ENTSO-E Report

Bidding Zone Review of the 2025 Target Year

April 2025

ANNEX VIII

General Results of the Sensitivity Analysis

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.

General Results of the Sensitivity Analysis

This annex contains some further details on the approach and results of the sensitivity analysis conducted in BZRR CE.

As explained in Annex II, BZRR CE originally intended to perform sensitivity analyses on multiple dimensions including: (a) higher fuel and carbon prices, (b) additional grid expansion projects, (c) additional build-out of renewable energy sources, and (d) additional load. However, due to challenges encountered in the course of the study in preparing the input data for the sensitivities (in particular the grid model) and limited time available after finalization of the main scenario runs, ultimately CE was only able to perform one sensitivity analysis considering the impact of higher fuel and carbon prices than in the main scenario, and alternative redispatch markups.

The sensitivity analysis is used to assess criterion 16, "robustness of bidding zones over time". Simulations were only performed for the configurations leading to a positive change in socio-economic welfare from the main study. Thus, only the splits of the German-Luxembourgish bidding zone (DE2, DE3, DE4, DE5), the split of the Dutch zone (NL2), and the combinations (DE2 + NL2, DE4 + NL2 and DE5 + NL2) were simulated. The French and Italian splits were not considered.

Compared with the main study, some additional simplifications were made regarding the modelling performed for the sensitivity analysis:

- In line with the BZR Methodology Article 14 (16) (a), BZRR CE 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.
- Consequently, only the monetized criteria were assessed, not the non-monetized criteria. For the simulations, this means all steps were simulated apart from the loop flow analysis (i. e. Base Case NTC simulation, capacity calculation, flow-based market coupling and OSA / RAO).
- Only one climate year was simulated (1989).

The main findings regarding the market coupling results for the sensitivity analysis are summarised below.

- **The sensitivity analysis runs result in less dispatch of gas and more dispatch from coal and lignite plants in the SQ than in the main scenario.** The reason is that with higher assumed gas prices, gas is pushed behind most coal and lignite plants in the merit order, despite the higher CO_2 price which has a significant effect on coal and lignite generation costs (Figure 1).
- **The alternative configurations lead to more generation from gas, and less generation from coal and lignite** versus the SQ in the sensitivities. This is because introducing additional bidding zone borders leads to less efficient dispatch (Figure 2).
- **Market clearing prices are (significantly) higher in the sensitivity than in the main scenario for all zones.** Average zonal prices are in the order of 100 € / MWh in the sensitivity runs, compared with roughly 50 € / MWh in the main scenario. This is due to the impact of higher fuel and carbon prices on the marginal cost of thermal power plants, which puts upward pressure on market prices (Figure 3).
- **Price difference between zones are typically higher in the sensitivity runs than in the main scenario.** This is the case for the SQ situations, as well as when existing zones are split in the alternative configurations. For example, in the DE2 split, the average price difference between the new North and South zones approaches 18 € / MWh for climate year 1989 (Figure 4), while for the main scenario this difference is limited to 7.5 € / MWh for the same climate year.

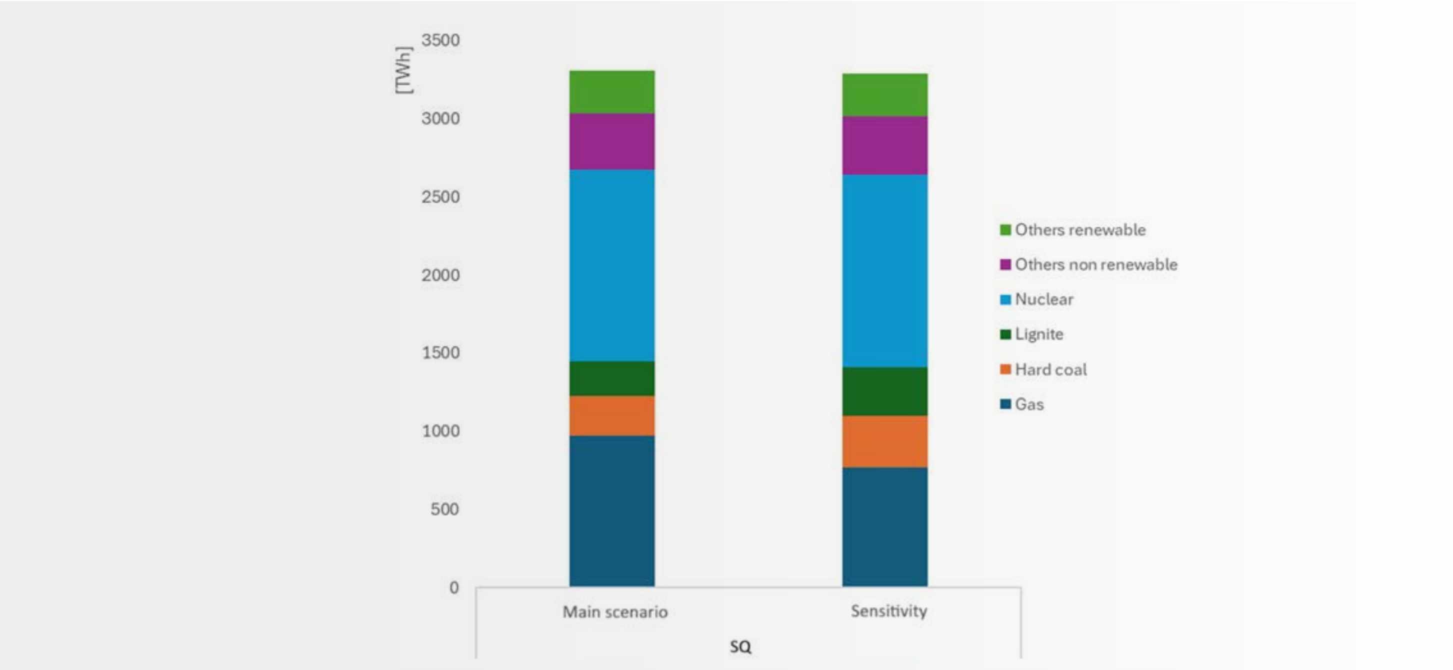

Figure 1: Comparison between the total dispatch in CE in the main scenario and in the sensitivity analysis for the SQ configuration (climate year 1989 only)

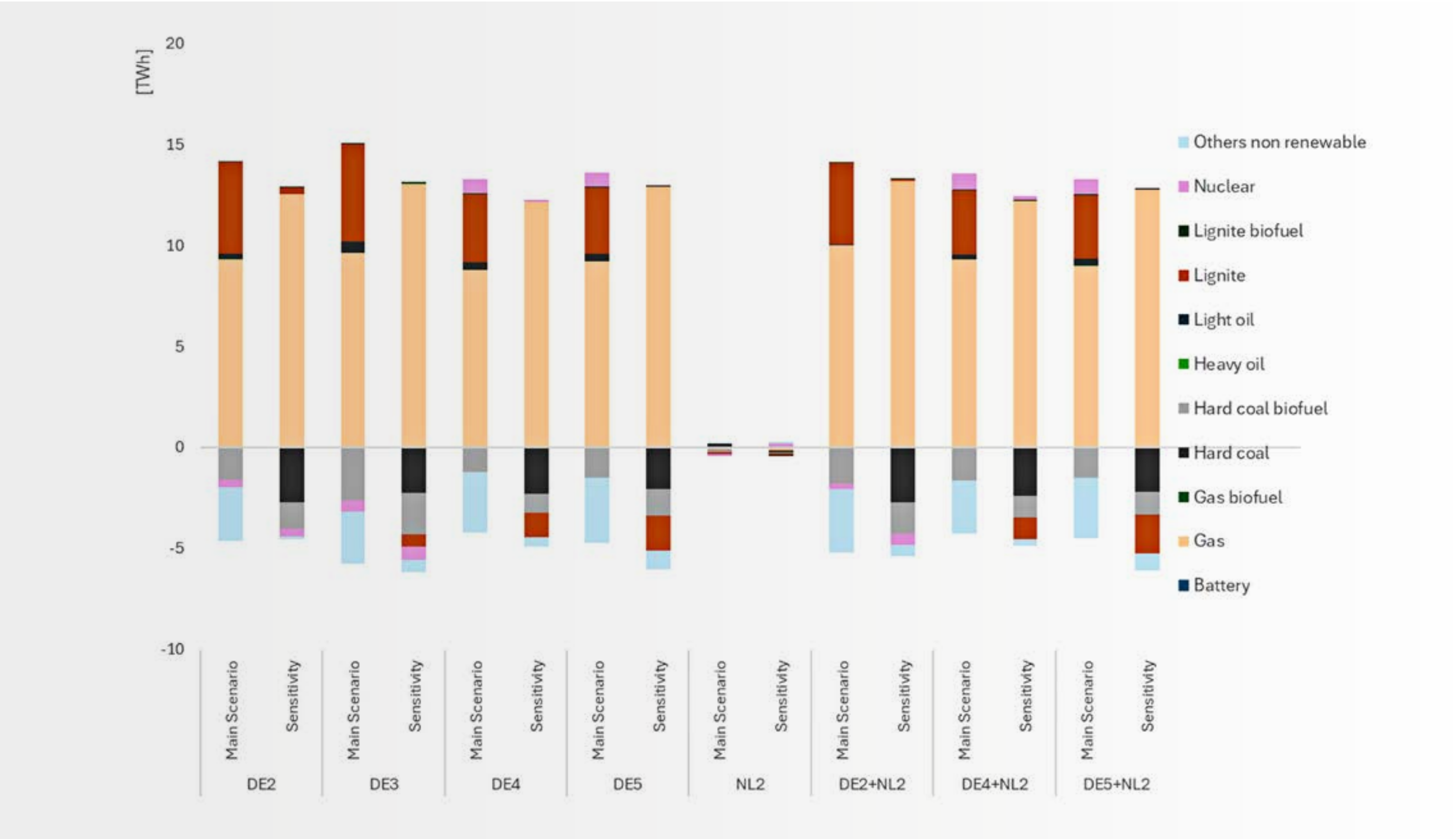

Figure 2: Deltas in dispatch between the alternative configurations and the SQ, compared for both the main scenario and the sensitivity analysis (climate year 1989 only)

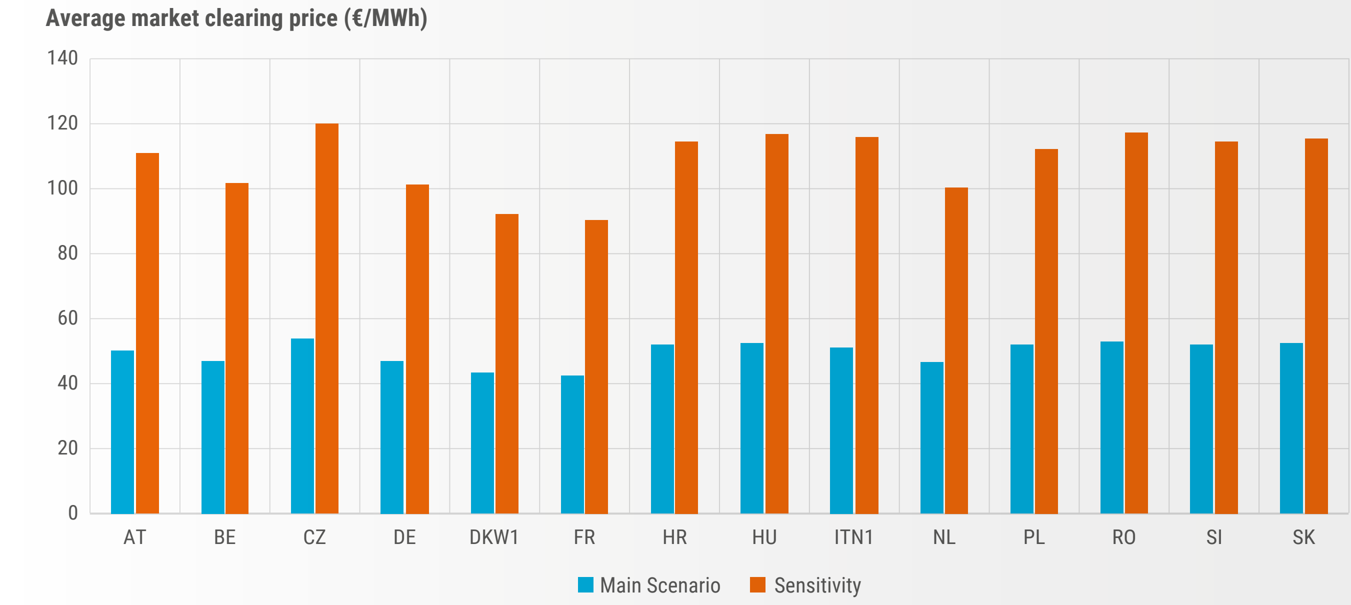

Figure 3: Comparison between annual average market clearing prices in selected CE zones between the main scenario and sensitivity run for the SQ configuration (climate year 1989 only)

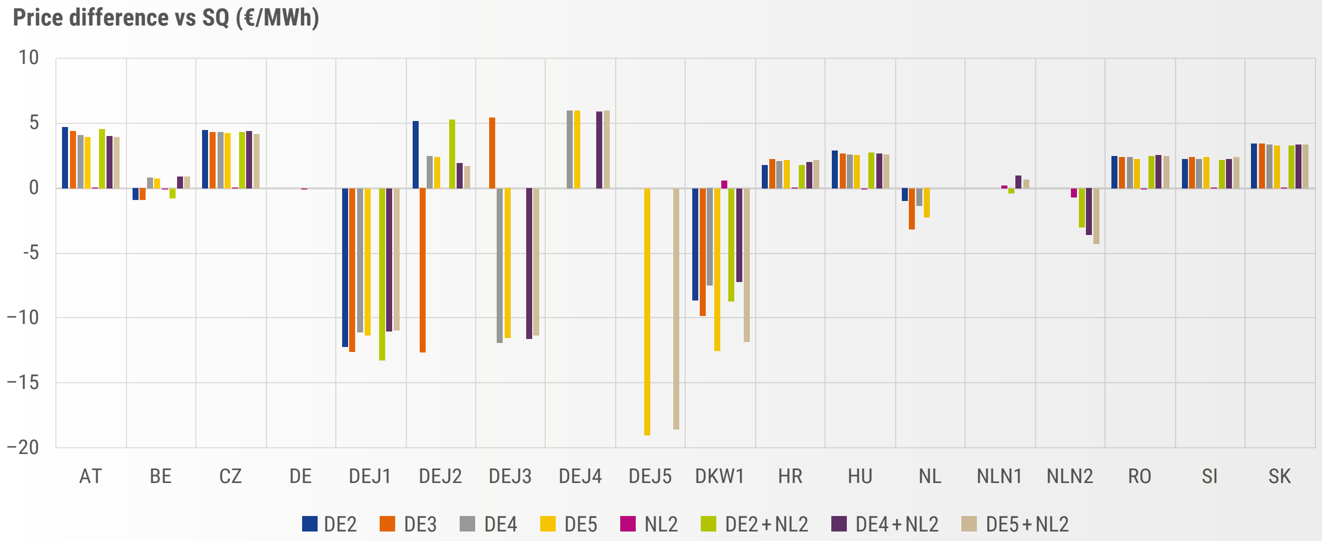

Figure 4: Differences between the average market clearing price in the alternative configurations vs the SQ for sensitivity analysis for selected CE zones (climate year 1989 only). In the case of the newly created zones for Germany – Luxembourg (DEJ1, DEJ2, DEJ3, DEJ4) and the Netherlands (NLN1, NLN2), the delta is shown with respect to the price in the parent zone in the SQ configuration for the sensitivity run.

Looking to the OSA and RAO results, it is observed that:

- **The sensitivity run shows more congestions after the flow-based market coupling than the main scenario for the SQ configuration.** This is most likely due to higher generation from hard coal and lignite and lower generation from gas in the sensitivity. As coal and lignite plants tend to be larger and more restricted in location (e.g. located in fewer member states, typically close to fuel sources), while gas plants are typically smaller and more distributed across the European grid, this may lead to higher congestions.
- **As a result of higher congestions, redispatch volumes are somewhat higher in the sensitivity run than in the main scenario.** For example, redispatch volumes are 6% higher than the main scenario for the SQ configuration, and nearly 16% higher for the DE2 split. In terms of thermal plants, downward redispatch is more frequently provided by gas plants due to their higher marginal costs. Limited upward redispatch is available from coal and lignite plants as they are typically dispatched at higher levels in the market coupling, leaving less room for further increasing dispatch.

- **Higher redispatch volumes leads to higher overall costs for redispatch in the sensitivity than in the main scenario.** The costs are driven mostly by higher costs for upward and downward redispatch, driven by (i) the higher redispatch volumes, and (ii) higher costs for providing redispatch, driven by the underlying higher generation costs from coal / lignite and gas (Figure 5).
- **As a result of higher redispatch costs overall, the redispatch savings from splitting a bidding zones are higher in the sensitivity than they are in the main scenario.** For example, for most splits, the total overall redispatch savings in climate year 1989 for the sensitivity are in the order of 1.7 bn € for target year 2025 for the German splits, almost twice as high as for the main scenario in the same climate year (Figure 6). Similar to the main study, there are only small differences in redispatch results between the considered German splits.

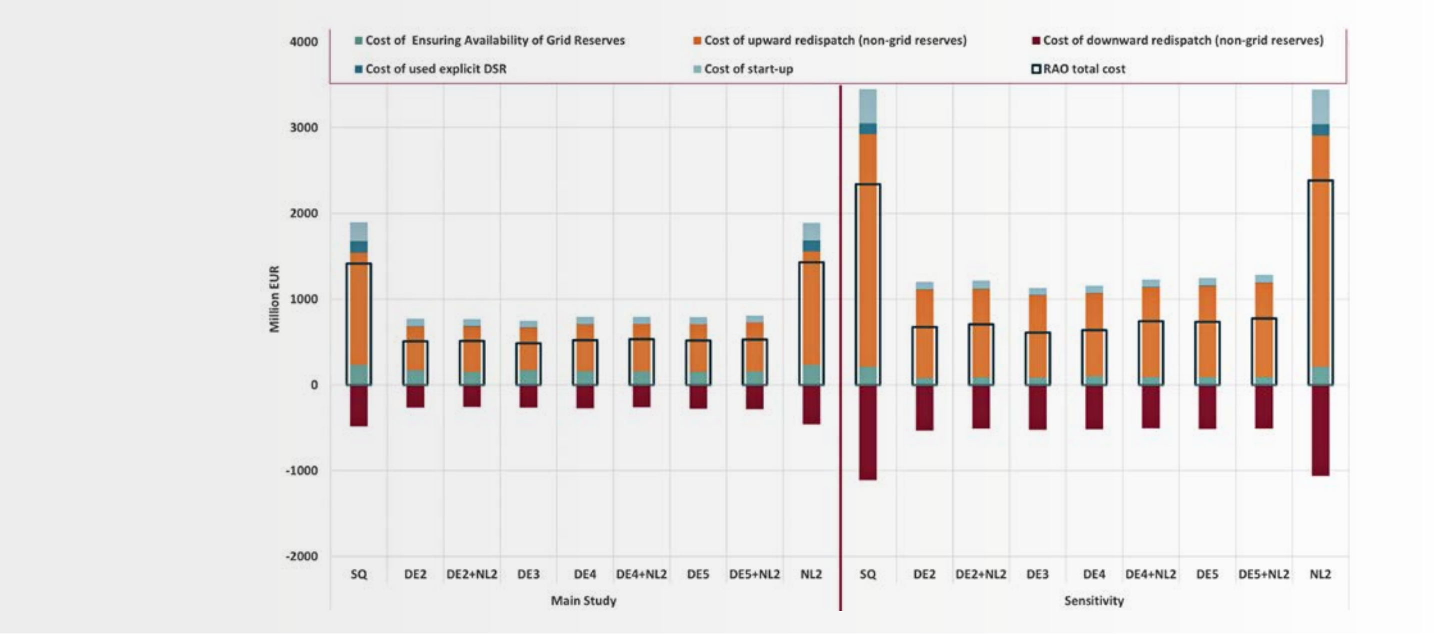

Figure 5: Comparison between total redispatch cost components between the main scenario and sensitivity run, for climate year 1989 only (annualised values).

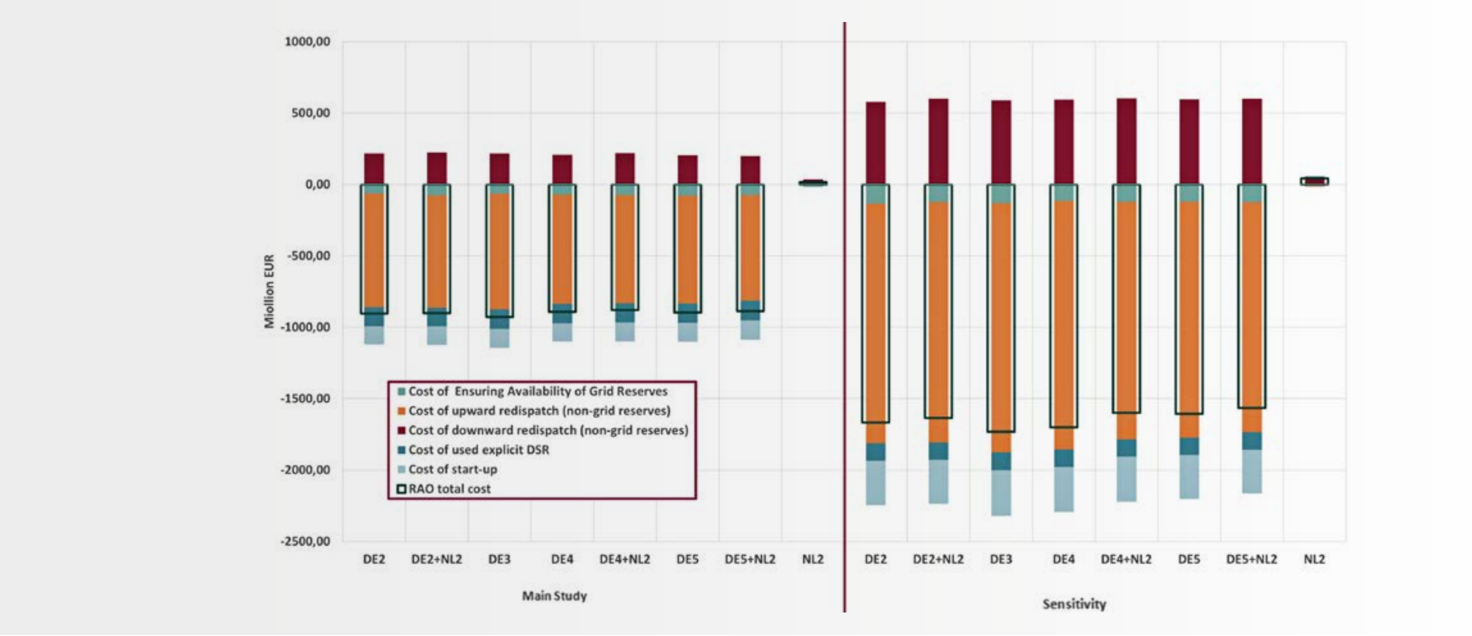

Figure 6: Comparison between redispatch savings between the alternative configurations and the SQ for the main scenario and sensitivity run, for climate year 1989 only (annualised values).

Considering the combined welfare impacts deriving from both the market coupling and the RAO, Table A shows the change in overall socio-economic welfare components vs the SQ for the alternative configurations for the sensitivity analysis (climate year 1989 only). Comparing these results with the overall welfare results for the same underlying climate year 1989 from the main scenario (Table 2) shows that:

› **The impacts of a BZ split in the sensitivity analysis largely mirror those in the main study.** For all the German-Luxembourgish splits and the combinations, overall market welfare decreases, while redispatch costs are lower.

› **In terms of magnitude, the sensitivity runs shows a higher deterioration in market welfare in the splits vs the SQ in the sensitivities than in the main scenario.** While consumer surplus and congestion revenues are higher, the loss of producer surplus is also higher. This is a result of the structurally higher prices in the sensitivity runs in general (driven by the higher fuel and carbon prices), and higher price differentials between zones.

› **At the same time, redispatch savings in the alternative configurations are also higher in the sensitivity runs, leading to an improvement in overall socio-economic welfare** in all the assessed configurations for the sensitivity in climate year 1989, apart from the NL2 split.

› **The magnitude of the total benefits to socio-economic welfare of the considered splits (Criterion 4) is in a similar range in the sensitivity results as in the main scenario,** in the order of 400 to 500 million EUR per year (in climate year 1989). This shows that higher market welfare losses and higher redispatch savings in the sensitivity largely cancel each other out, leading to similar overall welfare benefits in the sensitivity as in the main scenario.

› **The DE5 split is also the best performing configuration in the sensitivity run (for climate year 1989).** The other configurations have slightly different rankings than in the main study. However, as only one climate year was considered for the sensitivity, it is not possible to make a complete comparison of rankings with the main study results (but this is not the goal of the sensitivity analysis).

	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 the costly 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 1: Change in overall socio-economic welfare components vs the SQ for the alternative configurations for the sensitivity analysis (climate year 1989 only)

	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 the costly redispatch (€ million)	Socio-economic welfare (criterion 4) (€ million)
DE2	−480	387	−1,669	802	−927	447
DE2 + NL2	−444	934	−2,402	1,024	−905	461
DE3	−502	638	−2,102	963	−928	427
DE4	−425	670	−1,962	866	−892	467
DE4 + NL2	−444	143	−1,547	961	−880	437
DE5	−367	939	−2,582	1,276	−897	530
DE5 + NL2	−347	520	−1,903	1,036	−887	540
NL2	1	−40	−65	105	16	−15

Table 2: Change in overall socio-economic welfare components vs the SQ for the alternative configurations for the main scenario (climate year 1989 only)

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