# European Resource Adequacy Assessment

2022 Edition


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# 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 39 member TSOs, representing 35 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.

# 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) 2022

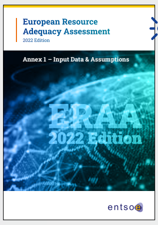
## Navigating the report

The ERAA 2022 is divided into six parts (Executive Report and Annexes) to help readers identify relevant information.

### Executive Report

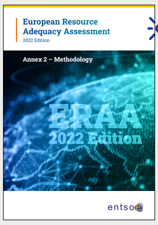
Description of the ERAA 2022 motivation, followed by adequacy results for the Central Reference Scenario Without Capacity Mechanism (CM) for 2024 through 2030, based on the National Estimates Scenario and updated through the application of the Economic Viability Assessment (EVA*) without CM.

* EVA is a risk assessment of what could happen regarding economic investment or divestment; it is not a prediction of what will happen.




### Annex 1: Assumptions

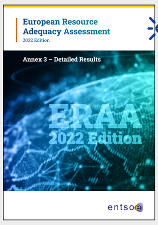
Presentation of the ERAA 2022 scenarios and assumptions.




### Annex 2: Methodology

Description of the main ERAA 2022 methodology, consisting of:

- Probabilistic methodology for assessing adequacy
- Methodology of the EVA
- Introduction to methodologies used to prepare demand and climate datasets

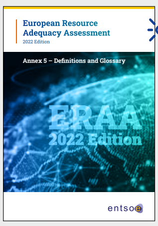



### Annex 3: Detailed Results

Presentation of the ERAA 2022 detailed results for the central scenarios


### Annex 4: Country Comments

Specific comments voluntarily provided by TSOs on the ERAA 2022 input data and results




### Annex 5: Definitions & Glossary

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# 1 Purpose and Motivation of the ERAA

## 1.1 General context

### What is the purpose of the European Resource Adequacy Assessment (ERAA)?

The ERAA is a pan-European monitoring assessment of power system resource adequacy as far as ten years ahead. Based on state-of-the-art methodologies and probabilistic assessments, it aims to model and analyse possible events that could adversely impact the balance between supply and demand of electric power. The ERAA is an important element for supporting qualified decisions by policymakers on strategic matters such as the introduction of capacity mechanisms (CMs).

The European electricity system is undergoing significant changes motivated by the EU's ambition to achieve climate neutrality (cf. Fit for 55 legislative package) as well as independence from Russian fossil fuel (cf. REPowerEU plan) by 2030. These ambitions are driving the integration of greater volumes of variable renewables, an increase in decentralisation, the emergence of new market players, innovation and digitalisation, and the phase-out of thermal generation units. These changes are happening 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 the balance between supply and demand across the interconnected system at all times throughout the year.

In this context, a pan-European analysis of resource adequacy – complemented by insights from national and regional analyses – is more important than ever. Cooperation across Europe is necessary to accelerate the development of common methodological standards, and a common 'language' is needed to perform these studies. Regulation (EU) 943/2019 (hereinafter 'Electricity Regulation') and Regulation (EU) 941/2019 (hereinafter 'Risk Preparedness Regulation'), adopted as part of the Clean Energy Package (CEP), recognise this need.

Assessments of electrical grid 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 supply of electric power. Such assessments continuously assess the balance between net available generation and net load levels in the European power system, as illustrated in Figure 1. The ERAA should not be interpreted as an effort to predict the system's security of supply, but rather as a measure of the future power system's ability to maintain security of supply under a very high number of possible future system states attributable to various plausible weather conditions as well as random outages of conventional power plants and relevant network elements. In summary, the ERAA does not predict the future; rather, it identifies potential shortcomings in the system that can be addressed proactively.

To identify these potential shortcomings, the ERAA relies on national standards for system reliability. Individual EU Member States apply reliability standards (RSs) to assess their national resource adequacy; an overview is presented in Table 1. Loss of Load Expectation (LOLE) is the most common reliability indicator used by EU Member States, with targets typically in the range of 3 – 8 hours per year. Setting such reliability standards is a complex issue because it involves economic as well as technical considerations. These standards are determined in accordance with the 'Methodology for calculating the value of lost load, the cost of new entry for generation or demand response, and the reliability standard'.[1]

1 https://acer.europa.eu/sites/default/files/documents/Decisions_annex/ACER Decision 23-2020 on VOLL CONE RS - Annex I.pdf

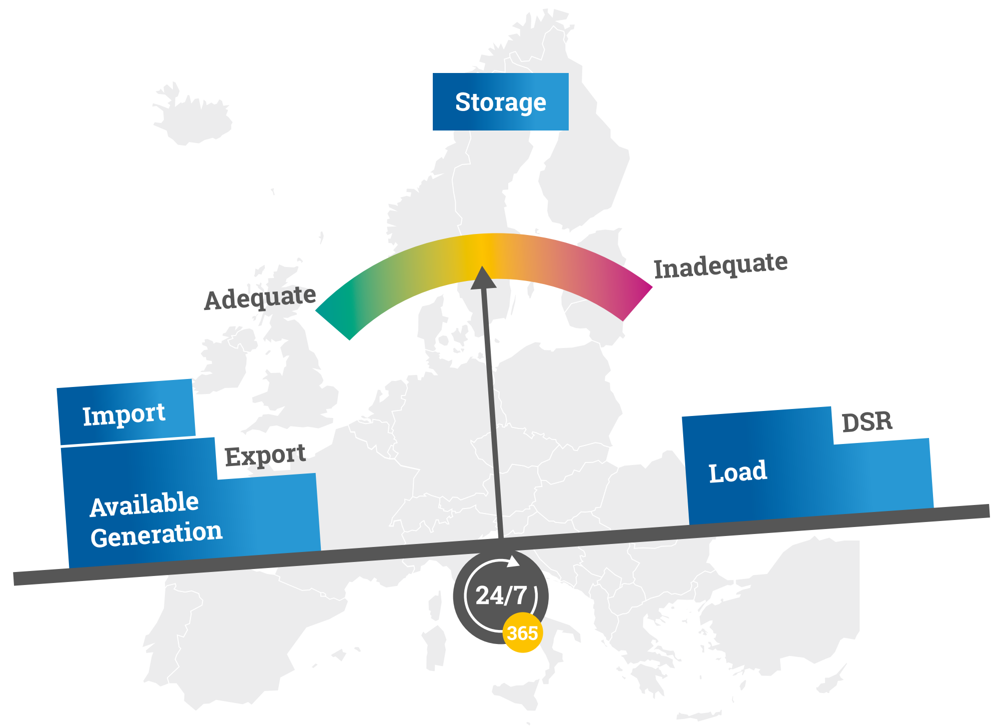



Figure 1: Resource adequacy – Balance between net available generation and net load

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

ERAA 2021 was the first step towards the implementation of the ERAA methodology. Each year, stakeholders can expect an even more useful and valuable tool with analyses that better account for the realities and complexities of the single electricity market – an unparalleled data set – as well as an improved economic viability assessment. The ERAA 2022 delivers a study with complex approaches and significant methodological improvements compared to the previous year's edition. This report is the result of an inherently complex task made possible only by the collaborative efforts of European TSOs.

The ERAA 2022 was developed over a period of more than a year, during which Europe experienced an energy crisis as a result of the war in Ukraine and an overhaul of many energy policies. Pan-European as well as national authorities continue to assess the market and security of supply measures for the years ahead. ENTSO-E is committed to delivering an ERAA that meets the objective of the Electricity Market Regulation and is fit for purpose, especially when decisionmakers seek guidance on risks and measures for the pan-European electricity system over the next decade.

ENTSO-E's work on ERAA 2022 has sought best available data and assumptions throughout the development of this study. In March 2022, a public consultation was held on scenarios and key data, which provided valuable stakeholder feedback but also confirmed there was no obvious consensus at that time as to how the electricity system could evolve differently in light of high energy prices and the need to diversify supply away from Russian fossil fuels. The ERAA 2022 assessment makes assumptions on long-term gas prices as provided for in the EC's REPowerEU Communication of May 2022. As such, the assessment is based on best available assumptions, while methodological improvements focus on meeting the legal requirements for ERAA as given in the Electricity Market Regulation.

ENTSO-E asks any reader to take note of this context, the assumptions on price levels and market response as made for this ERAA, as well as the Regulation's provisions that national assessments can provide more up-to-date context when needed. ENTSO-E's work on subsequent ERAAs will again be based on best available input received from extensive stakeholder engagement, more recent projections from European and national policies, and a commitment to provide an ERAA that meets its legal objective and is fit for purpose.

## 1.2 ERAA's role compared to the Winter Outlook

The ERAA and the seasonal outlook aim to model and analyse possible events that could adversely impact the balance between supply and demand of electric power in different time horizons ahead. The ERAA focuses on the horizon 10 years ahead (including intermediate years), while seasonal adequacy assessments, such as the Winter Outlook, assess the situation for the upcoming season.

The ERAA and the seasonal assessment are not forecasts or predictions of the future. Instead, both assessments provide a measure/view of the future power system's ability to maintain security of supply under a very high number of possible future states depending on various factors that impact adequacy (e.g. weather conditions, outages, generation availability) and identify potential shortcomings in the system that could be addressed proactively.

Although both assessments are based on state-of-the-art methodologies and probabilistic assessments, they do have their differences. Whereas the ERAA primarily indicates the impact on adequacy in the longer run through the economic viability assessment (estimation of resource capacity at risk), which is subject to specific assumptions for the next 10 years, the Seasonal Outlooks come with less uncertainty regarding the power system situation because they assess a shorter time horizon and are based on data/assumptions/information that much more accurately reflect the real situation ahead of each season assessed.

For example, more precise information on expected maintenance schedules/outages and hydro storage level is known and coordinated ahead of time for each season and is taken into account into the seasonal outlook studies. The ERAA also models maintenance (planned outages); however, given the uncertainty in the longer term on availability of power plants or network elements, the ERAA spans a much wider range of potential scenarios and outcomes for the future. Both the ERAA and the Seasonal Outlooks are based on an assessment of 34/35 climatic years.

The ERAA's economic viability assessment provides a mid-term view as well as a risk assessment to identify which capacities might be lack sufficient revenue to cover their operating costs. This mid-term horizon view is a very important indicator to inform policymaker decisions on potential incentives to support mid-term adequacy. In contrast, the Seasonal Outlooks provide insight into the short-term horizon through sensitivities linked to season-specific factors that could potentially impose strains on the power system.

## 1.3 Scope of ERAA 2022

ENTSO-E has relied on the contributions of stakeholders to develop the ERAA. Dedicated public consultations, focused webinars and workshops have been organised for ERAA 2022, all of which asked for stakeholders' feedback on the implementation of the methodology. ENTSO-E has also regularly consulted with ACER and EU Member States on the development of this report, and the ERAA 2022 will be accompanied by a public consultation on all aspects of the assessment.

The geographical scope of the ERAA covers 37 countries encompassing all EU members and the ENTSO-E perimeter.[2] For more information regarding the countries modelled within the ERAA 2022, please refer to Annex 1. Figure 2 below illustrates the geographical scope of the ERAA 2022, distinguishing between countries that have been explicitly modelled, neighbouring countries that have been modelled implicitly through fixed exchanges, and non-modelled countries.

Because the extended geographical scope of the ERAA 2022 generates highly complex and computationally heavy models, a pan-European study like ERAA must avoid diving into the specificities of each modelled country. For this reason, only the most relevant and impactful factors for assessing the European adequacy situation were identified and considered in the ERAA, while national and regional assessments are meant to provide complementary and deeper analyses of local constraints. The latter, more localised assessments – which rely on the same methodology and reference scenarios – can assess additional sensitivities related to both infrastructure and operational considerations.[3] For instance, national or regional studies can include considerations related to internal grid constraints or operational security, which are beyond the scope of the ERAA.

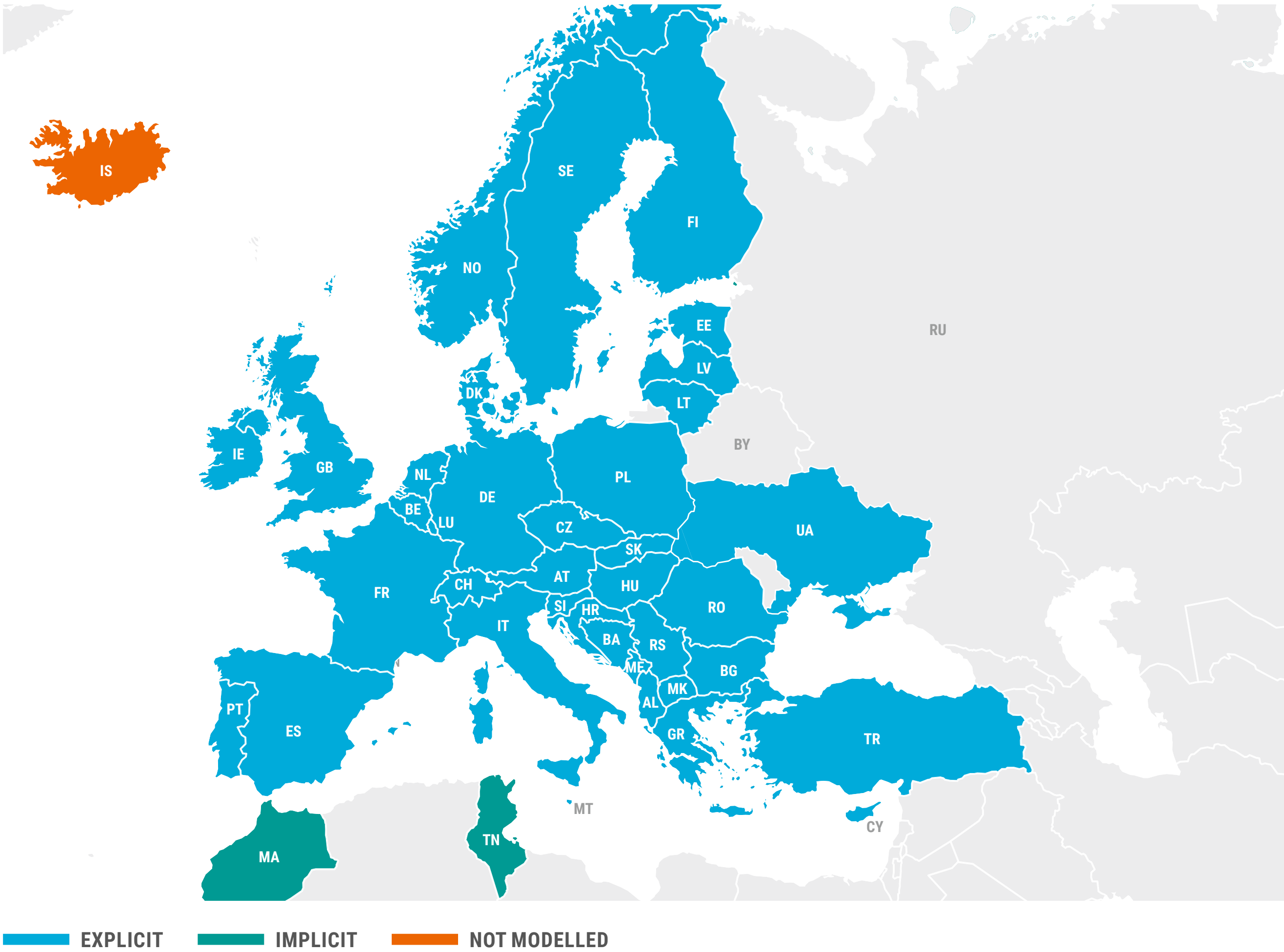



Figure 2: The ERAA 2022 geographical scope

2 This excludes Iceland, which is not connected to the pan-European grid and thus has no effect on the assessment. Ukraine is an observer member of ENTSO-E and is explicitly modelled. Turkey is in the process of becoming an observer member, but is explicitly modelled nonetheless, as in ERAA 2021. The GB TSOs are no longer ENTSO-E members as of 2022, but due to their impact on the wider region, they are still explicitly modelled. ERAA results are provided only for interconnected ENTSO-E member countries and Malta.

3 Regulation (EU) 2019/943 of the European Parliament and of the Council on the internal market for electricity, Chapter IV, Art. 20.1. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0943

## National Reliability Standards

| Member state | Type of reliability standard | Value |
|---|---|---|
| **Belgium*** | LOLE (hours/year) | 3.00 |
| **Czech Republic*** | LOLE (hours/year) | 15.00 |
| **Germany*** | LOLE (hours/year) | 2.77 |
| **Denmark**[†] | LOLE (Outage minutes) | 5 |
| **Estonia*** | LOLE (hours/year) | 9.00 |
| **Finland*** | LOLE (hours/year) | 2.10 |
| **France*** | LOLE (hours/year) | 3.00 (used in ERAA)<br>2.00 (with load shedding) |
| **Greece*** | LOLE (hours/year) | 3.00 |
| **Ireland**** | LOLE (hours/year) | 8.00 |
| **Italy*** | LOLE (hours/year) | 3.00 |
| **Lithuania** | LOLE (hours/year) | 8.00 |
| **The Netherlands** | LOLE (hours/year) | 4.00 |
| **Luxembourg*** | LOLE (hours/year) | 2.77 |
| **Portugal** | LOLE (hours/year) | 5.00 |
| **Poland** | LOLE (hours/year) | 3.00 |
| **Sweden**[‡] | LOLE (hours/year) | 1.00 |

* Based on the EU-wide methodology for calculating the value of lost load (VOLL), the cost of new entry (CONE) and the reliability standard. Implementation of the VOLL/CONE/RS methodology based on NRA declarations; the actual degree of compliance is not examined.

** The RS for the Integrated Single Electricity Market (ISEM) for the island of Ireland is set to 8 h. UKNI has a reliability standard of 4.9 h.

† https://energinet.dk/El/Horinger/Afsluttede-horinger/2022-09-Redegoerelse-for-elforsyningssikkerhed-2022

‡ https://www.regeringen.se/pressmeddelanden/2022/11/regeringen-beslutar-om-en-tillforlitlighetsnorm-for-sverige

Table 1: National reliability standards applied by EU Member States as of July 2022
(Source: ACER's Security of EU electricity supply in 2021, October 2022)

# 2 Reference scenarios and main assumptions

The ERAA 2022 is the second major step towards the implementation of the ERAA methodology, offering insights on two central reference scenarios: one that takes into account already approved capacity mechanisms, and one that does not. The ERAA contains innovative approaches that seek to understand the economic forces impacting capacity in Europe (EVA) and analyse the impact of the physical network on the possible commercial energy exchanges between different bidding zones (FB Analysis).

The EVA brings together multiple aspects and interdependencies to give a comprehensive economic analysis of Europe's generation assets. The incorporation of EVA into the ENTSO-E resource adequacy assessments poses a significant challenge that requires a number of assumptions with respect to input data, strong computational resources and pragmatic simplifications to achieve trustworthy results.

The ERAA 2022 also considers climate change in the input scenarios, though in a simplified manner using a transitionary solution while ENTSO-E is preparing an enhanced and forward-looking Pan-European Climate Database for future ERAA editions in collaboration with Copernicus Climate Change Service[4].

The 2022 assessment is carried out for three target years (TY), namely 2025, 2027 and 2030, expanding from the ERAA 2021 in an effort to build a robust and reliable methodology before reaching the targeted 10 TY objective. TY 2025 was chosen because there is a special interest in the system's short-term adequacy and because it represents a pivotal year for evaluating adequacy due to expected reductions in Europe's coal and nuclear capacity. TY 2030 allows for the evaluation of the adequacy situation further ahead, in a longer-term horizon. Lastly, TY 2027 is five years ahead, and is therefore an important year for decisions related to CMs.

### The ERAA methodology defines two central reference scenarios:

1. **Central Reference Scenario Without Capacity Mechanism (CM)**: This scenario spans the time horizon from 2024 through 2030. It is based on the National Estimates Scenario and is updated through the application of the Economic Viability Assessment (EVA). The scenario without CMs still accounts for CMs that already hold a CM contract granted in any previous auction of any existing or approved CM at the time of the assessment.

2. **Central Scenario With CM**: This scenario, in principle, is based on the National Estimates Scenario and is updated through the application of the EVA considering countries with approved CMs that meet their reliability standards.

**ERAA 2022 does not include the Central Reference Scenario With CM.** Regrettably, the latter could not be incorporated in the report due to increased computational complexity and important time constraints. ERAA is still in the implementation phase and ENTSO-E is committed in its continued efforts to deliver both central reference scenarios in future editions.

4 https://climate.copernicus.eu

# 3 Key takeaways

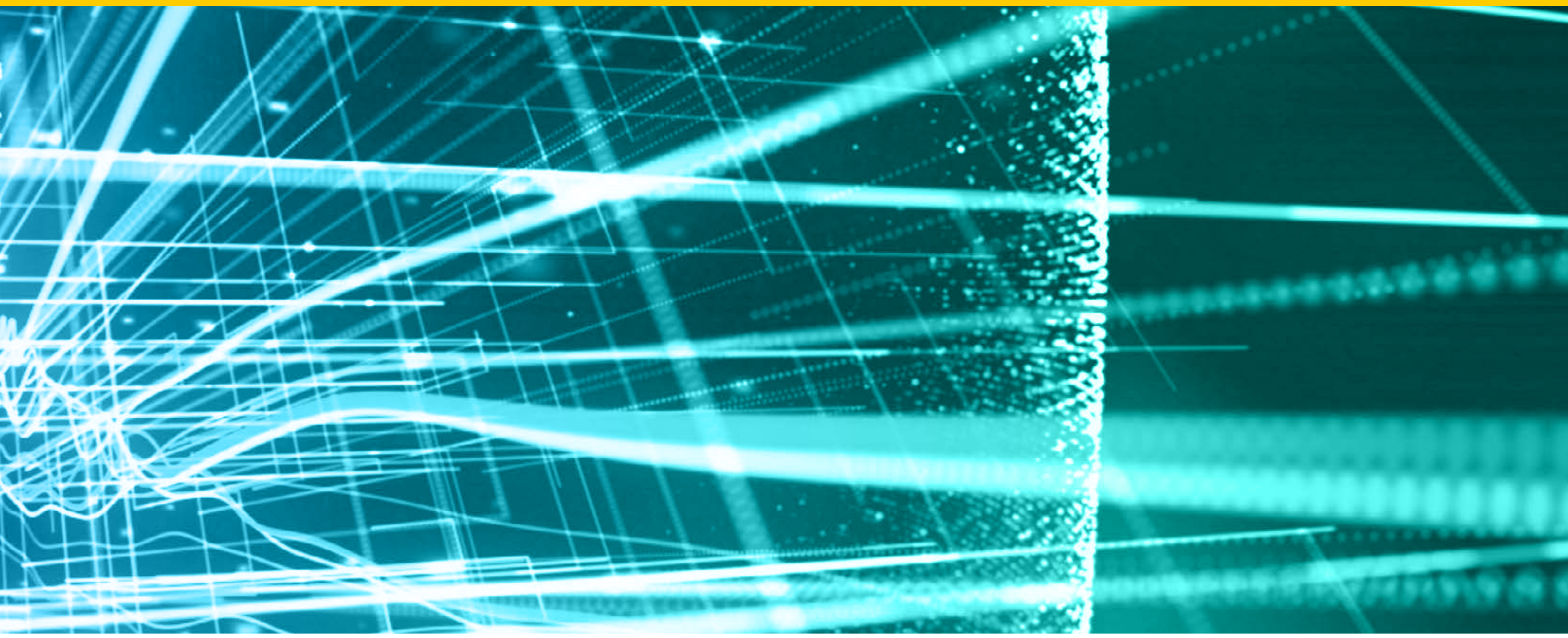
The ERAA 2022 shows that in the given scenario and methodology framework, high volumes of fossil-fuelled capacity are at risk of becoming economically non-viable in the mid-term. In that context, the right incentives and/or targeted intervention will be needed to avoid adequacy risks, especially in the countries of central Europe.

For TY 2025, similarly to ERAA 2021, the results of ERAA 2022 show that, under the given scenario and methodology framework, the evolving economics of thermal generation risk putting downward pressure on capacity. To avoid this risk, it will be necessary to implement new flexibility tools that facilitate the management of demand (ramps and peaks). It further necessitates capacity that can quickly respond to sudden variation of demand and supply, such as meeting demand spikes in the evening while decreasing PV supply. Furthermore, without intervention (see Central Reference Scenario Without CM – TY 2025), risks of system inadequacy could increase significantly in more than a dozen markets.

The need for coordination is underlined by the finding that adequacy issues in one country are highly dependent on assumptions in neighbouring countries – and, reciprocally, that any capacity investment in one country can greatly influence its neighbours. This highlights the importance of regional coordination in decision-making. The Central Reference Scenario Without CM for TY 2025 suggests that the future margins in Central and Western Europe may be significantly reduced, with LOLE estimates of several hours for most countries in the region.

In the longer term (i.e. TY 2030), the economic viability analysis still shows important risks for the assumed thermal generation fleet with more than 60 GW of capacity at risk of being retired by the model and 21 GW of potential new investments. The countries with the largest amount of capacity at risk are Italy, Spain, the United Kingdom, Greece and Germany.

Due to high gas prices, the merit order between gas and coal has shifted in the short term (until 2025), reducing the viability pressure on coal compared to gas. Economic viability of close-to-marginal gas units is dwindling further. Longer-term assessments beyond 2025 show progressive inversion of the merit order in favour of gas. Some volume of dispatchable capacity should be kept in the market, avoiding permanent decommissioning in the years around 2025, because it will be needed in the system to cope with coal unit phase-outs in the run-up to 2030.



# 4 Main findings

The main findings of the assessment are presented in this section, whereas more detailed results can be found in Annex 3. Assessing the adequacy situation in ERAA takes place in two steps: 1) the economic viability of the capacity resources is assessed solving a long-term planning optimisation problem, and 2) the adequacy situation is evaluated on viable scenarios probabilistically solving the Economic Dispatch problem.

Being an inherently complex study, ERAA is characterised by a significant degree of uncertainty and computational constraints. Thus, modelling decisions, assumptions as well as the probabilistic nature of the assessment shall be taken into account when interpreting the results. All modelling assumptions and decisions are described in Annex 2 of this report, together with the uncertainty characterising the assessment stemming from the climate variables and forced outages. As a result, the outcomes of the study are presented in expectation of the plausible scenarios (e.g. LOLE being the expected number of hours with unserved energy per year, averaged over all potential climate and outage scenarios).

## 4.1 Economic Viability Assessment results

The EVA step assesses the viability of capacity resources[5] participating in the energy-only market (EOM). The EVA is a risk assessment of what could happen; it is not a prediction of what will happen. Units with an awarded CM contract are excluded from the EVA for the duration of their contracts and the viability of resource capacities participating in EOM is assessed using a long-term planning model with the objective of minimising the total system costs.[6]

The key decision variables of that long-term model aim to identify the economic-optimal (least-cost) evolution of resource capacity over the modelled horizon. This assessment therefore delivers insight, per each bidding zone and over the TYs, on the resource capacities that are likely to be (i) retired, (ii) invested in, (iii) (de)mothballed or (iv) extended in lifetime. More on the assumptions behind the EVA can be found in Annex 1, while the detailed methodology is found in Annex 2.

5 Generation resources include storage units (e.g. batteries).

6 Article 6.2 of the ERAA methodology acknowledges the use of overall system cost minimisation for the EVA, albeit as a simplification and assuming perfect competition

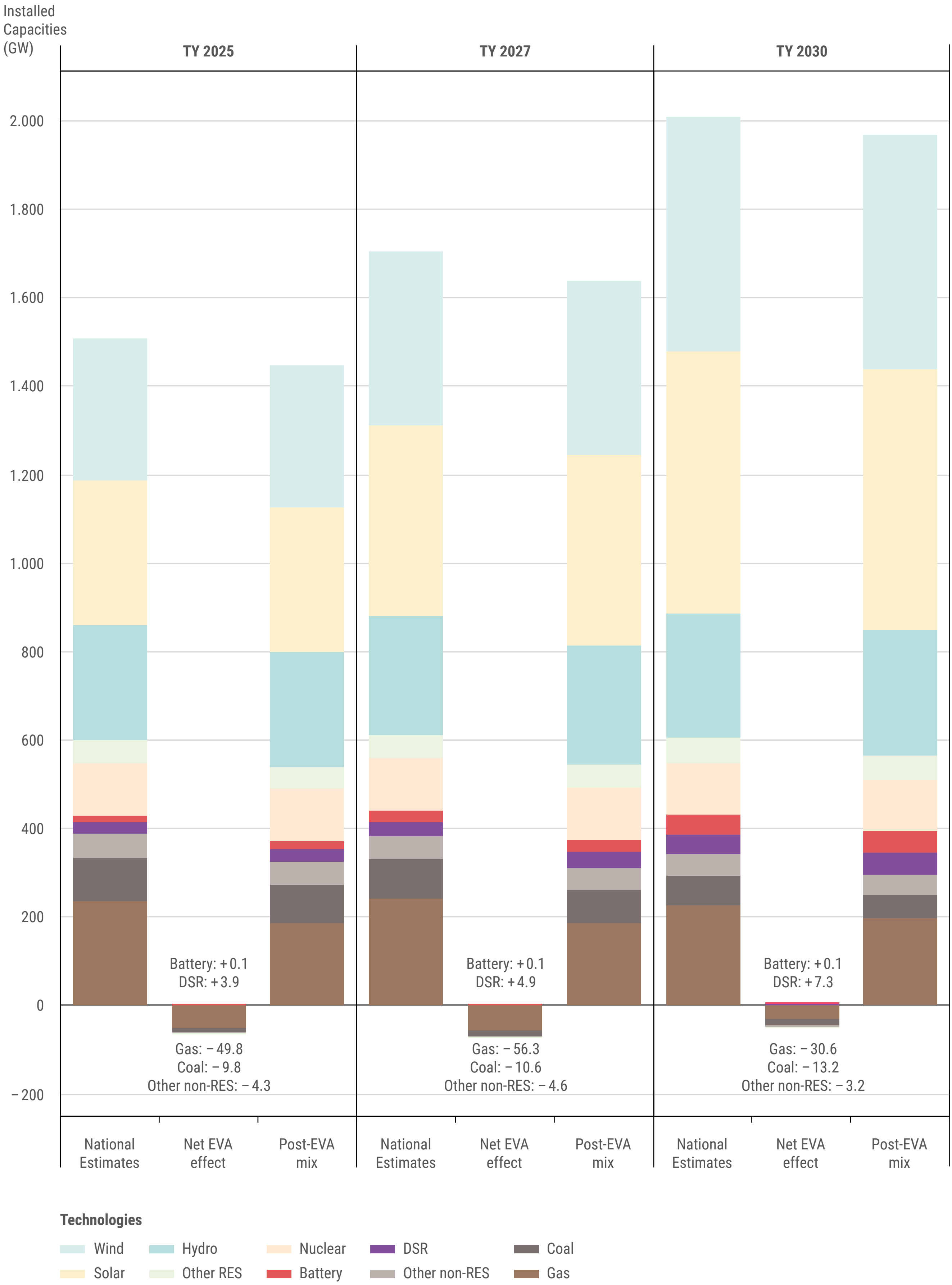



Figure 3: Net EVA results for the European Perimeter

The results of the EVA indicate that significant volumes of fossil fuel capacity in Europe are at risk of economic decommissioning. In Figure 3, one can see the installed capacities assumed in the National Estimates Scenario7 and the resulting post-EVA mix. Dark colours indicate the technologies whose part of the capacity is subject to EVA, while the viability of the technologies in light colour is not assessed. The net effect for all three target years is that, under the given scenario and methodology framework, a rather significant volume of gas capacity is found at risk of economic decommissioning, especially in the shorter to mid-term horizon, followed by a comparatively smaller capacity of coal. In Table 2 one can see clarification of the EVA effects as well as the countries where the capacity change is highest. The assumptions on gas prices had a clear impact on the aforementioned results, as they are based on the recently released assumptions of the REPowerEU and lead to considerably higher fuel prices, prioritising coal in the merit order. The evolution of the marginal price assumed are shown in Figure 4, where the plain lines indicate the lowest cost within each technology (often supported by old plants), and dashes the highest cost.

| Decision Variable | Technology | 2025 | 2027 | 2030 | Most-affected countries |
|---|---|---|---|---|---|
| **Economic Commissioning** | Battery | 0.1 | 0.1 | 0.1 | MT |
| | DSR | 3.9 | 4.9 | 7.3 | SE, ES, NL, DE, DK, PT |
| | Gas | 0.4 | 0.7 | 14 | DE, DK, IE, MT |
| **Economic Life Extension** | Gas | 0 | 0.5 | 4.1 | DE, BE, DK |
| **Economic Decommissioning** | Coal | – 9.8 | – 10.6 | – 13.2 | BG, PL, RO, BA, DE |
| | Gas | – 50.2 | – 57.7 | – 48.7 | UK, DE, ES, GR, IT, NL |
| | Other non-RES | – 4.3 | – 4.6 | – 3.2 | DE, UK, HU, EE |
| **Total** | | **– 59.9** | **– 66.7** | **– 39.6** | **UK, DE, ES, IT, PL, DK** |

Table 2: Capacity change compared to National Estimates Scenario [GW] – Non-cumulative

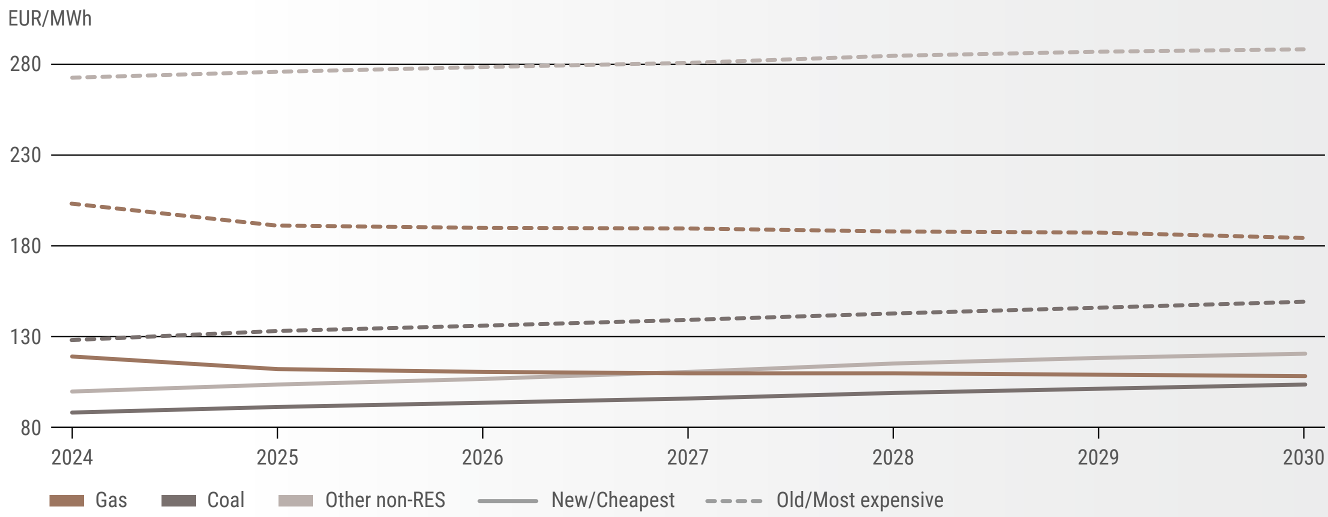



Figure 4: Marginal cost of thermal units

7 The National Estimates Scenario is the bottom-up scenario based on TSO's best estimates for the target years of ERAA 2022. After EVA is performed on this scenario, the result is a new 'post-EVA' mix, which constitutes the Central Scenario without CMs.

## 4.2 Adequacy Results – Central Reference Scenario Without Capacity Mechanism

Figure 5 to Figure 7 below illustrate the LOLE per region for the Central Reference Scenario Without CM and for target years 2025, 2027 and 2030. The LOLE values are represented by circles, with larger radius for larger LOLE values. A region's LOLE is calculated by averaging the Loss of Load Duration (LLD), i.e. hours with unserved energy, resulting from all the simulated Monte Carlo Years using the reference tool. More detailed results, including Expected Energy Not Served (EENS) per region, can be found in Annex 3. For the methodology and probabilistic indicators, please see Annex 2. Moreover, there are cases in which the results depend on the specificities of each country or zone. Thus, the reader should also consult Annex 4, which contains country-specific comments that enable more accurate conclusions.

The results of the EVA have, naturally, a significant impact on the adequacy assessment. Adequacy risks appear all around Europe, as can be observed in Figure 5 to Figure 7. Scarcity issues are identified in 2025 in Ireland with a LOLE exceeding 24 h/year, followed by Malta[8] with 22 h/year and then Germany, Italy, Spain, France and Belgium, Denmark and Hungary varying from 6 to 10 h/year LOLE. Lastly, Finland and Southern Sweden are also found to exceed national reliability standards in this scenario, having a LOLE of 3.5 h/year and 2 h/year respectively.

ERAA is still in the implementation phase, and the 2022 edition features considerable improvements over the previous one. As a consequence, the two editions' results shall be compared with specific care and in view of all the updates and differences between the two products; these include updates and changes in the assumptions and scenarios, but also modelling improvements with significant impact on the adequacy results, notably the implementation in the adequacy simulations of curtailment-sharing principles[9].

8 Adequacy results in the ERAA 2022 consider only resources available in the market and *CMs that already hold a CM contract*. In Malta, an additional 215 MW of non-market resource in the form of emergency gasoil-fired back-up plants are available for dispatch at any time and would largely mitigate the risk of scarcity.

9 For more information see Annex 2, Section 11.9.

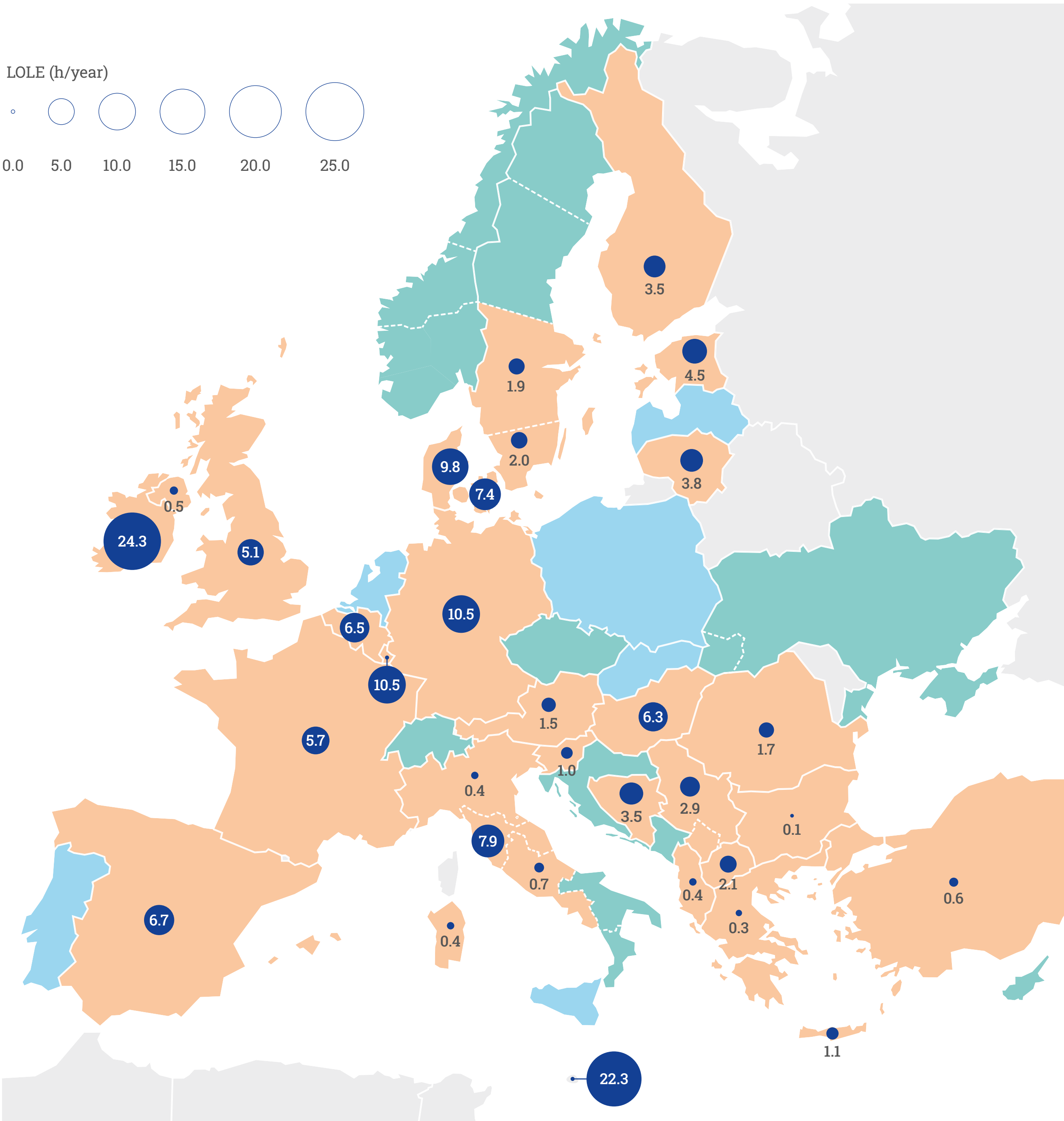



Figure 5: LOLE values for the Central Reference Scenario Without CM 2025[10]

In 2027 the adequacy situation appears to remain stressed, with adequacy risks even higher in Belgium, Germany, Denmark, Estonia, France, central and northern Italy, Lithuania, Luxembourg and Sweden (SE04). Adequacy risks are decreasing in Bosnia and Herzegovina, Spain, Finland, Hungary, Ireland, Malta, Romania and Serbia. In Ireland, in 2027 the LOLE drops below the national RS.

From 2027 to 2030, adequacy risks decrease in western Denmark, Estonia, central and northern Italy, Sweden (SE03) and Great Britain. On the other hand, LOLE values increase in Bosnia and Herzegovina, Germany, Hungary, Luxembourg, the Netherlands, Poland, Serbia and Slovenia. In 2030, Germany and Luxembourg face the highest LOLE value in Europe with 20.4 h/year, followed by Belgium, France and eastern Denmark.

Overall, and under the assumptions of the commissioning/decommissioning of capacities subject to EVA and the evolution of transmission capacities towards 2030, the scarcity issues tend to shift from the peripheral areas of Europe in 2025 to the central parts of the continent by 2030.

10 The Central Reference Scenario Without CM accounts for CMs that already hold a CM contract granted in any previous auction of any existing or approved CM at the time of the assessment, including strategic reserves, which are relevant for Sweden and Poland in TY 2025.

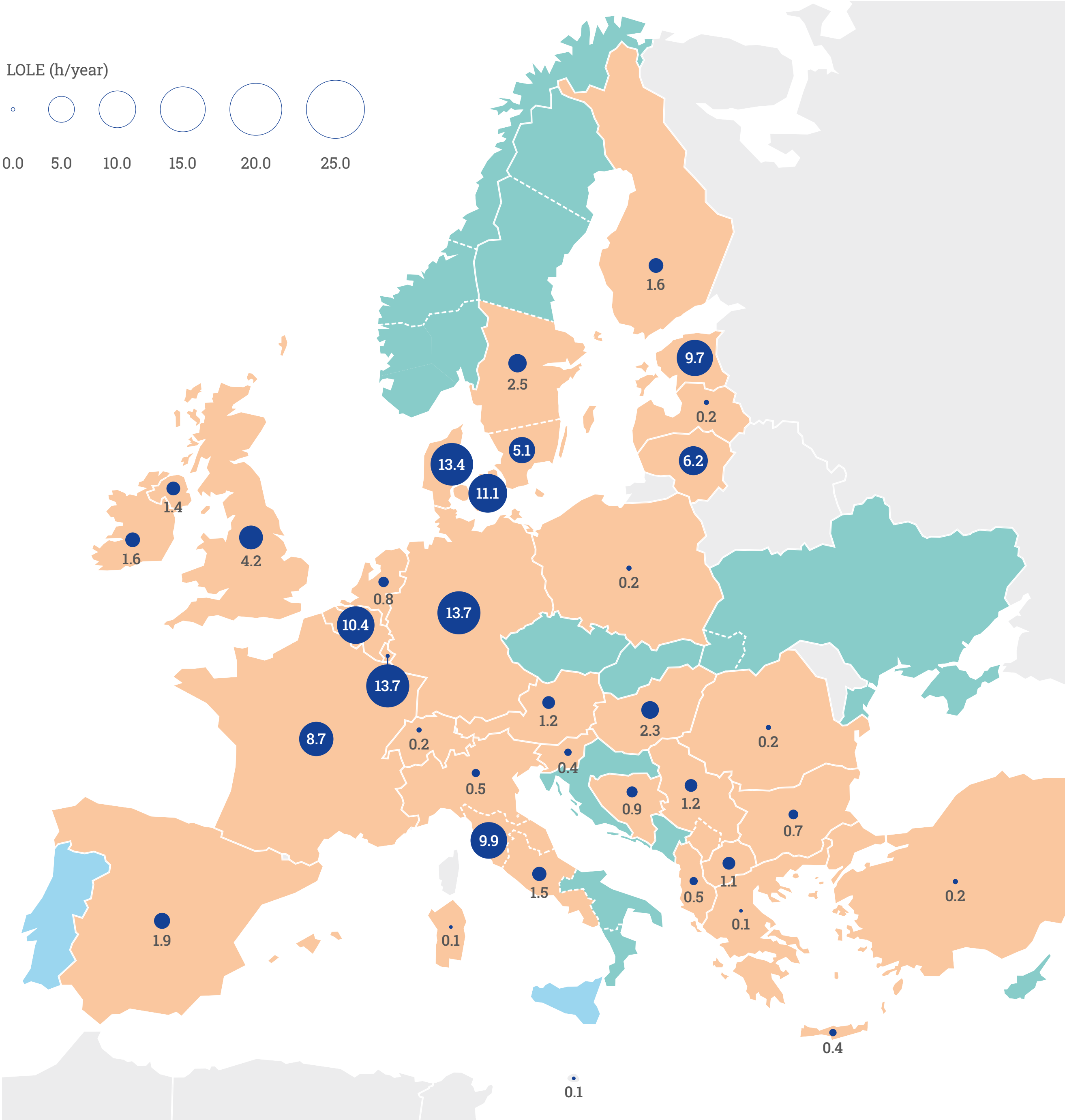
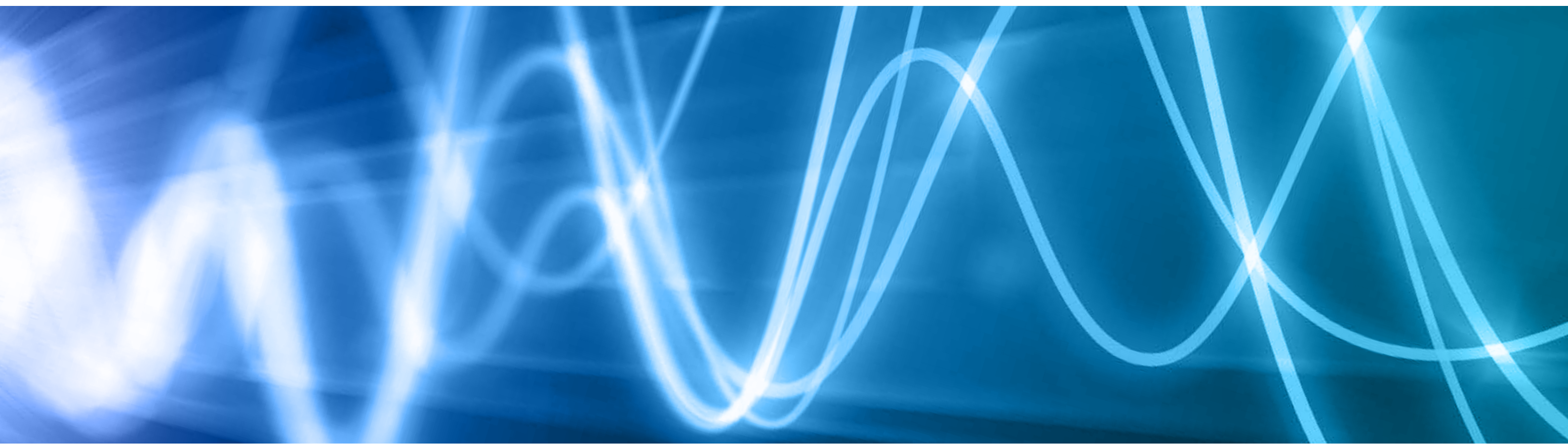



Figure 6: LOLE values for the Central Reference Scenario Without CM 2027



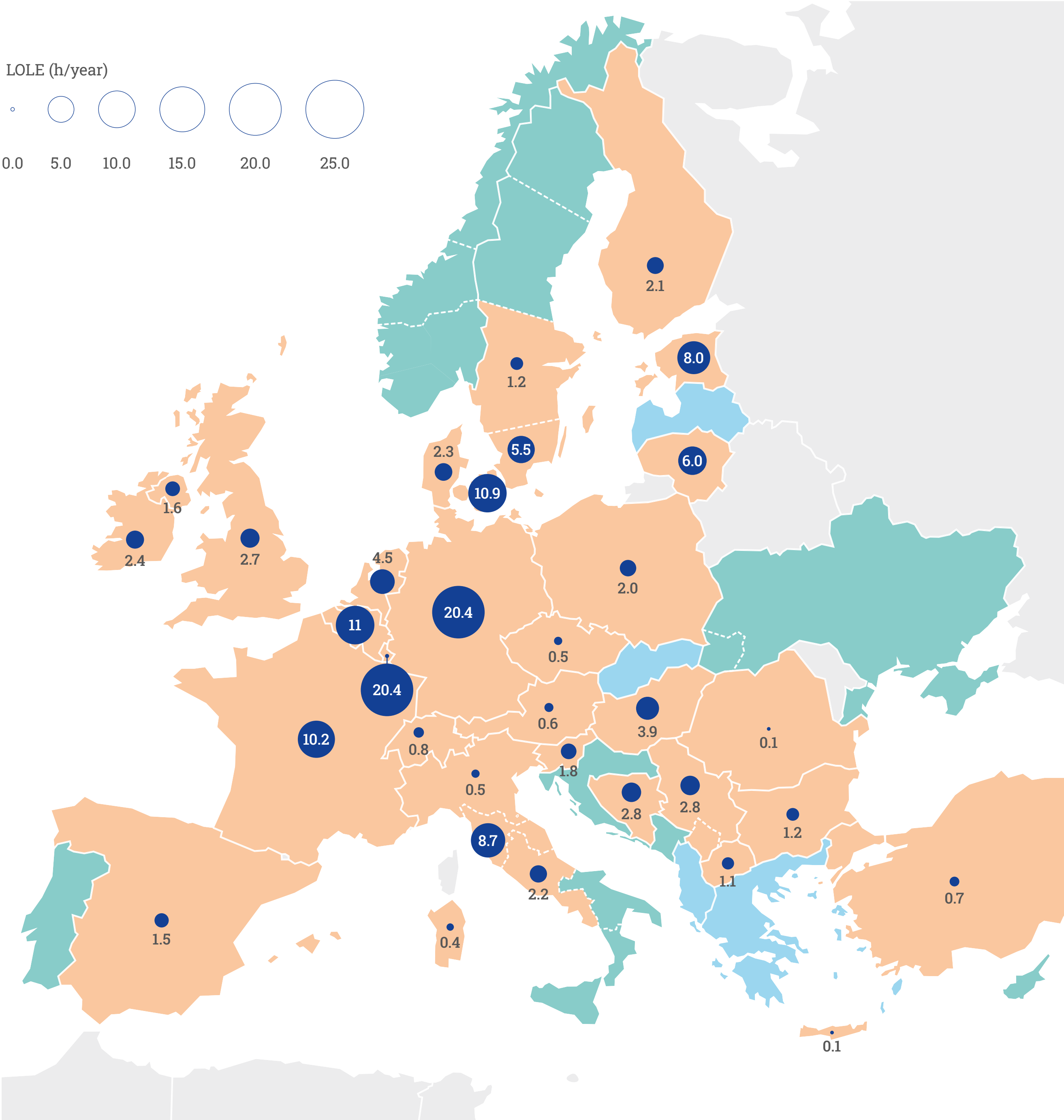



Figure 7: LOLE values for the Central Reference Scenario Without CM 2030

# 5 Beyond ERAA 2022

## 5.1 Keeping ERAA fit for purpose in a new context

Adopted in 2019 as part of the CEP, the Electricity Regulation tasked ENTSO-E with the development of the ERAA, which adopts a pan-European approach that can be complemented by regional or national analyses. Through this, ERAA aims to support an efficient and interconnected energy system by measuring the system's ability to maintain security of supply in a wide range of scenarios accounting for climate change and the rapid increase in renewables installed 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, proactively addressing the challenges while delivering secure and affordable energy to citizens and industries.

ENTSO-E firmly believes in the power of this analysis and has built on the significant knowledge base of its member TSOs to develop the approaches required for a comprehensive analysis.

The European energy context has changed drastically since the Clean Energy Package was released. Due to the current war in Ukraine and 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.

ENTSO-E is convinced that the ERAA role goes far beyond being a tool for CM decisions. ERAA can support policymakers on building their mid-term strategy. ERAA can also depict 'what if' scenarios to shed light on possible futures. Policy discussions are ongoing, especially on possible refurbishing of current market designs. In addition, high prices and scarcity periods may occur more often than in past decades.

## 5.2 ERAA implementation roadmap

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 decisionmakers have the best available information for approaching these challenges, and, although the report itself will not recommend specific actions, its data will inform decisions regarding CMs and other state policy interventions. The ERAA contains pioneering methodologies and tools to analyse future adequacy in an unprecedented combination of scope and detail, and it can be referred to when considering the overall direction of Europe's electrical grids. The ERAA provides an effective tool to identify system needs, and future development through methodological innovation, pilot programmes, consultation with stakeholders and refinement of scope will continue to strengthen ERAA's usefulness, whereas ENTSO-E remains committed to the multi-year planning, data delivery, scenarios and methodologies required to fulfil the ERAA's potential.

The stepwise approach endorsed by ACER on 2 October 2020[11] has served as the basis for the ERAA's evolution and implementation. Of particular focus will be the further development of the EVA and FB analysis, which together should add significant robustness to the findings of the report. Even now, hundreds of man-hours and thousands of computing hours have already been devoted to the development of these tools.

11 https://www.acer.europa.eu/Media/News/Pages/ACER-sets-the-methodologies-to-assess-electricity-resource-adequacy-in-the-EU.aspx

## What are the upcoming challenges and future steps for resource adequacy assessments as required under the CEP?

The CEP requires dedicated methodologies and features, such as an EVA, scenarios with CMs, the impact of climate change on input data, and FB representation of the grid, thus introducing significant challenges and improvements for pan-European and regional adequacy assessments.

Alongside the delivery of ERAA 2022, ENTSO-E is working on an updated implementation roadmap. This indicative roadmap is updated on an ad hoc basis, considering the best available approaches and know-how. It outlines how topics such as the role of electrolysers and DSR, alongside latest policy developments, will be factored into ERAA. It is important to stress that negotiations on the EU's Fit for 55 package and REPowerEU plan have led to changes in Europe's climate and energy objectives for 2030 that are being translated to national estimates. Stay tuned for more updates to the implementation roadmap on ENTSO-E's website.

# 6 Stakeholder engagement

Developing the ERAA relies on the contributions of many stakeholders to best understand how the system will develop. Gathering the views of policymakers, regulators and Member States, as well as electricity market participants, is crucial to informing the ERAA's outlook.

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 our underlying methodologies. The Electricity Coordination Group, comprising experts from EU Member States, was further instrumental in informing the production of the ERAA.

Building on ERAA 2021 stakeholder's feedback, the ERAA 2022 comprised expanded interactions with stakeholders at different phases of the project.

As part of the development of the ERAA 2022, ENTSO-E published its baseline assumptions and scenarios in May 2022. This was complemented by three dedicated webinars on the scenarios and methodologies, allowing stakeholder feedback. A further webinar will accompany the publication of this report in November 2022.

To make this information accessible and transparent for stakeholders, ENTSO-E created a dedicated webpage[12] where webinar recordings, responses to stakeholder questions and other key information regarding the ERAA implementation process are published.

12 https://www.entsoe.eu/outlooks/eraa/stakeholder-interactions

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