European Resource Adequacy Assessment

2021 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 42 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) 2021:

Navigating through the report

The ERAA 2021 is divided into eight documents (Executive Report and Annexes) to facilitate readers in identifying relevant information. The executive report describes the ERAA 2021 motivation followed by the adequacy results for the national estimate scenarios and central reference scenarios:

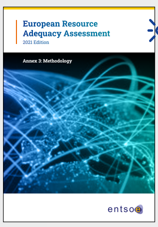
1) National Estimate for target year (TY) 2025 and TY 2030, as collected from TSOs;
2) Central Economic Viability Assessment (EVA) without Capacity Mechanism (CM) for TY 2025: based on "National Estimate" scenario and updated through the application of an EVA without CM;
3) Central EVA with CM for TY 2025: based on "National Estimate" scenario, and updated through the application of an EVA with CM;
4) National Estimate with Low Thermal Capacity for TY 2025 & TY 2030, scenario with reduced thermal capacity collected from transmission system operators (TSOs).

Annex 1 – Assumptions:

- Presentation of the ERAA 2021 scenarios and assumptions.

Annex 2 – Detailed Results:

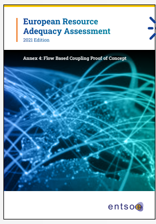
- Presentation of the ERAA 2021 detailed results



Annex 3 – Methodology:

Description of the main ERAA 2021 methodology, consisting of:

1) Probabilistic methodology for assessing adequacy;
2) Methodology of the EVA;
3) Introduction to methodologies used to prepare demand and climate datasets;
4) Methodological improvement targets.



Annex 4 – Flow-Based Market Coupling (FBMC) – Proof of Concept:

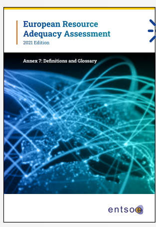
Proof of concept study focusing on the implementation of FBMC on the scenario "EVA without CM" for TY 2025.

Annex 5 – Country Comments

Voluntary-based specific comments provided by TSOs on the ERAA 2021 input data and results.

Annex 6 – Results benchmarking

Listing the results of the reference tool besides the results of other tools on the reference scenarios, aiming to offer an understanding of the uncertainty of the results.



Annex 7 – Definitions & Glossary

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1 Purpose and Motivation of the ERAA

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

The ERAA is a pan-European monitoring assessment of power system resource adequacy of up to 10 years ahead and is the successor to the Mid-term Adequacy Forecast (MAF). It is based upon state-of-the-art methodologies and probabilistic assessments, aiming to model and analyse possible events which can adversely impact the balance between supply and demand of electric power. It will be an important element for supporting qualified decisions by policy makers on strategic matters such as the introduction of capacity mechanisms (CMs).

The European electricity system is undergoing significant changes, driven by the EU's ambition for climate neutrality, the trajectory for which has been delivered by the Fit for 55 Package targets for 2030. This ambition will lead to 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 some thermal generation units. These changes are happening at unprecedented speed, and the power system needs to adapt swiftly to respond 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 grid at all times throughout the year.

In this context, a pan-European analysis of resource adequacy has become ever more important; complementing the insights of national and regional analyses. Cooperation across Europe is necessary to accelerate the development of common methodological standards, and a common "language" is required 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. Building on the work done with the MAF, the ERAA is a leap forward in system modelling. Following the methodologies as approved by ACER on 2 October 2020, the ERAA will be the key tool for the detection of adequacy concerns at a European level and the related potential introduction of CMs.

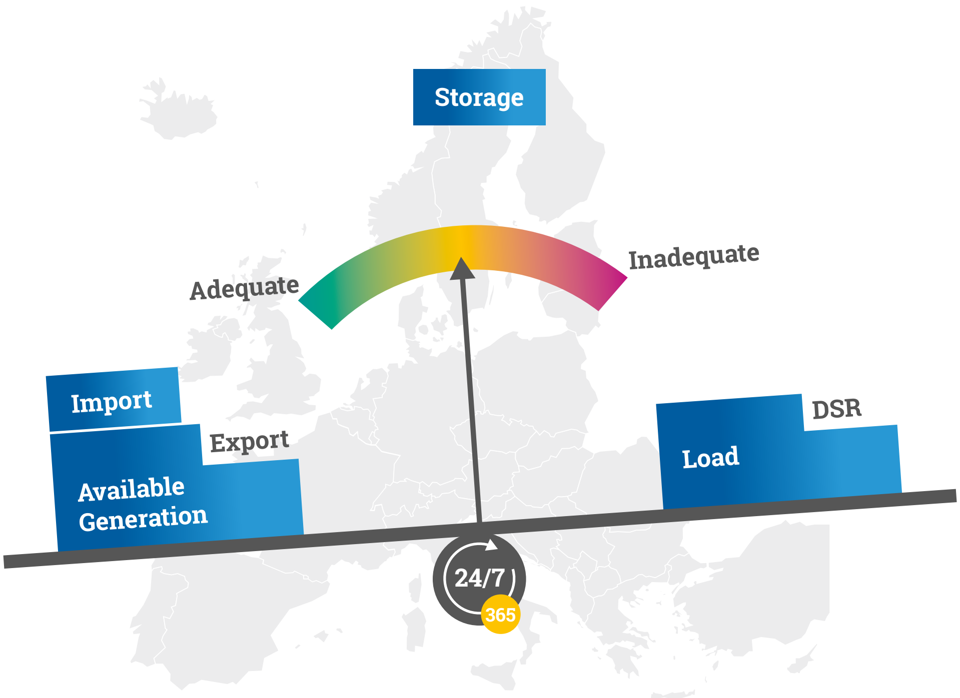

Figure 1: Resource adequacy: balance between net available generation and net load

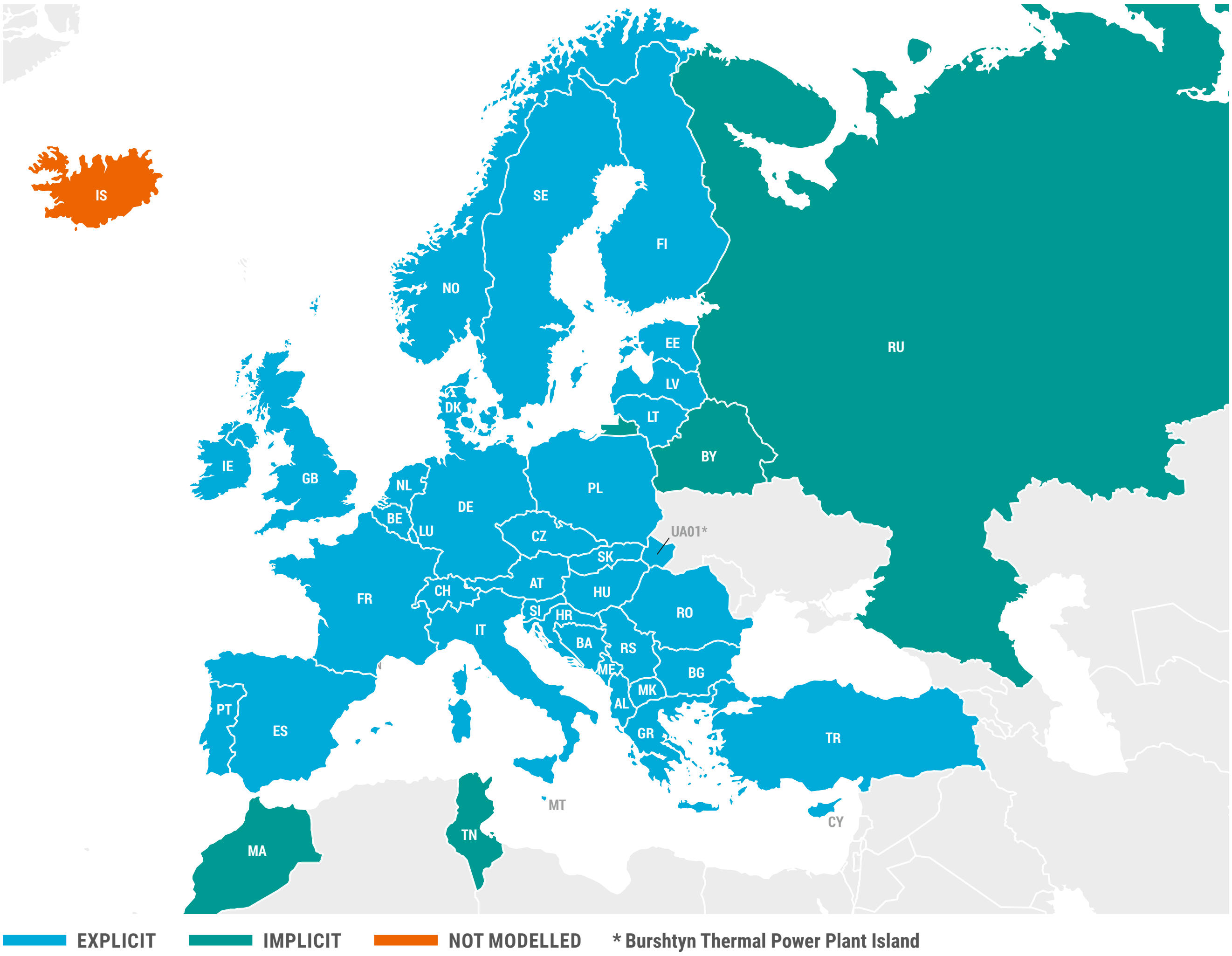

Figure 2: The ERAA 2021 geographical scope

Resource adequacy assessments on the electricity grid, such as the ERAA, are increasingly prominent studies which use advanced methodologies to model and analyse possible events with potentially adverse consequences for the supply of electric power. They assess the balance between net available generation and net load levels in the European power system on a continuous basis, 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 power system's ability to maintain security of supply under a very high number of possible future system states, due to different plausible weather conditions and random outages of conventional power plants and relevant network elements. In summary, the ERAA does not predict the future but rather identifies potential shortcomings in the system which can be addressed proactively.

To identify these shortcomings, the ERAA relies on national standards for system reliability. Individual EU Member States apply reliability standards (RS) to assess their national resource adequacy, an overview of which 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 h/year. Setting such reliability standards is a complex issue as it requires the consideration of both economic and technical aspects. 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].

The ERAA aims to provide stakeholders and policy makers 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.

1 https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Individual decisions Annexes/ACER Decision No 23-2020_Annexes/ACER Decision 23-2020 on VOLL CONE RS - Annex I.pdf

Resource adequacy assessments, such as the MAF 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 a leap forward from the MAF and complements those national assessments with a pan-European outlook. It is also coordinated and consistent with other timeframe studies 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. ENTSO-E and its TSO members will continue to ensure that further progress is made, following the implementation roadmap, until the full implementation of the targeted methodology[2] of the ERAA is achieved.

Stakeholders have found the MAF, and its extensive pan-European coverage, particularly useful for decision making. With the evolution of the MAF into the new ERAA, stakeholders can expect an even more useful and valuable tool. With analysis that better accounts for the realities and complexities of the single electricity market, an unparalleled data set, and an innovative economic viability assessment, the ERAA 2021 sets a global benchmark for system analysis. The realisation of this report is an inherently complex task only made possible as a result of the collaborative efforts of European TSOs.

ENTSO-E has relied on the contributions of stakeholders to develop the ERAA. Public consultations on the methodology began in 2020, and ENTSO-E has regularly consulted with ACER and EU Member States on the development of this report. The ERAA 2021, along with the roadmap for future editions, will be accompanied by a public consultation on all aspects of the assessment. Furthermore, there will be, in future editions, dedicated workshops on methodology, scenarios and assumptions, along with international benchmarking to ensure robustness.

The scope of the ERAA includes 37 countries explicitly modelled through 56 zones. It considers all EU member states as well as the ENTSO-E perimeter beyond EU[3]. For more information regarding the countries modelled within the ERAA 2021, please refer to Annex 1. Figure 2 below illustrates the geographical scope of the ERAA 2021, distinguishing between countries that have been explicitly modelled, neighbouring countries that have been modelled implicitly through fixed exchanges and non-modelled countries.

The extended geographical scope of the ERAA 2021 leads to significantly complex and computationally heavy models. Thus, it is necessary for the ERAA study to generalise where reasonable. The most relevant and critical factors were identified and used to deliver ERAA, with national and regional assessments providing complementary and deep analysis of local constraints. The latter assessments are also more suited to run various local sensitivities, highlighting the complementary nature of the pan-European ERAA and regional/national adequacy studies. Although such studies may rely on the same methodology and reference scenarios, they can assess additional sensitivities related to both infrastructure and operational considerations[4]. National and regional studies can use tools and data granularity complementary to those used by ENTSO-E.

2 https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Individual decisions Annexes/ACER Decision No 24-2020_Annexes/ACER Decision 24-2020 on ERAA - Annex I.pdf

3 With the exception of Iceland, which is not connected to the pan-European grid and thus does not have any effect on the assessment.

4 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	Binding (B)/non-binding (NB)
BE	LOLE	3 h/year	B
BG*	LOLE	16 h/year	
CY	Reserve margin	189 MW	B
DE	LOLE	5 h/year	NB
DK	Outage minutes	5 minutes	B
EE*	LOLE	9 h/year	
ES*	LOLE	3 h/year	NB
	Reserve Margin	10 %	NB
FI*	LOLE	3 h/year	B
FR*	LOLE	3 h/year	B
	LOLE	2 h/year (after post-market measures)	B
GR	LOLE	3 h/year	NB
ISEM	LOLE	8 h/year	B
IT	LOLE	3 h/year	B
LT	LOLE	8 h/year	B
NL	LOLE	4 h/year	NB
PT*	LOLE	5 h/year	B
	Load supply index	≥ 1	B
PL	LOLE	3 h/year	NB
UK (GB only)	LOLE	3 h/year	B

Table 1: National reliability standards applied by EU Member States as of the end of 2019 (ACER Market Monitoring Report 2019) and updated where relevant by more recent ENTSO-E information (updated information is marked with an *). Non-listed member states do not have a reliability standard in place.

- The load supply index in Portugal refers to the risk of inadequacy at the day-ahead market only.
- The reserve margin in Cyprus is the level of additional capacity readily available during the demand peak period.
- Outage minutes (OM) in Denmark are defined as OM = 8,760 × 60 × EU / Demand, where Demand equals the annual load and EUE is the expected unserved energy (i.e. the EENS adjusted to account for the fact that real load shedding occurs at predefined blocks of energy). OM indicates the expected proportion of the annual load that cannot be delivered due to a lack of adequacy, converted to minutes. OM and LOLE are different measures and are thus not comparable.
- For Germany, the reliability standard has been derived from a threshold presented by the German Federal Ministry for Economic Affairs and Energy in the 2019 security of supply monitoring report.
- ISEM is a wholesale electricity market where electricity is traded in bulk across the island of Ireland
- In Spain, a 10 % reserve margin (not legally established) was recently used, while a LOLE indicator is currently under discussion. For the non-mainland territories, there is a requirement of a maximum LOLP of one day every 10 years, equivalent to a LOLE of 2.4 hours/year.
- In Finland, a government resolution of 8 July 2021 set the reliability standard to EENS 1,800 MWh/year and LOLE 3 h/year.
- Estonia adopted in May 2021 a reliability standard of LOLE 9 h/year.

2 Reference scenarios and main assumptions

The ERAA 2021 is the first implementation of the ERAA methodology and includes for the first time the implementation of an EVA for a scenario with and a scenario without CMS as well as a proof of concept (POC) study for the future implementation of flow-based (FB) market coupling. The ERAA 2021 also considers climate change in the input scenarios, though in a simplified manner using a transitionary solution while preparing an enhanced and forward-looking Pan-European Climate Database for future ERAA editions.

The 2021 assessment is carried out for two target years (TY), namely 2025 and 2030, in an effort to focus on building a robust and reliable methodology before expanding the target horizon to the targeted 10-years ahead with annual granularity. TY 2025 is chosen as it represents a pivotal year for evaluating adequacy due to expected reductions in coal and nuclear capacity in Europe. TY 2030 is chosen to allow for the evaluation of the adequacy situation further ahead, at the end of the 10-year time horizon. The ERAA, which considers the medium term, is also coordinated and consistent with other timeframe studies as the TYNDP and Seasonal Outlooks.

In addition to the target years, the ERAA 2021 is structured by different scenarios. These scenarios are differentiated by levels of intervention (with or without CMs), and by the approaches used in their modelling. The ERAA contains innovative new approaches which seek to understand the economic forces impacting capacity in Europe (EVA), and analyse the impact of the network on the possible commercial energy exchanges between different bidding zones (FB Analysis). These have been piloted in the ERAA 2021 and will be applied across more target years in future editions.

ENTSO-E has invested heavily in proposing and implementing a first version of an EVA. This assessment brings together multiple aspects and interdependencies to give the most comprehensive economic analysis of Europe's generation assets ever. The EVA is a challenging addition to the ENTSO-E resource adequacy assessments, requiring a significant number of assumptions with respect to input data, strong computational resources and pragmatic simplifications to achieve trustworthy results. Due to its complexity, this first edition of ERAA includes the implementation of EVA on a single target year (2025) for both central reference scenarios required by the regulation, i.e. scenario with CMs and without CMs.

The two central reference scenarios are complemented in ERAA 2021 with two national reference scenarios: the "National Estimates" and "National Estimates – Low Thermal". These additional scenarios reflect the national estimates of TSOs with respect to installed capacities in both target years, with the latter expressing the uncertainty identified by TSOs in the commissioning and decommissioning of several assets in their national power systems.

Therefore, the ERAA 2021 includes 4 reference scenarios for TY 2025 and 2 for TY 2030:

1) National Estimate for TY 2025 and TY 2030, as collected from TSOs;
2) EVA without CM for TY 2025: starting from "National Estimate" scenario, and updated through the application of EVA without CM;
3) EVA with CM for TY 2025: starting from "National Estimate" scenario, and updated through the application of an EVA with CM;
4) National Estimate – Low Thermal Capacity for TY 2025 & TY 2030, scenario with reduced thermal capacity collected from TSOs.

The scenarios which do not implement the EVA, i.e. all "National Estimate" scenarios, are complemented in this report by an analysis of economic data and revenues of the asset categories modelled. Furthermore, flow-based market coupling (FBMC) is implemented in this ERAA report on the TY 2025 EVA without a CM scenario and presented in a dedicated Annex. This represents a POC of a main methodological evolution for ERAA, before its implementation in the central scenarios, foreseen for the ERAA 2022. Although modelling cross-border capacities as net transfer capacities (NTCs) is a simplification compared to a FB calculation, it is demonstrated in the report that the NTCs provided by TSOs generally provide at least as large market exchange capacities as would be the case under a 70% compliant FB calculation.

The scenarios used in the ERAA 2021 and presented in this report are summarised in Table 2 below, which also presents the main assumptions and differences of the scenarios.

Scenario name	National Estimates	Central Without CM	Central With CM	National Estimates with low thermal capacity	FB
Reference Scenario	Yes	Yes	Yes	Yes	No
TYs	2025, 2030	2025	2025	2025, 2030	2025
EVA	Revenues & Costs reported	Yes	Yes	Revenues & Costs reported	Yes [5]
CM	N/A	EVA: without CM Adequacy: same as EVA	EVA: with CM Adequacy: same as EVA	N/A	EVA: without CM Adequacy: same as EVA
Interconnection modelling	NTC	EVA: NTC Adequacy: NTC	EVA: NTC Adequacy: NTC	NTC	FB in Core, NTC in other zones Qualitative FB report for Nordics
Applicable sensitivities	N/A	EVA: › CO_2 price of 60 €/ton (40 € / ton in central scenarios) › Price cap of 3k € / MWh (15k € / MWh in central scenarios) Adequacy: N/A	EVA: N/A Adequacy: N/A	N/A	N/A

Table 2: Scenarios in the ERAA 2021

5 The FB POC was performed on the capacity mix of the scenario EVA without CM, where installed capacities were estimated without considering FBMC (NTC representation of the grid).

3 Key takeaways

The ERAA 2021 shows that with planning, coordination and, where necessary, targeted intervention, Europe's power system can provide secure electricity even in the face of an unprecedented transition. Nonetheless, system operators face adequacy challenges which must be managed proactively. In the absence of intervention, risks of system inadequacy rise substantially in 2025, and targeted measures should already be considered.

For TY 2025, the results of the ERAA 2021 show that the evolving economics of thermal generation, driven in particular by increasing integration of RES and evolutions in carbon pricing, will put downward pressure on capacity. This will require the implementation of new flexibility tools allowing the management of demand (ramps and peaks). It further necessitates capacity which can quickly respond to sudden variation of demand and supply; for instance, evening fast increasing demand while decreasing PV supply. Furthermore, without intervention (see scenario EVA without CM – TY 2025) risks of system inadequacy rise 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, any capacity investment in one country can greatly influence its neighbours. This highlights the importance of regional coordination in decision making. The central reference scenarios (EVA with/without CM for TY 2025) suggest that Central and Western Europe have especially low margins, with LOLE estimates of several hours for most countries in the region.

On the other hand, Southern Europe seems to be more robust adequacy-wise, with the exception of islands (Malta, Sardinia, Cyprus), due to their limited interconnection capacity.

In the longer term, i.e. target year 2030, the bottom-up analysis (i.e. National Estimates scenarios) shows important risks for the economic viability of the assumed thermal generation fleet. The qualitative approach used in this edition for 2030 is a first step. Refining in the next ERAA editions will allow for a better view on long-term assessment. Therefore, a one-on-one quantitative comparison with the 2025 results is not valid. In addition, there will always be even more uncertainty for long term than for midterm; thus, those results should be seen from a different perspective.

The above key takeaways show the contribution of CMs to ensuring system adequacy, though the ERAA 2021 does not specify in which technologies or geographic locations within a region. The ERAA is an innovative product, giving visibility on the impact of climate policies on the adequacy of the system with an acceptable level of approximation. Future editions will take the learnings of the ERAA 2021, including the new approaches such as the EVA and FB analysis, and, after further improvement, apply them to an increasing number of TYs and scenarios. Nonetheless, this first edition is already a significant leap forward compared to its predecessor MAF. For the future editions, an important range of uncertainty will intrinsically remain, even as models grow increasingly robust and are applied more widely. For this reason, the ERAA should not be considered as the only tool for decision-makers as other parameters (e.g. congestion management) should be considered as relevant.

As the ERAA develops towards the target methodology, it will factor in new assumptions and data, as well as the evolving policy environment. Although this will inevitably change the specific results, ENTSO-E is confident that the general findings outlined in the ERAA 2021 will remain valid.

4 Main findings of the ERAA 2021

The ERAA 2021 assessed the adequacy of the European system for two TYs, namely 2025 and 2030. The main findings of the assessment are presented in this section, whereas more detailed results can be found in Annex 2. TY 2025 was chosen as it represents a pivotal year for evaluating adequacy due to expected reductions in coal and nuclear capacity in Europe. TY 2030 was chosen to allow for the evaluation of the adequacy situation further ahead, at the end of the 10-year time horizon.

To obtain robustness and confidence in the results, five different market modelling tools were used, to benchmark the results of the reference tool presented in this executive report. The interested reader can find the results of the complementary tools in Annex 6. The simulation inputs differ among the four scenarios for TY 2025 and the two scenarios for TY 2030. More information on the scenarios' assumptions and input data can be found in Annex 1. As in all probabilistic studies, and especially Monte Carlo assessments such as the present, the results should be interpreted considering all necessary input assumptions and the uncertainty of input variables. In the ERAA 2021, the latter consist of climate variables and forced outages, and results are presented in expectation, e.g. LOLE being the expectation of number of hours with unserved energy per year.

National Estimates scenarios are bottom-up scenarios collected from TSOs as their best estimates of the capacity mix in the target years and are aligned with the latest National Energy and Climate Plans. Starting from National Estimates, TSOs were also asked to provide information about uncertainties around the commissioning and decommissioning of any assets in their country, focusing on uncertainty that would negatively impact the adequacy situations, e.g. possibility of earlier decommissioning or delayed commissioning of thermal units. This led to the **national reference scenario "National Estimates – Low Thermal Capacity"**. The aforementioned scenarios are then complemented by an EVA with and without CM for TY 2025, implemented with the "National Estimates" scenario as a starting point.

Figure 3 to 6 below illustrate the LOLE per region for all scenarios and both target years. The LOLE values are represented by circles, with the radius increasing for increasing LOLE values. A region's LOLE derived from a reference modelling tool is calculated by averaging the Loss of Load Duration (LLD), i.e. hours with unserved energy, resulting from all the simulated Monte Carlo Years. More detailed results, including Expected Energy Not Served (EENS) per region, can be found in Annex 2. For the methodology and probabilistic indicators, please see Annex 3. Moreover, there are cases in which the results depend on the specificities of each country or zone. Thus, the reader should also consult Annex 5, which contains country-specific comments that enable more accurate conclusions.

4.1 National Estimates

4.1.1 National Estimates 2025

The first scenario analysed in the ERAA 2021 is "National Estimates 2025". As a bottom-up scenario, it does not include any EVA[6]. Figure 3 illustrates that this scenario does not show any significant risk in most of the European perimeter. Naturally, islands are expected to face adequacy risks more commonly than the rest of Europe; thus, even for this scenario Malta[7], Sardinia and Sicily are identified with a high number of hours of loss of load expectation. More specifically, the planned coal phase-out in Sardinia creates adequacy concerns, if not counterbalanced by a stronger interconnection with the Italian peninsula and some replacement capacity. Lithuania also shows considerable adequacy risks for this scenario (7.5 h), followed by Finland (1.5 h), France (0.9 h) and Ireland (0.9 h).

6 An assessment of revenues and costs derived from the economic dispatch results are presented in Annex 2, complementing the adequacy results for the National Estimates scenarios.

7 Adequacy results in the ERAA 2021 consider only resources available in the market. In Malta, 215 MW of non-market resource is available and would mitigate the risk of scarcity.

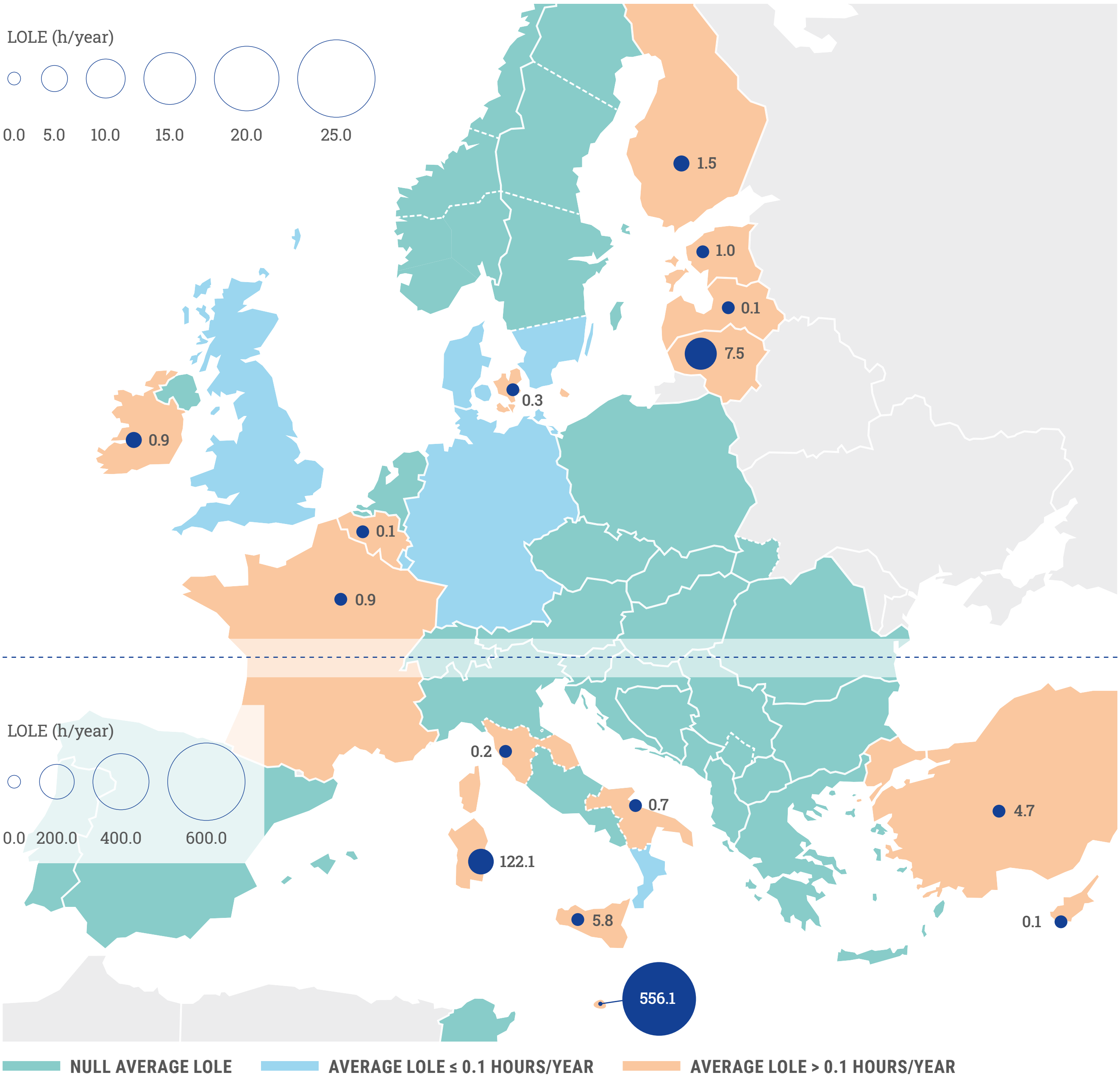

Figure 3: LOLE values for the scenario "National Estimates 2025". Circles for bidding zones with LOLE values smaller than 0.1 hours/year are not represented.

4.1.2 National Estimates 2030

The National Estimates[8] scenario for 2030 does not differ in terms of adequacy issues in Europe, compared to TY 2025. The high scarcity risk in Sardinia is no longer present due to the planned grid development and the new generation resources hypothesised. From the islands, only Malta[7] remains under risk even though that risk is expected to be reduced compared to target year 2025; this is also the case for Lithuania. New scarcity appears in Denmark (6.4 h) due to higher demand levels but apart from that all other zones, according to this scenario, are without scarcity risks under the capacity assumptions of this scenario.

8 An assessment of revenues and costs derived from the economic dispatch results are presented in Annex 2, complemented by the adequacy results for the National Estimates scenarios.

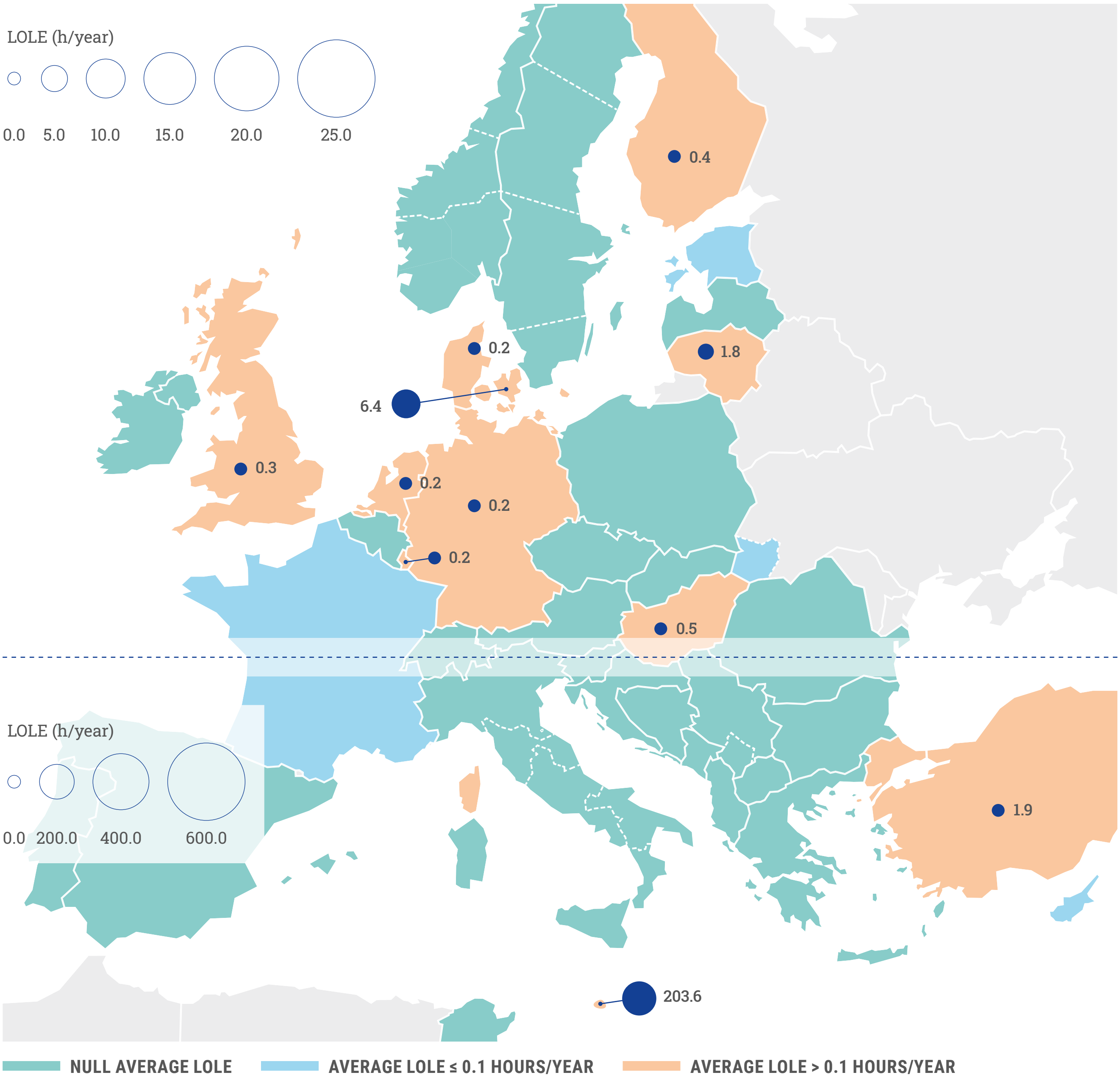

Figure 4: LOLE values for the scenario “National Estimates 2030”. Circles for bidding zones with LOLE values smaller than 0.1 hours/year are not represented.

4.2 EVA without Capacity Mechanism

For some thermal capacities (and also demand side response [DSR] in countries not having a specific support scheme), revenues from energy markets are not sufficient to cover operating costs (for existing capacities) or full costs (including CAPEX cost, for new capacities). Thus, when considering a price cap of 15k €/MWh in all bidding zones, implementing an EVA has led to an overall reduction in thermal capacity, compared to the National Estimates scenario for 2025. More specifically, capacity exit due to non-viability has been observed in most countries of the modelled perimeter, totalling approx. 75 GW of capacity withdrawal. This is mostly coal and lignite generation, and is far greater than the anticipated economic commissioning of 13 GW as a result of the EVA, which mainly appears in Turkey.

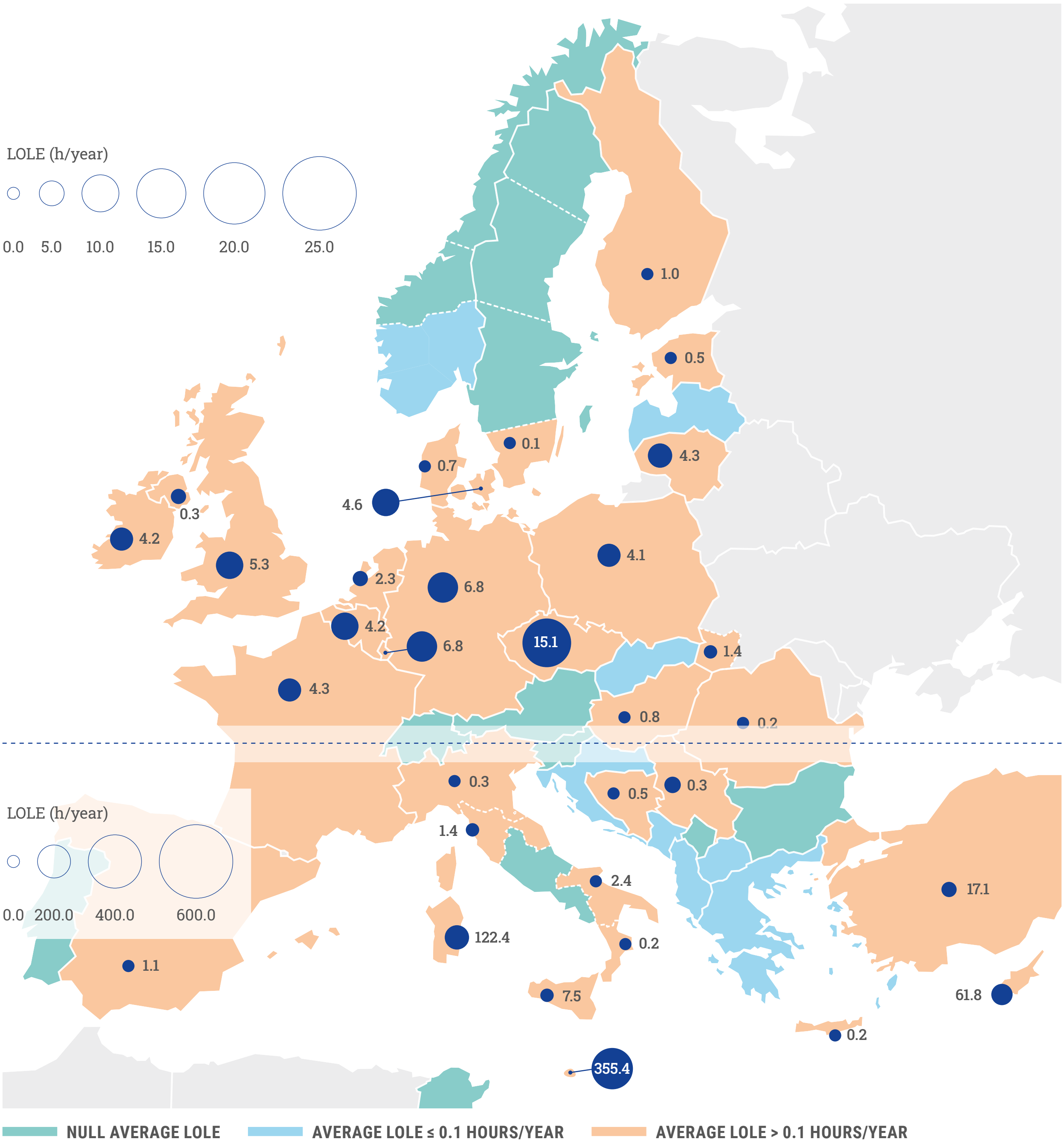

Figure 5: LOLE values for the scenario "EVA without CM 2025". Circles for bidding zones with LOLE values equal or smaller than 0.1 hours/year are not represented.

4.3 EVA with Capacity Mechanism

In the EVA scenario with CMs, countries with CMs in place are expected to reach their corresponding reliability standard. This is reflected in the modelling constraints of these scenarios, and is shown on the results in Figure 6. The assumption of CMs brings countries at risk (France, Belgium, UK, Italy, Germany) close to their reliability standards with approximately 5 GW additional capacity. This comes either as re-entry or new entry, compared to the scenario without CM. For some zones, e.g. IT and PL, the LOLE is still higher than the RS, indicating that more capacity should be anticipated in these zones. Furthermore, the introduced CMs also have a reducing effect on the LOLE values of neighbouring countries, e.g. Germany. The results of the economic assessment have, naturally, a significant impact on the adequacy assessment. Adequacy risks appear all around Europe, as can be observed in Figure 5. Most notable scarcity issues are identified in the islands of Malta[7], Sardinia[9], Sicily, Cyprus, UK and Ireland. In mainland Europe, the Czech Republic reaches 15 h of LOLE followed by Germany and Luxembourg (~7 h), France, Belgium, Denmark and Lithuania (~4 to 4.6 h).

9 Note that the reference tool has not sufficiently converged for ITSA for which it would need a higher number of random draws. LOLE is observed to be higher for ITSA when consulting the results of other tools. An overview of the LOLE range and uncertainty can be found by consulting the results from other tools in Annex 6.

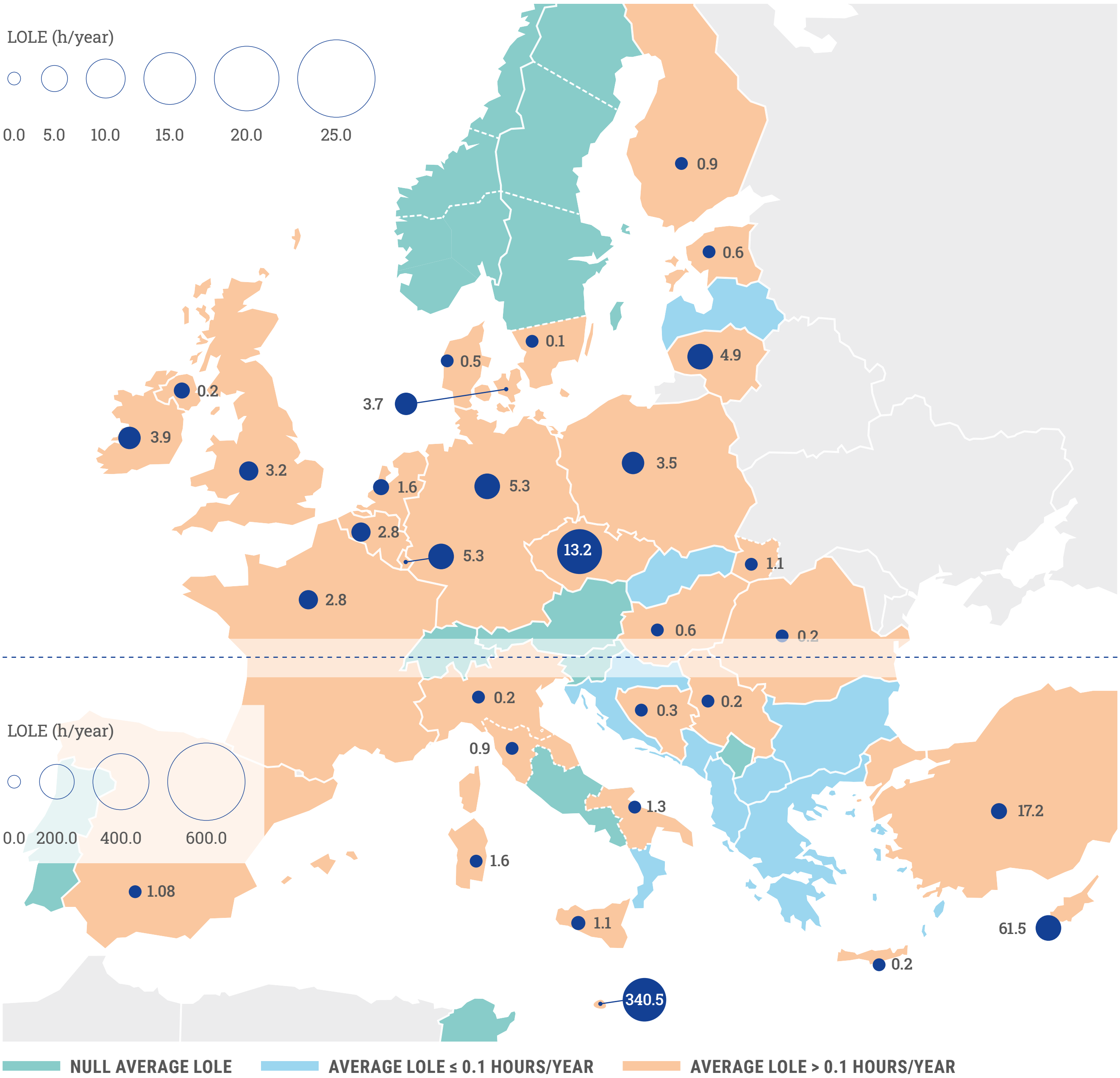

Figure 6: LOLE values for the scenario "EVA with CM 2025". Circles for bidding zones with LOLE values smaller than 0.1 hours/year are not represented.

4.4 National Estimates with Low Thermal Capacity

National Estimates scenarios are built in line with the National Energy and Climate Plans and are intended to follow official national decisions. However, such bottom-up scenarios are subject to change and the realisation of new projects can face delays, whereas, on the other hand, the decommissioning of some power plants might be accelerated, following an updated transition agenda that is not reflected in the official plans. Therefore, in the ERAA 2021, ENTSO-E includes an additional national scenario for both TYs, which reflects the impact of early decommissioning or delayed commissioning of thermal generation units, according to the expectations and knowledge of TSOs at the time of data collection.

4.4.1 National Estimates with Low Thermal Capacity 2025

The scenario National Estimates with low thermal capacity for 2025 is characterised by a total of 21.7 GW less installed capacity in Europe compared to National Estimates. This has a considerable impact on the results of the ERAA 2021 with respect to scarcity risks throughout Europe. The results of this scenario are presented in Figure 7 Similarly to previous sections, the islands face the highest LOLE. In continental Europe Poland, Lithuania, France also appear to have a considerable number of loss of load hours due to the reduced available capacity in the corresponding regions compared to the National Estimates scenario[10].

10 In the case of Poland, only hard coal / lignite units with already concluded contracts on the Capacity Market are considered in the National Estimates with Low Thermal Capacity scenario for TYs 2025 and 2030. The remaining units, in this scenario, are early decommissioned as they cannot receive support from the Capacity Market in the present form, due to the 550 kg CO_2 emission limits coming into force from July 2025. More details can be found in Annex 5 – country comments.

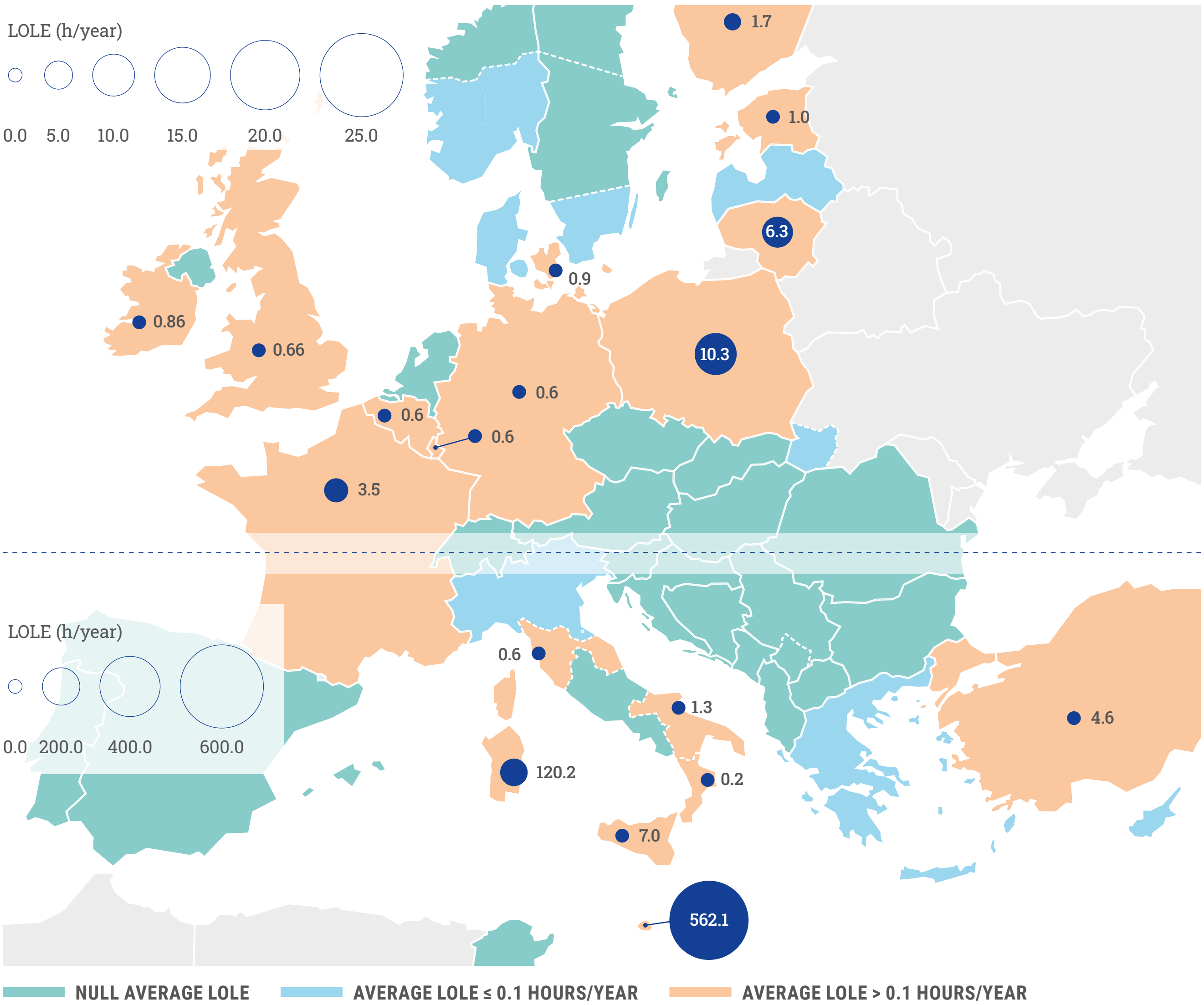

Figure 7: LOLE values for the scenario "National Estimates with low thermal capacity 2025". Circles for bidding zones with LOLE values smaller than 0.1 hours / year are not represented.

4.4.2 National Estimates with Low Thermal Capacity 2030

In 2030, approx. 36 GW of thermal capacity is flagged by TSOs as uncertain, with respect to the expectations illustrated in the National Estimates' scenario. The highest contributions to this reduction in capacity are in Poland[10], France and Germany, which are reflected in the adequacy results for the corresponding zones, as presented in Figure 8.

The uncertainty in the available thermal capacity in Poland results in significant LOLE and also has an appreciable impact also on neighbouring zones, for example Lithuania. Denmark is also affected by this scenario, with DKE reaching 11 hours of LOLE. Germany follows with more than 3 hours. In the rest of the European zones, risks are rather limited, similarly to the adequacy situation in the National Estimates scenario.

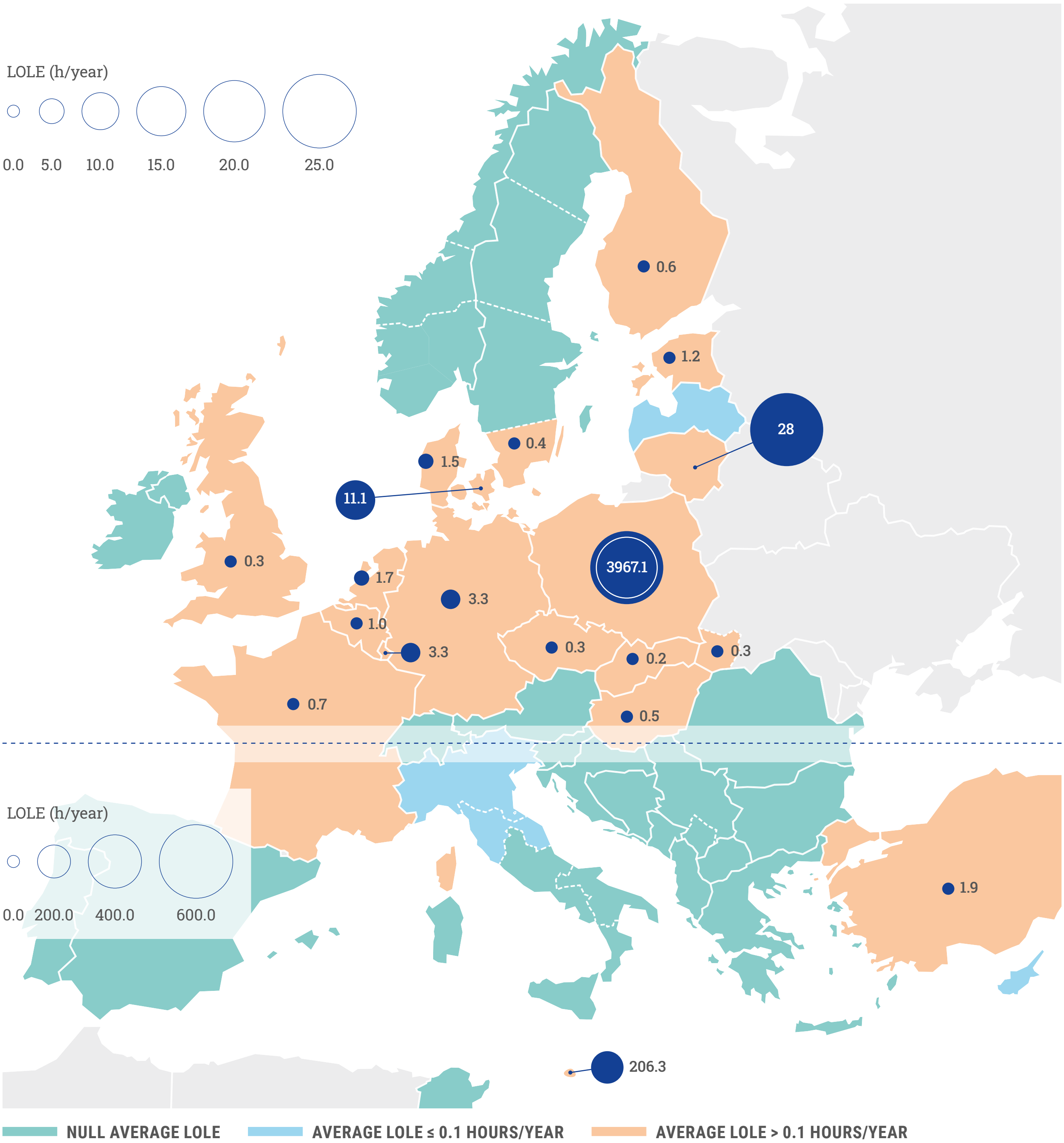

Figure 8: LOLE values for the scenario "National Estimates with low thermal capacity 2030". Circles for bidding zones with LOLE values smaller than 0.1 hours / year are not represented.

5 First step towards full methodology implementation

Adopted in 2019 as part of the CEP, the Electricity Regulation tasked ENTSO-E with the development of the ERAA. The ERAA takes a pan-European approach, complemented by regional 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, as well as previous work conducted for the MAF 2020, to develop the new methodologies required for a comprehensive analysis. At the same time, in accordance with the ERAA methodologies approved by ACER in October 2020[11, 12], ENTSO-E underlines that ERAA will be continuously improved in future editions to meet the specific requirements laid out within the Electricity Regulation. The ERAA 2021 already 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, delivering the data, scenarios and methodologies required to fulfil the ERAA's potential and allow full implementation by end of 2023.

5.1 Main methodological elements

Under the Electricity Regulation (Article 23), the ERAA, which is implemented stepwise starting from the current 2021 edition, is required to consider, among others, the following aspects:

- An EVA of resource capacities;
- FB modelling of the power network (when applicable);
- Impact of climate change on adequacy;
- Analysis of additional scenarios, including the presence or absence of CMs;
- Consideration of energy sectoral integration;
- Time horizons of 10 years with annual resolution.

Two of the most significant improvements in the future ERAA are **the assessment of the economic viability of existing and new capacities and the implementation of FB modelling**. The former provides a better insight into the adequacy situation considering the market impact on the withdrawal or expansion of generation, whereas the latter will come to replace the NTC approach that is currently used, aiming to provide a better representation of the grid elements in the model. ENTSO-E and its members are already actively preparing for the full implementation of the target ERAA methodology.

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

12 https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Individual%20decisions%20Annexes/ACER%20Decision%20No%24-2020_Annexes/ACER%20Decision%24-2020%20on%20ERAA%20-%20Annex%20I.pdf

Table 3 presents the main elements required by the electricity regulation and the way these have been addressed in this first edition of ERAA as part of the stepwise implementation roadmap. ENTSO-E aims to improve multiples of these and other methodological elements in the next ERAA editions, including the following:

- Consideration of FB domains in the central reference scenarios and preparation for FB expansion to the Nordic region;
- Improvements in combined heat and power (CHP), DSR and storage modelling in the EVA and the adequacy models;
- Multiyear EVA as opposed to separate EVA for each target year;
- Consideration of the curtailment sharing principles, both in NTC and FB where applicable;
- Consideration of dynamic price caps as opposed to the single price cap in the ERAA 2021.

For more information on the implementation targets and ENTSO-E's roadmap towards the full implementation of the ERAA see Section 5.2.

Although ENTSO-E has relied on some methodological simplifications throughout the ERAA, these do not undermine the robustness of the overall assessment and are in line with the ERAA overall objectives. There are, furthermore, simplifications which lead to more optimistic results, and understate overall adequacy concerns. For example, ENTSO-E believes that curtailment sharing, which is not yet factored within the reference scenarios when modelled under the NTC approach, could increase the occurrence of simultaneous scarcity situations in these reference simulations. Nonetheless, without modelling this explicitly it is not appropriate to speculate on the level of action required to address these concerns. Finally, it can be difficult to assess whether certain simplifications have positive or negative effects on adequacy concerns. This is especially the case with more challenging variables such as climate change modelling, which reacts in a complex manner with both supply and demand.

Article	Requirement	ERAA 2021 implementation
23 (1)	The ERAA should cover the next 10 years	A qualitative assessment of the energy mix trajectories is included per country in Annex 1, complementing the scenarios modelled.
23 (5) (b, c, f)	Central reference scenarios / sensitivities and EVA include variants with / without CM	An EVA is implemented in TY 2025. For TY 2030 a qualitative assessment of costs and revenues is complementing the adequacy results for National Estimates scenarios.
23 (5) (g) and 16 (8.b)	Use the FB approach, where applicable	FB implemented for TY 2025 in the CORE region as POC (see Annex 4). A qualitative assessment for the Nordic region is also provided with the ERAA 2021. The Annex 4 also shows that the NTCs provided by TSOs generally provide at least as large market exchange capacities as would be the case under FB calculation.
23 (5) (d)	Contribution of all resources	A characterisation and quantification of out-of-market resources are provided by TSOs and included in Annex 1.
23 (5) (e) and 20 (3)	Reflect market reform plans	TSO comments on how market reforms are reflected in the assumptions and the collected data of the ERAA 2021 are presented in Annex 1.
16 (8.a)	Minimum 70 % of transmission capacity respecting operational security limits after deduction of contingencies	This is included for the simulations under FB. For the NTC simulations, a compliance table for each border is included in the data publication and summarised in Annex 1. The FB assessment also provides a reflection of the 70 % compliance with respect to the NTC parameters used in the NTC simulations.

Table 3: Implementation of the ERAA 2021 based on requirements of the Electricity Regulation

5.2 ERAA implementation roadmap

With the integration of Europe's electricity markets, 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 decision makers have the best available information on how best to approach these challenges, and, although the report itself will not recommend specific actions, its data will inform decisions regarding CMs and other interventions.

The ERAA 2021 is the first step towards this objective. Already, it contains pioneering methodologies and tools which analyse future adequacy in an unprecedented combination of scope and detail and can be referred to when considering the overall direction of Europe's electricity grids.

The stepwise approach endorsed by ACER on 2 October 2020 is the basis for the evolution and implementation of ERAA. 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. Already, hundreds of man-hours and thousands of computing hours have been spent towards the development of these tools.

Alongside the delivery of ERAA 2021, ENTSO-E delivers an updated[13] implementation roadmap with clear next steps. This roadmap is indicative and will be updated at least on a yearly 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. Regarding policy developments, it is important to stress that ongoing negotiations on the EU's Fit for 55 Package will lead to changes in Europe's climate and energy objectives for 2030 that have to be translated to national estimates – changes which will be factored into future editions. In line with the methodology, ENTSO-E plans for a full implementation by end 2023, namely with the ERAA 2024, which will start in Autumn 2023. Figure 9 shows the latest version of the roadmap (November 2021 update).

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

The CEP will require the introduction of additional methodologies and features, such as an economic viability assessment, scenarios with capacity mechanisms, the impact of climate change on input data, and flow-based representation of the grid, thus introducing significant challenges and improvements for future pan-European and regional adequacy assessments.

13 Compared to the 10 December 2020 version published on ENTSO-E's website

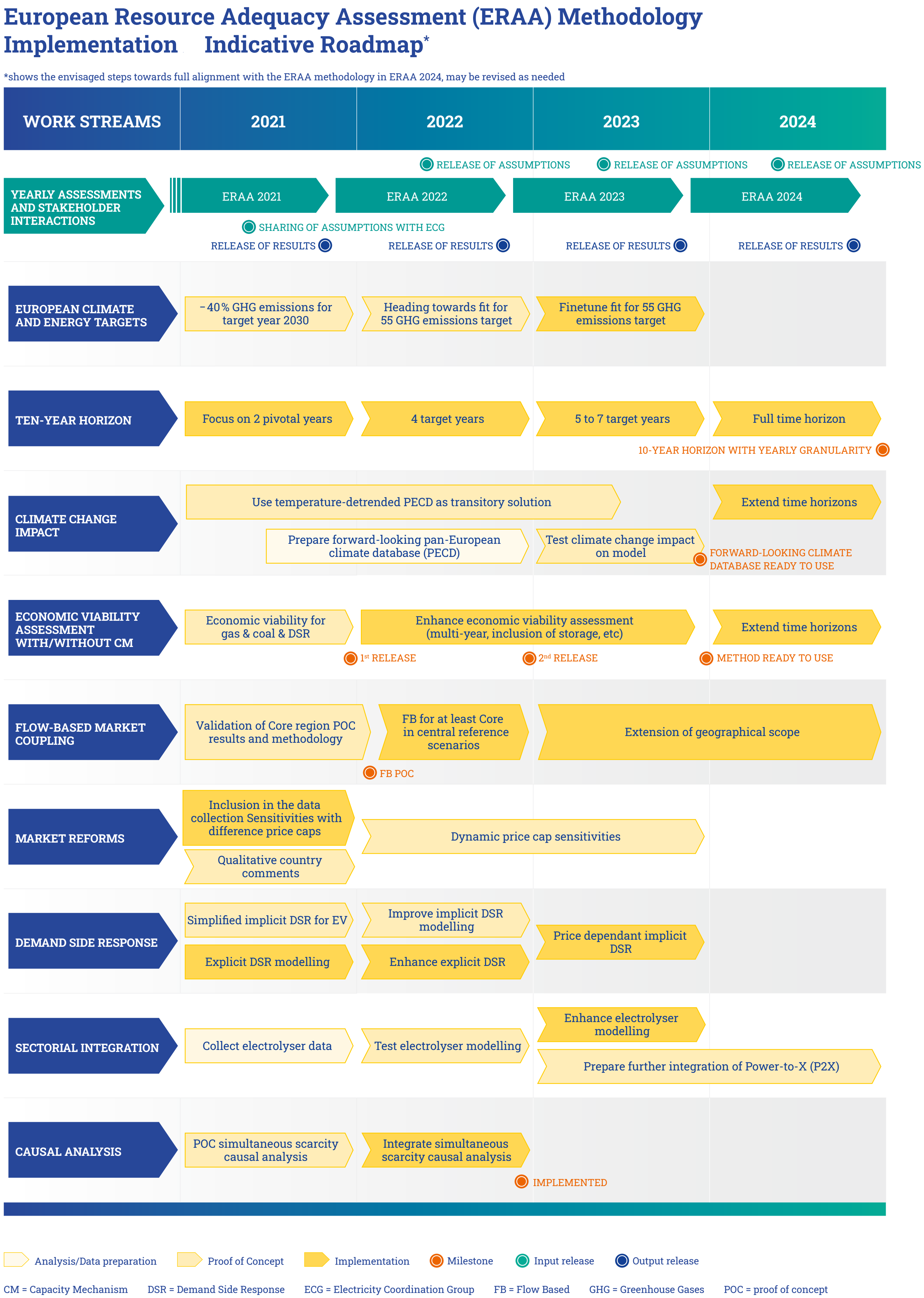

Figure 9: ERAA Implementation Roadmap

5.3 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 to informing the production of the ERAA.

Looking forward, ENTSO-E aims to give stakeholders even more opportunities to input to the next ERAA reports. As part of the development of the ERAA 2022, ENTSO-E will publish its baseline assumptions and scenarios in May 2022.

This will be complemented by a dedicated webinar, allowing stakeholder feedback. A further webinar will accompany the publication of the ERAA 2022's results in November. In addition to these fixed events, ENTSO-E will host ad-hoc webinars on methodological features of the ERAA including, for example, the EVA and how the ERAA accounts for DSR.

To make this information accessible and transparent for stakeholders, ENTSO-E will establish a dedicated webpage to host recordings of relevant webinars and responses to stakeholder questions as well as other key information regarding the ERAA implementation process.

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