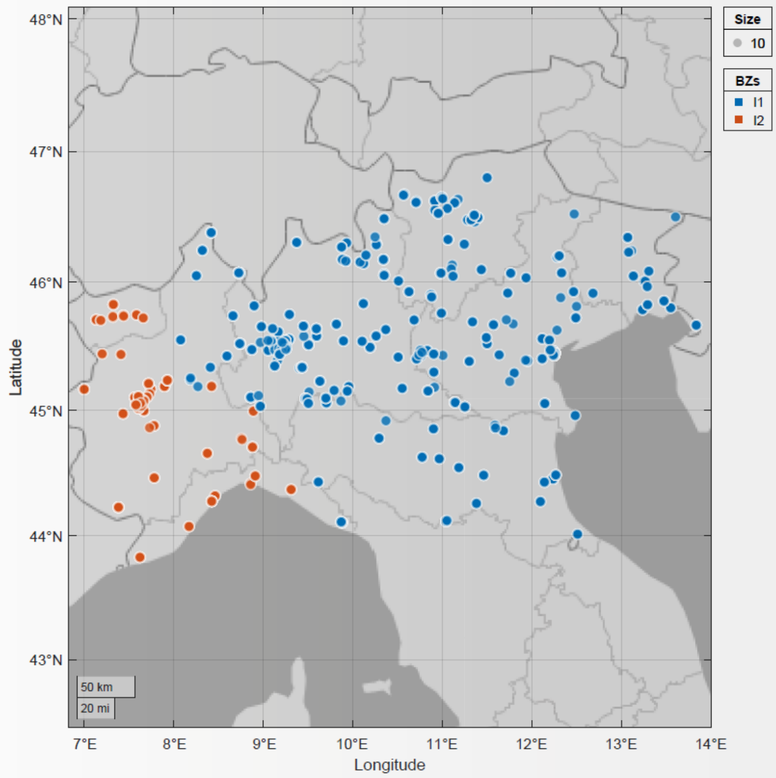


FR3 – ACER ID 5 (Spectral P1)



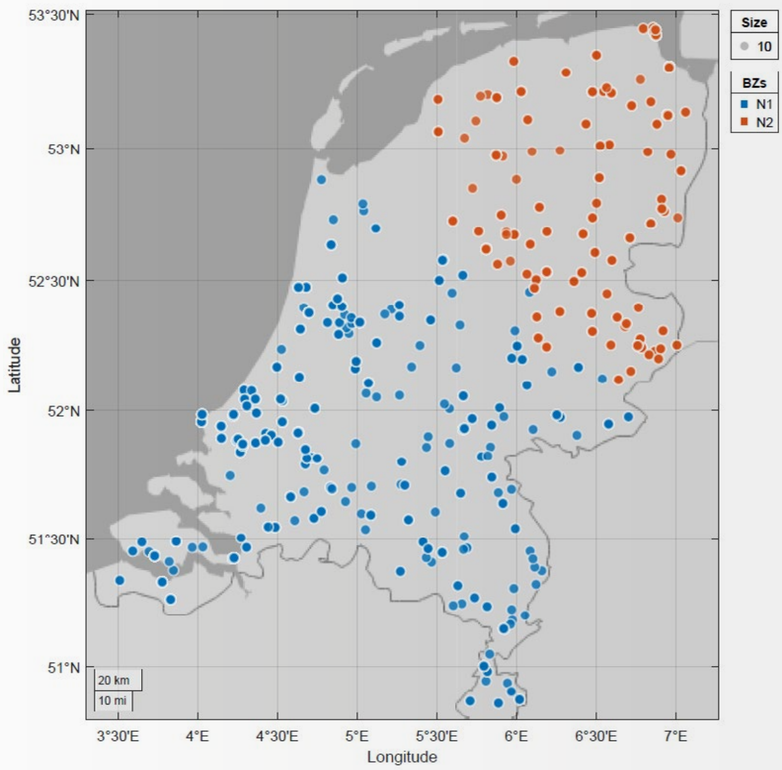
Note: F¹, F² and F³ are the three newly-defined French bidding zones.

IT2 – ACER ID 6 (k-means)



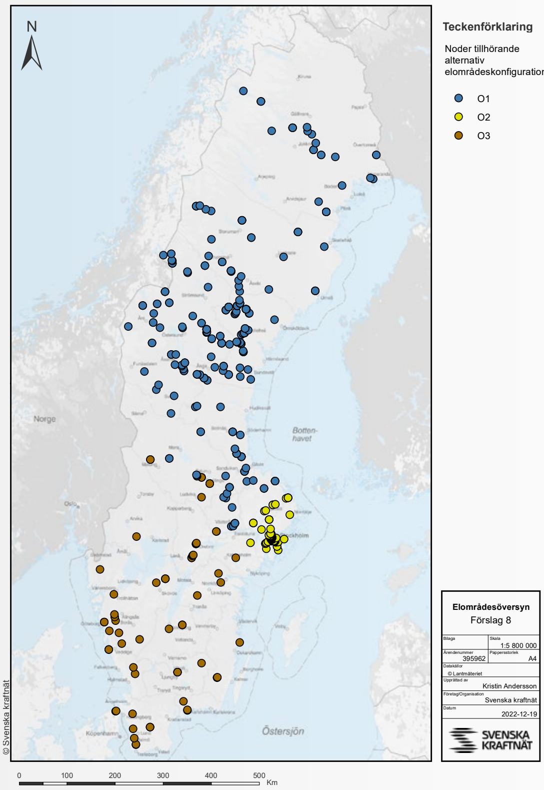
Note: I¹ and I² are the two newly-defined Italian bidding zones.

NL2 – ACER ID 7 (Spectral DIRC)

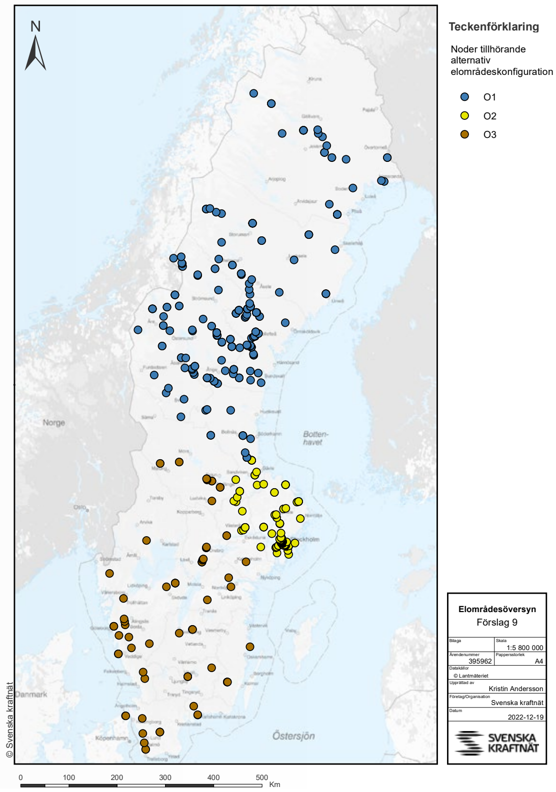


Note: N¹ and N² are the two newly-defined Dutch bidding zones.

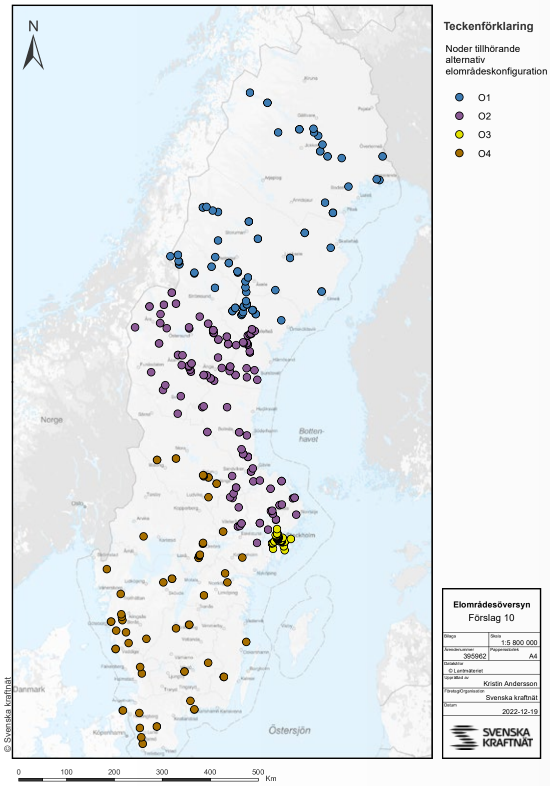
Nordic BZRR Configuration 8: ACER ID 8 (SE3 – Spectral P1)



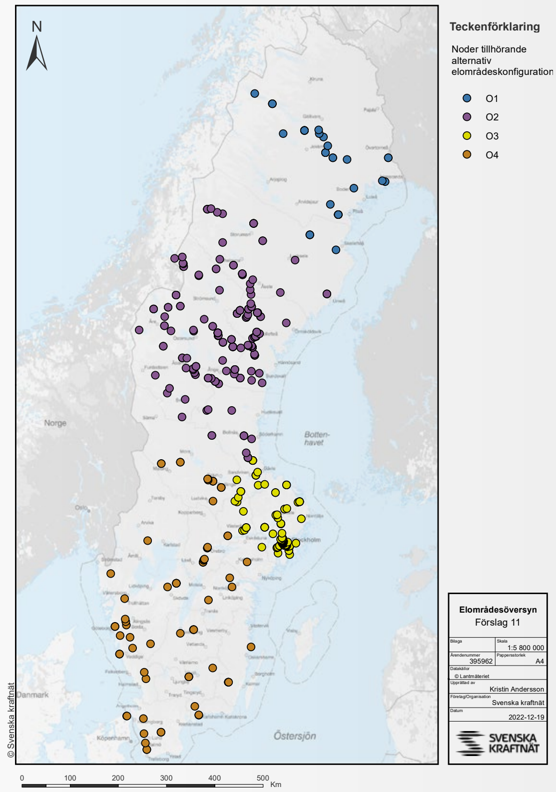
Configuration 9: ACER ID 9 (SE3 – modified version of Spectral P1 following remarks provided by Svenska kraftnät)



Configuration 10: ACER ID 10 (SE4 – Spectral P1)



Configuration 11: ACER ID 11 (SE4 – modified version of Spectral P1 following remarks provided by Svenska kraftnät)



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Acronyms

AC	Alternating current
ACER	Agency for the Cooperation of Energy Regulators
AT	Austria
BE	Belgium
BZ	Bidding zone
BZB	Bidding zone border
BZR	Bidding zone review
BZRR	Bidding zone review region
CACM	Capacity allocation and congestion management
CCR	Capacity calculation region
CE	Central Europe
CHP	Combined heat and power
CNE	Critical network element
CNEC	Critical network element and contingency
cNTC	Coordinated net transmission capacity
CZ	Czech Republic
DA	Day-ahead
DC	Direct current
DE	Germany
DK	Denmark
DSO	Distribution system operator
DSR	Demand-side response
EENS	Expected energy not served
ENS	Energy not served
ENTSO-E	European Network of Transmission System Operators for Electricity
ERAA	European resource adequacy assessment
EU	European Union
FB	Flow-based
FBMC	Flow-based market coupling
FR	France
FRM	Flow reliability margin
FRR	Frequency restoration reserves
GSK	Generation shift key
HHI	Herfindal–Hirschmann Index
HR	Croatia
HU	Hungary
HVDC	High-voltage direct current
ID	Intraday
IT	Italy
JAO	oint Allocation Office
LFC	Load frequency control
LMP	Locational marginal price
LOLE	Loss of load expectation
LU	Luxembourg
maxBEX	Maximum bilateral exchange
MESC	Market European Stakeholder Committee
MTU	Market time unit
MW	Megawatt
MWh	Megawatt hour
NEMO	Nominated electricity market operator
NL	Netherlands
NRA	National regulatory authority
NTC	Net transmission capacity
OSA	Operational security analysis
PEMMDB	Pan-European Market Modelling Database
PFC	Power flow colouring
PL	Poland
PSI	Pivotal supplier index
PST	Phase-shifting transformer
PTDF	Power transfer distribution factors
PV	Photovoltaics
RAM	Remaining available margin
RAO	Remedial action optimisation
RES	Renewable energy sources
RO	Romania
ROSC	Regional operational security coordination
RSI	Residual supply index
SEW	Socio-economic welfare
SI	Slovenia
SK	Slovakia
SQ	Status quo (configuration)
TSO	Transmission system operator
TYNDP	Ten-Year Network Development Plan
UK	United Kingdom
VAMOS	Varied Market-Model Operation System
VoLL	Value of lost load

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