European Resource Adequacy Assessment

2025 Edition

ENTSO-E's proposal for ACER's approval

Executive Report

entsoe

Foreword

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the association 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.**

Before ENTSO-E was established in 2009, there was a long history of cooperation among European transmission operators, dating back to the creation of the electrical synchronous areas and interconnections which were established in the 1950s.

In its present form, ENTSO-E was founded to fulfil the common mission of the European TSO community: to power our society. At its core, European consumers rely upon a secure and efficient electricity system. Our electricity transmission grid, and its secure operation, is the backbone of the power system, thereby supporting the vitality of our society. ENTSO-E was created **to ensure the efficiency and security of the pan-European interconnected power system** across all time frames within the internal energy market and its extension to the interconnected countries.

ENTSO-E is working to secure a carbon-neutral future. The transition is a shared political objective through the continent and necessitates a much more electrified economy where sustainable, efficient and secure electricity becomes even more important. **Our Vision: "a power system for a carbon-neutral Europe"*** shows that this is within our reach, but additional work is necessary to make it a reality.

In its Strategic Roadmap presented in 2024, ENTSO-E has organised its activities around two interlinked pillars, reflecting this dual role:

- "Prepare for the future" to organise a power system for a carbon-neutral Europe; and
- "Manage the present" to ensure a secure and efficient power system for Europe.

ENTSO-E is ready to meet the ambitions of Net Zero, the challenges of today and those of the future for the benefit of consumers, by working together with all stakeholders and policymakers.

* https://vision.entsoe.eu/

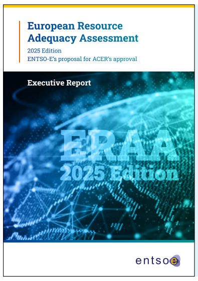
Disclaimer

ENTSO-E and the participating TSOs have followed accepted industry practice in the collection and analysis of available data. While all reasonable care has been taken in the preparation of this data, ENTSO-E and the TSOs are not responsible for any loss that may be attributed to the use of this information. The interested parties should not solely rely upon data and information contained in this report in taking business decisions.

Information in this document does not amount to a recommendation in respect of any possible investment. This document does not intend to contain all the information that a prospective investor or market participant may need. ENTSO-E emphasises that ENTSO-E and the TSOs involved in this study are not responsible in the event that the hypotheses presented in this report or the estimations based on these hypotheses are not realised in the future.

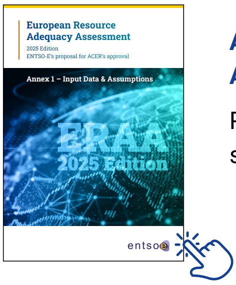
European Resource Adequacy Assessment (ERAA) 2025: Navigating the package

ERAA 2025 is divided into eight parts (Executive Report and Annexes) to help readers identify relevant information:



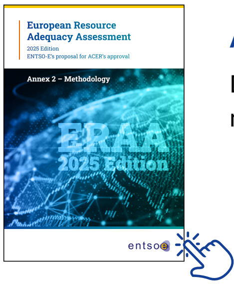
Executive Report

Overview of the main results followed by a description of the ERAA 2025 purpose and a high-level overview of the scenario, main assumptions and stakeholder engagement.



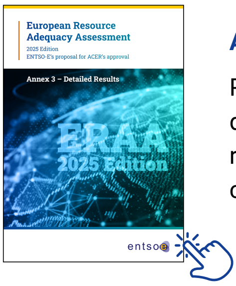
Annex 1: Input Data and Assumptions

Presentation of the ERAA 2025 scenarios and assumptions.



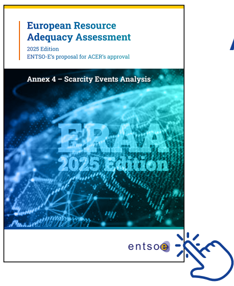
Annex 2: Methodology

Description of the ERAA 2025 methodology.

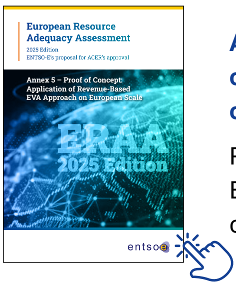


Annex 3: Detailed Results

Presentation of the ERAA 2025 detailed results for the central reference scenario and EVA comparisons related to CONE.

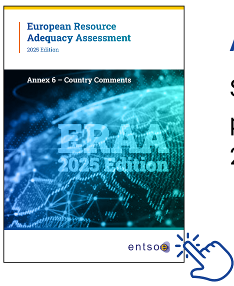


Annex 4: Scarcity Events Analysis



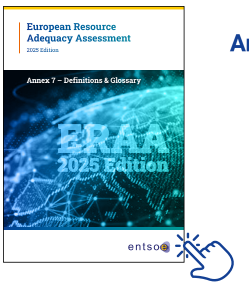
Annex 5: Case Study – Application of Revenue-Based EVA Approach on European Scale

Revenue-based approach for the EVA, including methodology and case study results.



Annex 6: Country Comments

Specific comments, optionally provided by TSOs on the ERAA 2025 input data and results.



Annex 7: Definitions & Glossary

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1 Executive summary

The ERAA is a pan-European monitoring assessment of power system resource adequacy up to 10 years ahead, as provided in Article 23 of Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast) (hereinafter the "Electricity Regulation"). It is based on state-of-the-art methodologies and probabilistic assessments, aiming to model and analyse investment behaviour under perfect market assumptions and all the key variables that could adversely impact the balance between electric power supply and demand.

ERAA results inform governments and institutions about resource adequacy concerns at the European and national levels, along with potential needs to ensure the security and reliability of their electricity systems. It is an important tool for supporting qualified decisions by policy makers on strategic matters such as the introduction of capacity mechanisms (CMs). Together with national resource adequacy assessments that also identify adequacy concerns, ERAA 2025 supports Member States in deciding how to address potential national adequacy concerns, including the implementation of CMs to guarantee resource adequacy.

The transformation of the European power system creates significant adequacy challenges

The European electricity system is undergoing significant changes motivated by the EU's ambition to achieve climate neutrality by 2050, as well as energy independence and security. The National Energy and Climate Plans (NECPs) revised in 2024 present updated assumptions of the pan-European power system. NECPs facilitate the objectives of the Fit for 55 Package and REPowerEU Plan, which accelerate the energy transition to "net zero" at a much larger scale, increasing renewable energy and energy efficiency targets for 2030. These ambitions are driving the integration of greater volumes of variable renewables, increased decentralisation, the emergence of new market players, the innovation and digitalisation of the electricity sector, and the phase-out of traditional fossil-fuelled thermal generation. These changes are occurring at an unprecedented speed, and the power system must adapt swiftly in response to new challenges. At the same time, the security and adequacy of the European energy infrastructure have become more critical than ever due to drastic changes in the geopolitical landscape. Amid this rapid transition, system operators must safeguard security of supply and maintain a balance between supply and demand across the interconnected system year-round. The ERAA and national resource adequacy assessments (NRAAs) aim to provide insight into this balance from both mid- and long-term perspectives.

Europe will see a rapid increase in renewable energy sources (RES), a decrease in fossil-fuelled generation, and a substantial increase in electrification of multiple sectors, such as industry, transportation, and heating. Several EU Member States anticipate an unprecedented rise in electricity demand over the coming decade, creating significant adequacy challenges. These changes will impact how Europe ensures the adequacy of its electricity system in the future. This is also crucial, alongside achieving carbon neutrality by 2050, to foster industry competitiveness and energy affordability as key policy objectives for the EU in the years ahead.

Transmission system operators (TSOs) use the latest information on the ever-evolving European power system to make future projections. The findings of ERAA 2025 include the impact of these projection updates on the evolution of adequacy concerns, underscoring the importance of regular monitoring of the situation.

The European power system is highly interconnected. Interconnections play an increasingly crucial role in ensuring security of supply, especially with the growing integration of solar and wind, with high spatial and temporal variability. Therefore, assumptions made for one country can significantly impact the adequacy results of neighbouring countries, or even of those not directly interconnected. It is therefore crucial that the methodology is based on sound, transparent and plausible investment assumptions.

The potential of demand-side response (DSR) deployment across Europe is highly uncertain. Additional market opportunities for DSR are assessed in the ERAA in the economic viability assessment (EVA), while policy-driven investments are also considered based on TSOs' best estimates stemming from national policy ambitions for DSR deployment. However, these ambitions are still uncertain, and the projections are refined in every ERAA edition.

Action is needed to maintain the security of supply for electricity in Europe

In addition to generation units approaching the end of their technical lifetimes in the next decade, ERAA 2025 finds that significant volumes of fossil-fuelled capacity are likely to become economically non-viable over the assessed horizon, with only local market opportunities for investments. Potential investors will apply different investment strategies for decision-making and exhibit different levels of appetite towards investment risk, which creates further uncertainties regarding whether investments will materialise. ERAA 2025 considers these uncertainties in the assessment of the central reference scenario.

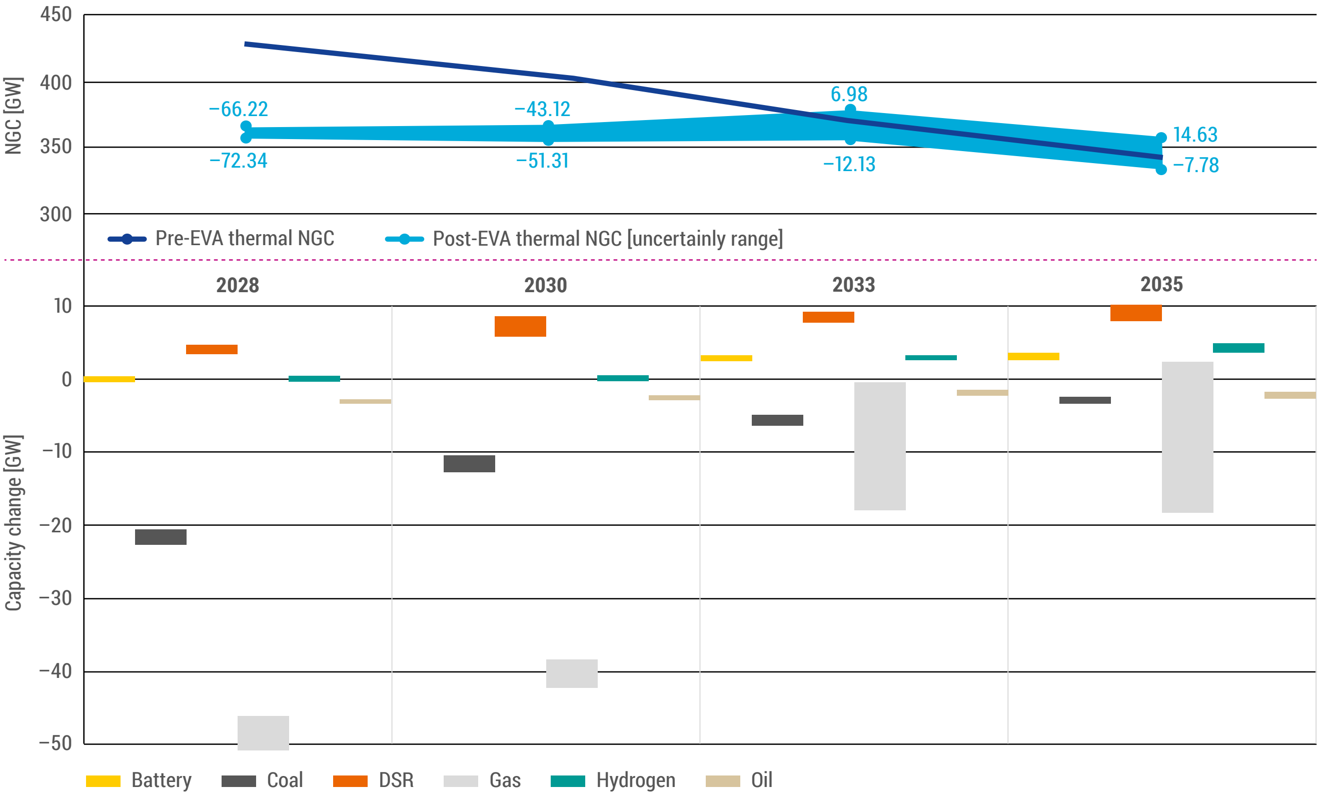

Figure 1: Net effect of the EVA on the European mix

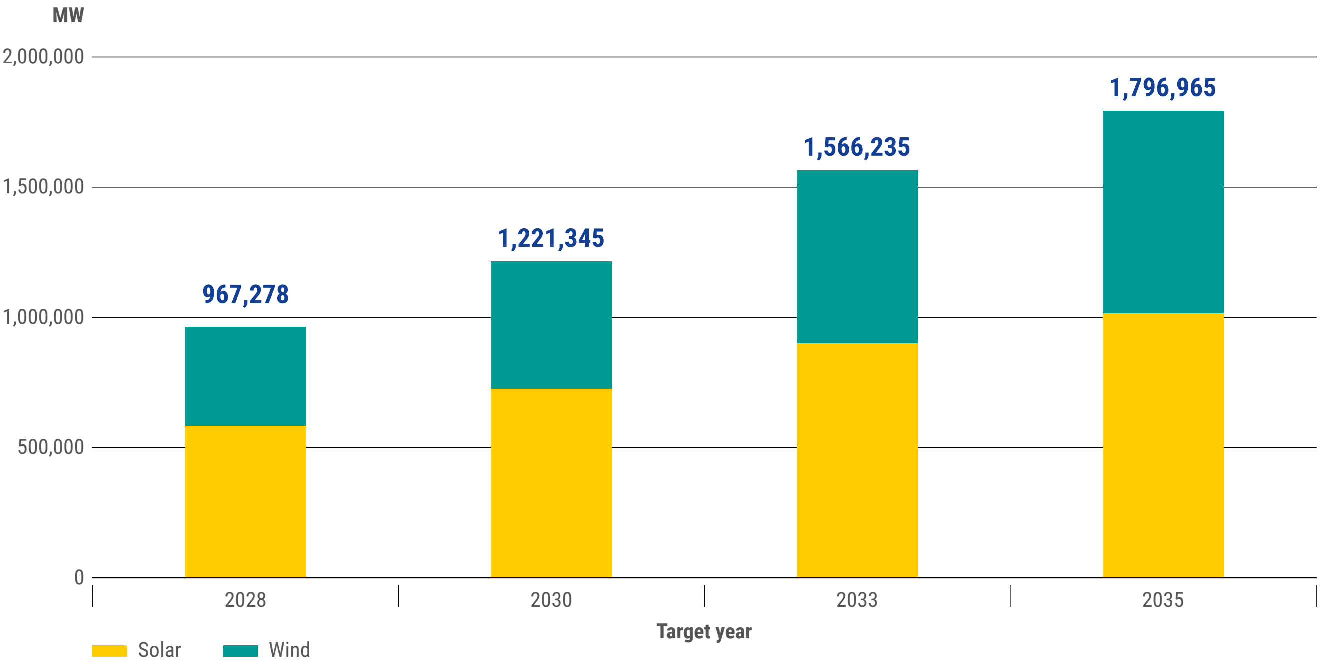

Figure 2: Anticipated wind and solar capacity evolution [MW]

ERAA findings reveal that different investment strategies may lead to a wide range of expected capacity resources. In 2035, the power supply fleet may vary by up to 21 GW due to the uncertainty of investment strategies adopted. In ERAA 2025, improved investor risk-aversion modelling was introduced, characterised by an enhanced calculation of hurdle premiums and a revenue cap to exclude rare scarcity events with exceptionally high price signals from investment decision-making, as these events may not be considered as reliable revenue sources from a rational investor's perspective.2 The EVA obtains a range of results by implementing two different risk-aversion modelling approaches: a) with the enhanced hurdle premium only, and b) with the enhanced hurdle premium combined with a revenue cap.

The main takeaways from the EVA are:

- In the short- and mid-term (years 2028 and 2030) significant capacities are at risk of being decommissioned, with a moderate uncertainty range (6–8 GW).
- In the longer term (2033 and 2035), the risks of decommissioning remain for the assumed thermal generation fleet in general. Some expansion may be expected in 2035, but this remains uncertain and dependent on the investment strategies adopted by investors, as shown by the range in Figure 2. Moreover, these investments would require a favourable context beyond the scope of the ERAA (supply chain considerations, energy transmission networks, primary energy availability, etc.).
- The development of the power system must be closely monitored to confirm that investments will be realised. ERAA 2025 demonstrates that investment strategies, which were simulated including different investor risk-aversion approaches, have a huge impact on esource adequacy. Relevant authorities can reflect on possible mitigation actions to secure European adequacy.
- The equivalent should be monitored for existing power plants to ensure that the decommissioning of the current fleet will not exceed the anticipated levels.
- Renewable generation capacity is expected to expand over the coming years based on national policy targets and TSO estimates (Figure 2). However, due to the intermittency of renewable resources, the capacity will not be sufficient to compensate for the expected decline in dispatchable thermal generation and the growing electrification by 2035.

Notable adequacy risks are observed across Europe. Available reliability standards (RSs) are exceeded widely (see Figure 3 and Figure 4). Only occasionally do adequacy risks remain below (compliant with) the RSs.

The results show adequacy risks with a notable range of uncertainty in the near future. The uncertainty range represents the impact of the aforementioned different modelling approaches to investor risk aversion on the investment decisions, which affect the expected available market capacity and thus the adequacy indicators. Adequacy risks generally increase the further we look into the future. They tend to be lower in the Balkan region and part of Scandinavia. Existing non-market resources for mitigating adequacy risks, such as contracted strategic reserves, have already been accounted for in these assessments. The identified notable adequacy risks indicate the need for additional resources to remedy them.

At the European level, the adequacy risk from decommissioning thermal capacity due to economic unviability remains, despite ambitious policy targets to support renewable generation capacity, storage, and DSR expansion, and some additional investment opportunities identified in the EVA. In this context, the right incentives and/or targeted intervention, such as long-term market mechanisms, are essential to avoid adequacy risks by providing efficient price signals. These signals would trigger both the retention of existing capacity in the market and the timely deployment of new capacity in the right location.

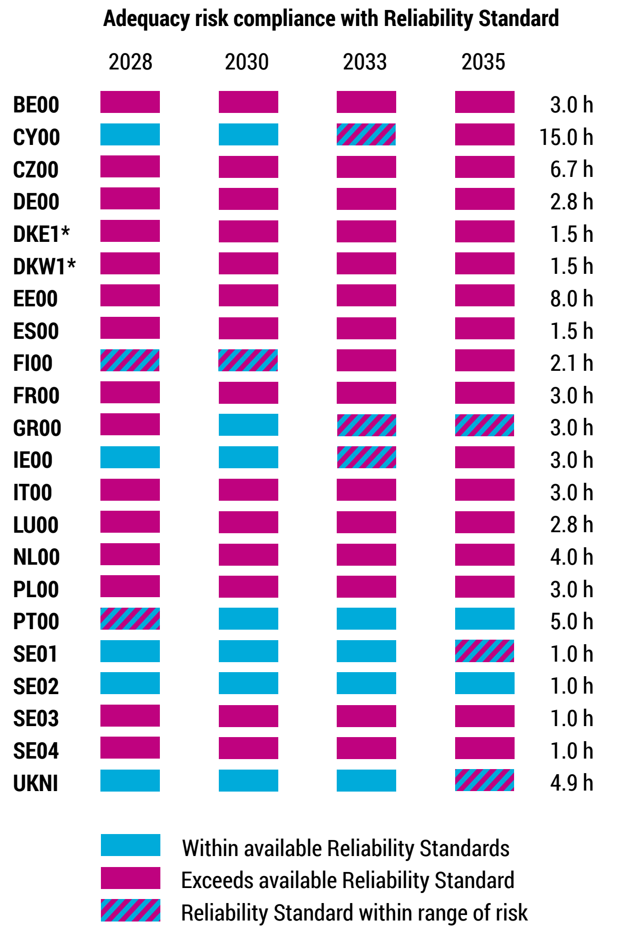

Figure 3: Overview of adequacy risk compliance with established reliability standards

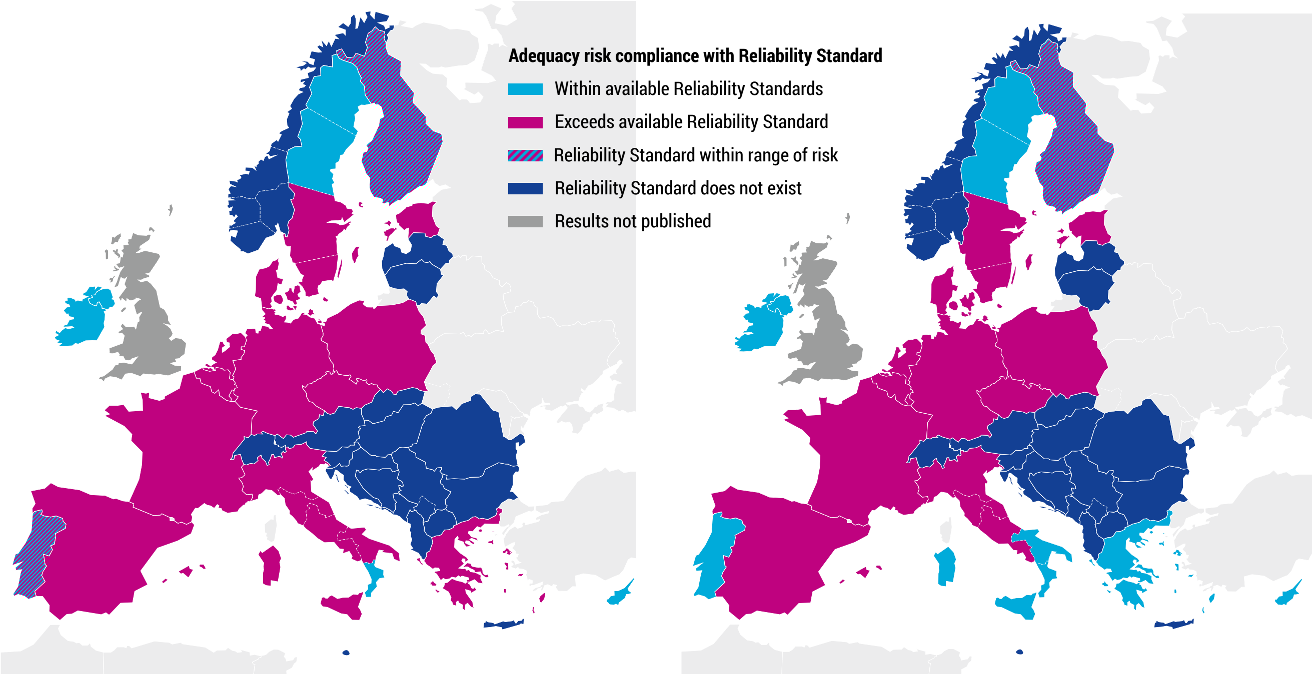

Figure 4: Adequacy risks in 2028 (left) and 2030 (right) – pivotal year for CM establishment (detailed maps on page 14–17)

Urgent action is needed: additional policy mechanisms must be promoted where necessary to enable the transition while maintaining system security until the aforementioned incentives and/or targeted interventions are established. To accelerate the implementation of CMs, in May 2025, the European Commission (EC) established a fast-track option under the Clean Industrial Deal State Aid Framework (CISAF).

To ensure electricity security and meet climate objectives, Europe must accelerate the deployment of flexibility solutions and infrastructure, including a cross-border electricity transmission network to direct electricity from renewable sources where it is most needed, as well as storage and other sources of flexibility, while safeguarding security of supply at all times.

National adequacy assessments complete the ERAA

Many Member States complement the ERAA with an NRAA across Europe. NRAAs can provide a more detailed picture of a Member State's adequacy concerns, taking into account specific characteristics of national systems that may not be reflected in ERAA outcomes given the enormous size and complexity of the EU power system and computational constraints.

While the ERAA is one of the instruments used to inform EU Member States and National Regulatory Authorities (NRAs) about the level of security of supply and serves as the basis for decisions on different market design options by providing a comprehensive pan-European overview of capacity concerns, it is not the sole basis for identifying resource adequacy concerns. NRAAs are also essential, as they provide a complementary and more detailed picture of national specificities and local sensitivities. The ERAA and NRAAs should therefore be considered in conjunction.

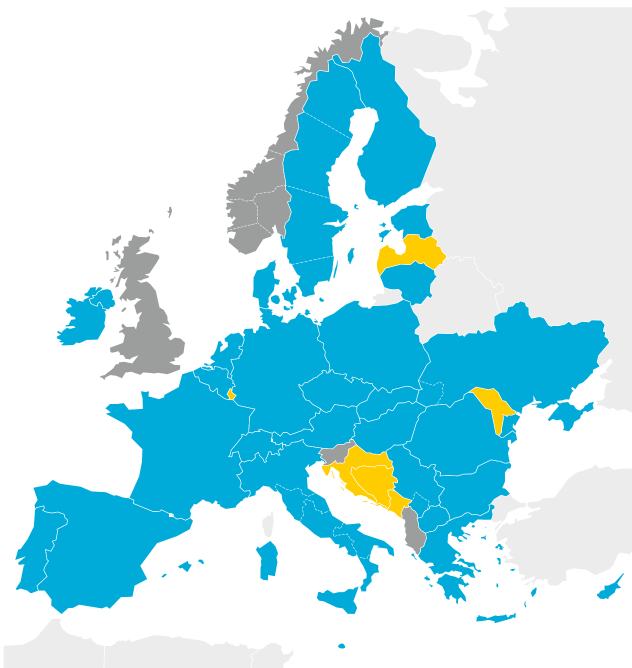

Figure 5: NRAA overview across Europe (August 2025 snapshot)

An evolving tool in a European power system undergoing a fundamental transformation

ERAA 2025's methodological approach is unmatched globally. The calculation complexity pushes the limits of computational power, given the constraints of preparation, execution, and delivery within a yearly publication timeframe. The implementation of the ERAA methodology has steadily advanced since 2021 and will continue to evolve.

ERAA 2025 includes significant improvements that were carefully selected based on their priority and the feasibility of deploying them within the same ERAA cycle. One major improvement was the inclusion of the aforementioned investor risk-aversion strategies in the EVA. Another was the application of an extended methodology for representative weather scenario selection for EVA models (see Annex 2). Finally, the proof-of-concept for the revenue-based EVA developed in the previous ERAA was expanded and completed, indicating that this approach is now mature enough for application in the next ERAA cycle.

With the increasing integration of Europe's electricity markets, along with the deployment of large quantities of renewable capacity and shifting demand patterns, resource adequacy will continue to be a major focus for decades to come. ENTSO-E believes that, in compliance with the Electricity Regulation, the purpose of the ERAA is to identify adequacy concerns and should not be reduced to a mere tool for central decisions on CMs. The ERAA supports the prerogative of Member States to decide how to address such adequacy concerns, and build mid- and long-term strategies accordingly. It includes pioneering methodologies and tools to analyse future adequacy with an unmatched level of scope and detail, making it a valuable resource for shaping the future of Europe's electricity grids. Therefore, ENTSO-E stresses the importance of refining credible reference scenarios in the ERAA, enhancing the complementarity of NRAAs, and respecting Member States' national prerogatives to define policy options for calculating CM parameters. ENTSO-E has submitted a draft revised ERAA methodology to ACER for approval. The ERAA continues to serve as an effective tool for identifying system needs. Ongoing methodological innovation, refinement of its scope, pilot programmes, and stakeholder consultation will continuous to enhance the ERAA's value.

2 Main findings of ERAA 2025

This section presents the main findings of the assessment, with more detailed results available in Annex 3. Assessing the adequacy situation in the ERAA is the outcome of a two-step modelling approach:

1. **Assessing the economic viability of the capacity resources:** This is the EVA, a risk assessment that evaluates potential outcomes related to the likely decommissioning of existing capacity or the possible new investment of capacity resources in the energy-only market.[1] The objective is to estimate, for all target years (TYs), the portfolio of capacity resources expected in the European system from an investor's perspective.

2 **Evaluate the adequacy situation in an economically viable scenario.** This step assesses the future power system's ability to maintain security of supply across a wide range of potential future system states resulting from various plausible weather conditions, as well as random outages of conventional power plants and relevant cross-border interconnectors. The objective is to calculate the adequacy indicators and identify adequacy concerns based on the portfolio of capacity resources obtained in Step 1.

The ERAA is characterised by a high degree of uncertainty and computational constraints. Thus, it is essential to consider the modelling decisions and assumptions, as well as the probabilistic nature of the assessment, when interpreting the results. A major improvement of ERAA 2025 was to refine investment strategies by integrating different modelling approaches to investor risk tolerance strategies. A hurdle premium and a revenue cap, designed to diminish the impact of rare scarcity events with exceptionally high price signals – or even exclude them from investment decisions entirely – are important elements that enable a more accurate representation of appropriate investor risk-aversion behaviour, as supported by a public survey conducted during the ERAA methodology improvement.[2] All modelling assumptions and decisions are described in Annex 2.

2.1 Significant volumes of fossil fuel capacity are at risk of economic decommissioning with high uncertainty regarding the degree of decommissioning

The EVA suggests that substantial fossil-fuelled generation capacity is at risk of insufficient revenues to maintain viability in the energy-only market. Different investment strategies can result in a wide range of future generation portfolios. By 2035, capacity could vary by up to 21 GW, depending on the modelling approach to investor risk-aversion, as one aspect of investment strategies. In ERAA 2025 the investor risk aversion is characterised by a) an enhanced hurdle premium only, and b) an enhanced hurdle premium combined with a revenue cap to diminish the impact of rare scarcity events with exceptionally high price signals, or even exclude them from investment decisions to better represent real market investor behaviour.

The decrease in fossil-fuelled capacity within the system may be steeper than currently anticipated through 2033. While some DSR expansion is observed over the horizon, only 2035 shows local potential for gas-fuelled generation expansion. For the first time ever, the EVA identifies viable market opportunities for investments in emerging hydrogen-fuelled generation.[3] Market opportunities for storage and DSR technology are assessed across all TYs. The post-EVA capacity graph suggests that viable market opportunities tend to remain strained overall in Europe.

1 Simulating potential investment decisions based on modelled market scarcity price signals with limited occurrence over a 10-year period is a highly complex task that involves uncertainties and could be non-representative for some investors.

2 Summary of responses to the "Investor Survey: How can ERAA better reflect real investment behaviour?"

3 These findings are primarily driven by future assumptions and especially by assumed commodity prices, in particular high CO_2 and gas blend cost, and investment costs, which are still highly uncertain for emerging technologies. Actual deployment of hydrogen-fuelled generation would largely depend on investors' perspectives towards future fuel prices and their risk aversion, which may be mitigated or exacerbated depending on the development of hydrogen policies at the European or national level. Important factors in the deployment of hydrogen-fired capacity are the availability of fuel supply and its distribution infrastructure. Both factors and associated costs are neglected in the EVA assessment.

Decision variable	Technology	2028	2030	2033	2035	Affected study zones
New entry	**Battery**	0.00	0.00	2.83* up to 2.9	2.86* up to 3.4	ES00
	DSR	3.74* up to 4.07	6.06* up to 8.37	8.03* up to 9.11	8.2* up to 10.05	BG00, DE00, DKE1, DKW1, FI00, GR00, HR00, HU00, NL00, PT00, RO00, SE01, SE02, SE03, SE04, SI00, SK00
	Gas OCGT	0.00	0* up to 0.76	6.71* up to 20.83	8.88* up to 26.98	DE00, DKE1, DKW1
	Hydrogen CCGT	0.00	0.00	2.73 up to 2.74*	3.85 up to 4.61*	CZ00, PL00
	Total	**3.74* up to 4.07**	**6.06* up to 9.13**	**20.31* up to 35.57**	**24.55* up to 44.28**	
Life Extension	**Gas CCGT**	0.14* up to 0.4	4.07* up to 5.09	4.75* up to 5.59	4.77* up to 6.01	BE00, DE00, HU00, NL00
	Gas OCGT	0.00	0.27 up to 0.3*	0.46 up to 0.55*	1.06 up to 1.15*	DE00, LT00
	Total	**0.14* up to 0.4**	**4.37* up to 5.36**	**5.3* up to 6.05**	**5.92* up to 7.07**	
Decom-mission-ing	**Gas CCGT**	−34.5 up to −37.83*	−40.3 up to −41.9*	−26.38 up to −28.22*	−30.66 up to −31.54*	AT00, BE00, BG00, FI00, FR00, GR00, HR00, HU00, IE00, ITCA, ITCN, ITCS, ITN1, ITS1, ITSI, MK00, NL00, PT00, RO00, SE03, SE04, UK00
	Gas OCGT	−12.26 up to −12.69*	−4.21 up to −4.82*	−1.28 up to −1.53*	−1.16 up to −1.4*	AT00, BG00, DE00, FI00, FR00, HR00, IE00, ITCS, ITS1, LT00, RO00, SE01, SE03, SI00, UK00
	Hard Coal	−4.19 up to −5.97*	−3.2 up to −5.01*	−0.69 up to −1.57*	−0.17 up to −0.5*	BG00, DE00, FI00, HU00, PL00
	Lignite	−16.63* up to −16.66	−7.5 up to −7.56*	−4.53 up to −4.58*	−2.63	BA00, BG00, CZ00, DE00, GR00, HU00, IE00, ME00, PL00, RO00, SI00
	Oil	−3.08 up to −3.1*	−2.4 up to −2.45*	−1.76 up to −1.84*	−2.1 up to −2.18*	CY00, DE00, FR00, GR03, HR00, IE00, ITCS, SE03, UK00, UKNI
	Total	**−70.69 up to −76.22***	**−57.61 up to −61.74***	**−34.64 up to −37.74***	**−36.72 up to −38.25***	
Total		**−66.22 up to −72.34***	**−43.12 up to −51.31***	**−12.13* up to 6.98**	**−7.78* up to 14.63**	

Table 1: Capacity change proposed by the EVA compared to the National Trends scenario [GW] – non-cumulative
(* denotes results where investors consider revenue cap under their strategy.)

About the EVA methodology

The cost-based EVA assesses the viability of capacity resources5 participating in the energy-only market using a long-term planning model to minimise total system costs. Generation capacities with an awarded CM contract, as well as other policy-driven capacities, are excluded from the EVA. The EVA is a risk assessment of what could happen; it is not a prediction of what will happen. The model's key decision variables aim to identify the economically optimal (lowest cost) evolution of resource capacity over the modelled horizon and from a coordinated total system perspective.

This assessment therefore delivers insight, for each study zone and over the TYs, on the resource capacities that could be (i) decommissioned, (ii) newly built, (iii) (de) mothballed, or (iv) extended in lifetime.

More details on the data and assumptions behind the EVA can be found in Annex 1, while the detailed cost-based EVA methodology is found in Annex 2. Annex 5 provides details on the revenue-based EVA approach and its results.

2.2 Adequacy risks appear in several European countries and margins are tight

Figure 6 to Figure 9 illustrate the loss of load expectation (LOLE) in TYs 2028, 2030, 2033, and 2035.[4] LOLE values indicate, for each study zone, the average number of hours per year during which demand is expected to exceed available domestic generation and imports, potentially requiring partial and controlled shedding. LOLE is represented by circles, with a larger radius indicating larger LOLE values. A study zone's LOLE is calculated by averaging the loss of load duration (LLD), i.e. hours with unserved energy, resulting from all simulated Monte Carlo years using the reference tool.

Adequacy risks are generally expected in hours with high electricity demand (95–100 % of peak demand value). While the impact of renewable generation is noted similarly across all TYs, adequacy risks appear to emerge even at lower demand levels. Details are provided in Annex 4.

More detailed results, including expected energy not served (EENS) per study zone, can be found in Annex 3. For the methodology and probabilistic indicators, please see Annex 2. In some cases, the results depend on the specific characteristics of each study zone. Annex 6 provides country-specific comments that enable more detailed conclusions.

2.3 Disclaimer on comparing ERAA 2025 results with ERAA 2024

Changes in results between ERAA editions are driven by input data updates and modelling enhancements. Input data updates incorporate recent development or policy revisions, ensuring simulations remain meaningful and current. Modelling enhancements are included when feasible and relevant, reflecting the latest developments and stakeholder needs, while aiming to improve the quality and robustness of the results. More details are available in Section 4.

4 The results presented below reflect the inclusion of contracted out-of-market measures, where their presence was reported by the TSOs. In Denmark, a planning target of max 5 annual interruption minutes due to resource adequacy is used. This is measured in the operation hour (i.e. after day-ahead, thus representing actual physical interruptions after activating reserves, for an average consumer). It is calculated as = 8,760 × 60 × Expected unserved energy/Demand. Denmark is in the process of establishing a reliability standard. The preliminary LOLE value is 1.49 hours (measured day-ahead, before reserves activation), subject to public consultation.

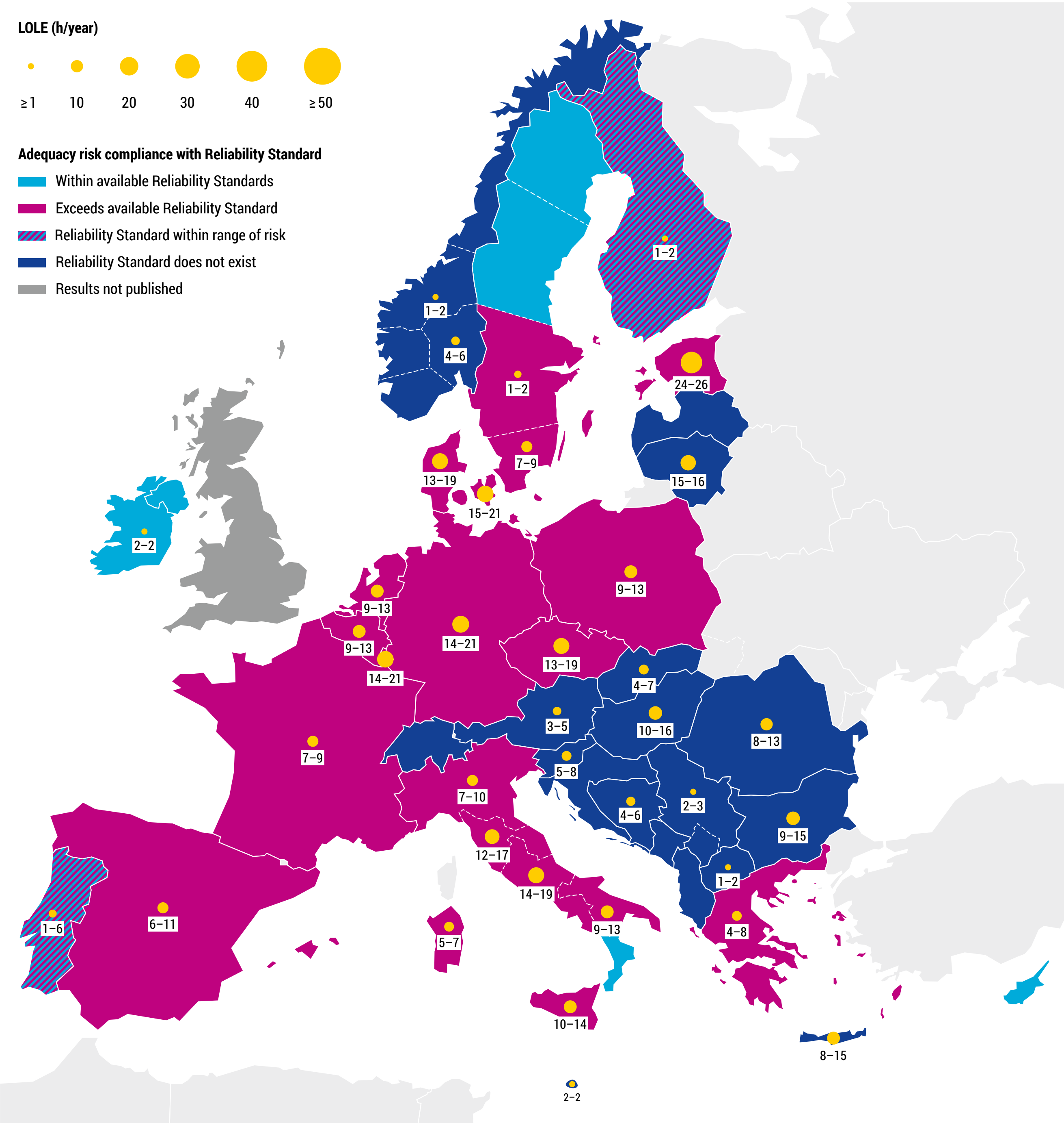

Figure 6: LOLE values in 2028

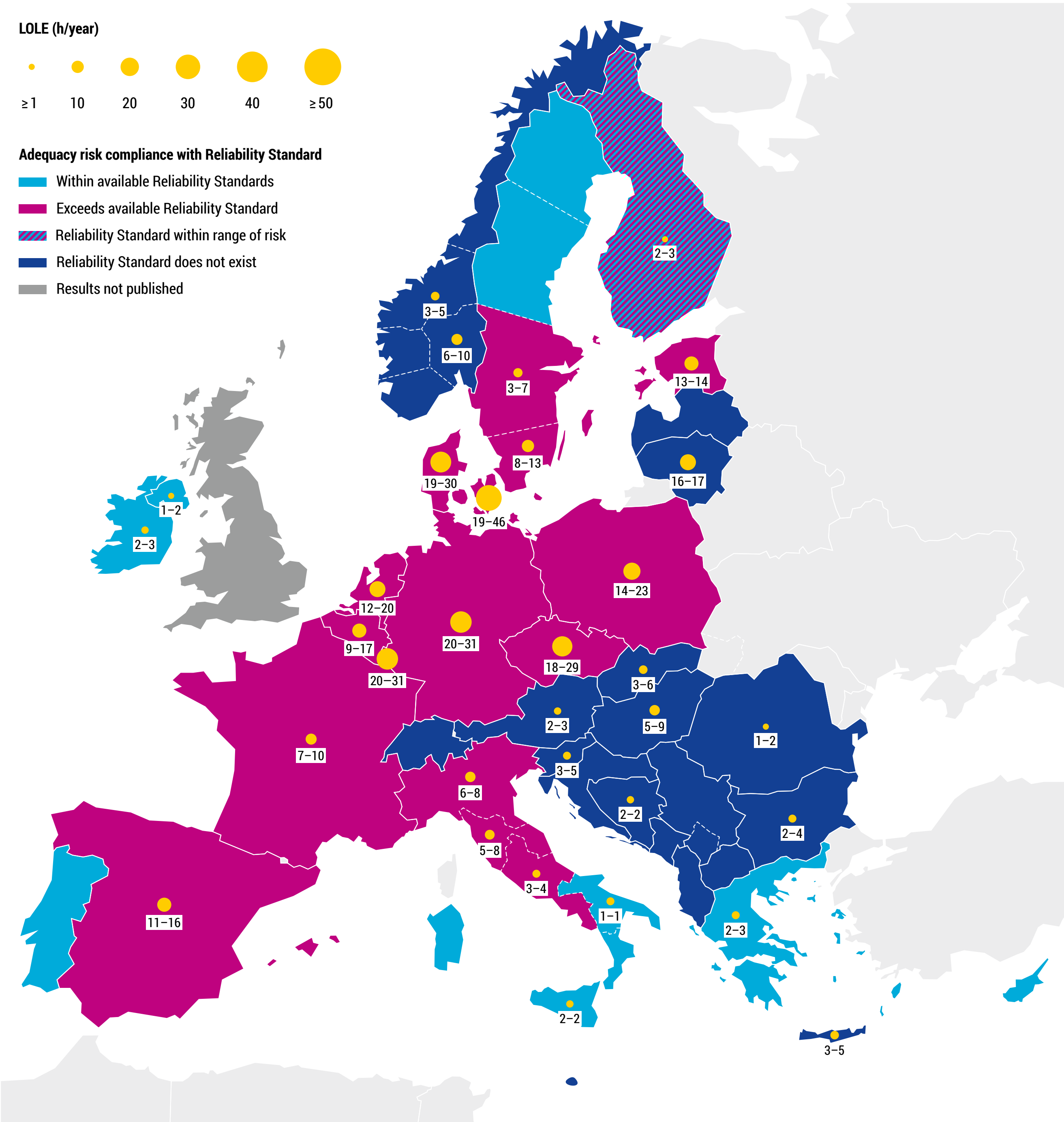

Figure 7: LOLE values in 2030

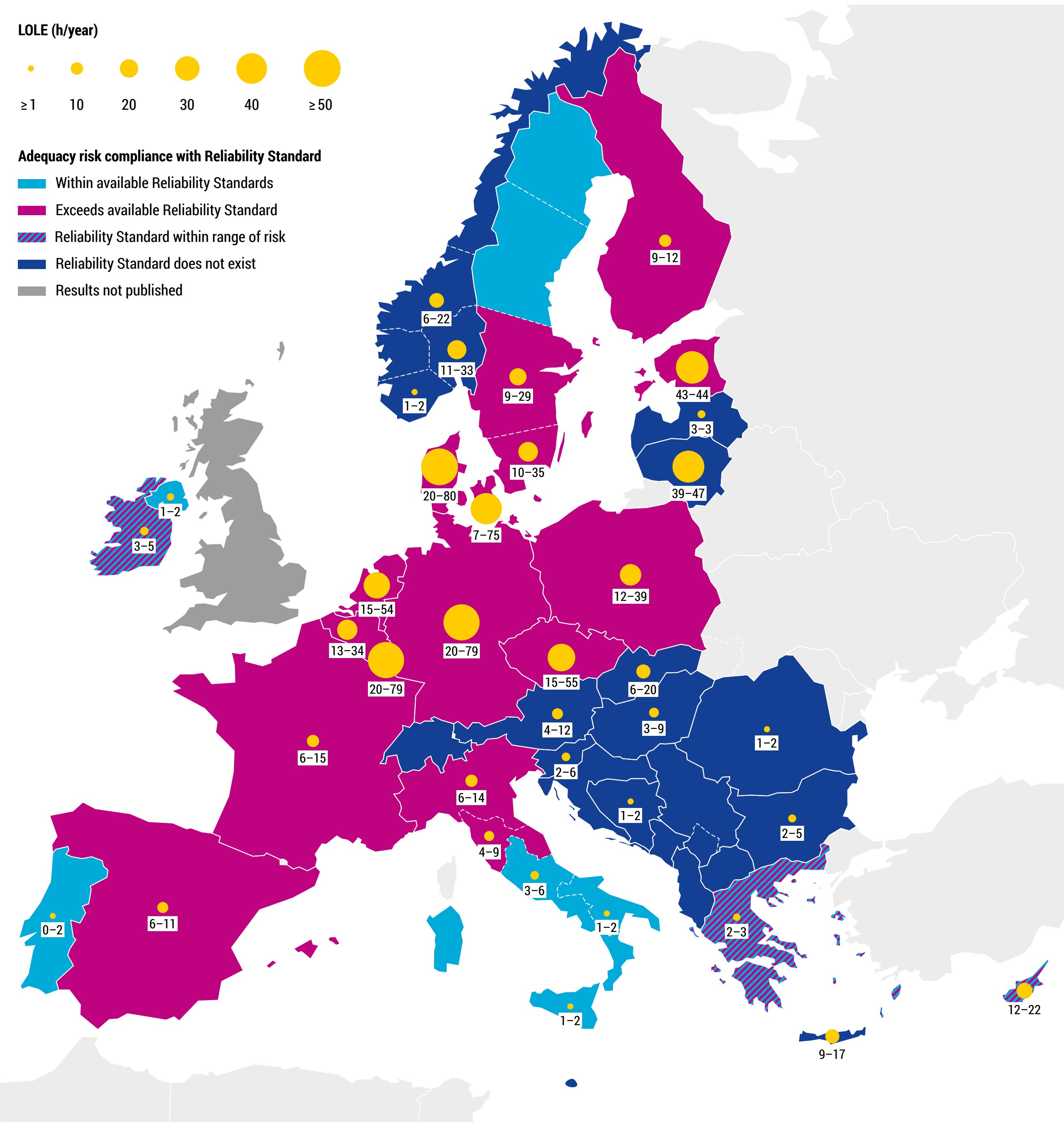

Figure 8: LOLE values in 2033

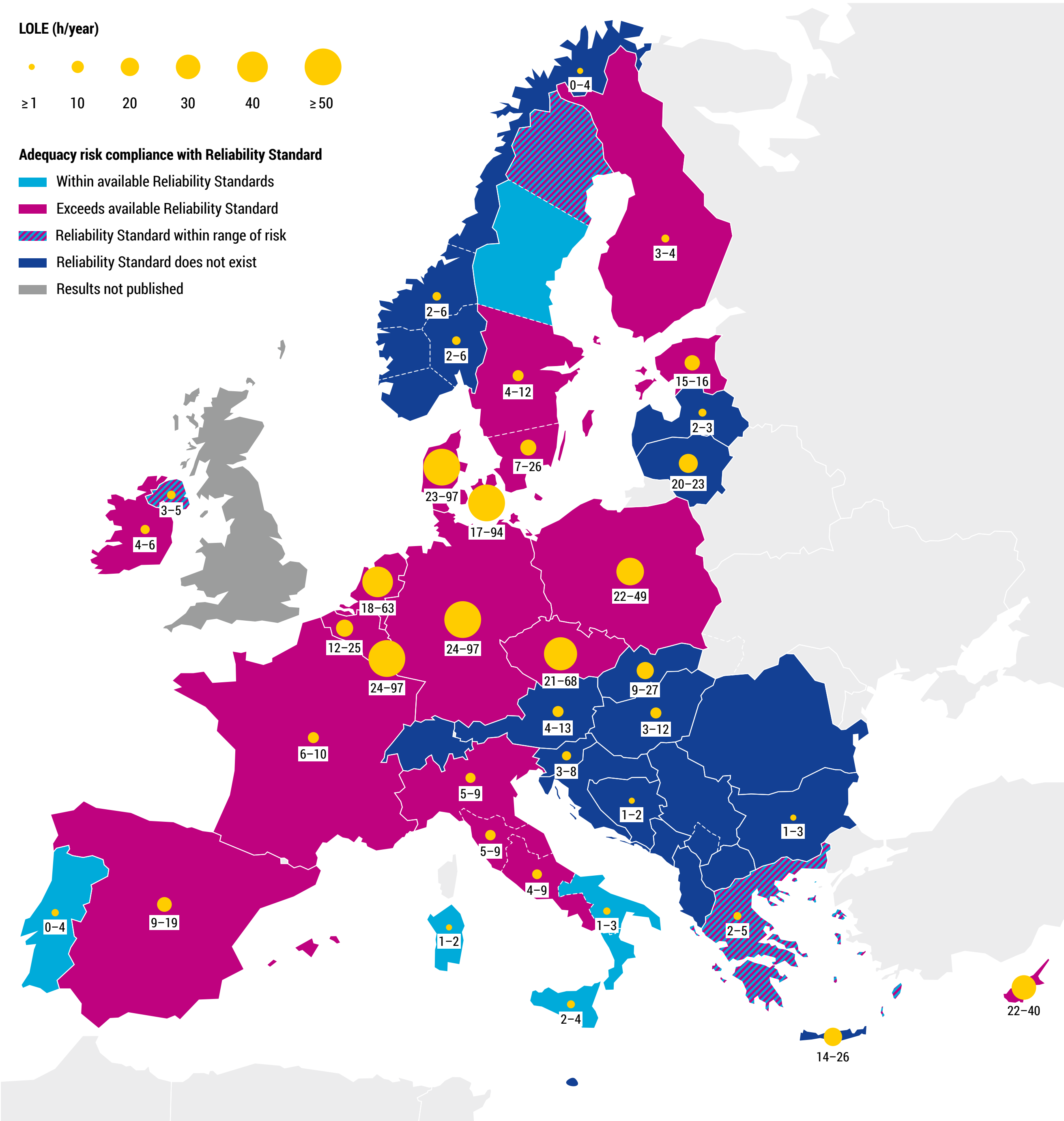

Figure 9: LOLE values in 2035

3 Purpose and motivation of the ERAA

3.1 General context

What is the purpose of the ERAA?

The ERAA is a pan-European monitoring assessment of power system resource adequacy up to 10 years ahead. Based on state-of-the-art methodologies and probabilistic assessments, it aims to model and analyse potential events that could adversely impact the balance between electric power supply and demand. The ERAA is a crucial tool for supporting informed decisions by policymakers on strategic matters to ensure power system security.

The European electricity system is undergoing significant changes, driven by the EU's ambition to achieve climate neutrality (cf. Fit for 55 legislative package) and independence from Russian fossil fuel (cf. REPowerEU plan and Wind Power package). These ambitions are driving the integration of greater volumes of variable renewables, increased decentralisation, the emergence of new market players, innovation and digitalisation, and the phase-out of thermal generation units. These changes are occurring at unprecedented speed, and the power system must adapt swiftly in response to new challenges. Amid this rapid transition, system operators must safeguard security of supply and maintain a balance between supply and demand across the interconnected system year-round.

In this context, a pan-European analysis of resource adequacy – complemented by insights from national assessments – is of key strategic importance. Cooperation across Europe is necessary to accelerate the development of common methodological standards, and a common "language" is necessary to perform these studies. The Electricity Regulation and Regulation (EU) 941/2019 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector (hereinafter "Risk Preparedness Regulation"), adopted as part of the Clean Energy Package (CEP), recognise this need.

Assessments of electrical system resource adequacy (such as the ERAA) are increasingly prominent studies that use advanced methodologies to model and analyse possible events with potentially adverse consequences for the electric power supply. Such assessments continuously assess the balance between net available generation and net demand levels in the European power system, as illustrated in Figure 5. The ERAA should not be seen as an effort to predict the system's security of supply, but rather as an assessment of the future power system's ability to maintain security of supply under a wide range of potential future system states resulting from various plausible weather conditions, as well as random outages of conventional power plants and relevant cross-border interconnectors. In summary, the ERAA does not predict the future; rather, it raises awareness on potential risks in the system to enable proactive intervention.

To identify these potential shortcomings, the calculated adequacy indicators of the ERAA can be benchmarked against available national reliability standards. Individual EU Member States apply the reliability standards to assess their national resource adequacy; an overview is presented Annex 1. LOLE, an indicator representing the expected number of hours during which supply would not meet demand, is the most common reliability indicator used by EU Member States, with targets typically in the range of one to a few hours per year.

The ERAA considers a perfect market and aims to provide stakeholders and policymakers with the data and insights necessary to make informed, qualified decisions and promote the development of the European power system in a reliable, sustainable, and connected manner. Resource adequacy assessments, such as the ERAA and those undertaken by national system operators, have contributed to the spatial harmonisation of adequacy methodologies across European

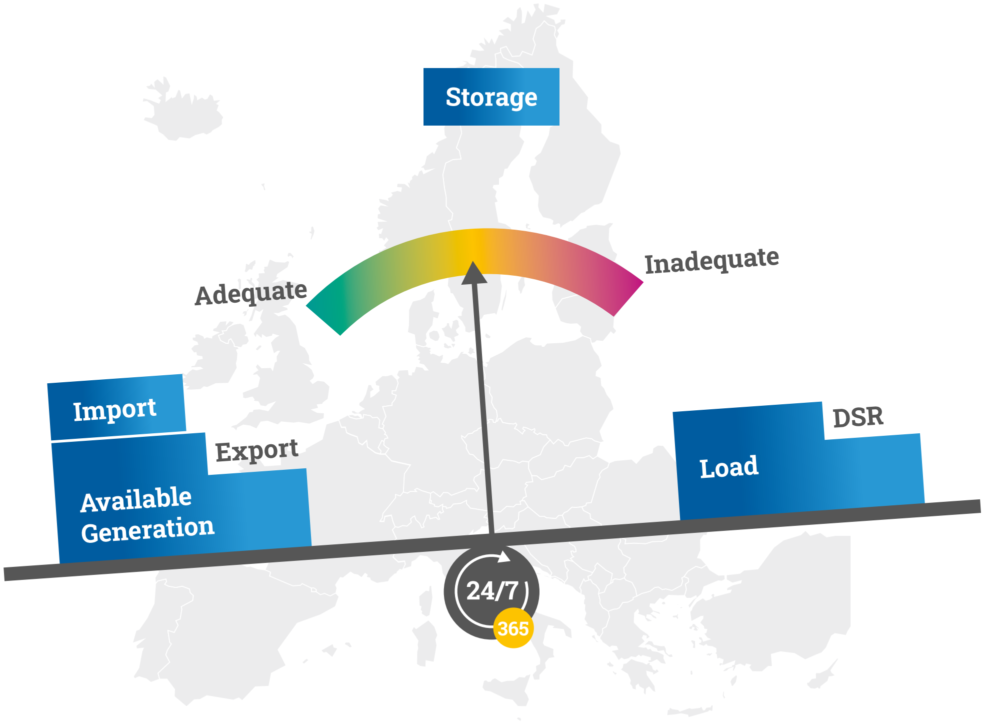

Figure 10: Resource adequacy: balance between net available generation and net load

TSOs. The ERAA is also coordinated and consistent with other time frame studies, such as the ENTSO-E's Ten-Year Network Development Plan (TYNDP) and Seasonal Outlook reports. Continuous developments in forecasting methodologies have improved the strength of these assessments, and the ERAA represents a substantial step forward.

Stakeholders can expect continuous improvements over different ERAA cycles, making the ERAA a useful and valuable tool, with analyses that better reflect the realities and complexities of the single electricity market. This includes an unparalleled dataset and an improved EVA. ERAA 2021 was the first step towards the implementation of the ERAA methodology. ERAA 2022 and ERAA 2023, while developed during a period when Europe was experiencing a deep energy crisis and an overhaul of many energy policies, delivered a study with complex approaches and significant methodological improvements. ERAA 2024 also demonstrated breakthrough advancement, most notably the first-ever integration of flow-based market coupling within the EVA. ERAA 2025 features further significant enhancements, which are detailed in Annex 2.

ENTSO-E is committed to an ERAA that meets the objective of the Electricity Regulation and is fit for purpose, especially when decision-makers seek guidance on risks and measures for the pan-European electricity system over the next decade. ENTSO-E's work on subsequent ERAAs will again consider the best available input received from extensive stakeholder engagement and more recent projections from European and national policies.

3.2 The ERAA's role within ENTSO-E's outlook studies

ERAA, the Seasonal Outlook and the TYNDP

The ERAA and the Seasonal Outlook aim to model and analyse potential events that could adversely impact the balance between electric power supply and demand in different future time horizons. The ERAA focuses on the medium-term horizon of 2 to 10 years ahead, while seasonal adequacy assessments assess the situation in the short-term for the upcoming season (weeks to months ahead). The TYNDP evaluates the long-term horizon, between 10 and 30 years ahead, from a different perspective than resource adequacy assessment, primarily transmission infrastructure system needs for market and RES integration.

Although all power system assessments are based on state-of-the-art methodologies, there are some key differences. The purpose of the ERAA is to identify adequacy concerns and raise awareness, with moderate uncertainty up to 5 years ahead that increases over longer horizons. It assesses long-term adequacy impacts through the EVA, which estimates resource capacity at risk based on specific assumptions for the next 10 years. The Seasonal Outlook aims to identify security of supply risks for the upcoming months, with low uncertainty due to its short-term focus and reliance on data and assumptions that closely reflect the near-term situation. The purpose of the TYNDP is to identify transmission infrastructure needs and no-regret investments through 2050, which involves a very high level of uncertainty about future developments.

Further to identifying adequacy concerns, the ERAA offers a midterm perspective on which capacities might lack sufficient revenues to cover their operating costs. This view is crucial for informing policymakers about potential incentives to support midterm adequacy.

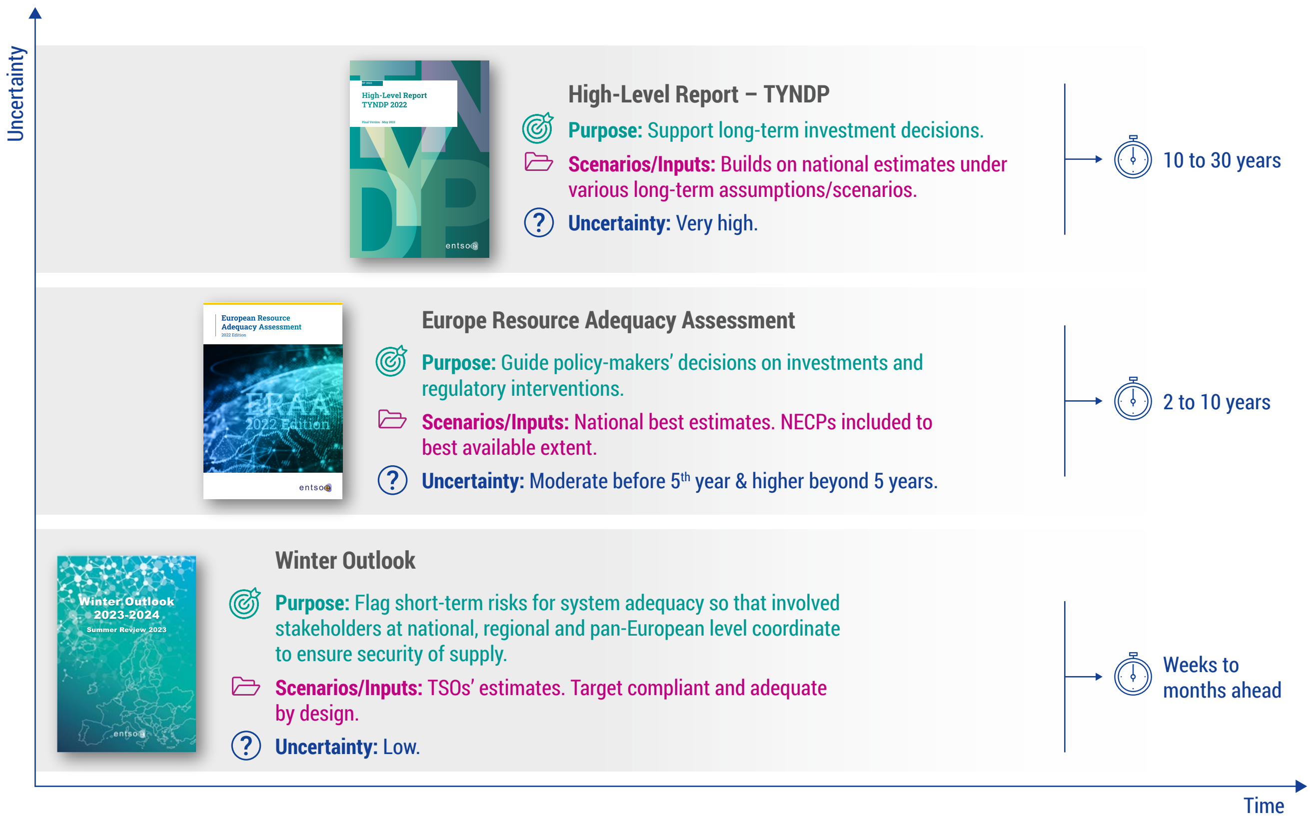

Figure 11: A comparison between the ERAA, the Seasonal Outlook and the TYNDP

4 Scenario and main assumptions

ERAA 2025, as a fifth edition, builds on the lessons learnt and improvements of the four past editions, striving for continuous methodological improvements to maximise its usefulness for policy-makers and market actors. The ERAA contains innovative approaches that analyse the economic rationale affecting generation capacity in Europe (the EVA) and assess how the physical network influences potential commercial energy exchanges between different study zones.

4.1 Scenarios and time frame

The ERAA 2025 assessment spans the coming decade and focuses on four TYs: 2028, 2030, 2033, and 2035. TYs 2028 and 2030 are particularly important, because, if adequacy concerns are identified, Member States (MSs) need to implement policy decisions now (for example, applying for a CM), to ensure additional capacities are available in time. The 2033 and 2035 TYs provide insights into the longer-term horizon.

Economic viability is assessed for a single reference scenario, with two different approaches to risk-aversion modelling for rational investors. The reference scenario is based on TSOs' projections considering various European and national policy targets (such as NECPs), accounting for capacities already contracted through auctions under CMs at the time of the assessment.

4.2 Input data

ERAA 2025 was built using the latest available data, especially considering NECPs revised in 2024, the EU's Fit for 55 package, and REPowerEU. A draft data package was published in April 2025 and shared with stakeholders for consultation before being applied in the models.

Input data have changed differently across Europe. For some countries – such as Spain or Denmark

- rather disruptive data changes can be observed, while for others – such as Italy or Northern Ireland
- moderated data refinements have been made.

Projections for the European power system are constantly changing and require continuous monitoring. This is shown in the figure below, where several countries already exhibit some changes following the closure of the ERAA 2025 call-for-evidence. This highlights the need to remain vigilant to system developments and to check that assumptions and projections remain robust. Unexpected events may require additional actions to ensure a secure energy system transition.

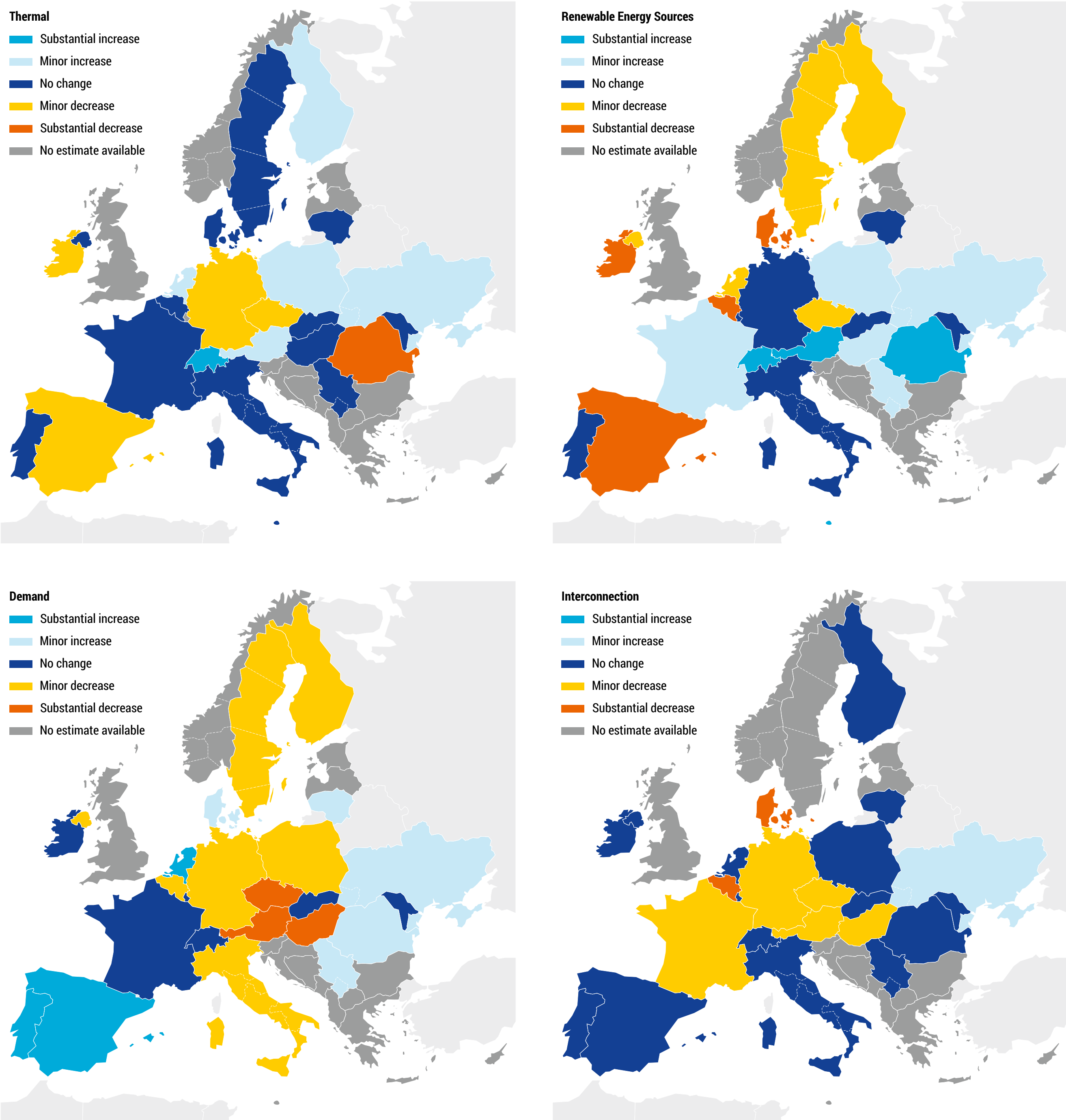

Figure 12: Overview of input data trends compared with ERAA 2024

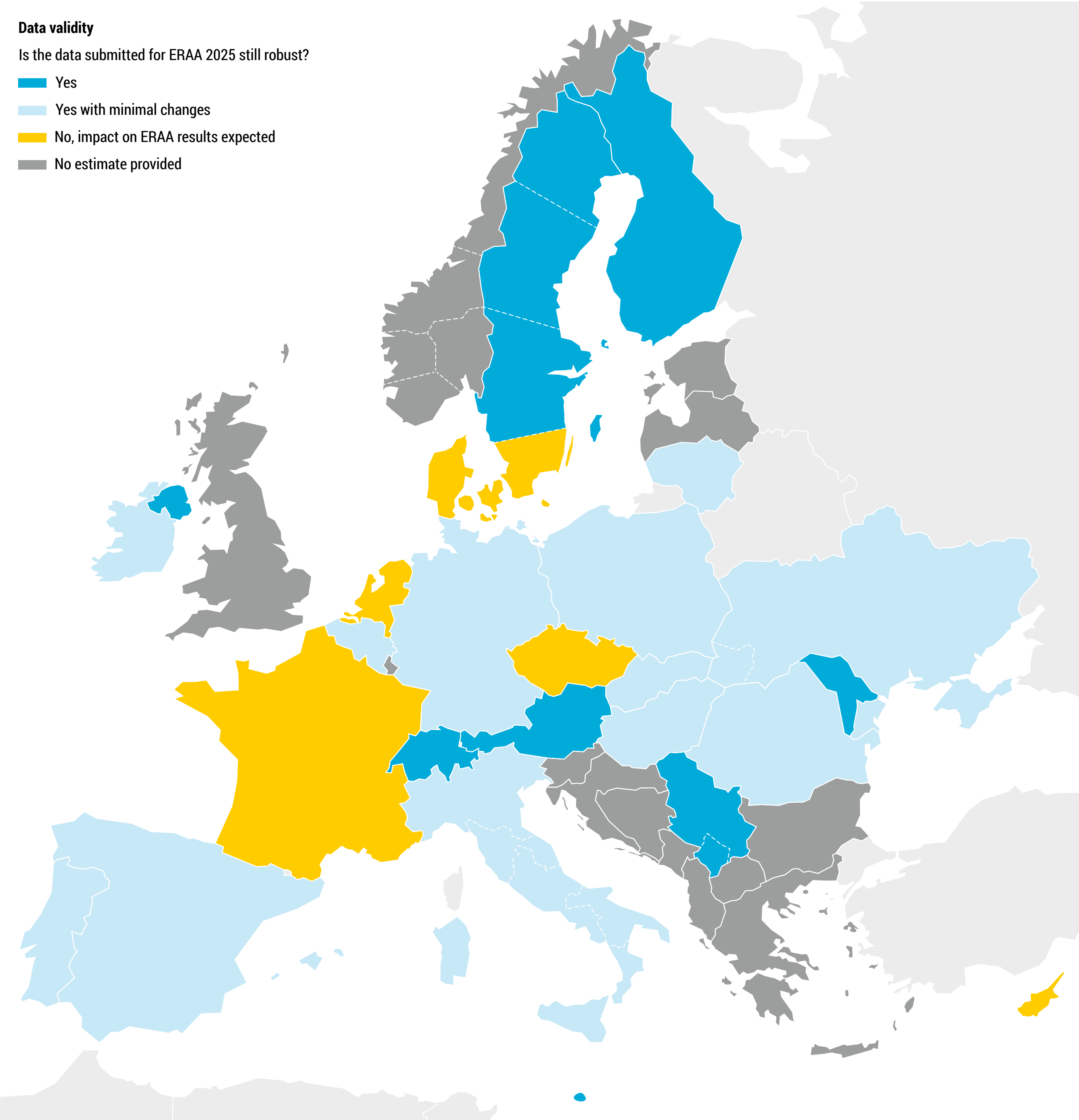

Figure 13: ERAA 2025 input data and assumption robustness at the time of publication (August snapshot)

4.3 Scope and methodology

The geographical scope of ERAA 2025 encompasses a large portion of the European continent.8 For more information regarding the modelled countries, please refer to Annex 1. Figure 14 illustrates the geographical scope of ERAA 2025, distinguishing between countries that have been explicitly modelled, neighbouring countries that have been modelled implicitly through fixed exchanges, and non-modelled countries.

The considerable geographical scope of ERAA 2025 results in highly complex and computationally intense models. As a pan-European study, the ERAA cannot delve into the specifics of each modelled country. For these reasons, only the most relevant and impactful factors for calculating the European adequacy indicators[5] were identified and considered in the ERAA, with national assessments providing complementary and deeper analyses of local constraints. These more local assessments, based on the same methodology, complement

5 Mainly LOLE and EENS

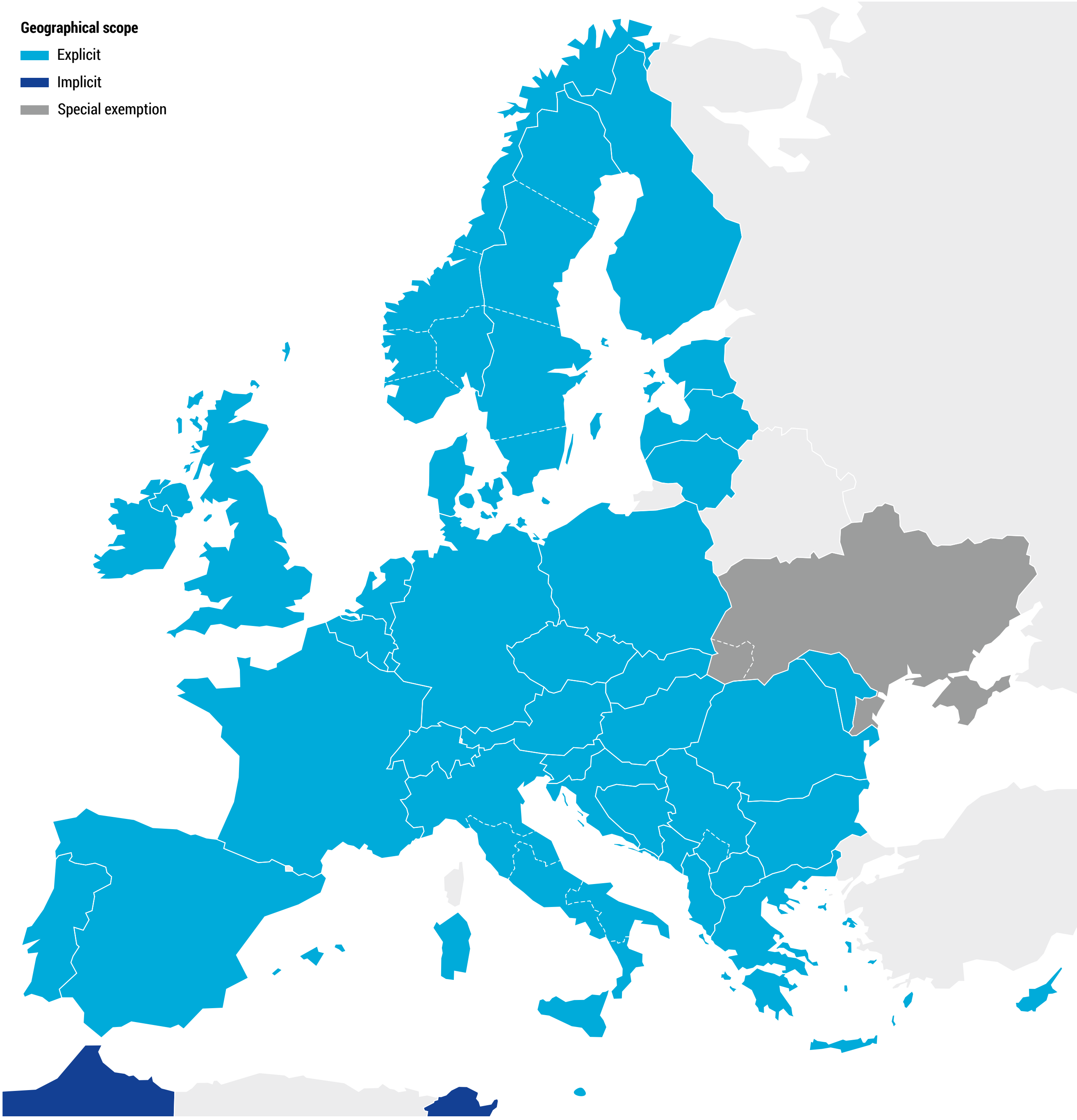

Figure 14: ERAA 2025 geographical scope

the ERAA by reflecting the particularities of national electricity demand and supply, and by using the most recent national data.[6]

The ERAA model is a simplified representation of the pan-European power system that, like any model, is based on a set of assumptions. The main assumptions in ERAA 2025 are:

1) **Cost-driven dispatch decisions:** Resource dispatch for each time horizon is based on their marginal cost of production and other plant parameters.

2) **Perfect foresight:** Available energy sources, DSR and grid capacities (including outages) are assumed to be known in advance with perfect accuracy (i.e. no deviations between forecast and realisation, except for the EVA decisions affecting the resource portfolio).

3) **Focus on energy markets only:** The analyses consider non-market resources designed for adequacy reasons, such as strategic reserves, from the perspective of balancing generation and demand only, but not from the perspective of congestion management and system stability/resilience.

6 Regulation (EU) 2019/943 of the European Parliament and of the Council on the internal market for electricity, Chapter IV, Art. 20(1) and 24

4) **Weather-dependent RES production:** Solar, wind, and hydro-power generation are modelled based on selected weather scenarios obtained from climate projections.

5) **Optimised planned maintenance of thermal units:** Planned maintenance for thermal units is scheduled in periods with an expected sufficient supply margin. Country-specific restrictions (e.g. maximum number of units simultaneously under maintenance) and the impact of weather conditions are considered.

6) **FB modelling for the CORE and Nordic area:** In the adequacy model, grid limitations within the CORE area (AT, BE, HR, Northern IT, CZ, FR, DE, HU, LU, NL, PL, RO, SK, and SI), and the Nordic area (DK, FI, NO, SE) are modelled using the flow-based (FB) approach, which mimics multilateral cross-border restrictions in simultaneous power exchange. All other regions are modelled based on bilateral net transfer capacity (NTC) exchange.

Further details on ERAA modelling assumptions are available in Annex 2 (Section 1.3).

Compared to ERAA 2024, three notable methodological enhancements were introduced in the EVA context: a refined weather scenario selection, an enhanced hurdle premium calculation methodology, and a revenue cap. All enhancements increase the quality and robustness of ERAA 2025. An extended dataset (i.e. net revenues from EVA technologies extracted from the full ERAA 2024 post-EVA economic dispatch (ED) results) was used for the weather selection to ensure better representativeness considering information from all TYs (previously only one) and from all possible forced outage scenarios (previously only one). The hurdle premium calculation methodology enhancement provides more tailored representative hurdle premium rates for gas-fuelled new open cycle gas turbine (OCGT) and combined cycle gas turbine (CCGT) investments in the ERAA, by leveraging a utility-based approach using the constant absolute risk aversion (CARA) function. The CARA utility function approach is a standard method to include risk considerations in investment modelling, significantly impacting hurdle rates and differentiating technologies like OCGT and CCGT based on their revenue distribution over the full ERAA 2024 ED results. The revenue cap was introduced based on the observed cumulated probability of occurrence of ERAA 2024 ED hourly market prices, benchmarked against realised historical day-ahead prices, to extrapolate a distribution and set reliable revenue expectations from a rational investor's perspective, as confirmed by the majority of respondents to the latest ENTSO-E investor survey.2 The analysis showed that a threshold of € 1000 per MWh could effectively capture more than 99.85% occurrences of hourly prices.

Investments in gas-fuelled generation capacities are expected to be more conservative compared to ERAA 2024 due to the hurdle premium update. The revenue cap generally impacts the EVA results, indicating a less optimistic viability of generation capacity than the one implied by the long-term (quasi) equilibrium of the overall cost EVA model, in which the optimal viable capacity tends to correspond to a range of price spike hours equal to the ratio between the modelled market price cap (up to € 7,500 /MWh in 2035) and the cost of new entry (CONE) of the marginal technology in each area. The objective of the revenue cap is therefore a simple yet effective attempt to prevent investment decisions from being based on extremely high but extremely rare and uncertain revenues driven by a few price spike hours, occurring only under very specific circumstances, e.g. extreme climate or outage conditions.

	ERAA 2024	ERAA 2025
OCGT	6.0%	9.9%
CCGT	4.5%	6.9%

Table 2: updated hurdle premiums for OCGT and CCGT new investments having a moderate impact on ERAA 2025 results (A complete list of hurdle premiums is provided in Annex 1.)

5 Stakeholder engagement

Developing the ERAA requires consultation with numerous stakeholders to best understand how the system will develop. Gathering the views of policymakers, regulators, and Member States, in addition to electricity market participants, is crucial to frame the ERAA's continuous improvement.

ENTSO-E has sought to involve a wide range of stakeholders from the start of the ERAA process, with substantial consultation during the development of its underlying methodologies. The Electricity Coordination Group, comprising experts from EU Member States, was further instrumental in informing the production of the ERAA.

As part of the development of each ERAA edition, ENTSO-E hosts at least three webinars at different phases of the study: assumptions and input data, methodological insights and results and takeaways.

ENTSO-E's work on ERAA 2025 has sought the best available data and assumptions throughout the development of this study. In April 2025, a call for evidence was held on scenarios and key data, which provided valuable stakeholder feedback.

The public consultation resulted in substantially more feedback compared to ERAA 2024. The majority of stakeholders' concerns about the data were confirmed to have no impact on the data submitted by TSOs, although some datasets were revised. The assessment is based on the best available assumptions at the time of data submission and validation.

To make information about all stakeholders' interactions accessible and transparent for stakeholders, ENTSO-E created a dedicated web page, where webinar recordings and stakeholder feedback are published. An update of the dataset following the feedback received during the public consultation was also published with information on how the data had changed.

6 Beyond ERAA 2024

6.1 Keeping the ERAA fit for purpose in a new context

Adopted in 2019 as part of the Clean Energy Package, the Electricity Regulation tasked ENTSO-E with the development of the ERAA, which adopts a pan-European approach complemented by national analyses (see, notably, Article 23 of the Electricity Regulation). The ERAA aims to support an efficient and interconnected energy system by measuring the system's ability to maintain security of supply while accounting for climate change and the rapid increase in installed renewable capacities. This measurement will increasingly be used to determine which interventions, including CMs, are required to ensure the security of supply of Europe's electricity system in the long run. This, in turn, will support Europe's energy transition by proactively addressing challenges while delivering secure and affordable energy to citizens and industries.

The European energy context has changed drastically since the CEP was released. Due to the war in Ukraine and the deep energy crisis, uncertainty is at an all-time high. Although the conflict has been a catalyst for accelerating the energy transition and reducing EU dependence on fossil fuels, it also likely ends an era of energy insouciance, with comfortable margins and moderate prices. With the integration of Europe's electricity markets, as well as the integration of large quantities of renewable capacity and shifting demand patterns, resource adequacy will be a major focus for decades to come. The ERAA will ensure that decision-makers have the best available information to address these challenges, and, although the report itself does not recommend specific actions, its analysis will inform decisions regarding CMs and other state policy interventions. The ERAA contains pioneering methodologies and tools to analyse future adequacy with an unprecedented combination of scope and detail, serving as a key reference when considering the future of Europe's electricity system. Future development through methodological innovation, scope refinement, pilot programmes, and stakeholder consultation will continuously enhance the ERAA's value. Meanwhile, ENTSO-E remains committed to the multi-year planning, data delivery, scenarios and methodologies required to fulfil the ERAA's potential.

Triggered by the energy crisis of 2022, the EC proposed an Electricity Market Design Reform (hereinafter "EMDR") with the adoption of Regulation 2024/1747 amending Regulations (EU) 2019/942 and (EU) 2019/943 regarding improving the EU's electricity market design, including targeted updates to the Electricity Regulation. During the legislative process, co-legislators agreed to recognise CMs as an integral part of the market design and called for streamlining and simplifying their approval process. Therefore, in line with the EMDR updates that entered into force in July 2024, the Electricity Regulation (recast) now provides that:

- CMs are no longer last-resort nor temporary measures, but are approved by the EC for a period of 10 years;
- The EC had to adopt a report assessing the possibilities of streamlining and simplifying the process of applying a CM, and request that ACER amends the ERAA methodology.
- The EC had to submit proposals to simplify the process of assessing CMs.

The EC outlines several proposals for the European resource adequacy framework in its report on the assessment of possibilities for streamlining and simplifying the process of applying a CM (the "CM streamlining report"), published on 3 March 2025. A key element is a new simplified state aid approval procedure for CM designs that follow pre-defined "off-the-shelf" models based on best practices, and can therefore be expected to limit competition distortions. The new procedure is included in the CISAF, which allows MSs to apply for the simplified process if they rely on the most recent (ACER-approved) ERAA report to demonstrate the necessity of the scheme, and the CM complies with several other criteria outlined in the CISAF.

Following a request from the EC, on 16 April 2025, ENTSO-E received a formal request from ACER to propose amendments to the ERAA methodology ("ACER's letter of 16 April 2025"). ACER shall approve or amend the submitted methodology in accordance with Article 27(3) of the Electricity Regulation.

On 6 November 2025, ENTSO-E submitted its proposed amendments to the ERAA methodology to ACER, taking into account the recommendations from the CM streamlining report, ACER's formal amendment request, ENTSO-E's own ERAA experience, and the requirements stemming from the Electricity Regulation. The main updates included in the proposal can be summarised as follows:

- **Scenario framework** (Article 3)
- **Complementarity between the ERAA and NRAAs** (Recitals, Articles 8 and 13)
- **Economic Viability Assessment** (Article 6)
- **Resource adequacy & data collection** (Articles 4 and 5)
- **Additional ERAA-based parameters to facilitate the simplified state aid approval process for CMs under CISAF** (Articles 12 and 13, Annex 1)
- **Other amendments related to transparency and implementation of the ERAA**

These proposals aim to:

- take into account the proposals of the EC streamlining report, as well as the CISAF, while ensuring the ERAA remains feasible to deliver in the mandated time frame;
- further streamline the ERAA methodology to reduce the risk of delays in its delivery, which is critical for timely national decision-making;
- increase the usefulness and value of the ERAA for MSs and other stakeholders;
- retain MSs' prerogatives on decision-making regarding security of supply matters;
- facilitate the preparation of complementary NRAAs at the national level, within the framework of the ERAA methodology; and
- improve the robustness of the ERAA.

6.2 Proof of Concept: EVA with a revenue-based approach

A proof-of-concept study of EVA based on a revenue-based iterative approach was commenced in ERAA 2024 and continued in ERAA 2025. It now confirms the maturity of this methodology for application in the next ERAA cycle. The approach complies with the ERAA methodology and has already been used by several TSOs in their national adequacy assessments. More details on the proof of concept and results are available in Annex 5.

The motivation for preparing a revenue-based EVA approach is to enhance the representation of investors' behaviour, mitigate the computational burden, and support a better understanding of investment decisions. Moreover, a revenue-based EVA can accommodate more weather scenarios than the current setup of the overall-cost minimisation EVA approach, improving consistency between the EVA and ED modules of the ERAA. While both modelling approaches are viable according to the methodology, several stakeholders, including ACER in its ERAA 2024 approval decision, pointed out that such a modelling refinement (referred to as an "iterative" modelling approach) would be considered an improvement of ERAA robustness and consistency.

7 List of data

Inputs:

- **Dashboard_raw data (folder)**
  - Aggregated Demand
  - Commodity Prices
  - Flow-Based Core KPI
  - Generation Capacities Maintenance Daily – Per Technology
  - Non-Market Batteries
  - Reserves Requirements
  - Storage
  - Hydro Capacities
- **Common Data**
- **Demand**
- **Dispatchable Consumption**
- **Economic and Technical Investment Parameters**
- **FB Domains**
- **iDSR Ratios**
- **NTCs**
- **PECD – RES**
- **PECD – Weather**

Results:

- **Dashboard of the results**
  - EVA
  - Case Study of revenue-based EVA
  - Adequacy
- **Hourly ENS time series**

Glossary

ACER	European Union Agency for the Cooperation of Energy Regulators
CEP	Clean Energy Package
CM	Capacity Mechanism
CONE	Cost of New Entry
DSR	Demand-Side Response
EENS	Expected Energy Not Served
EMDR	Electricity Market Design Reform
ENTSO-E	European Network of Transmission System Operators for Electricity
ERAA	European Resource Adequacy Assessment
EUE	Expected Unserved Energy
EVA	Economic Viability Assessment
LLD	Loss of Load Duration
LOLE	Loss of Load Expectation
NRA	National Regulatory Authority
NRAA	National Resource Adequacy Assessment
OM	Outage Minute
PECD	Pan-European Climate Database
RES	Renewable Energy Sources
TSO	Transmission System Operator
TY	Target Year
TYNDP	Ten-Year Network Development Plan
VoLL	Volume of Lost Load

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