red eléctrica
A Redeia company

Spanish peninsular power system National Resource Adequacy Assessment

As a complement to the European Resource Adequacy Assessment edition 2024

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Executive summary

Red Eléctrica has performed, for the Spanish peninsular power system, a National Resource Adequacy Assessment (NRAA) as a complement to the European Resource Adequacy Assessment (ERAA) edition 2024 by adapting some relevant assumptions and some modelling features. The main purpose of this edition is to assess national adequacy considering a limited number of national specificities in comparison to the last available ERAA that are relevant for the Spanish system, in terms of both modelling and hypotheses.

Electricity supply will become even more important than today as the share of electrification of the energy use increases. In addition to the inherent variability and uncertainty on availability of the main generation sources expected in the near future, it is therefore crucial to correctly assess the ability of the system to adequately meet the demand.

System adequacy monitoring is, according to Spanish legislation (Article 30 of the Law on the Electricity Sector), one of the main tasks of the system operator. The European regulatory framework (Articles 20, 23 and 24 of the Electricity Regulation) establishes the ERAA as a tool for Member States to monitor system adequacy with the possibility to conduct NRAAs to complement it.

Adequacy assessments aim to estimate the energy production and storage resources available in an electricity system and the expected electricity demand in order to identify the risks of a shortage in the capacity of supply based on a set of plausible scenarios. In an electricity system with high contribution of variable renewable energy sources it is key to identify possible situations in which availability of renewables could be simultaneously low, as for example during evenings on low wind days, without necessarily high demand levels.

The regulatory framework concerning the NRAA establishes that they may be carried out for the purpose of complementing the ERAA. NRAAs shall contain the reference central scenarios and may take into account additional sensitivities by making assumptions taking into account the particularities of national electricity demand and supply or by using tools and consistent recent data that are complementary to those used by the ENTSO-E for the ERAA. Under this framework, for this NRAA different assumptions over the generation, the demand and some modelling features have been considered compared to the ERAA.

As a complement to the ERAA, this NRAA has been performed in two steps. Firstly, a set of benchmark simulations have been run in order to verify if some modelling simplifications are possible without affecting the ERAA results for the Spanish peninsular power system. Once this is validated, the NRAA central reference scenario simulations are run: first the economic viability assessment (EVA) and then the adequacy assessment (ADQ).

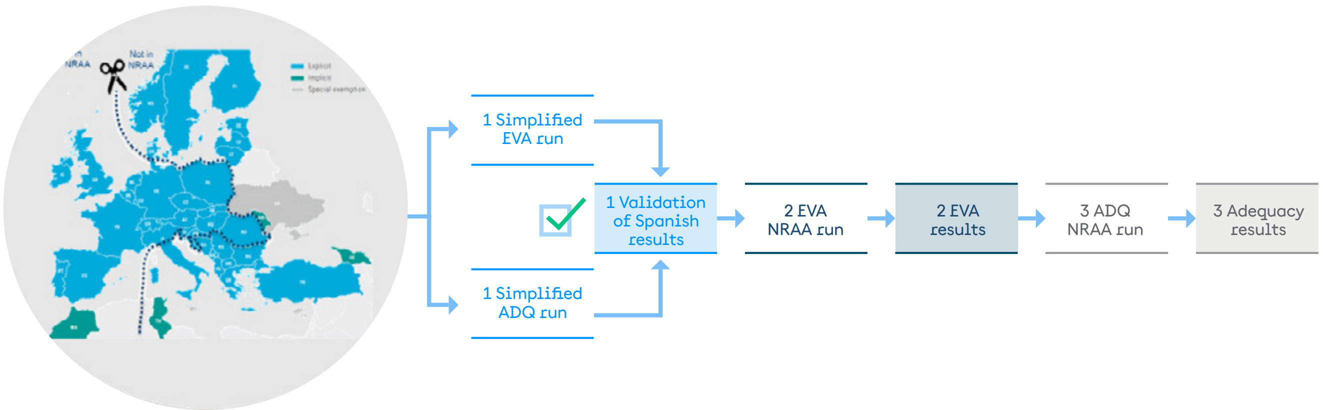


Figure 1. Steps followed for the production of the National Resource Adequacy Assessment.

As a conclusion, under the given scenarios and methodological framework following the considerations set out by the Electricity Regulation, the economic viability of an important part of the Spanish peninsular system generation mix is not guaranteed in the short, mid and long term if additional incentives are not put in place. The assessment of the scenarios which would result from the decommissioning of the economically unviable units shows a significant risk of adequacy issues in the following years. The ERAA 2024 already showed adequacy risks above the reliability standard for target years 2026 and 2028, and now the NRAA confirms it for 2028 and identifies them also for target year 2030.

These conclusions are aligned with the ones obtained in the previous ERAA and NRAA editions. This shows robustness despite the results in terms of economic equilibrium and adequacy indicators differ due to differences in the considered assumptions (national and international) and methodological evolutions used in each analysis.

The Spanish NECP also includes an adequacy assessment for target year 2030 following the ERAA probabilistic methodology. NECP shows that with 2030 target capacities no adequacy risks are observed, meaning the generation portfolio is sufficient to reach the electrification level. However, as the NECP mentions, ERAA and NRAA exercises are relevant to monitor any impact in security of supply that any deviation of the hypotheses based on the most updated information can imply.

A combined look of these three assessments allows us to understand that the energy market itself will not suffice to achieve proper system adequacy in Spain, and the importance of implementing measures, already considered in the NECP to reach the targets, that allow to achieve the desired level of decarbonization and electrification in time and with the required level of guarantee of supply.

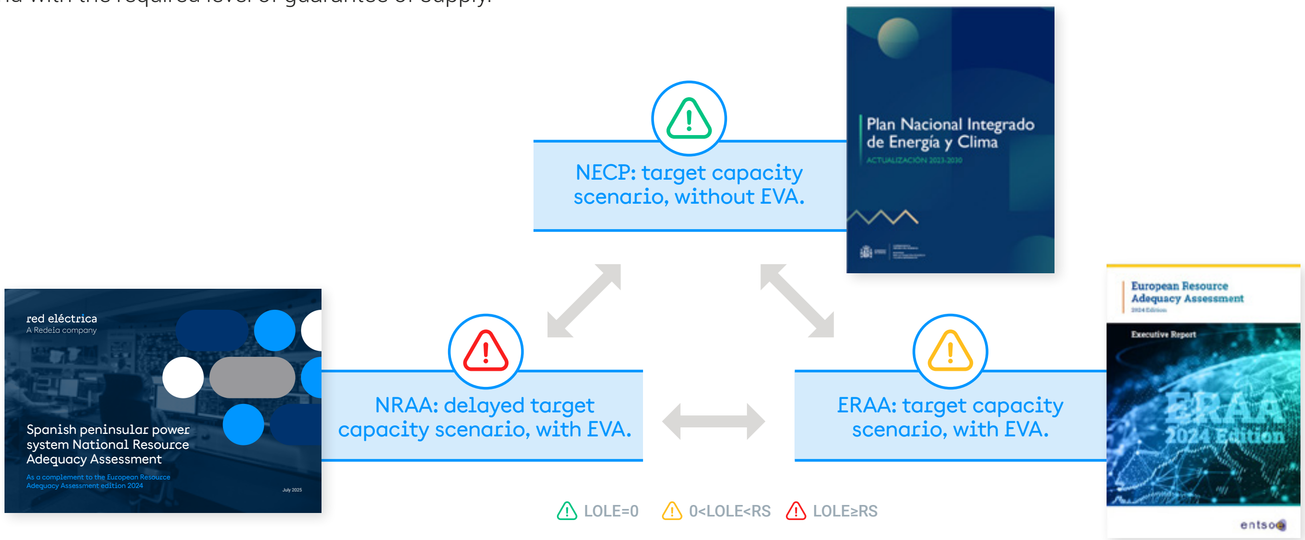


Figure 2. Complementary adequacy assessments for the Spanish peninsular power system in 2030.

A summary of the adequacy indicators, Loss Of Load Expectation (LOLE) and Expected Energy Not Served (EENS), produced both by ERAA 2024 and this NRAA for the different target years (TY) is listed in Table 1 and shown graphically in Figure 40 and Figure 41.

Table 1. Summary of target years, scenarios and adequacy indicators.

TY	Scenario	LOLE (h/y)*	EENS (GWh/y)
2026	ERAA 2024 (central reference scenario)	**4.03**	5.16
2028	ERAA 2024 (central reference scenario)	**4.83**	6.46
	NRAA (central reference scenario)	**4.08**	6.04
2030	ERAA 2024 (central reference scenario)	**0.28**	0.16
	NRAA (central reference scenario)	**2.41**	5.22
2035	ERAA 2024 (central reference scenario)	**0.54**	0.57

*LOLE values are colored as follows: red when equal or above the reliability standard, orange when nonzero values but below the reliability standard, green when zero.

1. Introduction to this National Resource Adequacy Assessment

Red Eléctrica has performed, for the Spanish peninsular power system, a National Resource Adequacy Assessment (NRAA) as a complement to the European Resource Adequacy Assessment (ERAA) edition 2024 by updating some relevant assumptions and adapting some modelling features. The main purpose of this edition is to assess adequacy considering a limited number of national specificities that are relevant for the Spanish system, in terms of both modelling and hypotheses.

Electricity supply will become even more important than today as the share of electrification of the energy use increases. In addition to the inherent variability and uncertainty on availability of the main generation sources expected in the near future, it is therefore crucial to correctly assess the ability of the system to adequately meet the demand.

Although the Spanish power system has been deeply integrating renewable generation for long time, objectives for the next years and in the long-term require a much higher participation of renewable sources in the generation mix. The variability of the primary resource that characterizes this type of generators can result in moments in which generation resources are insufficient to meet demand, even with full consideration of the support of neighboring systems. In addition, the need to decarbonize the economy and new foreseen electricity applications, recently accelerated to reduce the dependence on other energy sources, implies an important growth in electricity consumption.

The last edition of the ERAA showed that, in the given scenario and with the used methodology, system adequacy could be at stress in the next years in Spain if current thermal plants not economically viable are closed. According to ERAA 2024, such risks appear more in the short-term than in the long-term due to the expected investment goals in renewables, storage and international interconnections in the following years.

Entering specifics, the ERAA 2024 central reference scenario shows concerning adequacy results for the years 2026 and 2028 after a significant capacity reduction due to lack of economic viability, consisting of the decommissioning of 9.2 GW of combined cycle gas turbines. In fact, the results show high levels of loss of load expectation, 4.03 h/y and 4.83 h/y in 2026 and 2028 respectively, which is above the current reliability stadard of 1.5 h/y. In terms of the energy not served, the average expected unserved energy is 5.16 GWh and 6.46 GWh again in 2026 and 2028 respectively.

According to the ERAA 2024, looking at the results for 2030 and 2035, adequacy concerns are less probable with the considered long term scenarios as new investments in renewable generation and storage are expected, being below the reliability standard but not zero. However, the timely materialization of these investments is subject to uncertainties and delays due to economic, logistic or socioenvironmental difficulties.

The ERAA 2024 results show that energy only market even with the simplification of perfect market information for all participants and discarding other uncertainties associated with the commissioning of new renewable generation will not suffice to achieve proper system adequacy in Spain.

Moreover, the current ERAA scenarios are based on the targets set in the National Energy and Climate Plans (NECPs). It is important to notice that the Spanish NECP considers a capacity mechanism as one of the measures (4.3, 4.6 of section 3.4.2) that will be needed to achieve its targets. When the ERAA assesses the full NECP scenario, which implicitly considers a capacity mechanism, it ends up reinforcing its own assumptions. This leads to the identification of limited adequacy risks, reducing the usefulness of the assessment for adequacy monitoring and making it an invalid basis for justifying the need for a capacity mechanism.

The assessment in this NRAA of the "what if" scenario would allow to identify real adequacy risks that can really take place to achieve the level of decarbonization and electrification set in the NECP for 2030 and give relevant information to decision makers to take actions, such as a capacity mechanism, to address properly that risk.

The recent Communication of the European Commission on the assessment of possibilities of streamlining and simplifying the process of applying a capacity mechanism includes a proposal for the ERAA methodology revision related to this point. More specifically, the proposal is to revise the scenario framework in order to include an additional scenario that takes into account that delays may occur in the implementation of the measures described in NECP and that such delays could affect system adequacy. This is very similar to the approach Red Eléctrica already considered in the "Spanish peninsular power system National Resource Adequacy Assessment as a complement to the European Resource Adequacy Assessment edition 2022" which was published in 2023.

Finally, an important point in terms of background refers to time. The ERAA already shows adequacy risks for the closest target years (before 2030) which gives a signal of urgency to take actions that support the security of supply in Spain. In addition, in order to give an appropriate signal for new investments a capacity mechanism should ideally cover a longer time horizon.

The above-mentioned statements suggest that a NRAA that complements the ERAA would be of high value for exploring alternative scenarios of realistic possible future states of the Spanish peninsular power system that could result in additional adequacy risks, focusing on the mid term horizon of N+5. Such a study is useful for decision makers to foresee sufficiently long in advance the possibility of increased adequacy risks and take the corresponding decisions in order to ensure over the desired reliability standard.

The ERAA 2023 was the first approved ERAA while the ERAA 2024 has just been approved. As the ERAA 2024 is the most updated information, the approach for this NRAA is to complement the ERAA 2024 by introducing the minimum amount of changes needed to assess the "what if" scenario described previously. This is translated into the following differences when compared to ERAA:

a) Adaptation of assumptions: keeping most of the ERAA scenario and limiting input modifications to the most impactful and justified.

b) Adaptation of models: needed to allow computational feasibility and reduce simulation time while maintaining result robustness.

This implies to perform new simulations with the Economy Viability Assessment (EVA) and Adequacy (ADQ) models and therefore assess adequacy in the NRAA central reference scenario.

The following table shows a summary of the differences between the ERAA and the NRAA:

Table 2. Summary of the differences between the ERAA and the NRAA.

Type	Element	Description	Models affected	Qualitative impact
Assumption	Pumped storage	• Consider only new projects with granted support (1.1 GW) • Consider weekly availability profile	ADQ EVA	Increase adequacy risks
	Batteries	• Consider only new projects with granted support (1.5 GW) • Distinguish 2h and 4h batteries	ADQ EVA	Increase adequacy risks
	Combined cycles	• Update unplanned outage rate (9%) and duration (72h) • Update planned outages periods	ADQ EVA	Increase adequacy risks
	Demand	• Update ERAA24 demands to ERAA25 profile	ADQ EVA	Increase adequacy risks
Model	Curtailment sharing application	• Not implement curtailment sharing	ADQ	Reduce adequacy risks
	Geographical scope	• Simplify from European to regional scope (Core)	ADQ EVA	Limited impact
	Random outage samples	• Simplify from 15 to 5	ADQ	Limited impact
	Spanish non-peninsular systems	• Account the ENS of Balearic Islands and Ceuta through Peninsular KPIs	ADQ EVA	Increase adequacy risks

When these differences in methodology and assumptions are applied, the NRAA central reference scenario shows that impact in terms of economic viability assessment is minimal for the non-Spanish perimeter, while in Spain the retirement of CCGT would be 3524 MW. When adequacy is assessed in the NRAA central reference scenario (differences in methodology and assumptions, and applying the new economic viability results), the risks would be above the reliability standard for target year 2028 and also for 2030. These results allow to extract the same conclusions than for the ERAA, but now also valid for 2030: energy only market will not suffice to achieve proper system adequacy in Spain.

2. Structure of this report

This chapter describes the distribution of the information along the report of this National Resource Adequacy Assessment (NRAA).

This report is divided in five chapters, which start covering some general topics and then enter specifics, aiming to ease readability for all type of readers. The chapters and content are organized as follows. Firstly, the regulatory framework behind system adequacy monitoring which introduced the European and National Resource Adequacy Assessments (ERAA/NRAA) is described. Then, there is a chapter with a detailed description of the methodology that is used for the assessment, including a specific part for the differences between the ERAA and the NRAA in terms of methodology. The next chapter shows a summary of the main assumptions, including a specific part reflecting the differences between the ERAA and the NRAA in terms of hypotheses. The core of the report is the next chapter, dedicated to the analysis of the results produced under this NRAA. At the end, and to close the report, the final ideas and main outcomes are summarized.

1	Introduction	This first chapter aims to justify the need of such a NRAA.
2	Structure of this report	This chapter describes the distribution of the information along the report of this NRAA.
3	Regulatory framework	This chapter offers a short summary of the legal acts that regulate the security of supply monitoring, both at National and European level.
4	Methodology	This chapter includes an introduction to the ERAA methodology in order to understand the main methodological elements of this NRAA. In second place, specific methodological implementations of this NRAA, different to the ERAA ones, are also explained.
5	Assumptions	This chapter summarizes the hypotheses and assumptions used both in the ERAA and in this NRAA. The ERAA assumptions are divided into three different data blocks: the European perimeter, the Spanish perimeter and central economic parameters. A separate part of the chapter focuses on the different assumptions considered under this NRAA concerning the Spanish peninsular power system.
6	Results	This chapter firstly includes a summary of the results obtained across all the different scenarios available both in ERAA and in this NRAA, and then offers a detailed analysis of the results produced under this assessment.
7	Conclusions	This final chapter presents a summary of conclusions focused on the main outcomes of the NRAA.
8	Glossary of acronyms	A list of the acronyms used across the report is provided in order to ease its readability.

Figure 3. Structure of this report.

3 Regulatory framework

3.1 Spanish regulatory framework

3.2 European regulation framework

This chapter offers a short summary of the legal acts that regulate the security of supply monitoring, both at National and European level.

3.1 Spanish regulatory framework

In first place, the main pieces that regulate the security of supply monitoring in the National regulation are reflected.

Extractions of the main Law and the related Operational Procedure are included. Many other pieces that compose the regulation of the Spanish power sector are integrated in the Electric Power Code[1], which aggregates, organizes and compiles the main state regulations in force regarding the electricity system, in order to make available to the subjects of the system, companies, professionals, legal operators and interested citizens in general, a useful instrument to know, through a consolidated and permanently updated source, the state legislation of general application to electric energy, which constitutes an essential and indispensable good and service for the full participation of citizens in today's society, one of whose main characteristics is its inexorable process of electrification. However, it does not include regulations of the European Union or international or Autonomous Communities, nor, with some exceptions, provisions that are not of a normative nature, nor the Operating Procedures of the electrical system.

Please note that the translation provided in this report is non-official and is only offered for full comprehension of the report.

3.1.1 Ley 24/2013, de 26 de diciembre, del Sector Eléctrico

The Law on the Electricity Sector[2] is the central regulatory piece for the electricity sector and establishes several requirements regarding system adequacy monitoring.

The main purpose of this Law is to guarantee the supply of electricity. There is a special article regarding guarantee of supply. Also, the duties of the system operator are regulated, being its main function to guarantee the continuity and security of the electricity supply.

Article 1. Purpose

1. The purpose of this law is to establish the regulation of the electricity sector in order to guarantee the supply of electricity and to adapt it to the needs of consumers in terms of safety, quality, efficiency, objectivity, transparency and minimum cost.

Article 7. Guarantee of supply

2. The Government may adopt, for a specific period of time, the necessary measures to guarantee the supply of electric power when any of the following events occur:

   2.1. Certain risk for the provision of electric power supply.

   2.2. Situations of shortage of any or some of the primary energy sources.

   2.3. Situations that could result in a serious threat to the physical integrity or safety of persons, equipment or installations or to the integrity of the electric power transmission or distribution grid, after notifying the Autonomous Communities affected.

1. Link to Electric Power Code: https://www.boe.es/biblioteca_juridica/codigos/codigo.php?id=014_Codigo_de_la_Energia_Electrica&tipo=C&modo=2;
2. Link to Law of the Electric Sector : https://www.boe.es/buscar/act.php?id=BOE-A-2013-13645

2.4. Situations in which there are substantial reductions in the availability of the production, transmission or distribution facilities or in the supply quality indexes attributable to any of them.

3. The measures adopted by the Government to deal with the situations described in the preceding paragraph may refer, among others, to the following aspects:

3.1. Temporary limitations or modifications to the electricity market referred to in Article 25 or to the existing generation dispatch in isolated electricity systems.

3.2. Direct operation of generation, transmission and distribution facilities.

3.3. Establishment of special obligations regarding safety stocks of primary sources for the production of electric energy.

3.4. Limitation, temporary modification or suspension of the rights established in Article 26 for producers of electric energy from renewable energy sources, cogeneration and waste.

3.5. Modification of the general conditions of regularity of supply in general or referring to certain categories of consumers.

3.6. Limitation, temporary modification or suspension of the rights and guarantees of access to the networks by third parties.

3.7. Limitation or allocation of primary energy supplies to electricity producers.

3.8. Any other measures that may be recommended by the international organizations of which Spain is a member or that may be determined in application of those agreements in which it participates.

Article 30. System operator

1. The main function of the system operator will be to guarantee the continuity and security of the electricity supply and the correct coordination of the production and transmission system. It will perform its functions in coordination with the operators and subjects of the Iberian Electricity Market under the principles of transparency, objectivity, independence and economic efficiency. The system operator will be the operator of the transmission grid.

2. The functions of the system operator shall be the following:

2.1. To indicatively forecast and control the level of guarantee of electricity supply of the system in the short-term and mid-term, both in the peninsular system and in the non-peninsular systems. For these purposes, it shall make a forecast of the maximum capacity whose temporary shutdown may be authorized and, where appropriate, it shall report on the needs for the incorporation of power with authorization for temporary shutdown for reasons of guarantee of supply.

2.2. To forecast, in the short-term and mid-term, the demand for electrical energy, the use of production equipment, especially the use of hydroelectric reserves, in accordance with the demand forecast, the availability of electrical equipment, and the different levels of rainfall and wind power that may oc-cur within the forecast period, both in the peninsular system and in the non-peninsular systems.

2.7. To execute, within the scope of its functions, those decisions adopted by the Government in execution of the provisions of Article 7.2.

3.1.2 Procedimiento de Operación 2.2 Previsión de la cobertura y análisis de seguridad del sistema eléctrico

The Operational Procedure 2.2[3] includes a specific requirement to monitor on a yearly basis the Spanish peninsular system adequacy. This requirement is currently fulfilled with the European Resource Adequacy Assessment (ERAA) and/or National Resource Adequacy Assessment (NRAA) assessments.

Article 4. Long-term forecasts

The system operator will carry out a security analysis of the system's adequacy, which will cover the forecasts for the 10 years following the current year, which shall be communicated to the competent body of the Spanish Administration and the National Regulatory Authority in the month of December of each year.

The adequacy forecast will analyze various hypotheses of demand growth and the development of the generating the generation park, both in the ordinary and special regimes. In addition, energy policy assumptions (mining plans, etc.), environmental policy (limitation of CO_2 emissions, regulations, etc.), assumptions of additions and retirements of generating equipment, etc will also be considered.

As a result of the forecast, the annual power balances will be included, which will be used to assess the equipment needs. As a complement, the energy balances obtained in the different scenarios considered will be presented.

3.1.3 Resolución de 7 de julio de 2025 de la DGPEM, por la que se fijan los valores del valor de carga perdida y el estándar de fiabilidad, de conformidad con lo previsto en el Reglamento (UE) 2019/943 del Parlamento Europeo y del Consejo de 5 de junio de 2019 relativo al mercado interior de la electricidad

This Resolution[4] sets the value of lost load (VOLL) and reliability standard (RS) to be considered for the Spanish Peninsular Power System. These values are calculated according to Regulation 2019/943 and according to the ACER Decision 23/2020.

The value set for the VOLL is 22879 €/MWh and following the cost of new entry (CONE) value set in the "Informe INF/DE/114/24 de la Comisión Nacional de los Mercados y la Competencia sobre la Determinación del coste de nuevos entrantes (CONE) para la determinación del estándar de fiabilidad (RS)", the reliability standard is set at 1.5 hours/year.

This value defines the necessary level of security of supply, acting as a criterion to determine if there is an adequacy concern or not and, if positive, to determine the total capacity that the system would need in order to be adequate.

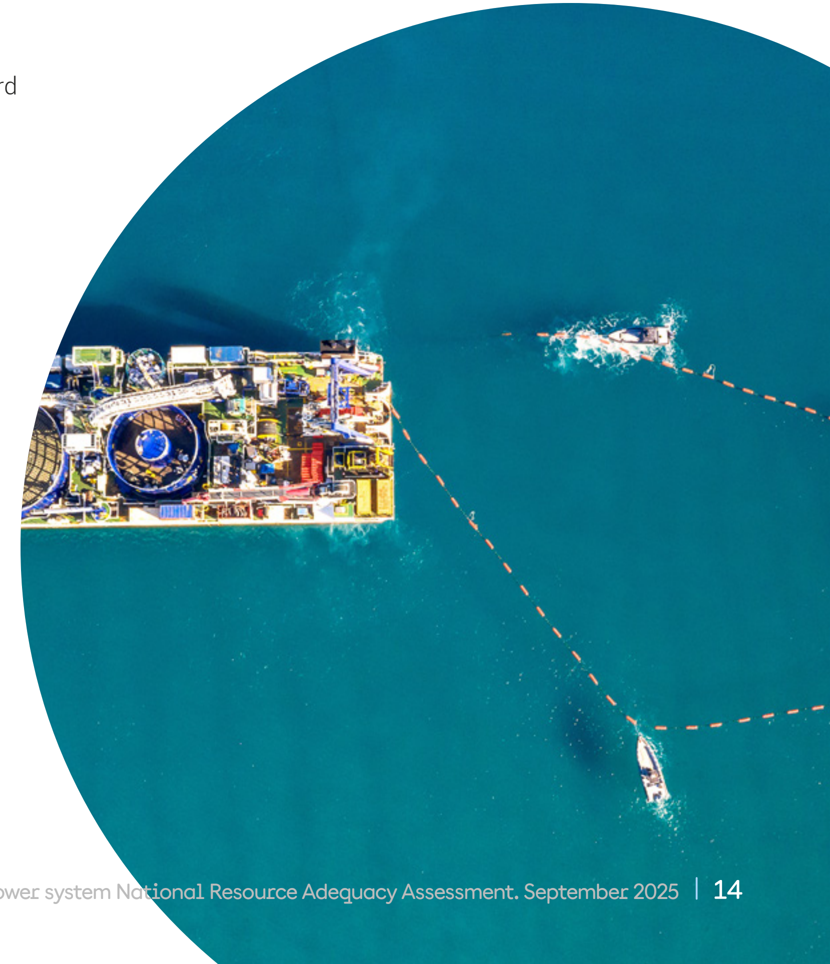
3. https://www.ree.es/sites/default/files/01_ACTIVIDADES/Documentos/ProcedimientosOperacion/PO_resol_24may2006_2.2.pdf
4. https://www.boe.es/eli/es/res/2025/07/07/(2)

3.1.4 Informe INF/DE/114/24 de la CNMC sobre la Determinación del coste de nuevos entrantes (CONE) para la determinación del estándar de fiabilidad (RS)

This Report[5], dated in October 2024, sets the Cost of New Entry (CONE) for the Spanish peninsular power system following the methodology defined in the ACER Decision 23-2020 on VOLL/CONE/RS (more detail in section 3.2.4).

The report lists the different reference technologies by evaluating if a given technology can be considered as standard and if there is new entry potential. The report also includes a justified estimation, for the different reference technologies, of several techno-economic parameters: de-rating factor, capital expenditure cost, fixed operation and maintenance cost, weighted average cost of capital, economic lifetime of investment and construction period. Then the calculation of the CONE is performed for each technology and the number of hours required at the Value of Lost Load for them to recover the CONE is assessed (LOLE of the reference technology). Through an estimation of the additional capacity that is needed in order to reach the LOLE of the different reference technologies and comparing it with the new entry potential of each one of them, the reliability standard is determined by the technology that can deliver the required additional capacity at the minimum cost.

In the case of the Spanish peninsular power system, existing combined cycles are the reference technology, and therefore the reliability standard could be in a range of 1.12-1.82 hours/year, with an average value of 1.5 hours/year.



5. https://www.cnmc.es/sites/default/files/5650953.pdf

3.2 European regulation framework

In second place, the main pieces that currently regulate the security of supply monitoring in European regulation are also examined.

As they are already officially in English, their content will be summarized but not included in the report as a translation is not needed and it would extend unnecessarily the report.

3.2.1 Treaty on the Functioning of the European Union

The Treaty on the Functioning of the European Union (TFEU)[6] is one of 2 primary treaties of the European Union (EU), alongside the Treaty on European Union (TEU)[7]. It forms the detailed basis of EU law by defining the principles and objectives of the EU and the scope for action within its policy areas. It also sets out organizational and functional details of the EU institutions. It has the following article related to energy:

Article 194. Energy
Union policy on energy shall aim, in a spirit of solidarity between Member States (MSs), ensure the functioning of the energy market, ensure security of energy supply in the EU, promote energy efficiency and energy saving and the development of new and renewable forms of energy, and promote the interconnection of energy networks. The European Parliament and the Council, acting in accordance with the ordinary legislative procedure, shall establish the measures necessary to achieve these objectives. Such measures shall not affect a MS's right to determine the conditions for exploiting its energy resources, its choice between different energy sources and the general structure of its energy supply.

6. https://eur-lex.europa.eu/eli/treaty/tfeu_2012/oj
7. https://eur-lex.europa.eu/eli/treaty/teu_2016/2020-03-01

3.2.2 Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 on the internal market for electricity

On July 16, 2024, Regulation (EU) 2024/1747 of the European Parliament and of the Council of June 13 came into force, amending Regulation (EU) 2019/943 regarding improving the Union's electricity market design.

This Regulation[8] (referred to as Electricity Regulation) is one of the main European pieces setting the framework for the European electricity market and a central element of the Clean Energy Package (CEP) for All European Citizens.

Set in the whereas, the medium to long-term ERAA is carried out to provide an objective basis for the assessment of adequacy concerns. The resource adequacy concern that capacity mechanisms address should be based on the ERAA, which may be complemented by national assessments. The ERAA has a different purpose than the seasonal adequacy assessments. Mid-term to long-term assessments are mainly used to identify adequacy concerns and to assess the need for capacity mechanisms whereas seasonal adequacy assessments are used to alert to short-term risks that might occur in the following six months that are likely to result in a significant deterioration of the electricity supply situation. Also set in the whereas, Member States (MSs) should have the freedom to set their own desired level of security of supply.

Chapter IV, which is divided in 8 articles, is focused on resource adequacy. An extraction of the main concepts of articles related to adequacy monitoring is provided.

Article 20. Resource adequacy in the internal market for electricity

This article establishes the ERAA as a tool for MSs to monitor resource adequacy and allows National Resource Adequacy Assessments (NRAAs) to complement it.

In addition, it establishes that where ERAA or NRAA identify resource adequacy concerns, the MS shall identify any regulatory distortions or market failures that caused or contributed to the emergence of the concern. An implementation plan aiming to eliminate these failures shall be developed, published, consulted and monitored.

Article 21. General principles for capacity mechanisms

MSs may, while implementing the abovementioned plan, introduce capacity mechanisms.

MSs shall not introduce capacity mechanisms where both the ERAA and the NRAA, or in the absence of a NRAA, the ERAA have not identified a resource adequacy concern.

Where a MS applies a capacity mechanism, it shall review that capacity mechanism and shall ensure that no new contracts are concluded under that mechanism where both the ERAA and the NRAA, or in the absence of a NRAA, the ERAA have not identified a resource adequacy concern.

Article 23. European resource adequacy assessment

It establishes the purpose of ERAA: to identify resource adequacy concerns by assessing the overall adequacy of the electricity system to supply current and projected demands for the next 10-year period.

It also establishes that it will be conducted annually by European Network of Transmission System Operators for Electricity (ENTSO-E), and that Transmission System Operators (TSOs) will provide ENTSO-E the data it needs to carry out the ERAA.

It sets some of the main methodological elements, such as the geographical scope and granularity, instructions for the scenarios, modelling basic indications, sets the adequacy indicators that shall be monitored as well as the identification of possible resource adequacy concerns.

8. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02019R0943-20240716

Article 24. National resource adequacy assessments

It establishes the regional scope of these assessments, that shall be based on the same methodology as ERAA. NRAAs shall contain the reference central scenarios and may take into account additional sensitivities, making assumptions taking into account the particularities of national electricity demand and supply or to use tools and consistent recent data that are complementary to those used by the ENTSO-E for the ERAA.

Where the NRAA identifies an adequacy concern that was not identified in the ERAA, the NRAA shall include the reasons for the divergence between the two resource adequacy assessments, including details of the sensitivities used and the underlying assumptions. MSs shall publish that assessment and submit it to the Agency for the Cooperation of Energy Regulators (ACER). NRAA and the opinion of ACER shall be made publicly available. Within two months of the date of the receipt of the report, ACER shall provide an opinion on whether the differences between the NRAA and the ERAA are justified. The body that is responsible for the NRAA shall take due account of ACER's opinion, and where necessary shall amend its assessment. Where it decides not to take ACER's opinion fully into account, the body that is responsible for the NRAA shall publish a report with detailed reasons.

Article 25. Reliability standard

It establishes that when applying capacity mechanisms MS shall have a reliability standard (RS) in place, which indicates the necessary level of security of supply of the MS in a transparent manner. The RS shall be set by the MS or by a competent authority designated by the MS, and shall be based on the methodology for calculating the Value Of Lost Load (VOLL), Cost Of New Entry (CONE) and the Reliability Standard (RS).

The RS shall be calculated using at least the VOLL and the CONE and shall be expressed as Expected Energy Not Served (EENS) and Loss Of Load Expectation (LOLE).

3.2.3 ACER Decision 24-2020 on ERAA methodology

ACER Decision 24-2020 (2 October 2020)[9,10] on the Methodology for the European resource adequacy assessment establishes the specific framework for the ERAA.

An extraction of the main methodological elements according to this Decision is provided:

1. In terms of scope, the ERAA methodology shall be used to identify resource adequacy concerns by assessing the overall adequacy of the electricity system to supply current and projected demand levels, fulfilling the requirements set in the Electricity Regulation.

2. In terms of scenario framework, the baseline data for the ERAA stems from the national projected demand, supply and grid outlooks prepared by each individual TSO. These national forecasts shall be consistent with existing and planned national policies. The Economic Viability Assessment (EVA) shall be performed on the baseline data. The ERAA shall rely on the central reference scenarios "With CMs" (this scenario considers Capacity Mechanisms, CMs, approved) and "Without CMs" (this scenario excludes CM revenues, except for CM contracts already awarded). It may complement the central reference scenarios with additional scenarios and/or sensitivities with European relevance.

3. In terms of resource adequacy assessment, the resource adequacy metrics are estimated through the Economic Dispatch (ED). Market entry and exit are modelled through the EVA. The ERAA shall use a probabilistic methodology to reflect the stochasticity of climate variables affecting supply and demand, as well as the expected availability of generation, storage and transmission resources. Uncertainty is represented through the availability of capacity resources and network, and climate conditions. Availability of capacity resources and interconnectors is represented through random unplanned outage patterns. Data related to climate variables is represented through a set of hourly time series of climate variables for multiple years.

4. In terms of EVA, it shall be defined based on the difference between revenues and costs. As a simplification, and assuming perfect competition, the EVA may minimize overall system costs. The EVA shall assess the likelihood of retirement, mothballing, new-build of generation assets and measures to reach energy efficiency).

5. In terms of ED, it shall determine the dispatch of generation, storage and demand units in order to meet demand for every Market Time Unit (MTU) of the Monte Carlo sample year, while minimizing the total system operating cost. It shall estimate the ENS. The ED shall rely on a "perfect foresight" principle.

6. In terms of identification of resource adequacy concerns, the ERAA shall identify a resource adequacy concern if (and only if) the relevant MS or competent authority designated by the MS has set a RS and the RS is not fulfilled for the target year (TY) for at least one central reference scenario.

7. In terms of stakeholder interaction, ENTSO-E shall establish adequate interaction channels for all relevant stakeholders, including civil society, to contribute to each step of developing the proposals for the ERAA methodology, the scenarios, the assumptions, and results, through a transparent, open, accessible, inclusive, efficient, and well-structured process. ENTSO-E shall strive to keep abreast of the latest innovations in Europe and globally, especially through interactions with academia, research institutions, industry experts and financial experts.

9. https://energy.ec.europa.eu/system/files/2020-12/methodology_for_the_european_resource_adequacy_assessment_0.pdf

10. Following Article 69.3 of the Regulation 2019/943 (included by Regulation 2024/1747 13th June 2024, Article 2.17.b), the ERAA methodology revisión has been triggered in April 2025 by ACER. ENTSO-E has already published a proposal to update it, but it is not yet approved. Publicly available through:
Revision of European Resource Adequacy Assessment Methodology - European Network of Transmission System Operators for Electricity - Citizen Space

8. In terms of transparency requirements, ENTSO-E shall ensure full transparency of the ERAA. In particular, the ERAA report shall strive to facilitate stakeholders' understanding regarding the inputs, data, assumptions, and scenario (and sensitivity) development. ENTSO-E shall publish on its website at least data collection guidelines, input and output data for each scenario and sensitivity. Upon request and for each ERAA, ENTSO-E shall provide ACER, MSs, to the bodies that are responsible for the NRAA, National Regulatory Authorities (NRAs) and Regional Coordination Centers (RCCs) all the relevant information necessary for the purpose of carrying out their tasks.

9. In terms of implementation, the ERAA methodology may be implemented through a gradual process, but it shall be fully implemented by the end of 2023.

3.2.4 ACER Decision 23-2020 on VOLL/CONE/RS

ACER Decision 23-2020 (2 October 2020)[11] on the Methodology for calculating the value of lost load, the cost of new entry, and the reliability standard aims to derive realistic estimates of the cost of additional capacity resource and of consumers' willingness to pay in order to avoid a supply interruption, thereby helping to calculate a socioeconomically efficient reliability standard.

It establishes that the reliability standard (RS) will be calculated by considering the estimated Value Of Lost Load (VOLL) and the estimated Cost Of New Entry (CONE) parameters, which defines how to calculate.

It also states that the responsibility to determine the general structure of its energy supply is a MS right, pursuant to Article 194(2) of the Treaty on the Functioning of the European Union. The freedom for a Member State to set its own desired level of security of supply is also recalled in recital (46) of the 'Whereas' section of Electricity Regulation. Pursuant to Article 25(2) of Electricity Regulation, the reliability standard shall be set by the Member State and shall be based on the VOLL/CONE/RS methodology.

11. https://acer.europa.eu/Decisions_annex/ACER%20Decision%2023-2020%20on%20VOLL%20CONE%20RS%20-%20Annex%20I.pdf

4 Methodology

4.1
European Resource Adequacy Assessment

4.2
Differences between the European and the National Resource Adequacy Assessments in terms of methodology

This chapter includes an introduction to the European Resource Adequacy Assessment (ERAA) methodology in order to understand the main methodological elements of this National Resource Adequacy Assessment (NRAA) as, in accordance with Article 24 of the Regulation, NRAAs shall be based on the ERAA methodology.

4.1 European Resource Adequacy Assessment

A full detailed description of the current ERAA methodology implementation can be found at the ERAA 2024 report (Annex 2 – Methodology)[12], but a summary of the main methodological elements is offered in this chapter.

Adequacy assessments aim to estimate the energy production and storage resources available in an electricity system and the expected electricity demand in order to identify the risks of mismatch between capacity of supply and demand based on a set of scenarios. In an interconnected electricity system such as the European one, this scope should be extended by considering the supply-demand balance under a defined grid infrastructure, which can have a considerable impact on the adequacy indicators. Figure 4 illustrates the general methodological framework.

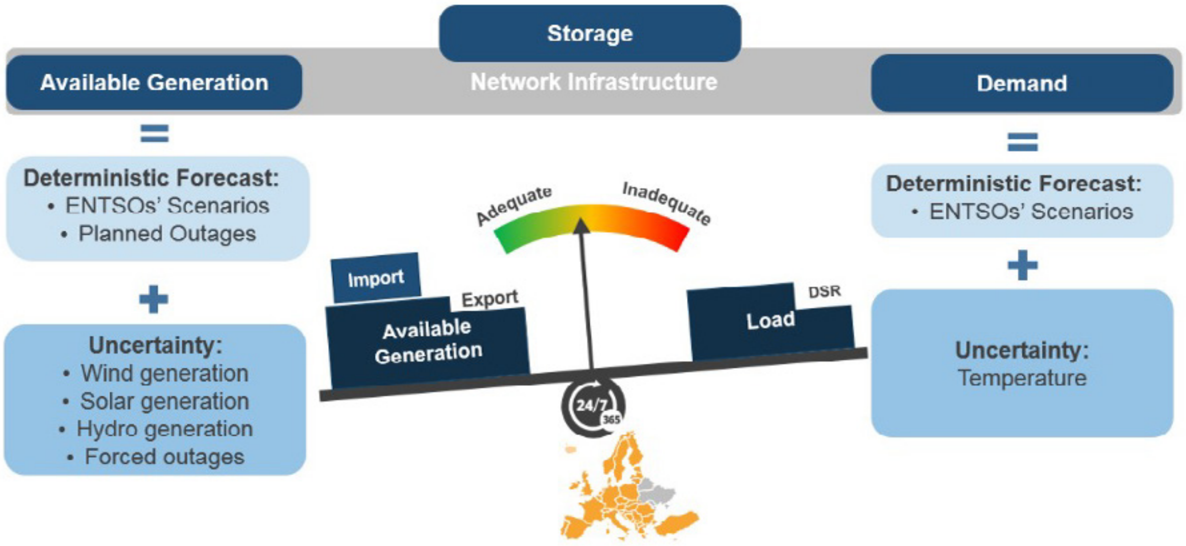


Figure 4. Overview of the ERAA methodological approach. Prepared by ENTSO-E.

12. Link to ERAA 2024 report (Annex 2 – Methodology): https://eepublicdownloads.azureedge.net/clean-documents/sdc-documents/ERAA/2022/data-for-publication/ERAA2022_Annex_2_Methodology.pdf

As demand and generation is becoming more volatile, due to new electrification in heat pumps or electric vehicles and as renewables grow in our energy mix, probabilistic assessments can provide better estimations than traditional deterministic ones that considered worst case scenarios and simple adequacy indicators. This is especially helpful to identify possible situations in which availability of renewables could be simultaneously low, as for example during evenings on low wind days, without necessarily extreme demand levels. On the other hand, system adequacy is becoming more critical as electrification of economy and renewable generation are progressing under the energy transition.

4.1.1 Geographical scope and time horizon

The methodology used for the ERAA assesses the adequacy of supply to meet demand over the mid-term to long-term time horizon, more precisely next 10 years period, while considering interconnections between different European power systems, as illustrated in Figure 6.

ERAA focuses on the pan-European perimeter and neighboring zones connected to the European power system. Zones are modelled either explicitly or non-explicitly. Explicitly modelled zones are represented by market nodes that consider complete information using the finest available resolution of input data and for which the Unit Commitment & Economic Dispatch (UCED) problem is solved. For non-explicitly modelled zones exogenous fixed energy exchanges with explicitly modelled zones are applied.

4.1.2 Scenarios and calculation flow

ERAA is based on the forecasted installed generation and demand covering each year of the study period extending over a 10-year horizon and takes into consideration national planning (indicative planning of national energy and climate plans, transmission grid development plans in force, etc.).

This baseline scenario, currently referred to as National Trends (NT) or National Estimates (NE), is assessed by the Economic Viability Analysis (EVA) model. With the results obtained from the EVA (changes in installed generation capacity for certain type of generators depending on their profitability) the National Trends scenario is modified in order to produce a Central reference scenario. This scenario is assessed by the UCED model (also referred to as ED or ADQ) and, by applying the probabilistic methodology, the adequacy indicators are obtained. This process is summarized in Figure 7.

4.1.3 Economic Viability Assessment model

To determine the economic viability of the different resources (generation, demand management, etc.), the ERAA methodology contemplates two possible approaches:

1. Assess the economic viability of generation resources: within the study period, for each capacity resource and target year, economic viability will be defined as a function of the difference between revenues and costs. Capacity will be viable if (and only if) its revenues are greater than or equal to its costs.
2. Minimize the overall system cost: as a simplification and assuming perfect competition, sum of fixed costs and the total operating costs are minimized.

At the moment, ERAA is applying the system cost minimization approach. The viability of resource capacities participating in Energy Only Market is assessed thanks to a long-term planning model with the objective of minimizing the total system costs. The key decision variables of such a long-term model aim at identifying the economic-optimal (least-cost) evolution of resource capacity over the modelled horizon. At the moment, only some of the investment decisions are applied to some of the technologies, as shown in Figure 5.

Technologies	Decommissioning	Life Extension	New Entry
Gas	✓	✓	✓
Lignite/hard coal/oil	✓	✓	
DSR			✓
Battery			✓

Figure 5. EVA decision variables. Prepared by ENTSO-E.

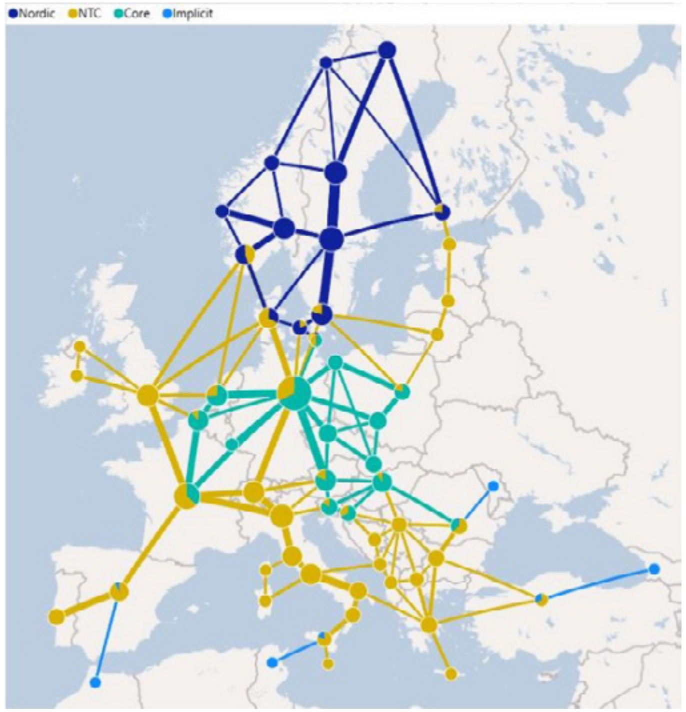


Figure 6. The interconnected European power system modelled in the ERAA 2024. Prepared by ENTSO-E.

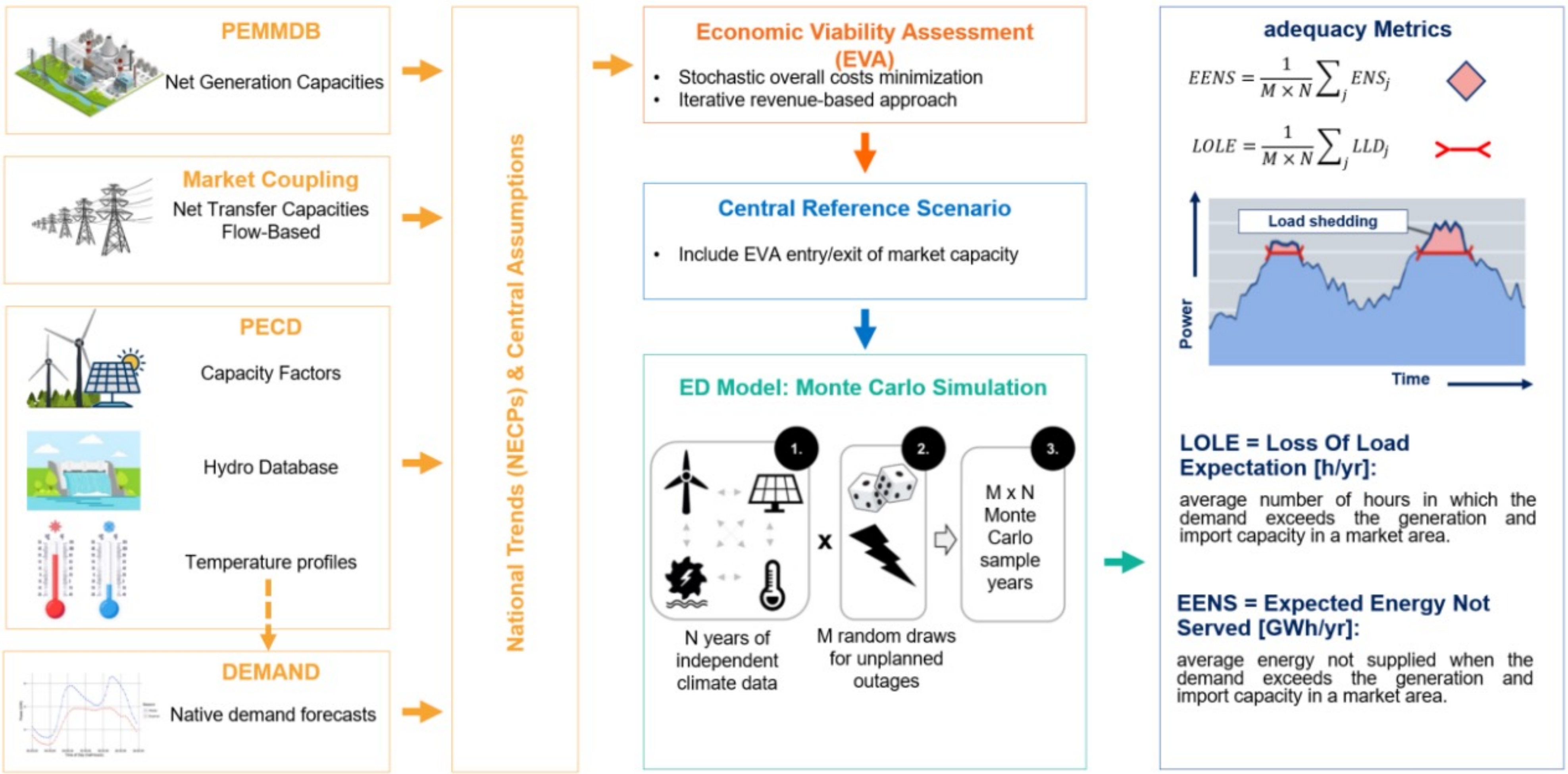


Figure 7. Overview of the ERAA process. Prepared by ENTSO-E.

The EVA simulation is performed over multiple years. The total costs of the system in consecutive years are totaled in the EVA simulation by calculating the net present value of all future costs. The total cost is equal to the sum of investment costs of new resources capacity (including a risk premium), fixed (including a risk premium) and variable unit operations and maintenance costs, and demand-side response activation costs, as well as the cost of curtailed energy represented by fictitious generators with the marginal cost equal to the market price cap.

Given a collection of weather scenarios, the EVA model finds the optimal stochastic solution. This means that the optimal entry/exit decision of resource capacities, making up the Fixed costs, are made considering several possibilities of operational conditions. EVA is an optimization model solved during multiple years for the whole pan-European perimeter, and this makes the EVA a heavy model; therefore, the number of weather scenarios introduced needs to be reduced. Due to this fact and to limit the number of simulations, a direct approach is taken by solving the EVA model over a reduced number (3 in ERAA 2024) of Weather Scenarios (WSs). One representative Forced Outage (FO) pattern was included in this model in ERAA 2024.

As a result, modifications in resource capacities are obtained, which are then transferred to the UCED model to simulate with a higher degree of detail the dispatch of these capacities and estimate the adequacy indicators.

The main considerations and assumptions underlying the EVA must be consistent with those included in the UCED to guarantee consistency between the two models.

4.1.4 Unit Commitment and Economic Dispatch model

The Unit Commitment (UC) problem aims to discover an optimal combination of on/off decisions for all generating units across a given horizon. The on/off decisions must imply both a feasible solution and an optimal solution in terms of the total system cost, including the cost of start-up and shutdown. The economic dispatch (ED) refers to the optimization of generator dispatch levels for the given unit commitment solution. The UC and ED are co-optimized such that the combined costs are minimized (UCED).

More specifically, the UCED optimization is a two-step approach with a system cost minimization target, it strives to minimize the sum of electricity production costs (being the main components of the costs: the fuel price, emission price and variable operation and maintenance costs) under the objective that electricity consumption must be fulfilled.

In the first step, an annual optimization for the target year is done to account for inter-temporal constraints that may span the whole year. Multiple hours are aggregated and optimized in blocks to deal with the large optimization problem in a reasonable computation time.

The UCED optimization is then performed in smaller time steps to determine which units are dispatched at each hour as well as the respective dispatch level for each unit. Each resulting UCED problem is optimized based on the hourly system state (demand, renewable energy sources feed-in, available thermal generation, cross border constraints). Subsequently, each UCED problem is given the final system state of the preceding UCED problem (used as the initial dispatching state for the current UCED problem).

As main adequacy results, unserved energy periods and volumes are obtained. In addition, the UCED will also provide other results, such as operating cost, generation/storage/demand values, marginal cost and interchange balance in each zone.

4.1.5 Probabilistic methodology

The probabilistic methodology is based on the execution of a Monte Carlo study, with a UCED model, reflecting weather variability, as well as the randomness of FO patterns of generation and transmission grid (only international interconnections are modeled). Monte Carlo simulations will be constructed by combining the weather dependent variables and the random outages. Each meteorological dataset (weather scenario) consists of a realistic combination of demand (taking into account temperature dependence), wind, solar and hydro inputs. Each set of weather scenarios is associated with a set of random outage samples, randomly assigning failure patterns for thermal units and interconnections. The number of random outage patterns considered in the simulation of a weather scenario will be the number necessary to achieve convergence of the adequacy indicators. The convolution of the weather scenarios and random outage patterns defines the final number of Monte Carlo scenarios analyzed. Figure 86 illustrates this process.

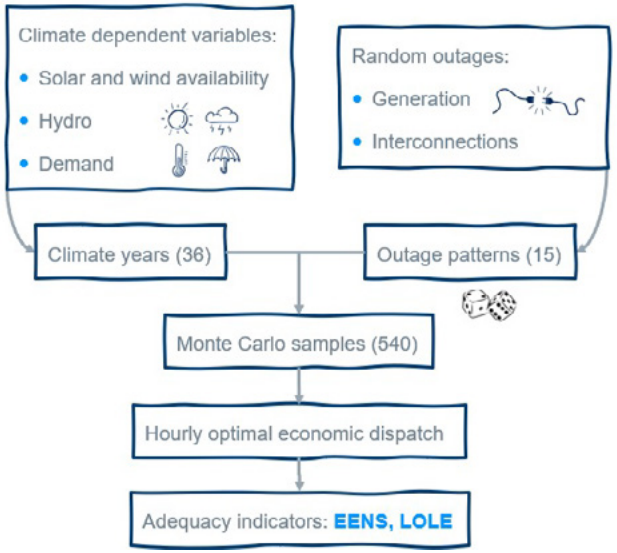


Figure 8. ERAA probabilistic methodology.

The methodology relies on the following main assumptions:

1. Perfect internal grid: the ERAA is matching supply and demand, as well as exchanges between Bidding Zones (BZs), without considering grid constraints within BZs.
2. Perfect foresight: it is assumed that the available renewable energy sources (RES), thermal capacities, demand side response (DSR) capacities, grid capacities and demand are known in advance with perfect accuracy; there are no deviations between forecast and realization. This also implies a perfect allocation of storage capacities (e.g. hydraulic storages) within the year.
3. Planned maintenance of thermal units is optimized: planned thermal unit maintenance is scheduled during the least critical periods, having perfect foresight of the demand pattern (i.e. periods with likely supply surplus rather than supply deficit).
4. Some technical parameters of thermal generators are modelled in a simplified manner: technical parameters considered to have a low impact on adequacy are modelled in a simplified manner or are neglected.
5. Flow-Based (FB) modelling for the CORE[13] region: in the adequacy model, grid limitations within the CORE area are modelled using the FB approach, which mimics multilateral import/export restrictions. The remaining part of Europe is modelled via bilateral Net Transfer Capacity (NTC) exchange limitations.

13. CORE region is composed of Austria, Belgium, Croatia, the Czech Republic, France, Germany, Hungary, Luxemburg, the Netherlands, Poland, Romania, Slovakia and Slovenia.

4.1.6 Adequacy indicators for probabilistic simulation

The following adequacy indicators are calculated as a result of the probabilistic method:

1. Loss of load duration (LLD): the duration in which resources are insufficient to meet demand. It depends on the granularity of the optimization problem, which is equal to one hour.

2. Loss of load expectation (LOLE): the expected number of hours during which resources are insufficient to meet demand over multiple Monte Carlo samples. In a probabilistic method where all samples have an equal probability, it is obtained as the average of the LLD in all the Monte Carlo simulations:

$$LOLE = \frac{1}{MC_{tot}} \sum_{j=1}^{MC_{tot}} LLD_j,$$

   (where LLDj is the load of loss duration in the j Monte Carlo simulation and MCtot is the total number of Monte Carlo simulations.)

3. Energy not served (ENS): the electricity demand which cannot be supplied due to insufficient resources.

4. Expected energy not served (EENS): the electricity demand which is expected not to be supplied due to insufficient resources. In a probabilistic method where all samples have an equal probability, it is obtained as the average of the ENS in all the Monte Carlo simulations:

$$EENS = \frac{1}{MC_{tot}} \sum_{j=1}^{MC_{tot}} ENS_j$$

   (where ENSj is the energy not served in the j Monte Carlo simulation and MCtot is the total number of Monte Carlo simulations.)

4.2 Differences between the European and the National Resource Adequacy Assessments in terms of methodology

As specified in Article 24 of Regulation EU 2024/1747943, the NRAA shall be based on the ERAA methodology. Nonetheless, there are some methodological differences that are explained in this chapter. These differences are mainly needed to allow computational feasibility and reduce simulation time while maintaining result robustness.

Following the ACER opinion "Best practices for providing the reasons for the divergence between the national and European resource adequacy assessments" [14] this subchapter aims to explain the main differences in terms of methodology between the Spanish National Resource Adequacy Assessment (NRAA) and the European Resource Adequacy Assessment (ERAA) that could lead to differences in the results obtained in both analysis.

4.2.1 Differences in curtailment sharing application

The following differences in curtailment sharing application are applicable only to the ADQ model , as the EVA does not include this feature.

4.2.1.1 Explanation of the difference

The curtailment sharing step will not be implemented in the NRAA due to time constraints.

4.2.1.2 Description of the difference

The curtailment sharing step is currently applied in ERAA in the ADQ model. In the NRAA, this step will not be applied to the ADQ model.

4.2.1.3 Impact of the difference

Curtailment sharing step redistributes the ENS that occurs in a given hour between all the countries that in that hour are depending on imports. Therefore, this step always increases the LOLE. By not considering it in the NRAA, all the LOLE indicators shown in the NRAA should be understood as a minimum.

To assess the impact of this difference, the hourly ENS values of the ERAA 2024 previous to the curtailment sharing step have been used in order to recompute the LOLE and EENS indicators.

14. https://www.acer.europa.eu/sites/default/files/documents/Official_documents/Acts_of_the_Agency/Opinions/Documents/ACER_Opinion_NRAAs_best_practices_2025.pdf

Table 3. Differences between the ERAA and the NRAA (methodology). Curtailment sharing application. Impact of the difference comparing ERAA 2024 final EENS and LOLE results (for Spain) with the ones before the curtailment sharing application.

Name	Descr.	Prop.	2026	2028	2030	2035
ERAA24	Final	EENS (GWh)	5.16	6.46	0.16	0.57
		LOLE (h)	4.03	4.83	0.28	0.54
	Previous to CS	EENS (GWh)	5.15	6.04	0.10	0.18
		LOLE (h)	3.55	3.96	0.06	0.08

The following figure shows the hourly ENS monotone curve for Spain for TY2028 that would result from the ERAA if the curtailment sharing step is not considered compared to the final ERAA one.

The differences between the ERAA and the NRAA are expected to reduce the adequacy risks.

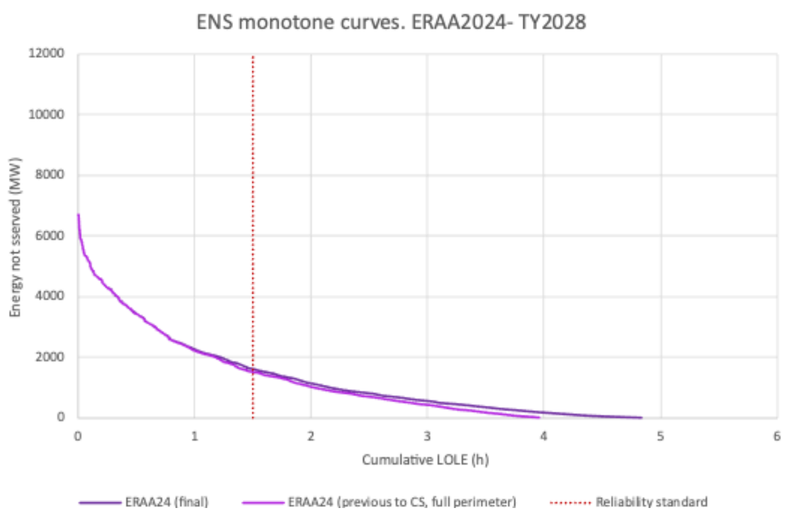


Figure 9. Differences between the ERAA and the NRAA (methodology). Curtailment sharing application. Impact of the difference comparing ERAA 2024 final ENS monotone curve (for Spain) with the one before the curtailment sharing application. Focus on TY2028.

4.2.2 Differences in geographical scope

The following differences in geographical perimeter are applicable both to the EVA and to the ADQ models.

4.2.2.1 Explanation of the difference

The geographical scope of ERAA encompasses a large part of the European continent that implies a big model with very complex and time-consuming simulations. However, for the NRAA a reduction of this perimeter is possible with a minimal impact on results but big impact in terms of computational resources (EVA model) and time (ADQ model).

4.2.2.2 Description of the difference

The following figure shows the perimeter modelled in the ERAA, and a dashed line indicating the bidding zones that are not modeled in the NRAA:

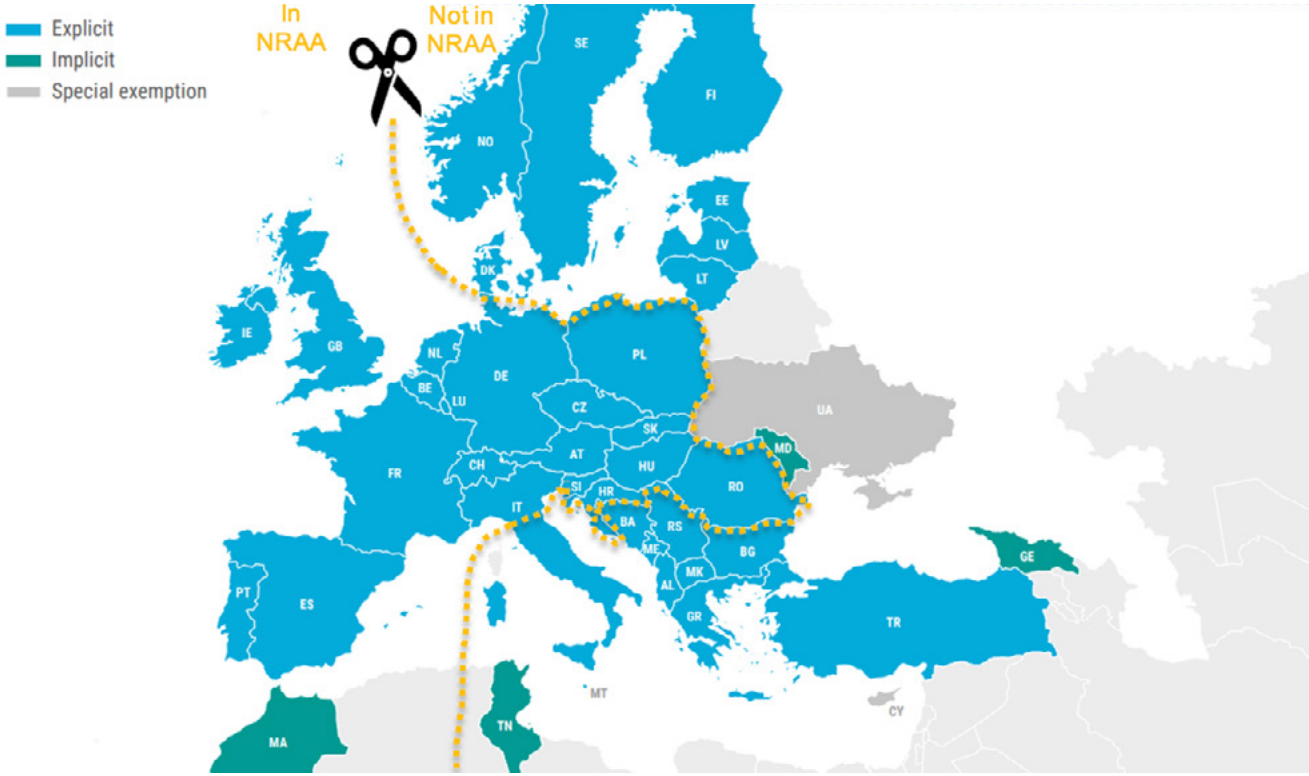


Figure 10. Differences between the ERAA and the NRAA (methodology). Geographical scope. Visual description.

In order to capture the possible impact of the bidding zones that are not considered in the NRAA models, fictitious generators are included in the modeled zones that are interconnected to non-modeled ones. The fictitious generators have a maximum capacity that equals the maximum import capacity of the represented border, and is only allowed to generate when prices are close to the maximum clearing price.

The following table reflects if a bidding zone is included in the NRAA and how. When the BZ is modeled as a fictitious generator, the capacity for each target year is reported:

Table 4. Differences between the ERAA and the NRAA (methodology). Geographical scope. Detailed description.

Country	BZ in ERAA	BZ in NRAA
Albania	AL00	No
Austria	AT00	Yes
Belgium	BE00	Yes
	BEOF	Yes
Bosnia and Herze-govina	BA00	BA00-HR00: 800, 800, 800, 800
Bulgaria	BG00	BG00-RO00: 2000, 2000, 2000, 2300
Croatia	HR00	Yes
Czech Republic	CZ00	Yes
Denmark	DKW1	DKW1-DE00: 3500, 3500, 3500, 3500 DKW1-NL00: 700, 700, 700, 700 DKW1-UK00: 1400, 1400, 1400, 1400
	DKE1	DKE1-DE00: 585, 585, 585, 585
	DKKF	DKKF-DEKF: 400, 400, 400, 400
	DKNS	No
	DKBH	DKBH-DE00: 0, 0, 2000, 2000
Estonia	EE00	No
Finland	FI00	No
France	FR00	Yes
Germany	DE00	Yes
	DEKF	Yes
Greece	GR00	No
Greece	GR03	No
Hungary	HU00	Yes
Ireland	IE00	Yes
Italy	ITN1	Yes
	ITCN	ITCN-ITN1: 3500, 4500, 4500, 4500
	ITCS	ITCS-ITN1: 0, 0, 2000, 2000
	ITS1	No
	ITCA	No
	ITSA	No
	ITSI	No
Latvia	LV00	No
Lithuania	LT00	LT00-PL00: 150, 150, 150, 850
Luxembourg	LUG1	Yes
	LUB1	Yes
	LUV1	Yes
	LUF1	Yes
Republic of North Macedonia	MK00	No
Malta	MT00	No

Country	BZ in ERAA	BZ in NRAA
Montenegro	ME00	No
Netherlands	NL00	Yes
	NLLL	Yes
	NL60	Yes
Norway	NON1	No
	NOM1	No
	NOS1	No
	NOS2	NOS2-DE00: 1400, 1400, 1400, 1400 NOS2-NL00: 700, 700, 700, 700 NOS2-UK00: 1400, 1400, 1400, 1400
	NOS3	No
Poland	PL00	Yes
Portugal	PT00	Yes
Romania	RO00	Yes
Serbia	RS00	RS00-HR00: 300, 300, 300, 300 RS00-HU00: 750, 750, 1390, 1390 RS00-RO00: 800, 1229, 1300, 1949
Slovakia	SK00	Yes
Slovenia	SI00	Yes
Spain	ES00	Yes
Sweden	SE01	No
Sweden	SE02	No
	SE03	No
	SE04	SE04-DE00: 615, 615, 615, 1315 SE04-PL00: 600, 600, 600, 600
Switzerland	CH00	Yes

Country	BZ in ERAA	BZ in NRAA
United Kingdom	UK00	Yes
	UKNI	Yes
Türkiye	TR00	No

red eléctrica

4.2.2.3 Impact of the difference

As a starting point of the NRAA, it has been confirmed through specific simulations that this geographical reduction has minimal impact in terms of results both for the adequacy model and also for the economic viability assessment model.

The following figures and tables show a comparison of some relevant results from the ADQ model:

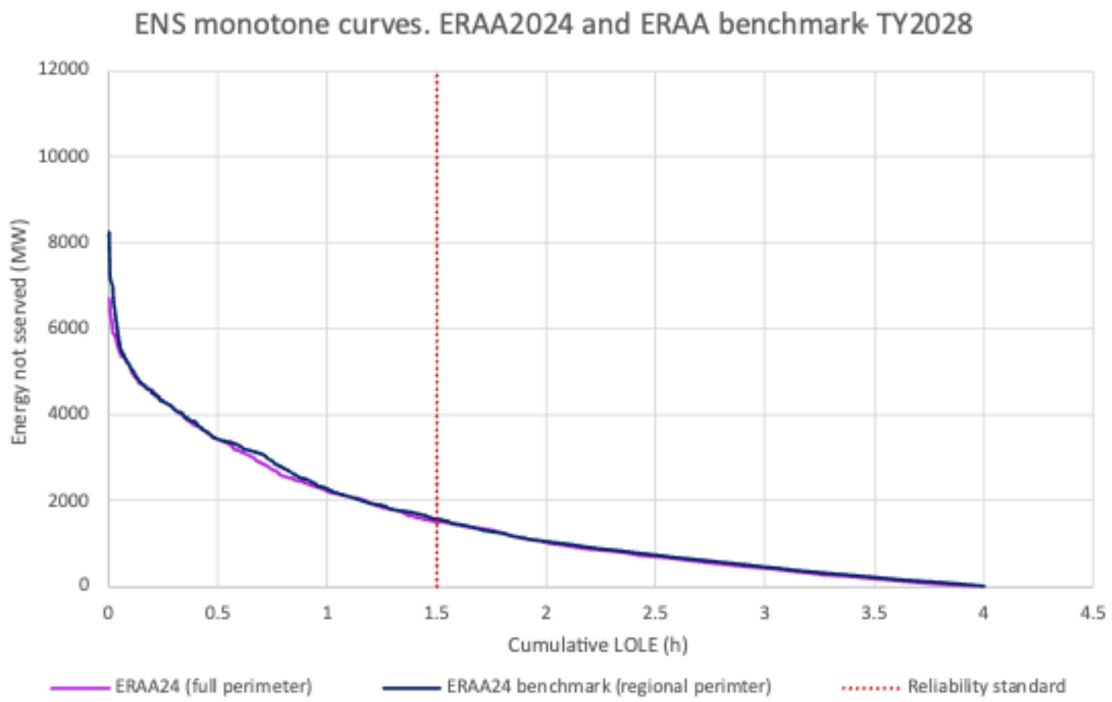


Figure 11. Differences between the ERAA and the NRAA (methodology). Geografical scope. Impact of the difference comparing ERAA 2024 pre-CS ENS monotone curve (for Spain) and the one resulting from the benchmark simulations performed under this NRAA. Focus on TY2028.

Table 5. Differences between the ERAA and the NRAA (methodology). Geographical scope. Impact on EENS and LOLE (for Spain). TY2028.

Prop.	Descrip.	Prop.	2028
ERAA24	Full perimeter	EENS (GWh)	6.04
		LOLE (h)	3.96
ERAA24 benchmark	Regional perimeter	EENS (GWh)	6.24
		LOLE (h)	4.01

The results show that for the purpose of identifying if there is an adequacy issue or not, and to estimate the additional capacity needed to comply with the reliability standard the reduction of the perimeter is valid.

The following figures show a comparison of the relevant results from the EVA model. The first figure shows the aggregated investment decisions for all the regions that are modelled in the reduced EVA model used for the NRAA, while the second one shows the result for the Spanish system:

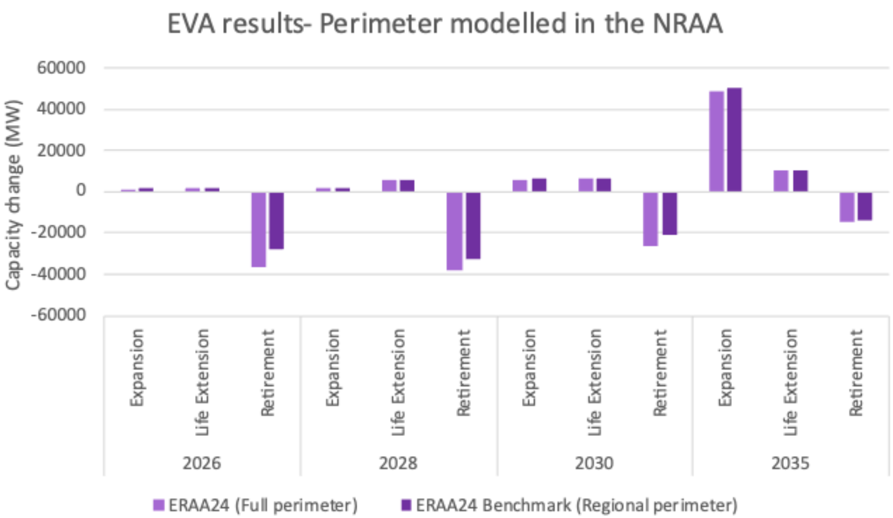


Figure 12. Differences between the ERAA and the NRAA (methodology). Geografical scope. Impact of the difference comparing ERAA 2024 EVA results (for the perimeter modelled in the NRAA) and the ones resulting from the benchmark simulations performed under this NRAA.

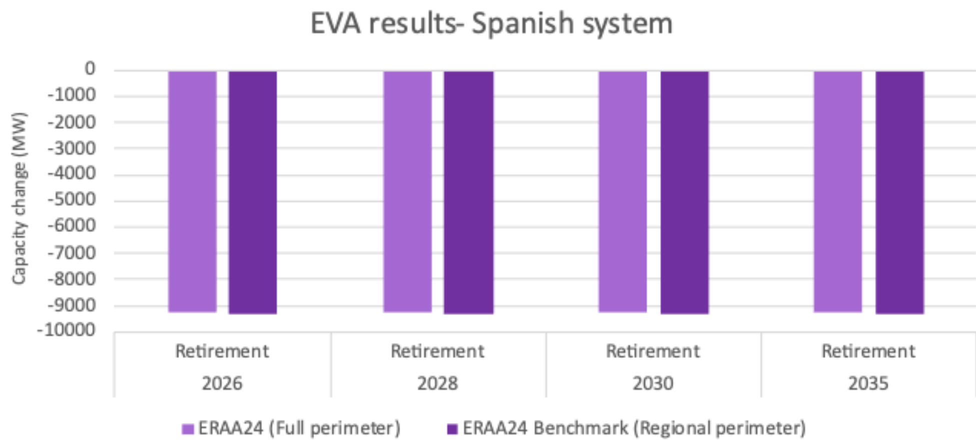


Figure 13. Differences between the ERAA and the NRAA (methodology). Geografical scope. Impact of the difference comparing ERAA 2024 EVA results (for Spain) and the ones resulting from the benchmark simulations performed under this NRAA.

The results show that the reduction of the geographical scope allows to run the EVA model and is also valid in terms of economic decisions, with a good level of alignment for the modelled region and also for the Spanish system throughout the horizon.

4.2.3 Differences in random outage samples

The following differences in the number of random outage samples are applicable only to the ADQ model, as the EVA does not include this feature.

4.2.3.1 Explanation of the difference

The ERAA methodology is probabilistic, meaning that a high number of simulations are performed with different combinations of some parameters in order to obtain average indicators. When the number of simulations is sufficiently high, the average indicators tend to stabilize. The ERAA combines the following two factors to produce the Monte-Carlo assessment: weather scenarios and forced outage patterns.

However, for the NRAA a reduction of the number of forced outage patterns to reduce the complexity of the model is possible with a minimal impact on results, given the size of the generators is small compared to the size of the system. On the other hand, a reduction of the number of weather scenarios is considered to have a higher impact and is therefore discarded for the NRAA.

4.2.3.2 Description of the difference

The ERAA considers, for each of the 36 weather scenarios assessed for each of the 4 target years, 15 different random outage patterns for some of the generators and interconnections. In this NRAA the number of random outage samples will be reduced to 5 and, to allow the individual impact assessment of changes in assumptions performed in the NRAA, it is necessary that the random elements of the model, such as the random outage samples, are respected throughout the simulations.

The following table highlights the differences between the ERAA and the NRAA:

Table 6. Differences between the ERAA and the NRAA (methodology). Random outage samples. Description.

Name	Forced outage samples	Weather scenarios
ERAA24	15	36
NRAA	**5**	36
Difference	**10**	0

4.2.3.3 Impact of the difference

As a starting point of the NRAA, it has been confirmed through specific simulations that this random outage samples reduction has minimal impact in terms of results for the adequacy model.

The following figures and tables show a comparison of some relevant results:

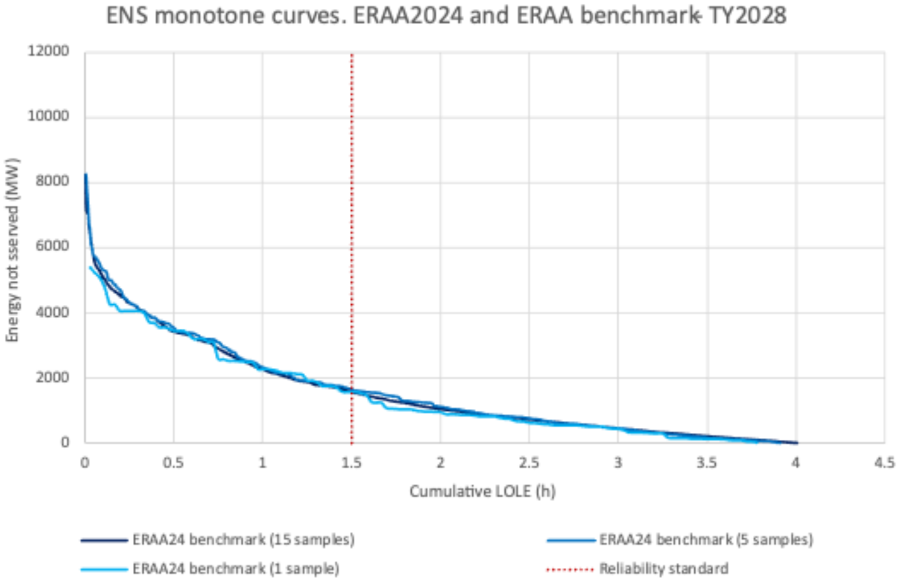


Figure 14. Differences between the ERAA and the NRAA (methodology). Random outage samples. Impact of the difference comparing ENS monotone curve (for Spain) resulting from the benchmark simulations performed under this NRAA. Focus on TY2028.

Table 7. Differences between the ERAA and the NRAA (methodology). Random outage samples. Impact of the difference comparing ERAA 2024 final EENS and LOLE results (for Spain) with the ones before the curtailment sharing application.

Name	Descrip.	Prop.	2028
ERAA24 benchmark	15 samples	EENS (GWh)	6.24
		LOLE (h)	4.01
	5 samples	EENS (GWh)	6.40
		LOLE (h)	3.91
	1 sample	EENS (GWh)	5.82
		LOLE (h)	3.78

The results show that for the purpose of identifying if there is an adequacy issue or not, and to estimate the additional capacity needed to comply with the reliability standard the reduction to 5 random outage samples is sufficient. The biggest impact is observed in the maximum hourly ENS value, which is higher when 15 samples are assessed as this gives room to a worse combination of outages to appear. The reduction to 1 sample could also be valid in terms of indicative annual EENS and LOLE results but captures a lower number of hourly stress situations.

4.2.4 Differences in Spanish non-peninsular connected systems

4.2.4.1 Explanation of the difference

Spanish power system is modeled in ERAA through a main node representing the peninsular power system and two additional nodes representing non-peninsular power systems. In reality, the adequacy of these two non-peninsular systems is expected to be guaranteed through the peninsular system, but ERAA sometimes creates ENS in these systems to avoid ENS in the peninsula. Therefore, in order to be able to supply these non-peninsular systems from the peninsular system, it is necessary to account for the ENS assigned to them in the ERAA results or, alternatively, to introduce a modeling parameter to give their demand a higher value of lost load than the peninsular one to capture all the ENS through the peninsular indicators.

4.2.4.2 Description of the difference

Spanish power system is composed by the peninsular power system, which is synchronously connected with the whole European continental system, and several non-peninsular power systems of which two of them are expected to be connected to the peninsular system:

- Balearic Islands: non-synchronously connected to the peninsula, currently through a bipole HVDC link and planned to connect with a second bipole HVDC.
- Canary Islands: currently not connected to the peninsula, nor planned to be connected
- Ceuta: currently not connected to the peninsula, but planned to be synchronously connected in the near future through an HVAC double circuit.
- Melilla: currently not connected to the peninsula, nor planned to be connected in the near future.

The ERAA includes the Balearic Islands and Ceuta as implicit regions, where their consumption from the peninsular system is represented through hourly interchange profiles that are collected as input (as an output of periodical calculations performed nationally under the non-peninsular adequacy assessments). These exchanges should be treated as a hard constraint as the adequacy of these systems is expected to be guaranteed through the peninsular system, but it can be observed in the ERAA results that this is sometimes not respected.

Therefore, in the NRAA the parameter representing the value of lost load of these two non-peninsular Spanish systems will be set to a value higher than the one used for the different target years in the peninsular system in order to capture all the Spanish ENS through the peninsular indicators.

The following table highlights the differences between the ERAA and the NRAA:

Table 8. Differences between the ERAA and the NRAA (methodology). Spanish non-peninsular connected systems. Description.

Region	Prop.	Name	2026	2028	2030	2035
ES00-ESCE, ES00-ESIB	Price cap (€/MWh)	ERAA24	4500	5000	6000	6500
		NRAA	**4510**	**5010**	**6010**	**6510**
		Difference	**10**	**10**	**10**	**10**

4.2.4.3 Impact of the difference

To assess the impact of this difference, the hourly ENS values of the ERAA 2024 (previous to the curtailment sharing step) have been used in order to recompute the LOLE and EENS indicators if the ENS of regions ES00-ESCE and ES00-ESIB would have been assigned to ES00:

Table 9. Differences between the ERAA and the NRAA (methodology). Spanish non-peninsular connected systems. Impact of the difference comparing ERAA 2024 final EENS and LOLE results (for Spain).

Name	Descrip.	Prop.	2026	2028	2030	2035
ERAA24	ES00	EENS (GWh)	5.15	6.04	0.10	0.18
		LOLE (h)	3.55	3.96	0.06	0.08
	ES00, ESCE, ESIB	EENS (GWh)	6.74	7.89	0.22	0.44
		LOLE (h)	4.88	5.63	0.19	0.47

The following figure shows the ENS monotone curve that would result from the ERAA if only ES00 is considered, or if also Ceuta and Balearic Islands are considered:

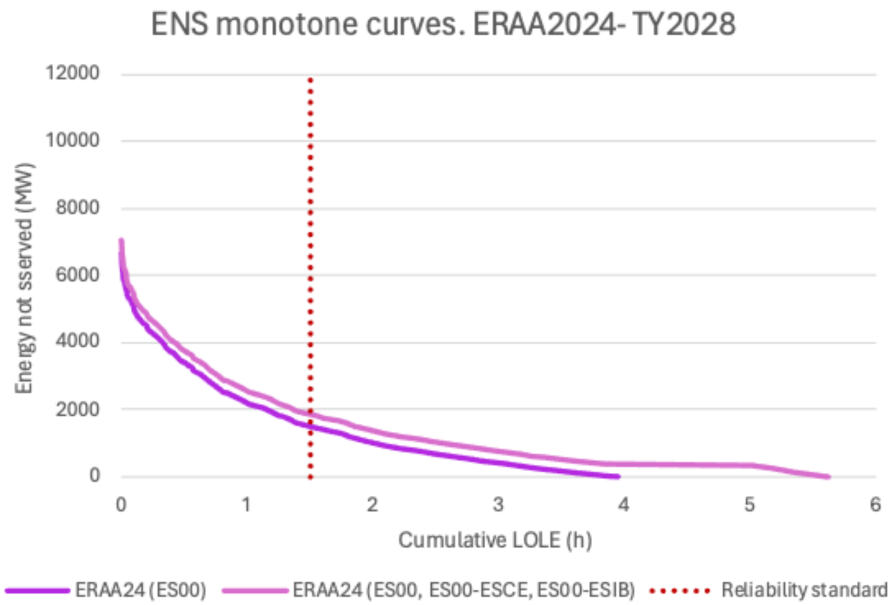


Figure 15. Differences between the ERAA and the NRAA (methodology). Spanish non-peninsular connected systems. Impact of the difference comparing ERAA 2024 final ENS monotone curve (for Spain). Focus on TY2028

The differences between the ERAA and the NRAA are expected to increase the adequacy risks.

5 Hypotheses

5.1
European Resource Adequacy Assessment 2024

5.2
Differences between the European and the National Resource Adequacy Assessment in terms of hypotheses

This chapter summarizes the hypothesis and assumptions used both in the European Resource Adequacy Assessment (ERAA 2024) and in this National Resource Adequacy Assessment (NRAA). The ERAA 2024 assumptions are divided into three different data blocks: the European perimeter, the Spanish perimeter and central economic parameters. A separate part of the chapter focuses on the different assumptions considered under this NRAA concerning the Spanish peninsular power system.

5.1 European Resource Adequacy Assessment 2024

A full detailed description of the input data and assumptions that were used for European Resource Adequacy Assessment (ERAA 2024) can be found at the report (Annex 1 - Input data & Assumptions)[15], but a summary of the main assumptions for the European and Spanish perimeter are included. Also, economic parameters are listed. An interactive dashboard is also available, allowing to explore the input data in a more versatile way[16].

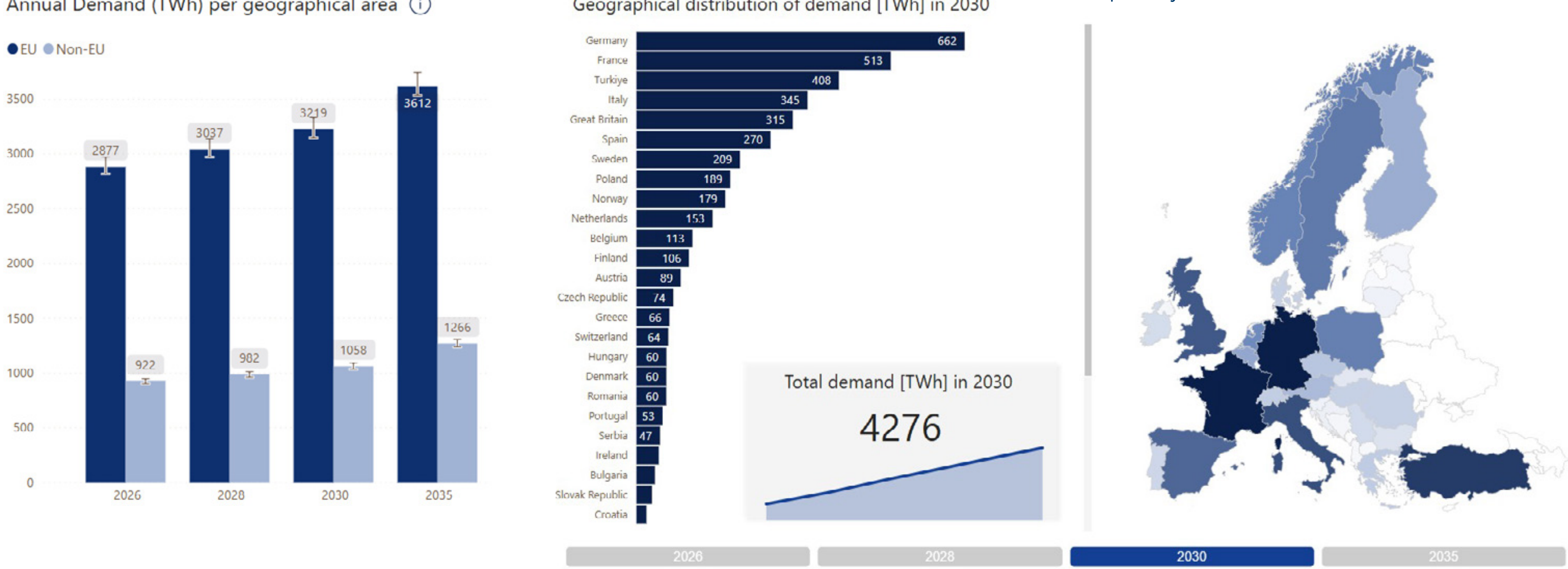
5.1.1 European perimeter

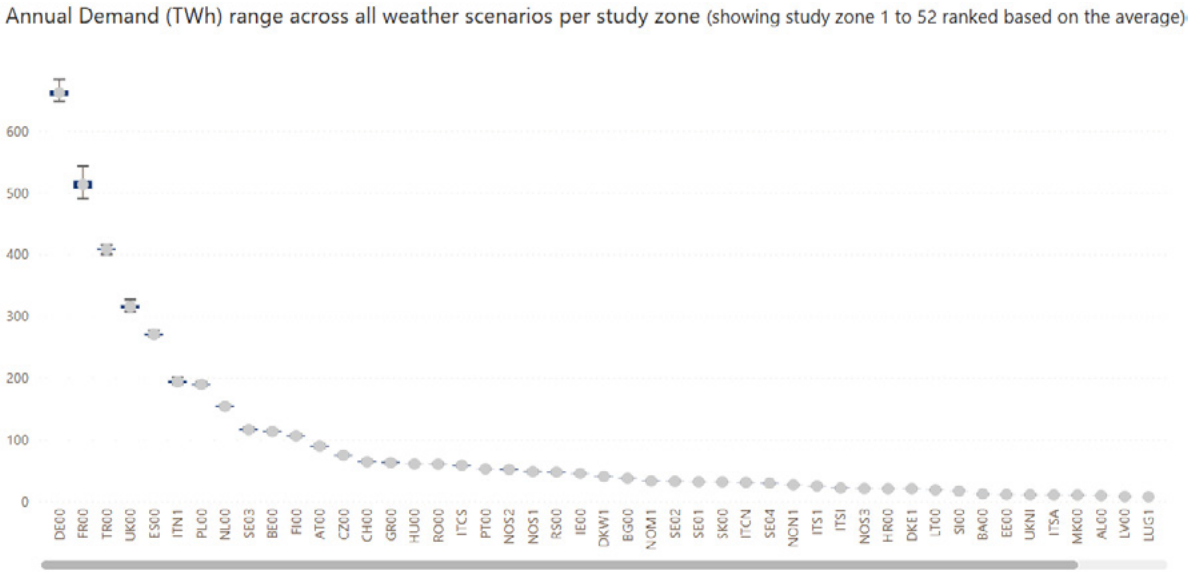
A short summary of the pan-European data considered in the ERAA 2024 for each target year (TY) is graphically shown in order to give a general idea of the whole scenario framework. Data, extracted from the ERAA 2024 webpage, includes: Demand; Resource capacities under 'National Estimates' scenario; Storage capacities; Pan European Climate Database (PECD) for energy variables and hydro inflows; Reserve requirements; Planned maintenance; Net import/export capacities and exchanges with implicit regions. As data is available online, tables are not included to avoid extending unnecessarily this report.

15. Link to ERAA 2024 report (Annex I - Input data & Assumptions): https://eepublicdownloads.azureedge.net/clean-documents/sdc-documents/ERAA/2022/data-for-publication/ERAA2022_Annex_1_Assumptions.pdf
16. Link to ERAA 2024 report (Visuals): https://www.entsoe.eu/eraa/2024/visuals/

Demand

Figure 16. ERAA 2024 assumptions. Pan-European average annual demand (TWh) and geographical distribution in 2030 (TWh). Prepared by ENTSO-E.





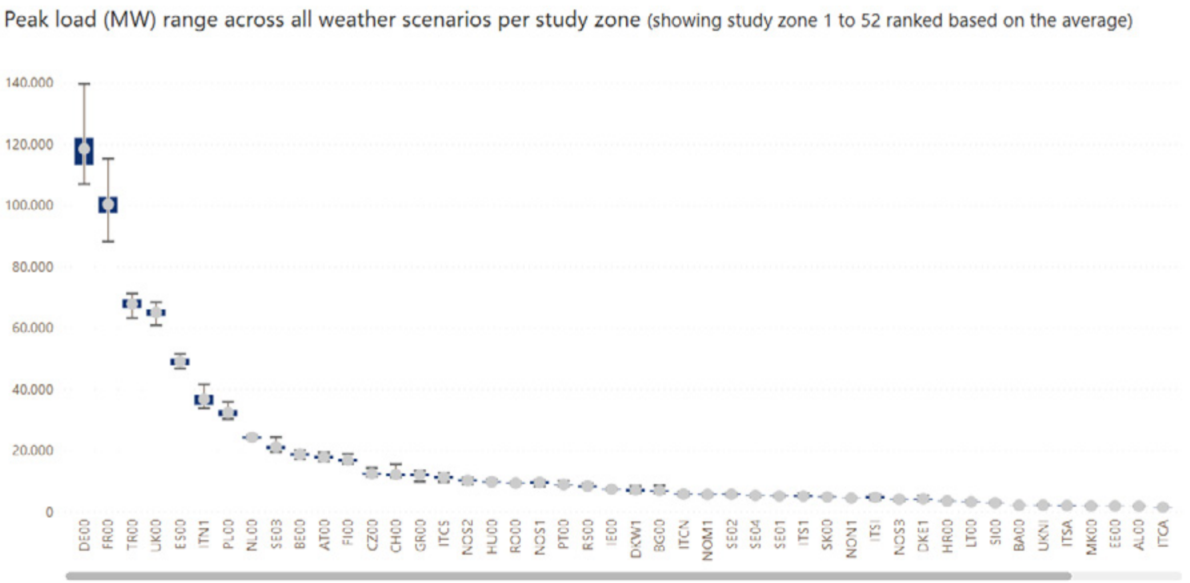


Figure 17. ERAA 2024 assumptions. Annual demand (TWh) and peak load (MW) range across all weather scenarios per study zone. Prepared by ENTSO-E.

Resource capacities under 'National Estimates' scenario

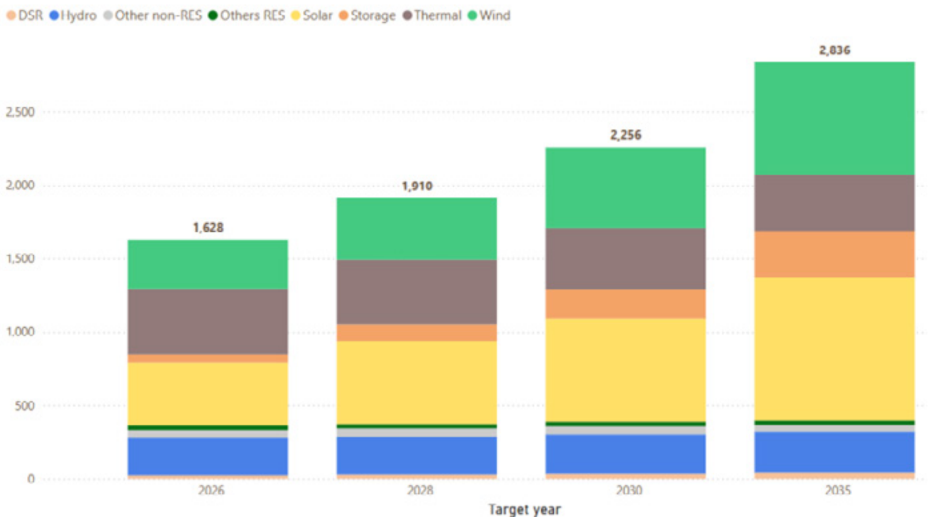


Figure 18. ERAA 2024 assumptions. Pan-European resource capacities under 'National Estimates' scenario (GW). Prepared by ENTSO-E.

Storage capacities

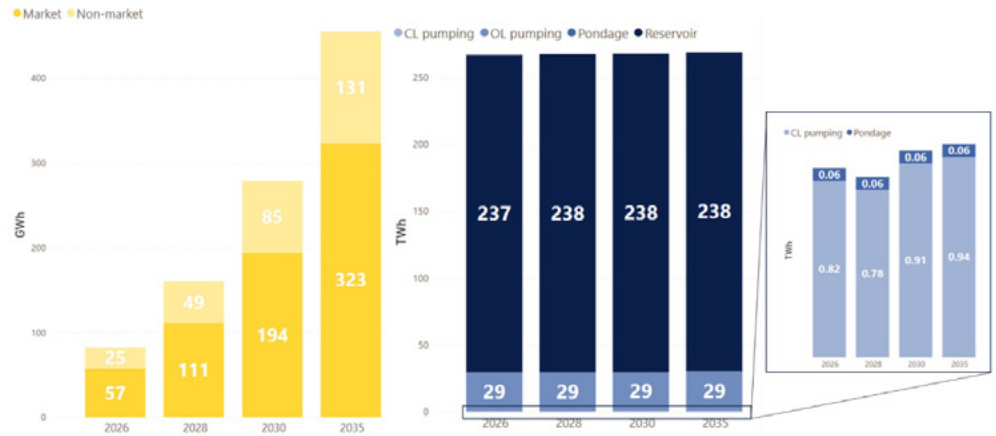


Figure 19. ERAA 2024 assumptions. Pan-European battery storage capacities (GWh) and hydro storage capacities (TWh). Prepared by ENTSO-E.

Renewable generation potential

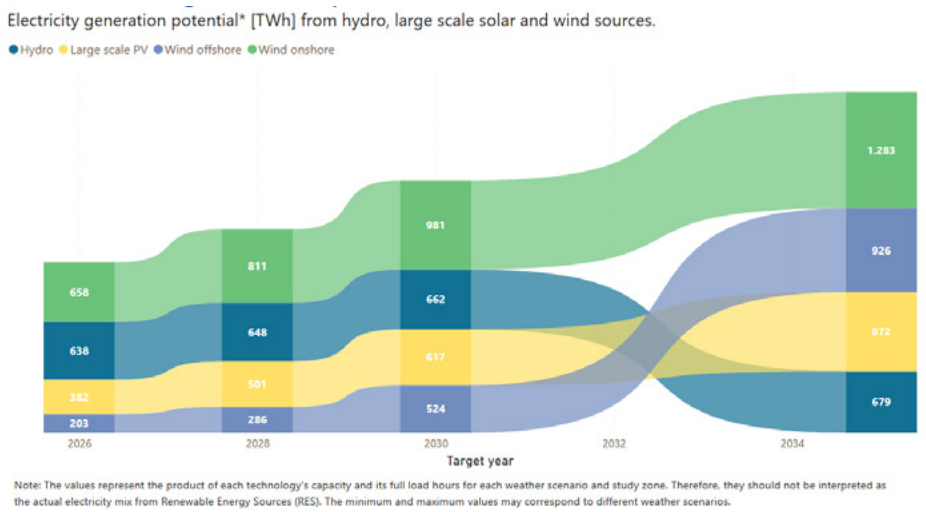


Figure 20. ERAA 2024 assumptions. Pan-European renewable generation potential (TWh). Prepared by ENTSO-E.

Reserve requirements

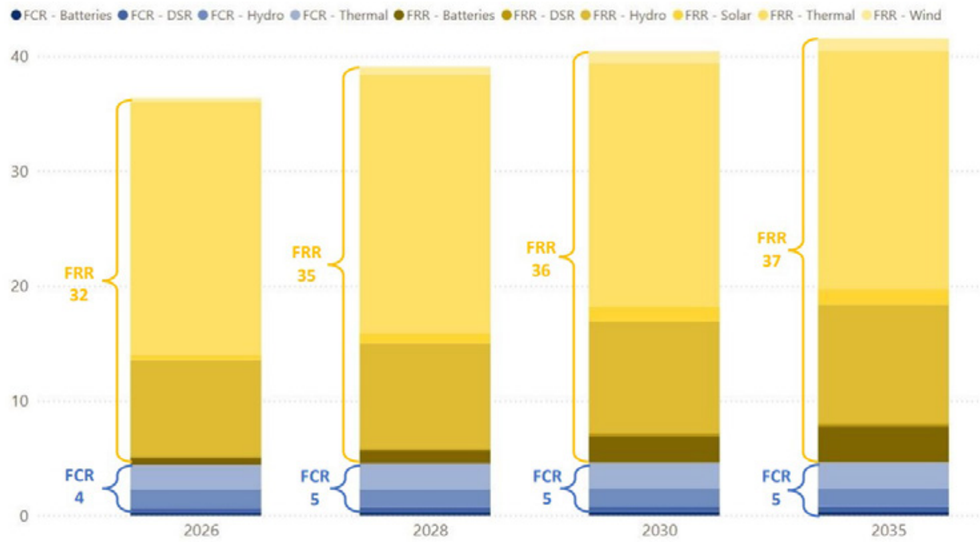


Figure 21. ERAA 2024 assumptions. Aggregated reserve requirements (GW). Prepared by ENTSO-E.

Planned maintenance

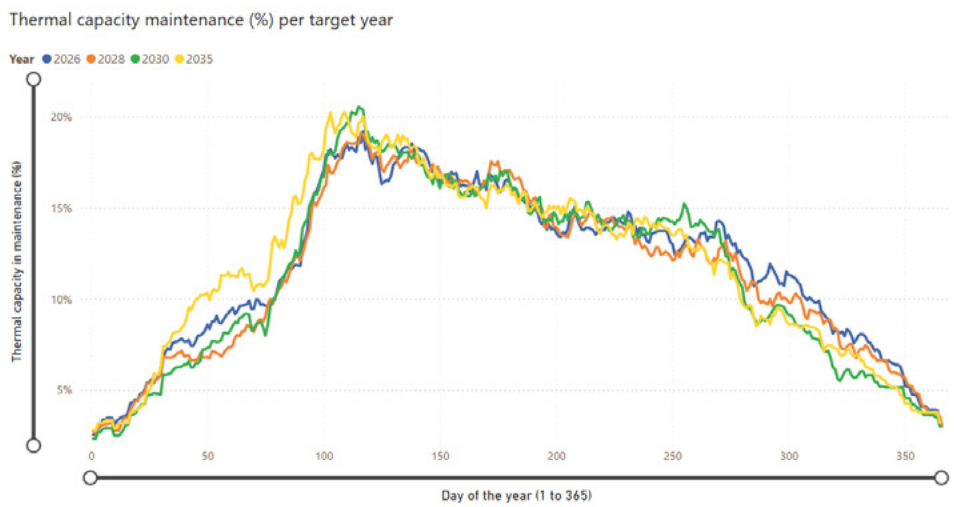


Figure 22. ERAA 2024 assumptions. Aggregated thermal capacity in maintenance (%). Prepared by ENTSO-E.

Net import/export capacities

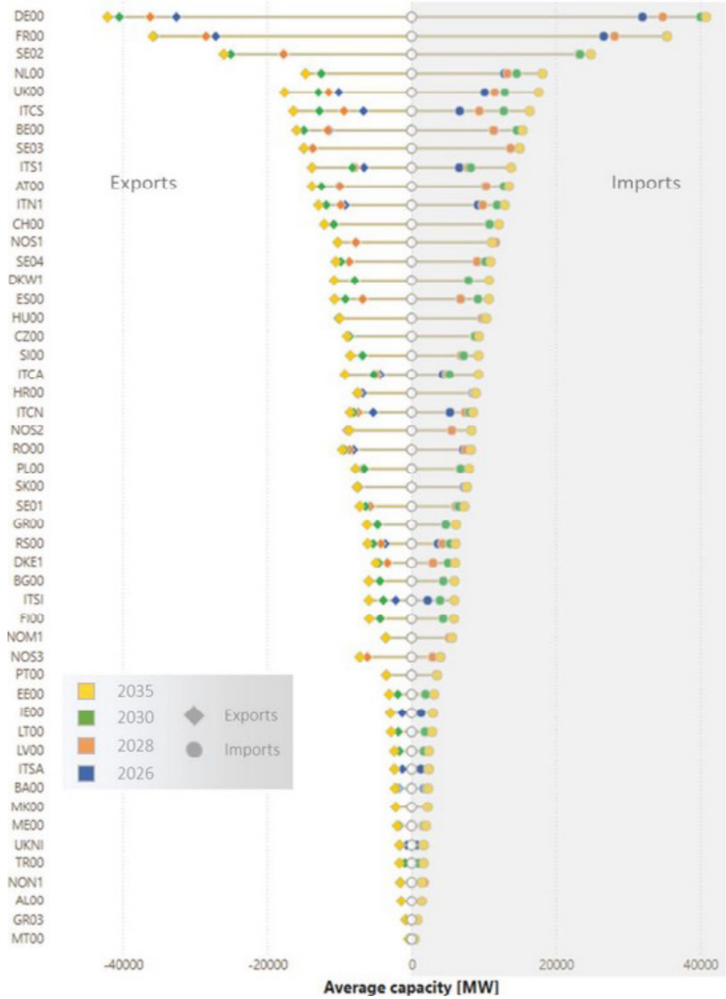


Figure 23. ERAA 2024 assumptions. Average maximum net import/export capacities. Prepared by ENTSO-E.

Exchanges with implicit regions

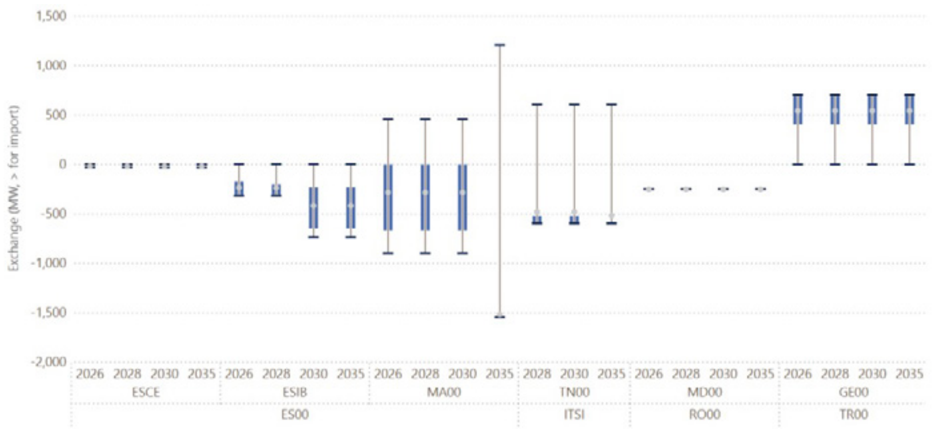


Figure 24. ERAA 2024 assumptions. Exchanges with implicit regions. Prepared by ENTSO-E.

Flow-based domains

Figure 25. ERAA 2024 assumptions. Core and Nordic illustrative theoretical maximum export and import capacities. Prepared by ENTSO-E.

5.1.2 Spanish perimeter

A short summary of the Spanish data considered in the ERAA 2024 is included: total system demand; Resource capacities under 'National Estimates' scenario; Storage capacities; PECD energy variables and hydro inflows; Reserve requirements; Planned maintenance; Net import/export capacities and exchanges with implicit regions; explicit DSR potential for EVA.

Demand

Table 10. ERAA 2024 assumptions. Spanish Yearly (TWh) and Peak (GW) total system demand.

	TY2026		TY2028		TY2030		TY2035	
Attribute	Power (GW)	Yearly Demand (TWh)	Power (GW)	Yearly Demand (TWh)	Power (GW)	Yearly Demand (TWh)	Power (GW)	Yearly Demand (TWh)
Min	42.3	245	44.3	256	46.6	267	50.0	282
Avg	44.5	249	46.5	259	49.0	270	52.4	285
Max	47.0	255	48.9	266	51.4	277	54.8	291

Resource capacities under 'National Estimates' scenario

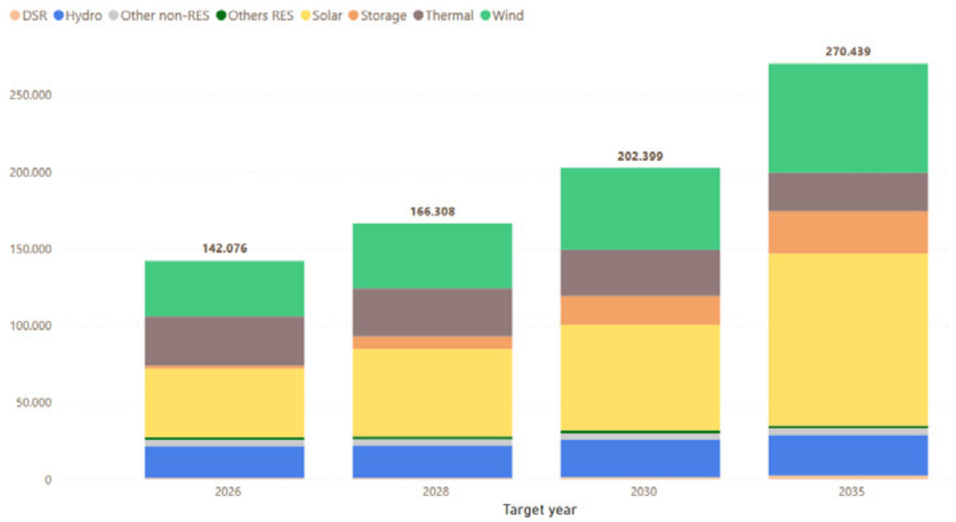


Figure 26. ERAA 2024 assumptions. Spanish capacities in 'National Estimates' scenario (MW).

Table 11. ERAA 2024 assumptions. Spanish resource capacities under 'National Estimates' scenario.

Installed capacities (MW)	TY2026	TY2028	TY2030	TY2035
Hydro	**20603**	**21138**	**24428**	**26247**
Run of river	3412	3412	3667	3667
Reservoir	11177	11177	11177	11177
Pumped storage - Open	2683	2683	3123	3123
Pumped storage - Closed	3331	3866	6461	8280
Renewables	**82485**	**101058**	**123841**	**184841**
Wind - Onshore	36132	42038	50222	68222
Wind - Offshore	0	100	2800	2800
Solar thermal - Current	2304	2304	2304	2304
Solar thermal - Future	0	50	2500	2500
Solar photovoltaic - Rooftop	8268	13337	18405	24405
Solar photovoltaic - Farm	34350	41532	45646	82646
Other renewables	1431	1697	1964	1964
Thermal	**36518**	**34443**	**32172**	**29132**
Coal	0	0	0	0
Combined cycle gas turbines	25061	25061	25061	25061
Nuclear [Nuc]	7117	5110	3040	0
Other non-renewables	4340	4273	4071	4071
Batteries y DSR	**1681**	**2778**	**8900**	**17218**
Batteries	915	1915	7000	13690
Batteries (behind the meter)	157	254	700	928
DSR	609	609	1200	2600
TOTAL CAPACITY	**141286**	**159417**	**189340**	**257438**

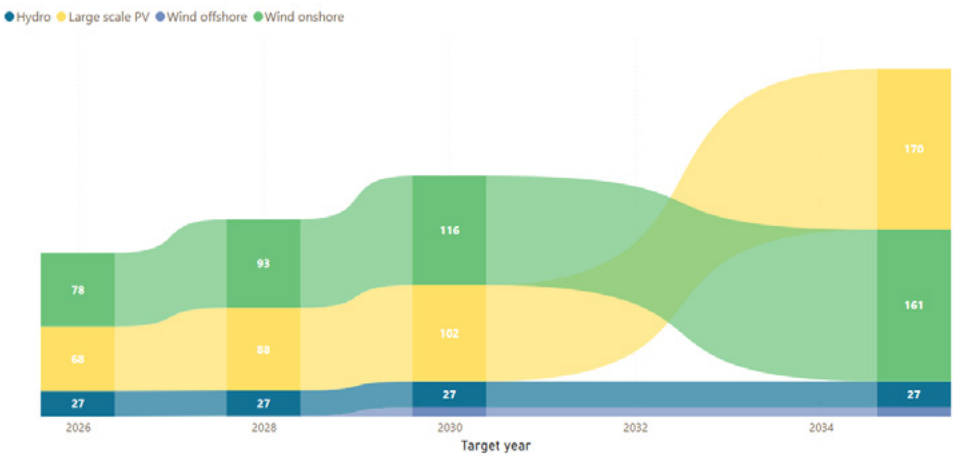
(Nuc) Values shown at end of year, but modelled following current nuclear phase-out calendar: 7.1GW to 1/11/27, 6.1GW to 01/10/28, 5.1GW to 1/10/30, 4.1GW to 1/11/30, 3GW to 1/9/32, 2GW to 1/2/35, 1GW to 1/5/35, 0 W after.

Storage capacities

Table 12. ERAA 2024 assumptions. Spanish storage capacities.

	TY2026		TY2028		TY2030		TY2035	
Attribute	Installed capacity (GW)	Storage capacity (GWh)	Installed capacity (GW)	Storage capacity (GWh)	Installed capacity (GW)	Storage capacity (GWh)	Installed capacity (GW)	Storage capacity (GWh)
Reservoir	11.2	13313	11.2	13313	11.2	13313	11.2	13313
Pump Storage Open	2.7	5937	2.7	5937	3.1	5898	3.1	5898
Pump Storage Closed	3.3	104	3.8	108	6.5	164	8.3	182
Batteries	0.9	1.8	1.9	3.8	7	18	13.7	31.4
Batteries (behind the meter)	0.2	0.4	0.3	0.6	0.7	1.8	0.9	2.3

Renewable generation potential



Note: The values represent the product of each technology's capacity and its full load hours for each weather scenario and study zone. Therefore, they should not be interpreted as the actual electricity mix from Renewable Energy Sources (RES). The minimum and maximum values may correspond to different weather scenarios.

Figure 27. ERAA 2024 assumptions. Spanish renewable generation potential (TWh).

Reserve requirements

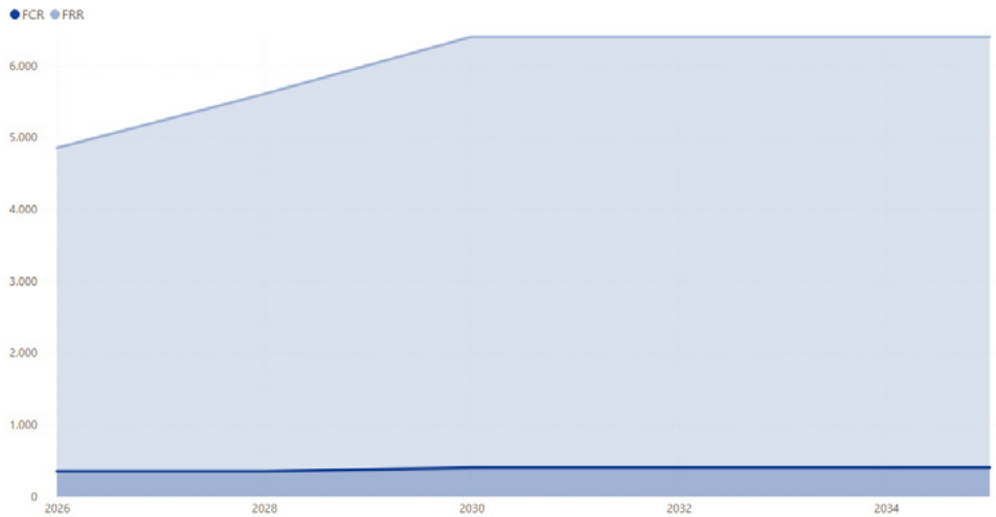


Figure 28. ERAA 2024 assumptions. Spanish reserve requirements.

Planned maintenance

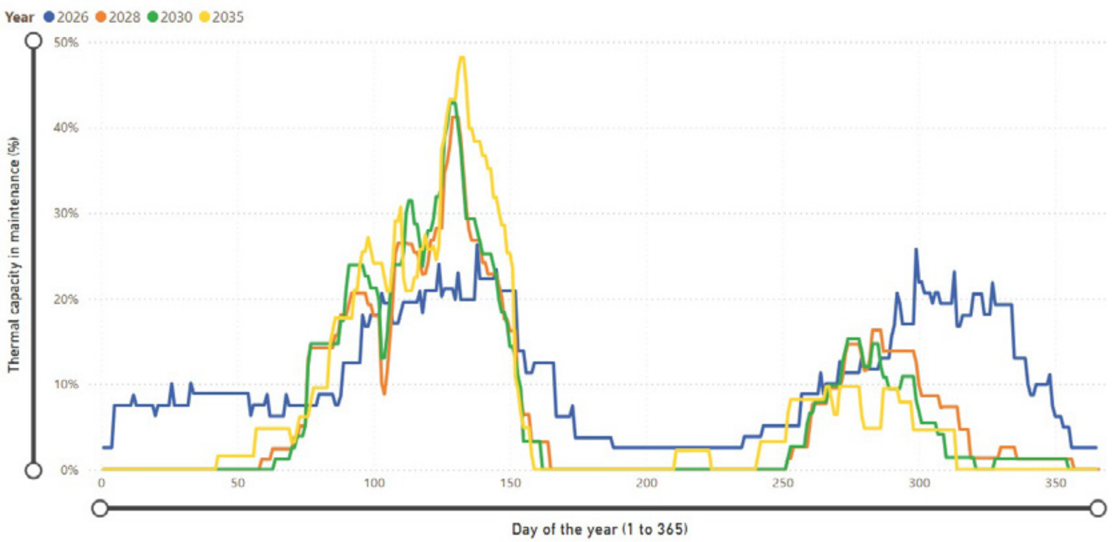


Figure 29. ERAA 2024 assumptions. Spanish thermal capacity in maintenance (%).

Net import/export transfer capacities

Table 13. ERAA 2024 assumptions. TY206, 2028, 2030, 2035, Spanish NTCs (GW).

<table>
<tr><th rowspan="2">Spain-France interconnection</th><th colspan="4">2026, 2028</th><th colspan="4">2030</th><th colspan="4">2035</th></tr>
<tr><th colspan="2">Winter</th><th colspan="2">Summer</th><th colspan="2">Winter</th><th colspan="2">Summer</th><th colspan="2">Winter</th><th colspan="2">Summer</th></tr>
<tr><th></th><th>O-P</th><th>P</th><th>O-P</th><th>P</th><th>O-P</th><th>P</th><th>O-P</th><th>P</th><th>O-P</th><th>P</th><th>O-P</th><th>P</th></tr>
<tr><td>ES00 → FR00 (exp)</td><td>2.9</td><td>2.4</td><td>2.8</td><td>2.3</td><td>5.6</td><td>5.4</td><td>5.5</td><td>3.6</td><td colspan="4" rowspan="2">8.0</td></tr>
<tr><td>FR00 → ES00 (imp)</td><td>2.9</td><td>3.1</td><td>2.6</td><td>2.8</td><td>5.3</td><td>5.3</td><td>5.1</td><td>5.3</td></tr>
<tr><th>Spain-Portugal interconnection</th><th colspan="12">2026, 2028, 2030, 2035</th></tr>
<tr><td>ES00 → PT00 (exp)</td><td colspan="12">4.2</td></tr>
<tr><td>PT00 → ES00 (imp)</td><td colspan="12">3.5</td></tr>
</table>

Exchanges with implicit regions

Table 14. ERAA 2024 assumptions. TY2026, 2028, 2030, 2035. Spanish hourly profile exchanges.

<table>
<tr><th></th><th></th><th>2026</th><th>2028</th><th>2030</th><th>2035</th></tr>
<tr><td rowspan="2">ES00 → Ceuta
(Spanish non-peninsular connected system)</td><td>Annual (GWh)</td><td>188</td><td>192</td><td colspan="2">201</td></tr>
<tr><td>Max hour (MW)</td><td>35</td><td>35</td><td colspan="2">38</td></tr>
<tr><td rowspan="2">ES00 → Balearic Islands
(Spanish non-peninsular connected system)</td><td>Annual (GWh)</td><td>2077</td><td>2103</td><td colspan="2">3695</td></tr>
<tr><td>Max hour (MW)</td><td>320</td><td>320</td><td colspan="2">740</td></tr>
<tr><td rowspan="2">ES00 → Morrocco</td><td>Annual (GWh)</td><td colspan="3">2908</td><td>13328</td></tr>
<tr><td>Max hour (MW)</td><td colspan="3">900</td><td>1550</td></tr>
<tr><td rowspan="2">Morrocco → ES00</td><td>Annual (GWh)</td><td colspan="3">387</td><td>6</td></tr>
<tr><td>Max hour (MW)</td><td colspan="3">450</td><td>1200</td></tr>
</table>

Explicit DSR potential for EVA expansion

Table 15. ERAA 2024 assumptions. TY2026, 2028, 2030, 2035. Spanish DSR potential for EVA.

<table>
<tr><th>Target year</th><th>Potential (MW) [17]</th><th>CAPEX (€/kW)</th><th>FOM (€/kW/year)</th><th>Activation Price (€/MWh)</th><th>Activation limit (h)</th></tr>
<tr><td>2026</td><td>1991</td><td rowspan="4">0</td><td rowspan="4">234.5</td><td rowspan="4">700</td><td rowspan="4">No limit</td></tr>
<tr><td>2028</td><td>1991</td></tr>
<tr><td>2030</td><td>1404</td></tr>
<tr><td>2035</td><td>0</td></tr>
</table>

17. EVA expansion potential reduces along the years because the National Trends scenario already considers an increasing evolution of the installed capacity. The total potential (National Trends installed capacity + EVA expansion potential) is kept at 2600 MW, corresponding to the highest volume procured in the latest auctions of the former interruptibility service.

5.1.3 Technoeconomic parameters

A short summary of the technoeconomic parameters considered both in the UCED and in the EVA in the ERAA 2024 is graphically shown in order to give a general idea of the whole scenario framework. Data, extracted from the ERAA 2024 report, includes: Economic dispatch parameters used both for the adequacy assessment and the economic viability assessment; Economic investment parameters used for the EVA investment decisions are shown.

Economic dispatch parameters for the adequacy assessment and the economic viability assessment

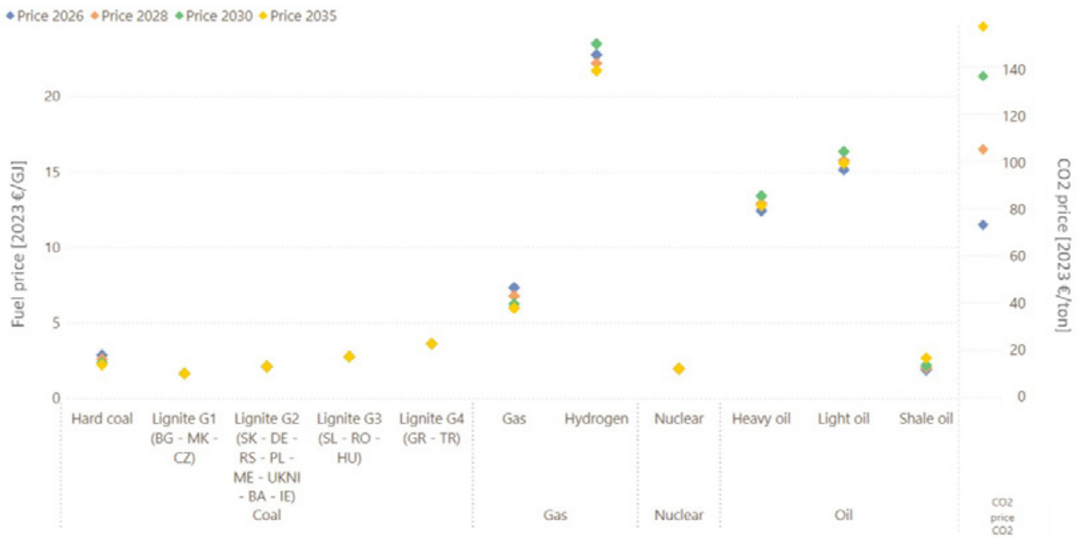


Figure 30. ERAA 2024 assumptions. Evolution of fuel and CO_2 prices. Prepared by ENTSO-E.

Table 16. ERAA 2024 assumptions. Variable operation and maintenance cost per generation category and target year (€/MWh). Prepared by ENTSO-E.

Generation Unit Category	Variable O&M cost (€/MWh)			
	2025	2028	2030	2035
CCGT	2.3-2.7	2.3-2.7	2.3-2.7	2.3-2.7
OCGT	2.4	2.4	2.4	2.4
Lignite	3.5-4.7	3.5-4.7	3.5-4.7	3.5-4
Hard Coal	2.8-4.1	2.8-4.1	2.8-4.1	2.8-4.1
Oil	3.2	3.2	3.2	3.2
Nuclear	8	8	8	8

Table 17. ERAA 2024 assumptions. Efficiency (%) and CO2 emission factor (CO2kg/GJ) per generation category. Prepared by ENTSO-E.

Generation Unit Category	Efficiency
CCGT	40 - 60
OCGT	35-42
Lignite	35-46
Hard coal	35-46
Oil	29 - 40
Nuclear	33

Generation Unit Category	CO_2 emission factor
Gas (OCGT&CCGT)	57
Lignite	101
Hard coal	94
Oil	78-100
Nuclear	0

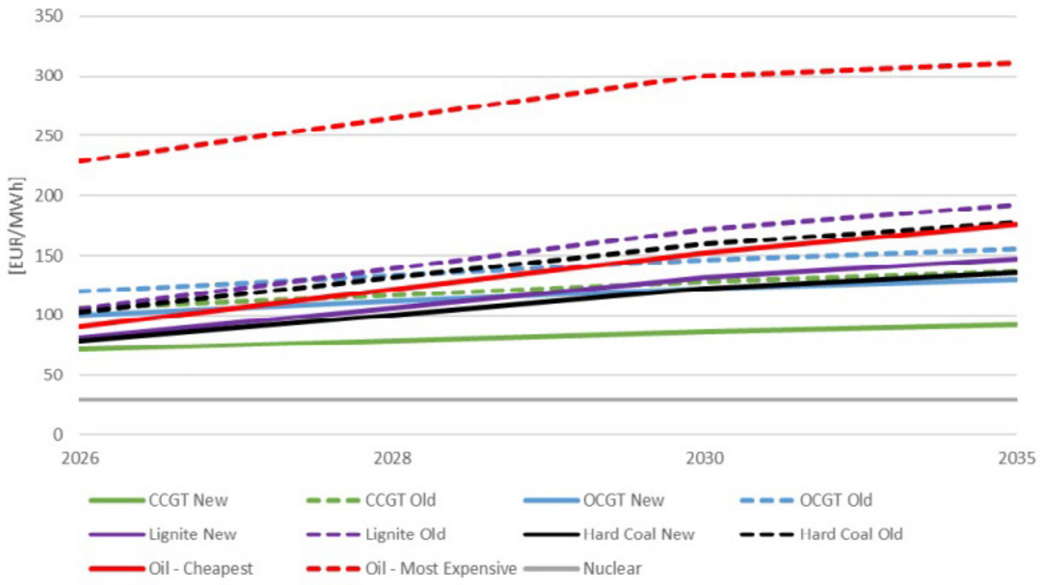


Figure 31. ERAA 2024 assumptions. Marginal cost of thermal units per generation category and target year. Prepared by ENTSO-E.

Table 18. ERAA 2024 assumptions. Price cap (€/MWh) per target year. Prepared by ENTSO-E.

TY	2026	2028	2030	2035
Price cap (€/MWh)	4500	5000	6000	6500

Economic investment parameters for the economic viability assessment

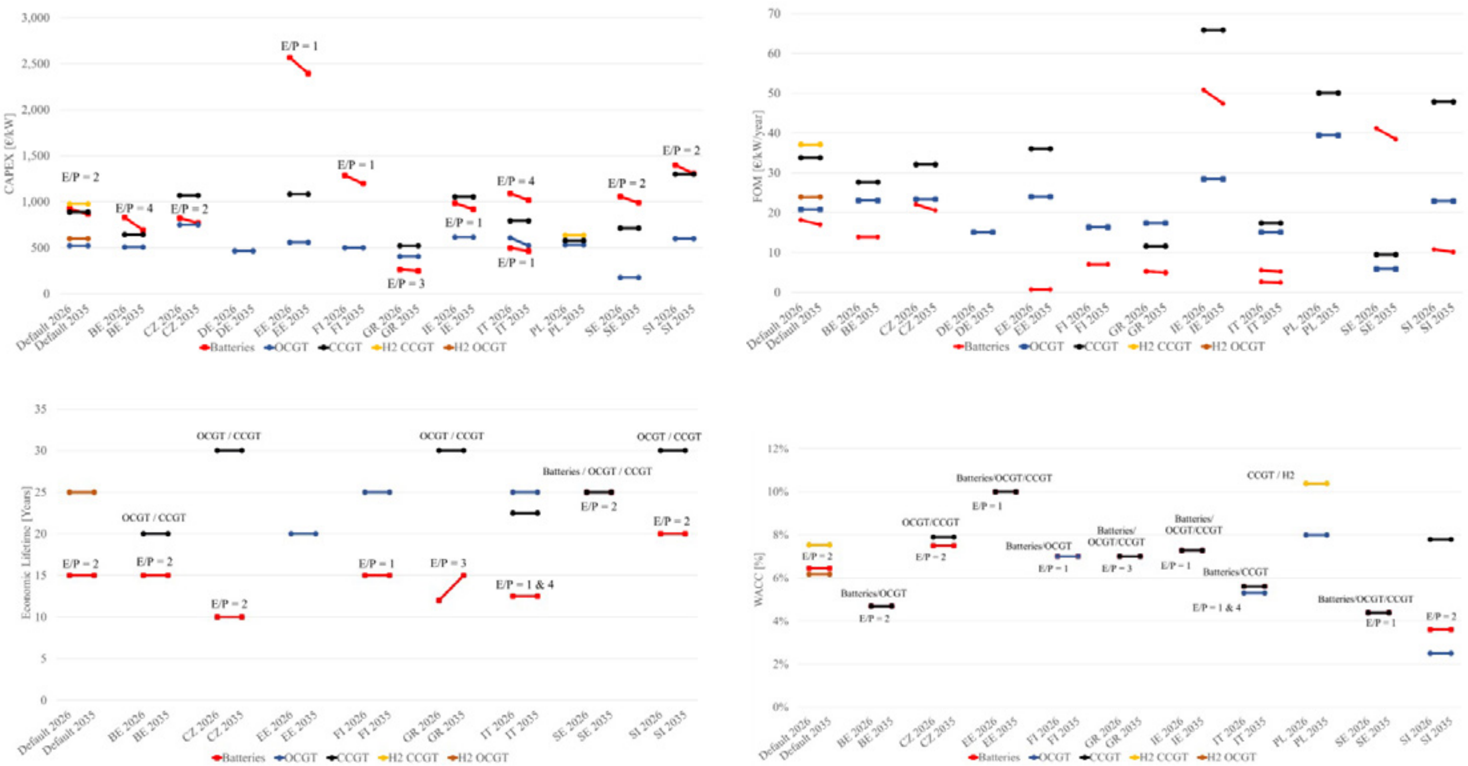


Figure 32. ERAA 2024 assumptions. Parameters for economic commissioning candidates: CAPEX, FOM, EL and WACC. Prepared by ENTSO-E.

Table 19. ERAA 2024 assumptions. Parameters for economic commissioning candidates: Default values for the hurdle premium (%) and TY for new entry. Prepared by ENTSO-E.

Generation Unit Category	Hurdle premium
Battery	3
CCGT	4.5
OCGT	6

Generation Unit Category	TY for new entry
OCGT new	2028
CCGT new	2028
Grid-scale batteries	2026
Explicit DSR	2026

Table 20. ERAA 2024 assumptions. Economic parameters for economic decommissioning candidates. Prepared by ENTSO-E.

Resource Unit Category	FOM cost [€/kW/y]	WACC [%]	Hurdle Premium [%]	Source of Fixed Cost Value
Hard coal	26-39	6.2	3.5	EU reference scenario 2020
Lignite	33	6.2	3.5	EU reference scenario 2020
CCGT	34	7.5	3	Average of CONE studies
OCGT	21	6.2	3.5	Average of CONE studies
Light oil	21	6.2	3.5	EU reference scenario 2020/ASSET 2018
Heavy oil	21	6.2	3.5	EU reference scenario 2020/ASSET 2018
Oil shale	21	6.2	3.5	EU reference scenario 2020/ASSET 2018

Table 21. ERAA 2024 assumptions. Economic parameters for lifetime extension. Prepared by ENTSO-E.

Resource Unit Category	CAPEX [€/kW]	Life Extension [years]	Hurdle Premium [%]	WACC [%]	Source of Fixed Cost Value
CCGT	103				Elia
OCGT	82				Elia
Lignite	283	10	4-5	6.2 - 7.5	Extrapolation
Hard Coal	247				Extrapolation
Oil	193				Extrapolation

5.2 Differences between the European and the National Resource Adequacy Assessment in terms of hypotheses

The regulatory framework concerning the NRAA establishes that they may be carried out for the purpose of complementing the ERAA. The main purpose of this edition is to assess adequacy in a scenario considering a limited number of national specificities that are relevant for the Spanish system, in terms of both modelling and hypotheses.

Following the ACER opinion "Best practices for providing the reasons for the divergence between the national and European resource adequacy assessments"[18] this subchapter aims to explain the main differences in terms of hypotheses between the Spanish National Resource Adequacy Assessment (NRAA) and the European Resource Adequacy Assessment (ERAA) that could lead to differences in the results obtained in both analysis.

5.2.1 Differences in pumped storage

The following differences in pumped storage assumptions are applicable both to the EVA and to the ADQ models.

5.2.1.1 Explanation of the difference

The NECP scenario, on which the ERAA is based, considers an expansion of storage in the form of hydro pumped storage. This expected expansion of storage is subject to the implementation of a capacity market[19], such as the one that is in the final steps of approval under State aid rules[20], but in order to implement such capacity remuneration mechanism, first an adequacy concern has to be identified. Therefore, the scenario in this NRAA only considers the volume of capacity that has been already granted some kind of public support.

5.2.1.2 Description of the difference

The ERAA scenario assumes the achievement of the NECP targets, which set a total storage capacity of 22500 MW. ERAA assumptions considered that 9637 MW of them would be in the form of hydro pumped storage capacity. This means an increase of approximately 3600 MW to the current capacity.

18. https://www.acer.europa.eu/sites/default/files/documents/Official_documents/Acts_of_the_Agency/Opinions/Documents/ACER_Opinion_NRAAs_best_practices_2025.pdf
19. Other public support schemes could also contribute to reaching the target goals for storage, such as non-fossil flexibility support schemes as per article 19g of the recast Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity. However, since such schemes have not yet been implemented at the time of drafting this document, only capacity markets are considered for such purposes for the time being.
20. Public consultation under Guidelines on State aid for climate, environmental protection and energy of the capacity market ended in January 2025. The link to the public consultation: https://www.miteco.gob.es/es/energia/participacion/2024/detalle-participacion-publica-k-721.html

However, at the moment, only one public funding has awarded new pumped hydro capacity[21]. As a result, and for the purposes of the NRAA implementation, only three awarded projects (Alcántara, Navaleo and Velilla) will be considered in the national analysis with a total of 1.1 GW of new capacity.

Among the facilities granted with public State-aid, only those with a sufficient level of aid intensity to justify the investment have been considered.

The following table highlights the differences between the ERAA and the NRAA:

Table 22. Differences between the ERAA and the NRAA (hypotheses). Pumped storage capacity.

Tech.	Prop.	Name	2026	2028	2030 (to 31/05)	2030 (from 01/06)	2035
PS - open	Installed capacity (MW)	ERAA24	2683	2683	3123	3123	3123
		NRAA	2683	2683	**2683**	3123	3123
PS - closed		ERAA24	3331	3866	6461	6461	8280
		NRAA	3331	**3331**	**4000**	**4000**	**4000**
PS - total		Difference	0	**535**	**2901**	**2461**	**4280**

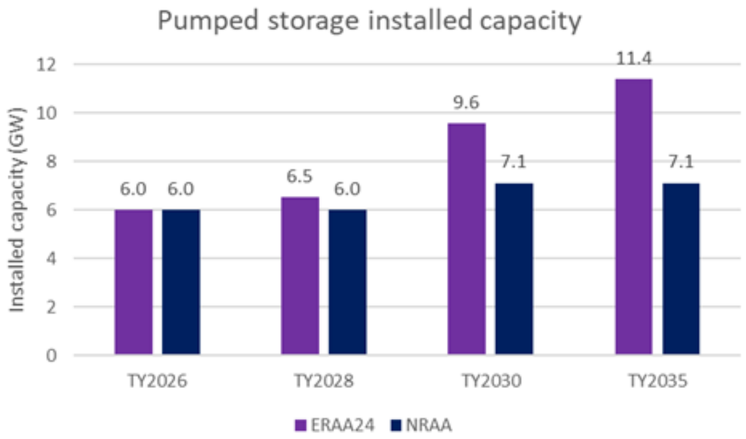


Figure 33. Differences between the ERAA and the NRAA (hypotheses). Pumped storage capacity.

21. Resolución de la Secretaria de Estado de Energía y Presidenta de E.P.E Instituto para la Diversificación y Ahorro de la Energía (IDAE), M.P., por la que se aprueba la concesión de ayudas correspondientes a la primera convocatoria de ayudas para proyectos innovadores de almacenamiento mediante bombeo reversible en el marco del Plan de Recuperación, Transformación y Resiliencia – Financiado por la Unión Europea – Next GenerationEU, publicada mediante la Resolución de 20 de julio de 2023 del Consejo de Administración del E.P.E Instituto para la Diversificación y Ahorro de la Energía (IDAE), M.P. y cuyas bases reguladoras fueron establecidas mediante la Orden TED/807/2023, de 17 de julio, del Ministerio para la Transición Ecológica y el Reto Demográfico (B.O.E. núm. 171, de 19 de julio de 2023): https://sede.idae.gob.es/sites/default/files/documentos/2024/almacenamiento/_381_boralmac_resoluciondefinitiva_adjudicacion.pdf

In addition, the ERAA considers Closed pumped storage to be fully available during the whole period. However, the NRAA includes a weekly availability profile, shown in the following figure, based on recent historical information, which considers this national specificity. This adaptation is important for representativity of results in terms of adequacy and also in case a calculation of the average capacity during scarcity events is performed for this technology. This improvement will be also considered in the ERAA 2025.

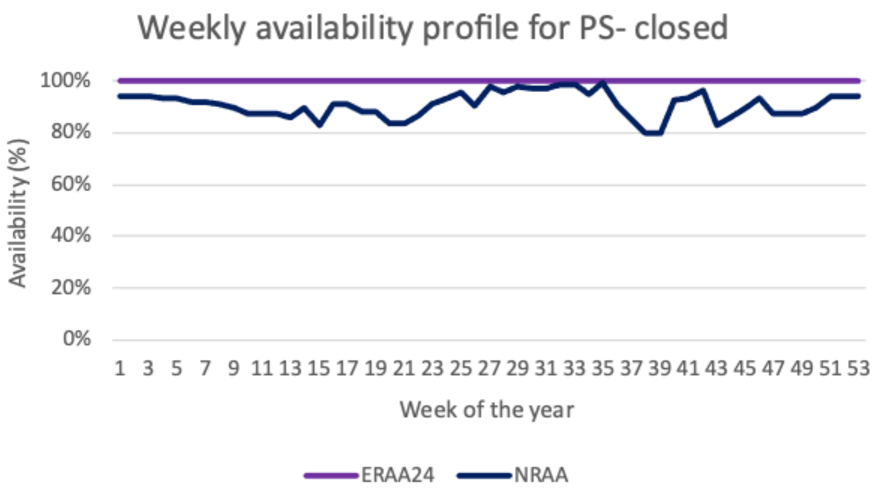


Figure 34. Differences between the ERAA and the NRAA (hypotheses). Closed pumped storage weekly availability.

5.2.1.3 Impact of the difference

Hydro pumped storage plays an important role in system adequacy as it normally has the capacity to deliver previously stored energy for a number of hours higher than the expected consecutive hours with adequacy risks (normally 5-6 consecutive evening peak load hours). The national study "Cost of New Entry for the establishment of the Reliability Standard published by the CNMC in October 2024" estimates the availability factor of hydro storage in a 73-82% range.

The differences between the ERAA and the NRAA would increase the adequacy risks.

5.2.2 Differences in batteries

The following differences in batteries assumptions are applicable both to the EVA and to the ADQ models.

5.2.2.1 Explanation of the difference

The NECP scenario, on which the ERAA is based, considers an expansion of storage in the form of batteries. Similar to the differences with pumped storage, this expected expansion of storage is subject to the implementation of a capacity market, but in order to implement such regulatory mechanism, first an adequacy concern has to be identified. Therefore, the scenario in this NRAA only considers the capacity that has been already granted some kind of public support.

5.2.2.2 Description of the difference

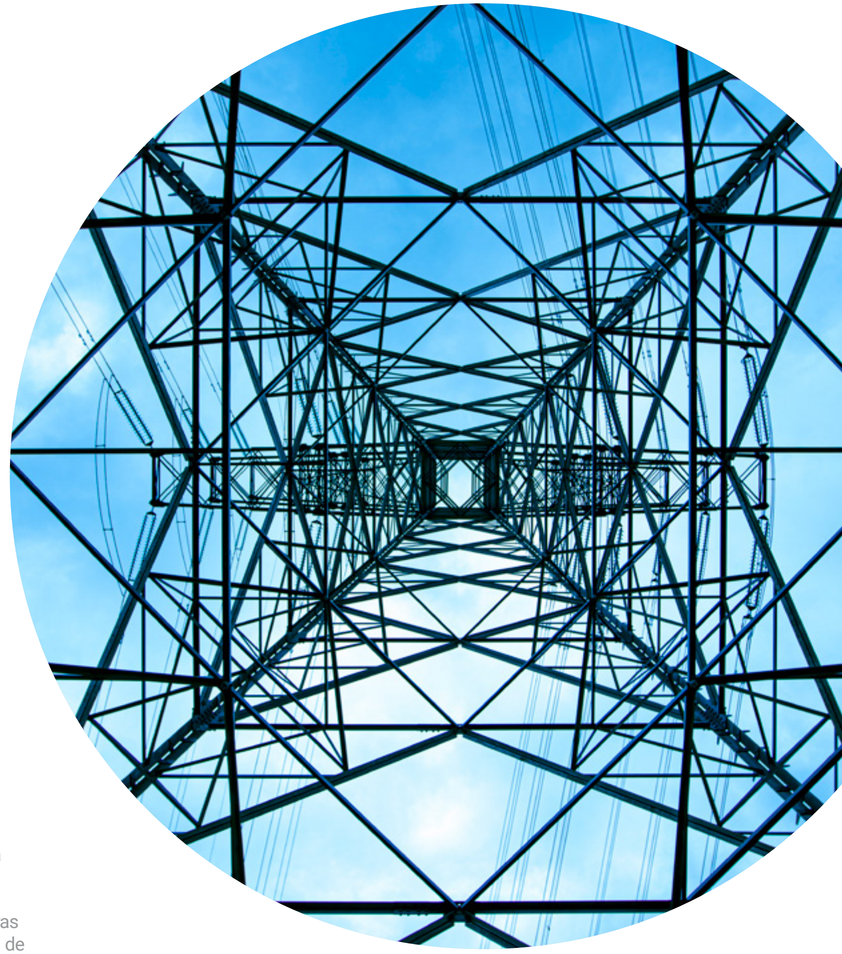
The ERAA scenario assumes the achievement of the NECP targets, which set a total storage capacity of 22500 MW. ERAA assumptions considered that 6675 MW of them would be in the form of market wide battery capacity. This means an increase of approximately 6650 MW to the current capacity.

However, at the moment only two public fundings have awarded new battery capacity. The projects awarded in the peninsula have the following characteristics:

Table 23. New battery projects considered in the NRAA.

Public fund	N projects	Capacity (MW)	Avg Capacity (h)	Avg Efficiency (%)	Deadline
Hybrid [22]	35	900	2	84	30/06/2026
Stand alone [23]	29	635	4	85	30/06/2026

This makes the NRAA consider only 1535 MW of additional capacity, and only available after the deadline.



22. Resolución de la Secretaria de Estado de Energía y Presidenta de E.P.E Instituto para la Diversificación y Ahorro de la Energía (IDAE), M.P., por la que se aprueba la concesión de ayudas correspondientes a la primera convocatoria de ayudas para proyectos innovadores de almacenamiento energético hibridado con instalaciones de generación de energía eléctrica a partir de fuentes de energía renovables en el marco del Plan de Recuperación, Transformación y Resiliencia – Financiado por la Unión Europea – Next GenerationEU, publicada mediante la Resolución de 21 de diciembre de 2022 del Consejo de Administración del IDAE y cuyas bases reguladoras fueron establecidas mediante la Orden TED/1177/2022, de 29 de noviembre, del Ministerio para la Transición Ecológica y el Reto Demográfico (B.O.E. núm. 288, de 1 de diciembre de 2022): HIALMAC_Resolucion_Definitiva.pdf
23. Resolución del Director General de Política Energética y Minas y Vicepresidente del Consejo de Administración de E.P.E Instituto para la Diversificación y Ahorro de la Energía (IDAE), M.P., por la que se aprueba la concesión de ayudas correspondientes a la primera convocatoria de ayudas para proyectos innovadores de almacenamiento eléctrico independiente y almacenamiento térmico en el marco del Plan de Recuperación, Transformación y Resiliencia – Financiado por la Unión Europea – Next GenerationEU, publicada mediante la Resolución de 20 de julio de 2023 del Consejo de Administración del E.P.E Instituto para la Diversificación y Ahorro de la Energía (IDAE), M.P. y cuyas bases reguladoras fueron establecidas mediante la Orden TED/807/2023, de 17 de julio, del Ministerio para la Transición Ecológica y el Reto Demográfico (B.O.E. núm. 171, de 19 de julio de 2023): 388_resolucion_definitiva.pdf

The following table highlights the differences between the ERAA and the NRAA:

Table 24. Differences between the ERAA and the NRAA (hypotheses). Battery capacity.

Tech.	Prop.	Name	2026 (to 30/06)	2026 (from 01/07)	2028	2030	2035
Market wide battery	Installed capacity (MW)	ERAA24	915	915	1915	7000	13690
		NRAA	**0**	**1535**	**1535**	**1535**	**1535**
		Difference	**915**	**620**	**380**	**5465**	**12155**

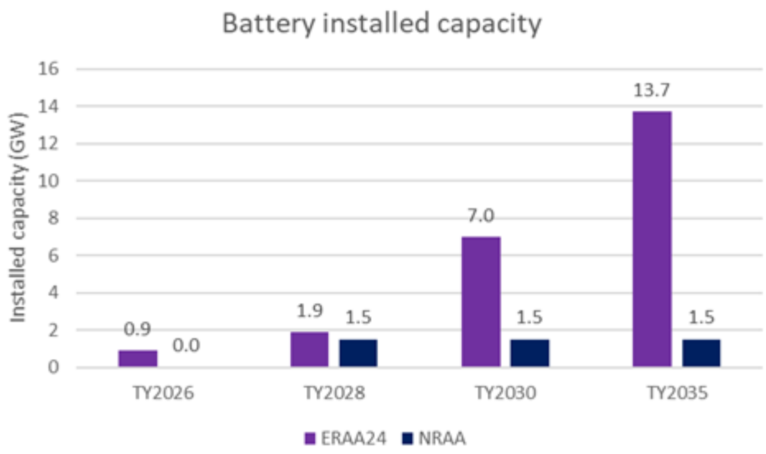


Figure 35. Differences between the ERAA and the NRAA (hypotheses). Battery capacity.

In addition, the ERAA models all the market-wide batteries in an aggregated unit. However, the NRAA distinguishes between 2h batteries and 4h batteries. This adaptation is important for representativity of results in terms of adequacy and also in case a calculation of the average capacity during scarcity events is performed for this technology.

5.2.2.3 Impact of the difference

Batteries are expected to play an important role in system adequacy, especially those that can deliver previously stored energy for a higher number of hours. However, none of the assumed technologies in this NRAA has a number of hours higher than the expected consecutive hours with adequacy risks (normally 5-6 consecutive evening peak load hours). The national study "Cost of New Entry for the establishment of the Reliability Standard published by the CNMC in October 2024" estimates the availability factor of batteries in a 27-70% range.

The reduction of the installed capacity would stress the system, although the separation of two types of batteries can slightly compensate this effect.

The differences between the ERAA and the NRAA would increase the adequacy risks.

5.2.3 Differences in combined cycles

The following differences in combined cycles assumptions are applicable both to the EVA and to the ADQ models.

5.2.3.1 Explanation of the difference

The existing combined cycle fleet was mainly built during the 2000-2010 period and is experiencing an ageing process, which is being already observed through a reduction of the availability of the units. In a scenario without capacity mechanisms, as the one being assessed in this NRAA, the investments needed to revert this process will not materialize.

In addition, the optimization of their maintenance period (not to schedule them during periods where adequacy risks are more probable) is not an option currently reflected in the national regulation, and can be conditioned by technical constraints such as number of running hours or startups, or by existing contracts with the maintenance provider. This means that the system operator does not have the capacity to approve or not the maintenance of generation units, although traditionally the generators are open (when possible) to adapt their schedules if it is beneficial for the system.

Therefore, the scenario in this NRAA will update the planned and unplanned availability of combined cycles to consider unexpected outages and maintenance profiles based on recent historical ones.

5.2.3.2 Description of the difference

It has been observed recently that the combined cycle fleet is experiencing a higher rate of unplanned outages. This NRAA will update the forced outage rate parameter from the default 5% used in the ERAA to 9%, and the mean time to repair from the default 24 h used in the ERAA to 72 h. The following figure shows the evolution of the observed unplanned outage rate of the Spanish CCGT fleet, which is clearly growing in the last years. The 72 h duration of the unavailability period is also based on the data from recent years, with an average of 3.56 h in 2024 and 2.49 h in 2023.

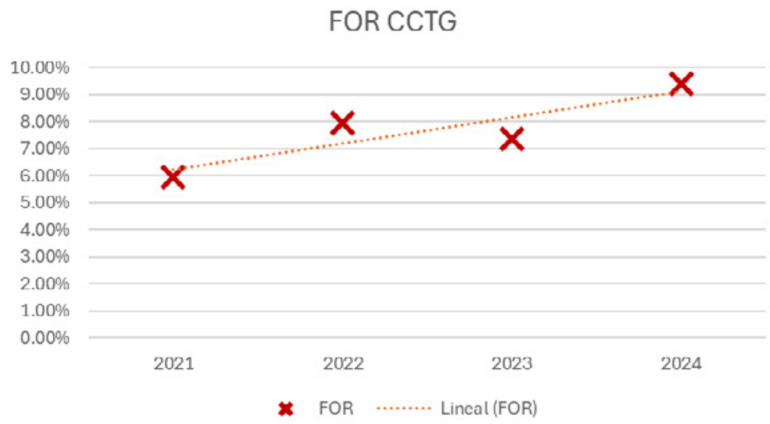


Figure 36. Recent evolution of the observed unplanned outage rate of the Spanish CCGT fleet.

The following table highlights the differences between the ERAA and the NRAA:

Table 25. Differences between the ERAA and the NRAA (hypotheses). CCGT unplanned availability parameters.

Tech.	Prop.	Name	2026	2028	2030	2035
Combined cycles	Forced outage rate (%)	ERAA24	5	5	5	5
		NRAA	**9**	**9**	**9**	**9**
		Difference	**4**	**4**	**4**	**4**
	Mean time to repair (h)	ERAA24	24	24	24	24
		NRAA	**72**	**72**	**72**	**72**
		Difference	**48**	**48**	**48**	**48**

Also, the ERAA assumes that the maintenance of the combined cycles will be optimized to avoid scheduling maintenance when adequacy risks are likely to occur. However, this assumption deviates from the tendencies observed in the last years where it has been observed that there are periods where a high number of units are undergoing maintenance and this creates stress situations. Therefore, in this NRAA the maintenance profiles of target year 2026 (where the profile is not optimized in the ERAA) will be applied to the rest of the target years (where the profile is optimized in the ERAA). The differences can be observed clearly in the following figure.

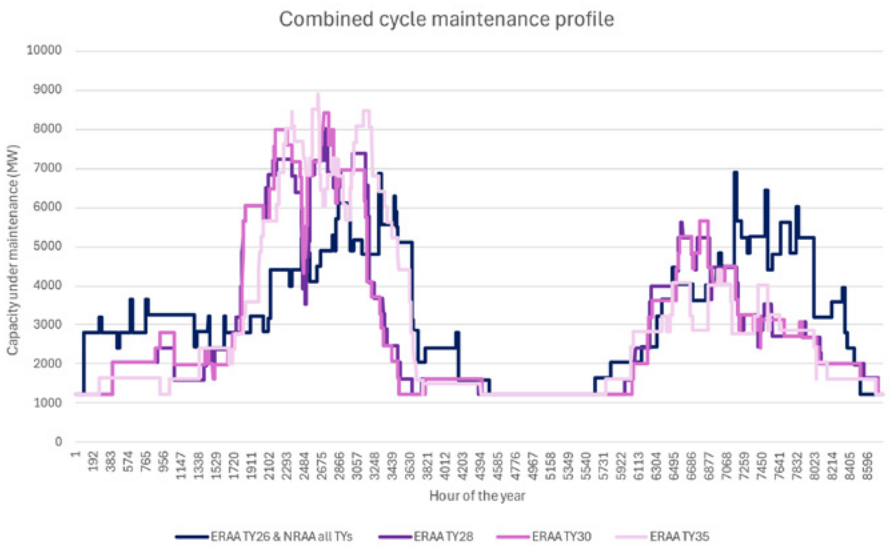


Figure 37. Differences between the ERAA and the NRAA (hypotheses). CCGT planned availability profile.

The next figure shows the maintenance periods of the Spanish CCGT fleet in the last years and the expected schedule for 2025. The average based on these recent years is very similar to the profile that will be used in the NRAA for all the target years, which is shown also in the figure to facilitate the comparison (equal to the one shown in the previous figure, only that shown at day scale instead of hour scale).

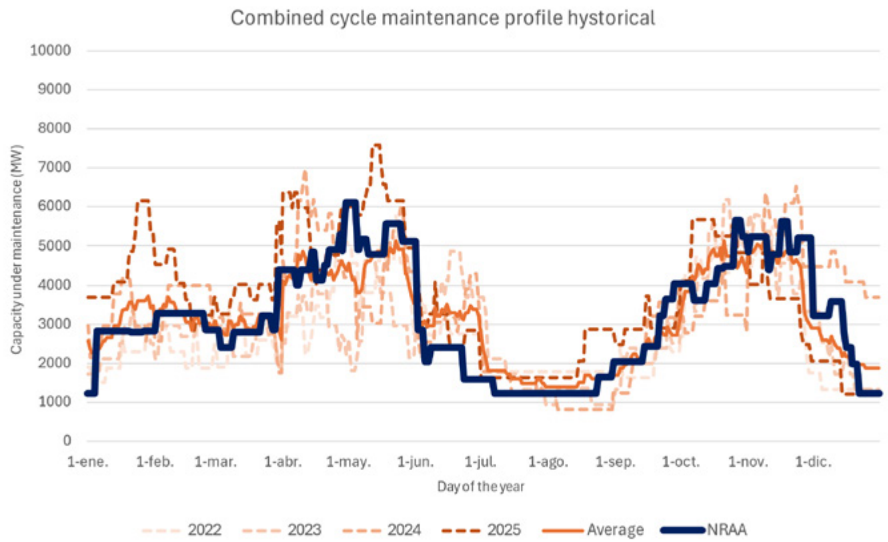


Figure 38. Maintenance schedule of the Spanish CCGT fleet in the last years.

5.2.3.3 Impact of the difference

Combined cycles play an important role in system adequacy as they have the capacity to deliver energy whenever required, provided the units and fuel are available. The national study "Cost of New Entry for the establishment of the Reliability Standard published by the CNMC in October 2024" estimates the availability factor of combined cycles in a 82-93% range.

The differences between the ERAA and the NRAA would increase the adequacy risks.

5.2.4 Differences in demand profiles

The following differences in demand profile assumptions are applicable both to the EVA and to the ADQ models.

5.2.4.1 Explanation of the difference

The demand profiles produced for the Spanish system in ERAA 2025 are considered more updated and reliable than the ones produced for ERAA 2024. Spanish demand timeseries for ERAA 2024 were generated with the Demand Forecasting Tool, being the first edition for which this tool was used for the Spanish peninsular system as a replacement of the previous one, Trapunta. This evolution was necessary as ERAA 2024 also transitioned to a new pan-European climate database that considers future weather scenarios (WS) instead of historical climate years (CY). ERAA 2025 is the second time this tool has been used, meaning that there has been room for learning from the experience and introducing some improvements in the tool.

Therefore, the scenario in this NRAA will update the demand profiles for the Spanish peninsular system considering the ERAA 2025 ones, while keeping the average yearly consumptions as they were in ERAA 2024.

5.2.4.2 Description of the difference

As ERAA 2025 demand timeseries are already available since quite recently, a comparison of the average profile shows that ERAA 2025 timeseries are more representative as the peak is observed mostly in winter, in contrast with the ERAA 2024 series that show the average peak in summer. In Spain the peak loads have always occurred in winter during the evening, and this characteristic is expected to be maintained in the medium term. In ERAA 2024 half of the weather scenarios presented peaks during summer period, while this proportion in ERAA 2025 is lower with around 40% of the weather scenarios with peaks in summer.

The following figure shows the original ERAA24 TY2030 average profile (hourly average of the 36 weather scenario hourly demands for that target year) in comparison with the NRAA TY2030 average profile. Both series consider the same yearly demand, but the hourly distribution differs.

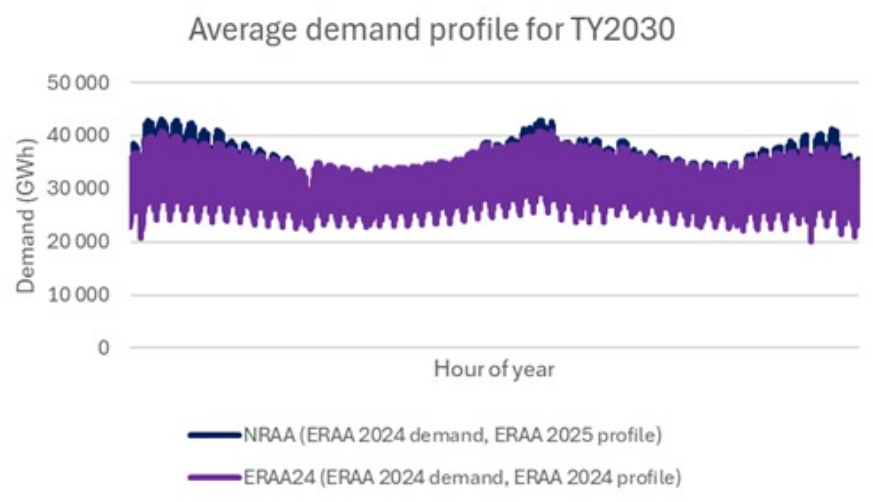


Figure 39. Differences between the ERAA and the NRAA (hypotheses). Average demand profile for TY2030.

While keeping the yearly average demand (and the yearly demand for each weather scenario), the ERAA 2025 unitary profiles have been extracted and applied to the ERAA 2024 demands. In order to respect the yearly demands of ERAA 2024 but replicate the ERAA 2025 average profiles, the unitary profile of each of the weather scenarios for each target year of the ERAA 2025 has been applied to the ERAA 2024 yearly demand of that particular weather scenario for the different target years. As ERAA 2025 does not consider TY2026, the TY2028 profile has been used instead.

The following table highlights the differences between the ERAA and the NRAA:

5.2.4.3 Impact of the difference

Although the peak loads appear to be lower, it is expected that a higher number of weather scenarios presenting the peak load in winter would increase the adequacy risks.

The differences between the ERAA and the NRAA would increase the adequacy risks.

Table 26. Differences between the ERAA and the NRAA (hypotheses). Demand main characteristics.

Demand	Char.	Name	2026			2028			2030			2035		
			Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Average profile	Annual (TWh)	ERAA24		249			259			270			285	
		NRAA		249			259			270			285	
		Difference		0			0			0			0	
	Peak (GW)	ERAA24		38.1			39.5			40.9			43	
		NRAA		**38.7**			**40.4**			**43.2**			**43.1**	
		Difference		**0.6**			**0.9**			**2.3**			**0.1**	
Weather Scenario profiles	Annual (TWh)	ERAA24	255	249	245	266	259	256	277	270	267	291	285	282
		NRAA	255	249	245	266	259	256	277	270	267	291	285	282
		Difference	0	0	0	0	0	0	0	0	0	0	0	0
	Peak (GW)	ERAA24	47.1	44.5	42.3	48.9	46.5	44.3	51.4	49	46.6	54.8	52.4	50
		NRAA	**44.1**	**41.7**	**39.6**	**46**	**43.5**	**40.4**	**49.3**	**46.8**	**44.5**	**48.7**	**46.3**	**44.1**
		Difference	**3**	**2.8**	**2.7**	**2.9**	**3**	**3.9**	**2.1**	**2.2**	**2.1**	**6.1**	**6.1**	**5.9**

6 Results

6.1 Summary of results

6.2 Analysis of ERAA 2024 benchmark

6.3 Analysis of the NRAA central reference scenario

6.4 CCGT LOLE threshold as reliability standard

This chapter first includes a summary of the results obtained across all the different scenarios available both in European Resource Adequacy Assessment (ERAA) 2024 and in this National Resource Adequacy Assessment (NRAA), and then offers a detailed analysis of the results produced under this assessment.

6.1 Summary of results

As a complement to the ERAA, this NRAA has been performed in two steps:

- Firstly, ERAA 2024 EVA and ADQ benchmark runs are included. They show that the differences in geographical scope (see chapter 4.2.2) and differences in random outage samples (see chapter 4.2.3), needed to allow computational feasibility and reduce simulation time, do not affect the ERAA results and are valid for the Spanish system, when compared to the ERAA previous to the application of the curtailment sharing (see chapter 4.2.1). This confirms the validity of using the benchmark models as a starting point for the specific simulations of the NRAA.

  The ERAA 2024 shows the same tendency for the Spanish peninsular power system as the two previous editions: under the given scenarios and methodological framework following the considerations set out by the Regulation EU 2024/1747, the economic viability of a part of the generation mix is not guaranteed in the short, mid and long-term. The assessment of the scenarios which would result after the decommissioning of the economically unviable units shows a risk of adequacy issues above the reliability standard in the short (2026) to mid-term (2028). The risks tend to be reduced to values below the reliability standard in the long-term (2030, 2035) although nonzero, despite the expected demand increase, due to the targeted investments both in new generation and international interconnection capacities according to the NECP.

- As a second step, the NRAA central reference scenario simulations are included, where all the differences with the ERAA in terms of methodology (curtailment sharing, geographical scope, random outage samples, Spanish non-peninsular connected systems. For more info see chapter 4.2) and hypotheses (pumped storage, batteries, combined cycles, demand profiles. For more info see chapter 5.2) are considered.

  The NRAA central reference scenario shows that if the deployment of some capacities is delayed, the economic viability of a part of the generation mix is not guaranteed in the short, mid and long-term. The assessment of the scenarios considering a delay in the achievement of some of the NECP targets and after the decommissioning of the economically unviable units shows a risk of adequacy issues above the reliability standard also in 2030.

As a result of the ERAA and also this NRAA, the assessment of the scenarios which would result from the decommissioning of the economically unviable units shows a significant risk of adequacy issues in the following years in the Spanish peninsular system if additional incentives are not put in place.

Table 27. Summary of target years, scenarios and adequacy indicators.

TY	Scenario	LOLE (h/y)*	EENS (GWh/y)
2026	ERAA 2024 (central reference scenario)	**4.03**	5.16
2028	ERAA 2024 (central reference scenario)	**4.83**	6.46
	NRAA (central reference scenario)	**4.08**	6.04
2030	ERAA 2024 (central reference scenario)	**0.28**	0.16
	NRAA (central reference scenario)	**2.41**	5.22
2035	ERAA 2024 (central reference scenario)	**0.54**	0.57

*LOLE values are colored as follows: red when equal or above the reliability standard, orange when nonzero values but below the reliability standard, green when zero.

Please note the large amount of information produced under this assessment, due to the number of probabilistic simulations (both on weather scenarios and forced outage patterns), with hourly detail for the European system on a multitude of variables. The values presented in this report are all mean values resulting from the Monte Carlo simulations and should be understood as such. Results with more detail are included in 6.3.2.

Figure 40. Summary of target years, scenarios and adequacy indicators: LOLE.

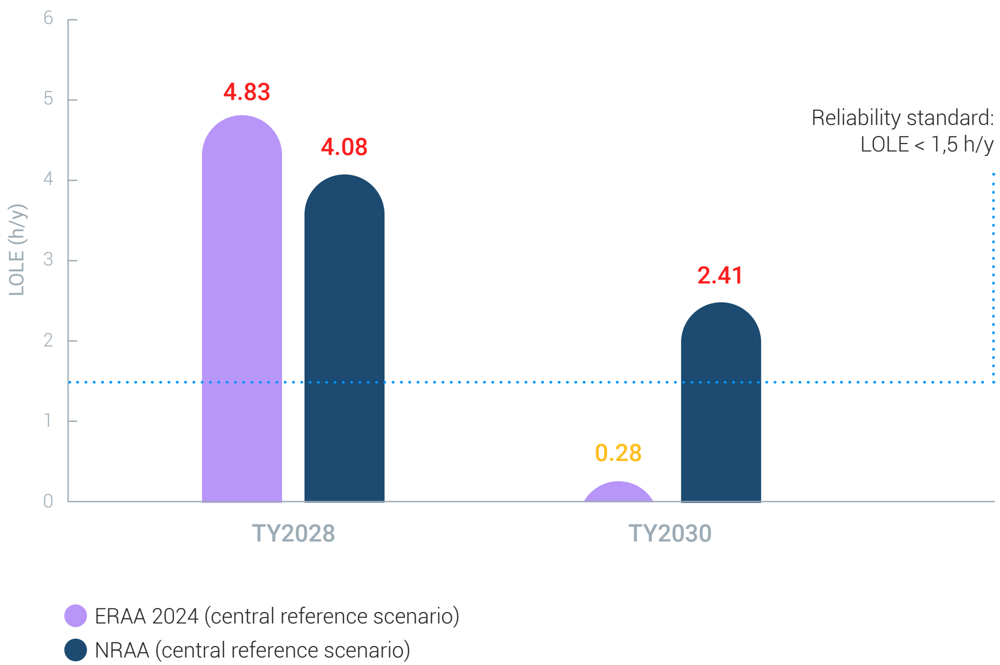
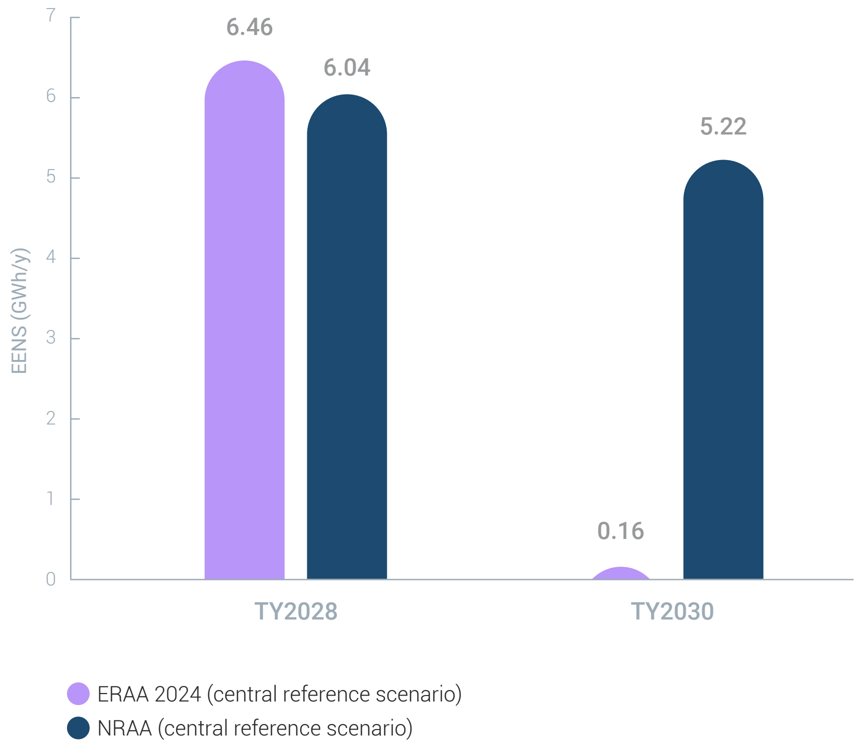


Figure 41. Summary of target years, scenarios and adequacy indicators: EENS.



6.2 Analysis of ERAA 2024 benchmark

As a starting point of the NRAA, the latest ERAA EVA and ADQ models were run in order to properly benchmark the rest of the results produced under the NRAA. These runs show that the differences in geographical scope (see chapter 4.2.2) and differences in random outage samples (see chapter 4.2.3), needed to allow computational feasibility and reduce simulation time, do not affect the ERAA results and are valid, when compared to the ERAA previous to the application of the curtailment sharing (see chapter 4.2.1), as a starting point for the specific simulations of the NRAA.

6.2.1 Economic viability assessment

The EVA model benchmark is only affected by the differences in geographical scope. The explanation, description and impact assessment of this difference between the ERAA and the NRAA are already reflected in chapter 4.2.2, so only the Spanish results and conclusion shown in chapter 4.2.2 is repeated here.

The following figure shows a comparison of the EVA results from the ERAA 2024 and the benchmark models for the Spanish system. The results show that the differences in the geographical scope have limited impact in the economic decisions, with a good level of alignment for the Spanish system throughout the horizon.

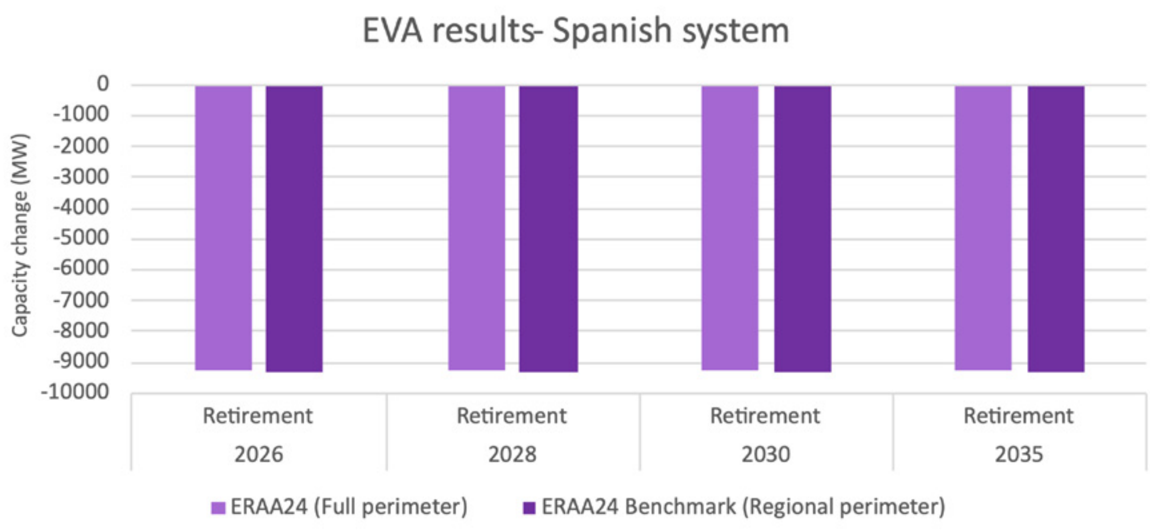


Figure 42. Differences between the ERAA and the NRAA (methodology). Geographical scope. Impact of the difference comparing ERAA 2024 EVA results (for Spain) and the ones resulting from the benchmark simulations performed under this NRAA.

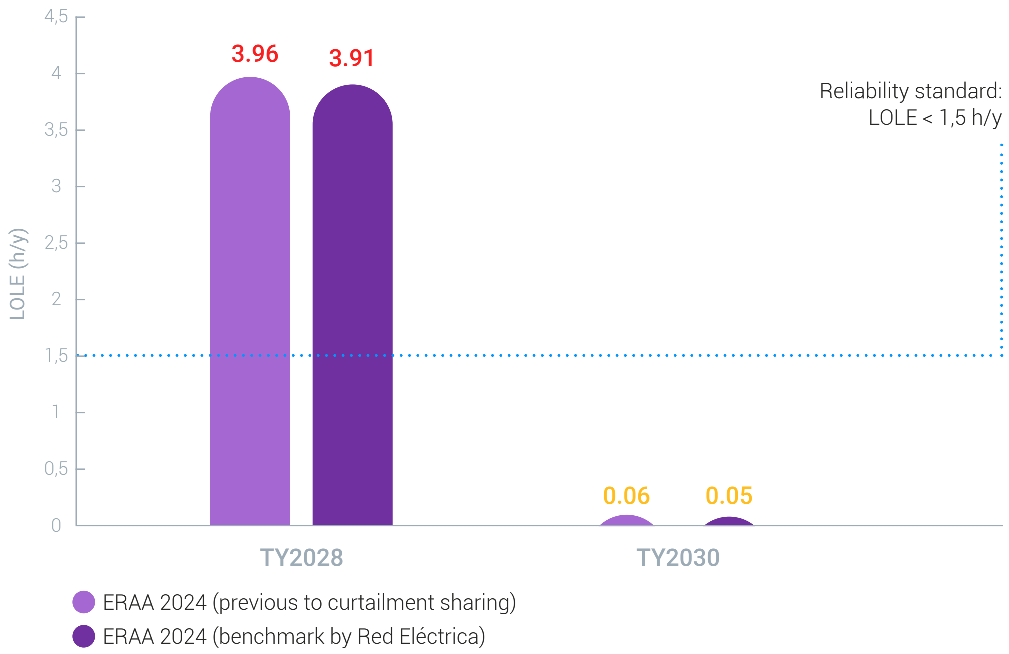
6.2.2 Adequacy assessment

The ADQ model is affected by the differences in curtailment sharing, geographical scope and random outage samples. The explanation, description and impact assessment of these differences between the ERAA and the NRAA are already reflected in chapters 4.2.1, 4.2.2 and 4.2.3, but for convenience the results and conclusion are merged here.

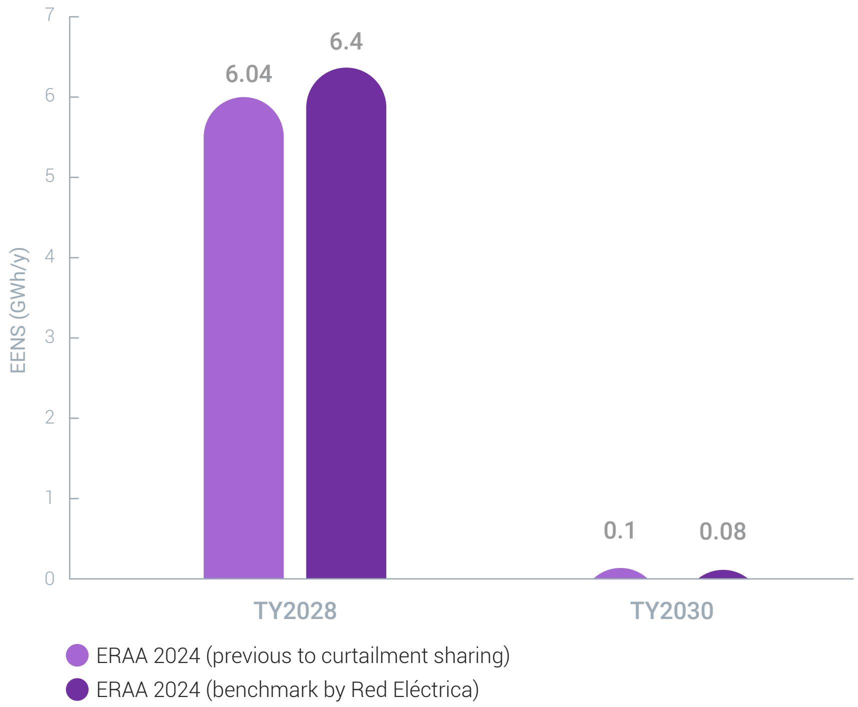
The following figures show a comparison of the ADQ results from the ERAA 2024 and the benchmark models for the Spanish system for the two target years that will be assessed under the NRAA central reference scenario. The results show that the differences in the geographical scope and random outage samples have limited impact in the adequacy indicators, with a good level of alignment for the Spanish system throughout the horizon.

Figure 43. Differences between the ERAA and the NRAA (methodology). Geographical scope, random outage samples. Impact of the difference comparing ERAA 2024 LOLE and EENS results (for Spain) previous to curtailment sharing and the ones resulting from the benchmark simulations performed.

ERAA 2024 (previous to curtailment) benchmark: LOLE.



ERAA 2024 (previous to curtailment sharing) benchmark: EENS.



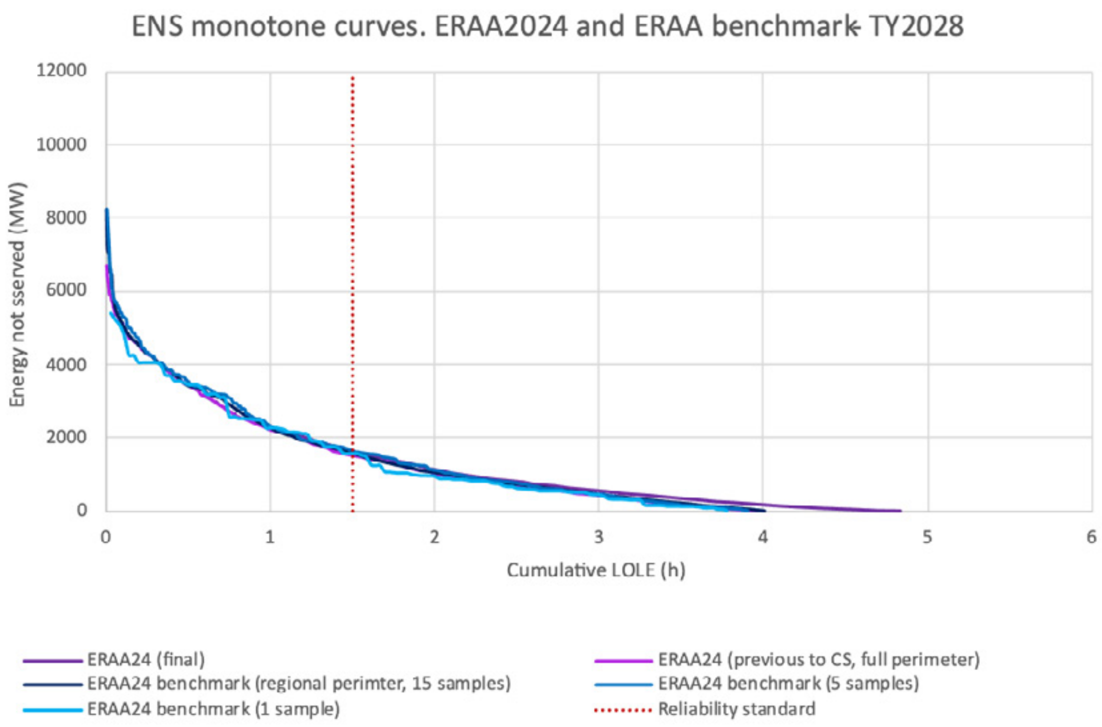


Figure 44. Differences between the ERAA and the NRAA (methodology). Curtailment sharing, geographical scope, random outage samples. Impact of the difference comparing ERAA 2024 ENS monotone curves and the ones resulting from the benchmark simulations performed.

6.3 Analysis of the NRAA central reference scenario

The NRAA simulations are divided, as the ERAA, into two sequential steps: the EVA first, and then the ADQ.

6.3.1 Economic viability assessment

Once all the differences in assumptions are applied to the EVA benchmark model, the new EVA results show the following:

- The changes in the Spanish perimeter have a minimal effect on the EVA results for the non-Spanish perimeter when compared to the benchmark simulation. This is clearly observed in Figure 45.
- In Spain, the retirement of CCGT would be 3524 MW throughout the horizon.

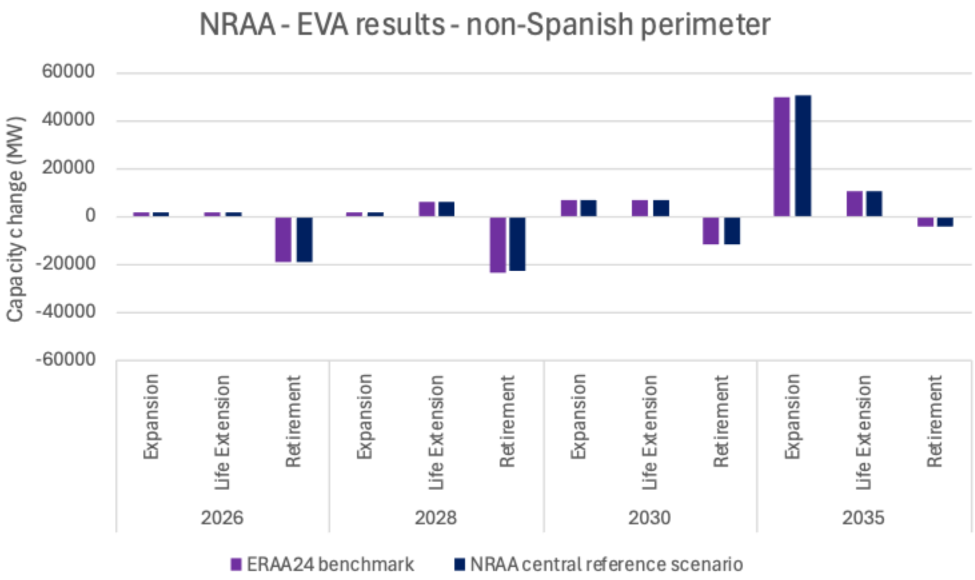


Figure 45. NRAA results. EVA results for the non-Spanish perimeter.

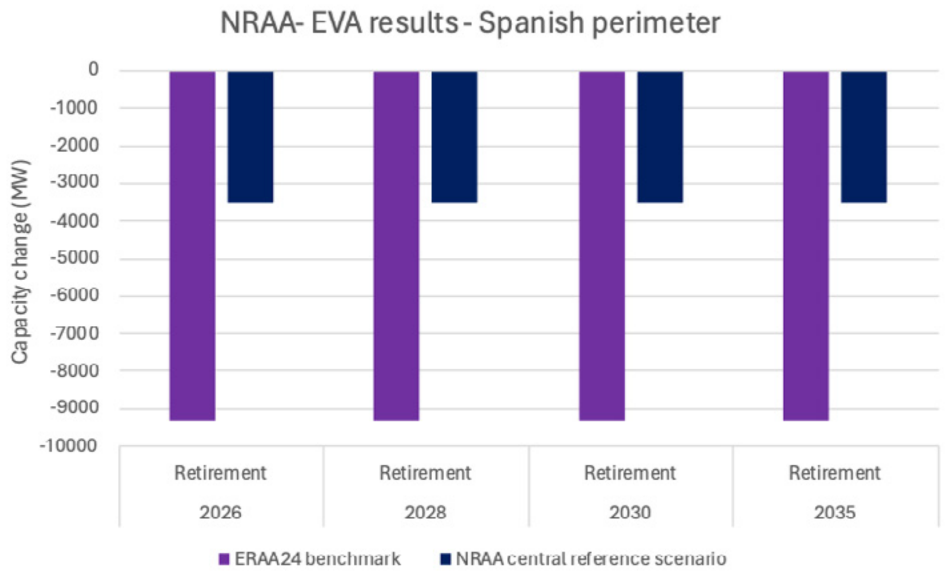


Figure 46. NRAA results. EVA results for the Spanish perimeter.

Following the ACER opinion "Best practices for providing the reasons for the divergence between the national and European resource adequacy assessments" individual simulations have been performed for each of the differences in assumptions to understand the impact:

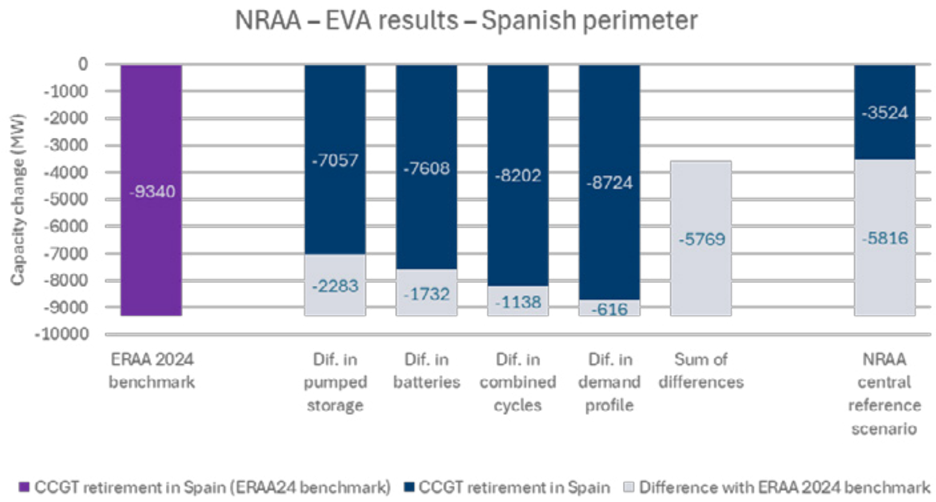


Figure 47. NRAA results. EVA results for the Spanish perimeter.

It is observed as a positive sign that the sum of the differences of the individual simulations (5769 MW) with regards to the ERAA 2024 benchmark is very similar to the difference of the final simulation that includes all the differences (5816 MW).

Please note that the EVA results of the NRAA central reference scenario only reflect possible market decisions but real-life decisions could be different, especially depending on the validity of the assumptions and modelling regarding investor behavior.

6.3.2 Adequacy assessment

After the EVA step, the ADQ benchmark model is updated in order to include the different assumptions of the NRAA and also to accommodate the new EVA results for the Spanish perimeter. For convenience, Table 29 shows the capacities considered in the NRAA central reference scenario, highlighting the values that are different than the ERAA central reference scenario. The new adequacy simulations are performed for the 36 weather scenarios of the target years that are assessed, obtaining the following key adequacy indicators:

Table 28. NRAA results. ADQ results for the Spanish perimeter.

TY	Scenario	LOLE (h/y)*	EENS (GWh/y)
2028	NRAA (central reference scenario)	**4.08**	6.04
2030	NRAA (central reference scenario)	**2.41**	5.22

*LOLE values are colored as follows: red when equal or above the reliability standard, orange when nonzero values but below the reliability standard, green when zero.

The loss of load expectation for the analyzed years 2028 and 2030 after taking out the generation not economically viable, is 4.08 and 2.41 hours per year, respectively, which is above the official reliability standard of 1.5 hours per year and indicates an adequacy concern according to the NRAA central reference scenario. This means that as a result of the probabilistic assessment the adequacy risks are higher than the security criterion and system development measures are needed in order to bring the risk below the threshold established by the reliability standard.

The analysis of the results allows to draw the following additional conclusions regarding the characterization of the unserved energy:

- The maximum observed values of the unserved energy are 8.7 GW and 9.7 GW for 2028 and 2030 respectively, for an individual hour of an individual sample and weather scenario. These values would imply very important disruptions for the Spanish peninsular power system and, as a consequence, for the national activity. The unserved energy when the cumulative LOLE reaches the reliability standard is 1.5 GW and 1.0 GW for 2028 and 2030 respectively. The non-linear behavior of the unserved energy is very well observed. All this information can be extracted from Figure 48.

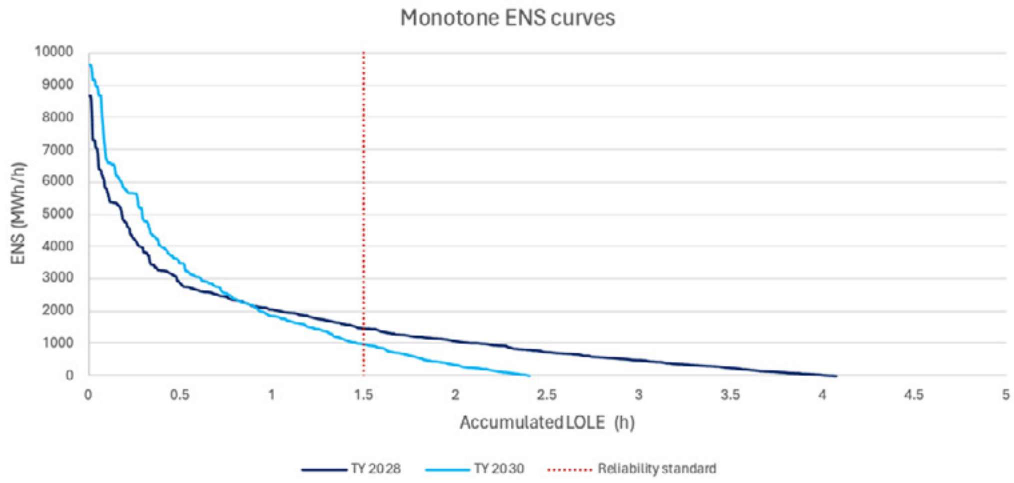


Figure 48. NRAA results. ADQ results for the Spanish perimeter. Detail of the hourly ENS monotone curve.

- The LOLE and EENS distribution per weather scenario shows a high variability, with several individual values well above the reliability standard. For example, weather scenario 26 presents a LOLE of 34.8 and 25.6 h/y for 2028 and 2030 respectively, which are 23 and 17 times the reliability standard. In addition, adequacy risks are identified in more than half of the weather scenarios (75% in 2028, 53% in 2030) possibly indicating structural risks, instead of a very adverse situation that concentrates all the risks. All this information can be extracted from Figure 49 and Figure 50.

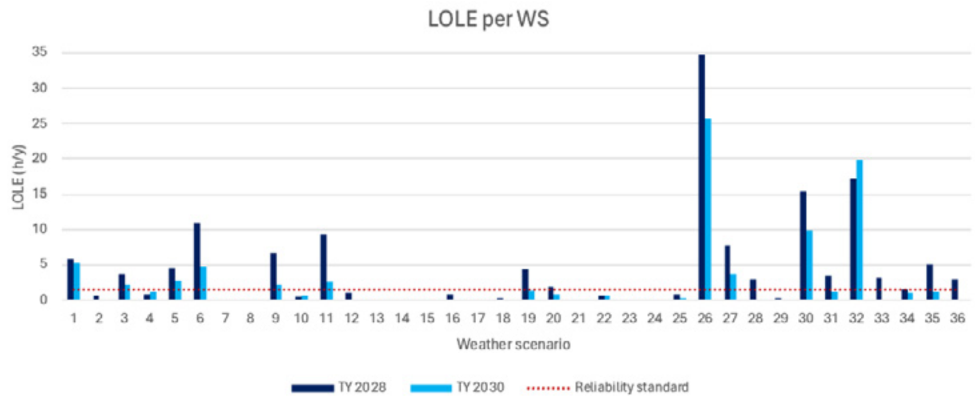


Figure 49. NRAA results. ADQ results for the Spanish perimeter. Detail of the LOLE distribution per weather scenario.

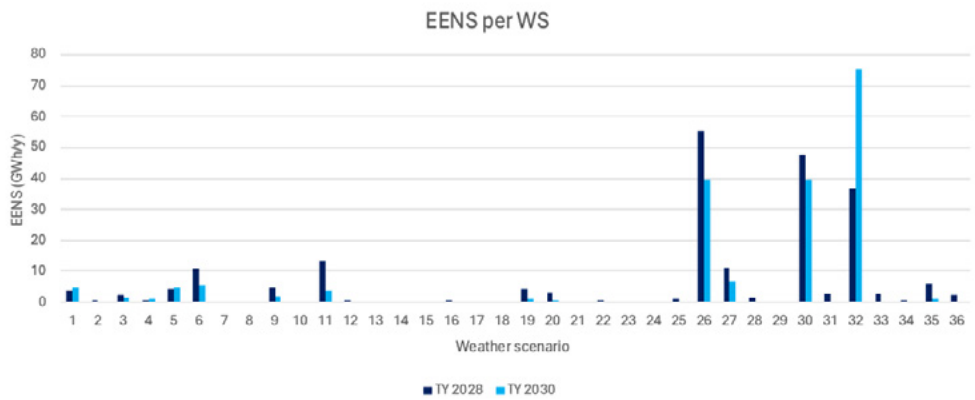


Figure 50. NRAA results. ADQ results for the Spanish perimeter. Detail of the EENS distribution per weather scenario.

- In terms of seasonal distribution, it is clear that the adequacy risks are more probable during winter. More specifically, the November-February period concentrates 89% or 96% of LOLE in 2028 and 2030 respectively, which is coherent with stress situations that the Spanish system has faced in the recent years. This information can be extracted from Figure 51.

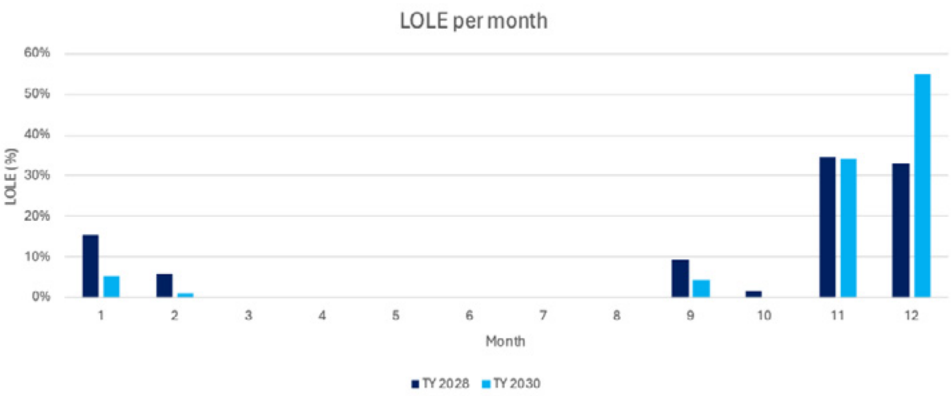


Figure 51. NRAA results. ADQ results for the Spanish perimeter. Detail of the LOLE distribution per month of the year.

- In terms of hourly distribution, it is clear that the adequacy risks are more probable during the evening peak. More specifically, the window between 16:00 h and 23:00 h concentrates 98% or 95% of LOLE in 2028 and 2030 respectively, which is coherent with stress situations that the Spanish system has faced in the recent years. See Figure 52.

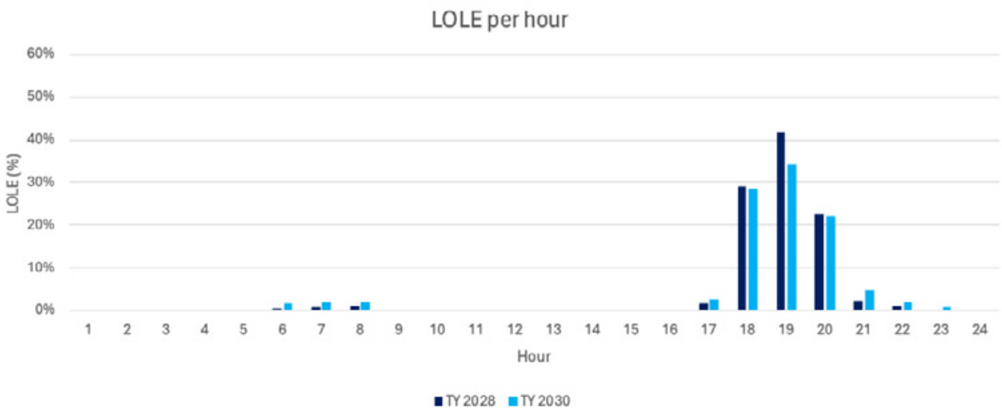
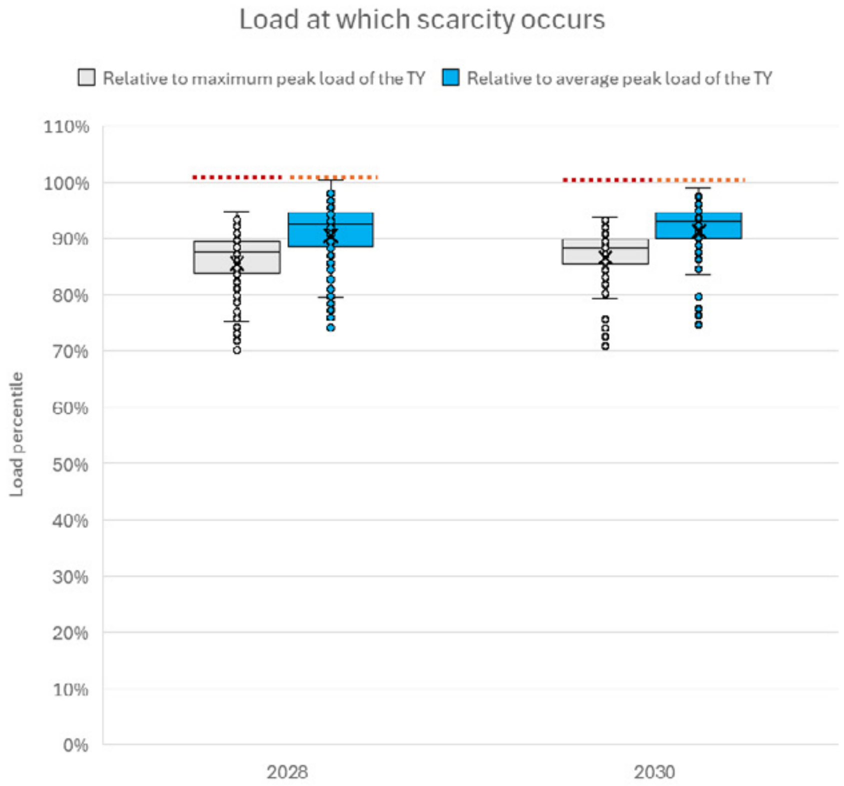


Figure 52. NRAA results. ADQ results for the Spanish perimeter. Detail of the LOLE distribution per hour of the day.

In addition, the following figures aim to explain what are the root causes of the unserved energy. Please consider that the points shown in the next figures represent the average, for a given datapoint, of 5 forced outage samples.

- An important information can be extracted from the distribution of the ENS with regard to the demand. The box plot shows, for each target year, the distribution of the demand levels at which scarcity occurs comparing the demand with the average peak demand (average of the peaks of the 36 weather scenarios) and with the maximum peak demand (highest of the 36 peaks). It can be observed that the ENS normally occurs during high load events, around 85% of the maximum peak load of the target year, although some events can take place with loads below 75-80%. It is observed that the risks start to appear above certain demand levels, but the maximum peak load is not affected by unserved energy, possibly pointing to a lack of generation in some situations more than to a high demand as a cause of scarcity. Also in the lower part of the figure it can be observed that normally the higher the demand level, the higher the ENS value. The average peak is represented in orange dotted line, while maximum peak is represented in red dotted line. This is coherent with the distribution of ENS per month and hour, where it was observed that adequacy risks would be more probably in winter during the evening peak, which is normally where the highest demands occur.



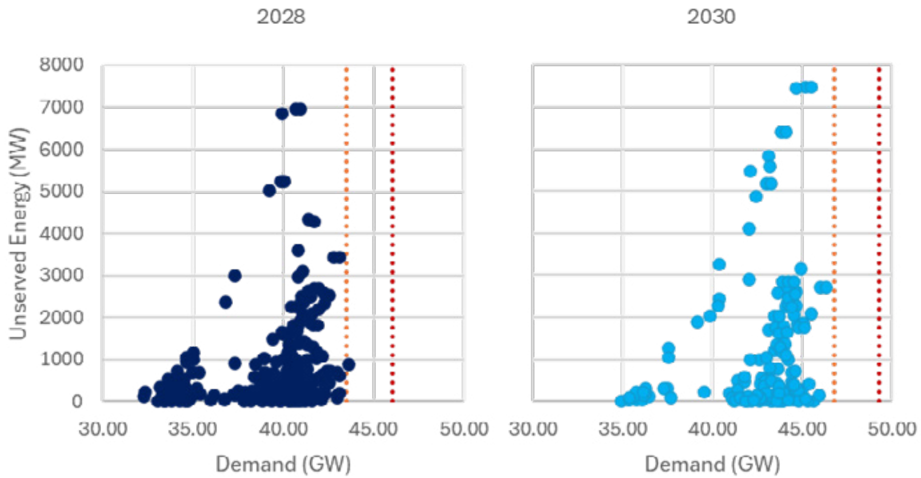


Figure 53. NRAA results. ADQ results for the Spanish perimeter. ENS distribution depending on demand levels.

- Regarding the generation resources to attend the demand, the following figure shows the contribution of dispatchable (hydro storage and pumped storage, combined cycle, nuclear, solar thermal with storage, batteries, DSR) and non-dispatchable (hydro run of river, wind onshore and offshore, solar photovoltaic and thermal without storage, other renewables, other non-renewables) generators during scarcity events. It is observed that dispatchable generators have a high contribution, but it is not up to the installed capacity (represented in grey dotted lines in the right-hand side of the figure) due to unplanned and planned unavailability. Non-dispatchable generators present a very low contribution during scarcity events due to lack of primary resources, especially considering their high installed capacity (represented in blue dotted lines in the right-hand side of the figure). This is also coherent with the distribution of ENS per hour of the day, where it was observed that adequacy risks were more probable during the evening (non-solar) hours.

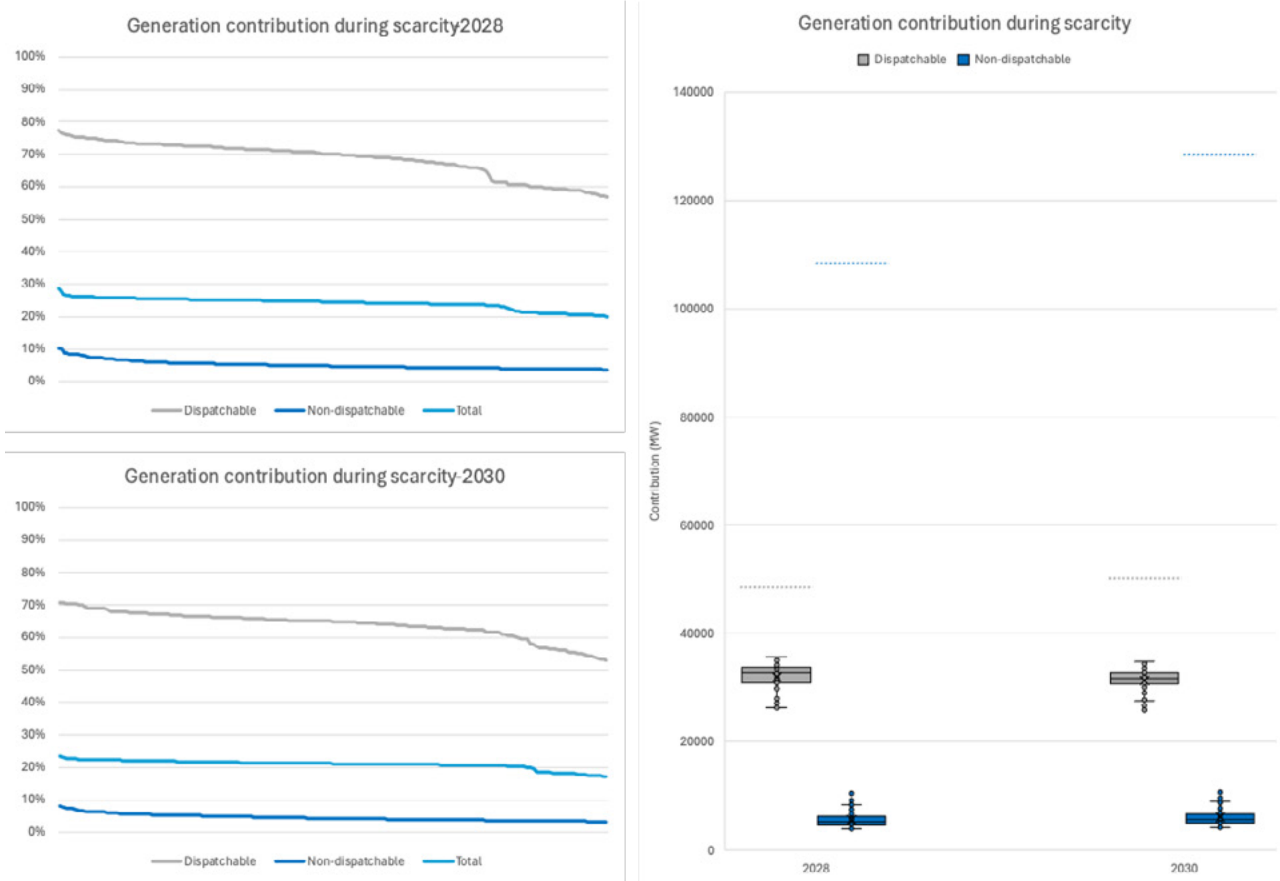


Figure 54. NRAA results. ADQ results for the Spanish perimeter. Generation contribution during scarcity.

- Finally, regarding the contribution of the interconnections it is observed that imports are quite relevant, especially in target year 2030 when the Gulf of Biscay project is available in the scenario. However, the total capacity (represented in dotted lines in the figure) is not always fully used, which is a signal that at some moments the scarcity events occur simultaneously at the two sides of the interconnector. Also there is a very steep decrease of the imports for an important part of the events.

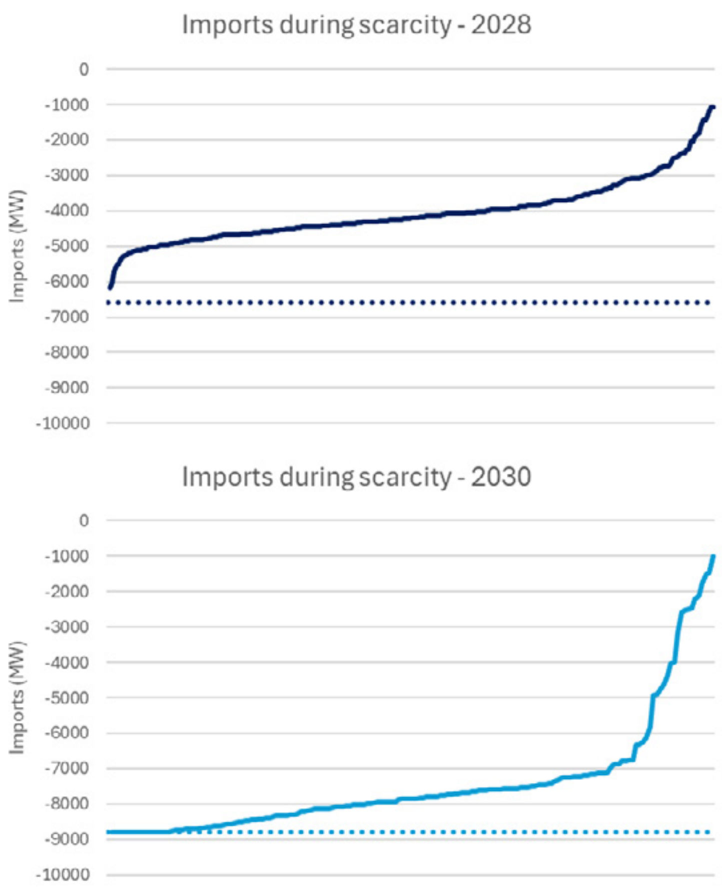


Figure 55. NRAA results. ADQ results for the Spanish perimeter. Total imports during scarcity.

Table 29. Spanish resource capacities under the NRAA central reference scenario.

Installed capacity (MW)	TY2028	TY2030
Hydro	**20603**	**21967**
Run of river	3412	3667
Reservoir	11177	11177
Pumped storage - Open PSO	2683	3123
Pumped storage - Closed	3331	4000
Renewables	**101058**	**123841**
Wind - Onshore	42038	50222
Wind - Offshore	100	2800
Solar thermal - Current	2304	2304
Solar thermal - Future	50	2500
Solar photovoltaic - Rooftop	13337	18405
Solar photovoltaic - Farm	41532	45646
Other renewables	1697	1964
Thermal	**30919**	**28648**
Coal	0	0
Combined cycle gas turbines	21537	21537
Nuclear Nuc	5110	3040
Other non-renewables	4273	4071
Batteries y DSR	**2398**	**3435**
Batteries (2h)	900	900
Batteries (4h)	635	635
Batteries (behind the meter)	254	700
DSR	609	1200
TOTAL CAPACITY	**154978**	**177890**

(PSO) Values shown at end of year, but modelled following deadline established in the support scheme resolution: 2.7 GW to 1/06/30, 3.1 GW after.
(Nuc) Values shown at end of year, but modelled following current nuclear phase-out calendar: 7.1GW to 1/11/27, 6.1GW to 01/10/28, 5.1GW to 1/10/30, 4.1GW to 1/11/30, 3GW to 1/9/32, 2GW to 1/2/35, 1GW to 1/5/35, 0 W after.

6.4 CCGT LOLE threshold as reliability standard

Finally, an additional simulation has been performed considering that all the currently existing CCGT fleet is available. All the other assumptions are kept as they are in the central reference scenario.

These results show that currently existing CCGT capacity (24500 MW) is sufficient to guarantee the LOLE threshold set for this reference technology (1.12-1.82 h/y) under the given VOLL and CONE values, confirming that this LOLE threshold is valid as the target reliability standard for the Spanish peninsular power system.

Table 30. Adequacy indicators when all the currently existing CCGT capacity (24500 MW) is considered to be available.

TY	Scenario	LOLE (h/y)*	EENS (GWh/y)
2028	NRAA (central reference scenario) with 24500 MW of CCGT	0.92	1.40
2030		0.88	1.85

*LOLE values are colored as follows: red when equal or above the reliability standard, orange when nonzero values but below the reliability standard, green when zero.

7. Conclusions of the National Resource Adequacy Assessment

This final chapter presents a summary of conclusions focused on the main outcomes of the National Resource Adequacy Assessment, but also includes some additional conclusions though comparisons with other recent adequacy assessments.

Focusing on this National Resource Adequacy Assessment (NRAA) the main conclusion is that under the given scenarios and methodology framework following the considerations set out by the Electricity Regulation, the economic viability of an important part of the Spanish peninsular system generation mix is not guaranteed in the short, mid and long term if additional incentives are not put in place.

The assessment of the scenarios which would result from the decommissioning of the economically unviable units, if allowed, would imply a situation with values above the official reliability standard, showing adequacy concerns for all the years up to 2030, that would require system development measures to be solved.

The key messages from the current assessment are:

- The benchmark models used in this NRAA for the economic viability assessment and the adequacy assessment produce results aligned with those produced by the ERAA 2024 models for the Spanish peninsular power system. This confirms their validity as the starting point for the rest of the simulations.

- The changes in the Spanish perimeter have a minimal effect on the economic viability assessment (EVA) results for the non-Spanish perimeter, but the impact in the Spanish perimeter is relevant. The volume of economically unviable combined cycles in Spain identified in the NRAA scenario is of 3.5 GW instead of the 9.2 GW identified in the ERAA scenario.

- The loss of load expectation for the analyzed years 2028 and 2030 after taking out the generation not economically viable, is 4.08 and 2.41 hours per year, respectively, which is above the official reliability standard of 1.5 hours per year and indicates an adequacy concern according to the NRAA central reference scenario. This means that as a result of the probabilistic assessment the adequacy risks are higher than the security criterion and system development measures are needed in order to bring the risk below the threshold established by the reliability standard.

- The variability of loss of load expectation for different weather scenarios is very high, with several individual values well above the reliability standard. Adequacy risks are identified in more than half of the weather scenarios. This is possibly indicating structural risks, instead of a very adverse situation that concentrates all the risks.

- Adequacy risks are more probable during winter (November-February period accounts 89% in 2028 and 96% in 2030) in the evening peak (16:00-23:00 accounts 98% in 2028 and 95% in 2030). This is coherent with stress situations that the Spanish system has faced in the recent years.

- It is observed that the risks start to appear above certain demand levels, but the maximum peak load is not affected by unserved energy, possibly pointing to a lack of generation in some situations more than to a high demand as a cause of scarcity.
- It is observed that dispatchable generators have a high contribution, but it is not up to the installed capacity due to unplanned and planned unavailability. Non-dispatchable generators present a very low contribution during scarcity events due to lack of primary resources, especially considering their high installed capacity.
- The Spanish peninsular power system remains close to an energy island in terms of adequacy due to limited capacity exchange with central Europe, meaning that mainly national resources would be needed to meet the reliability standard.

When compared to the latest edition of the European Resource Adequacy Assessment (ERAA) and also with previous editions of the ERAA and the NRAA:

- The conclusions derived from the NRAA are aligned with the ones obtained in the ERAA 2024, ERAA 2023, ERAA 2022 and also the ones derived in the NRAA that Red Eléctrica performed as a complement to the ERAA 2022. This is robust despite the results in terms of economic equilibrium and adequacy indicators reasonably differ due to differences in the considered assumptions (national and international) and methodology used in each analysis.
- The different ERAA editions have identified risks above the reliability standard only for target years before 2030 because they assume the NECP scenario for 2030. However, when the NRAAs have assumed a delay in the deployment of some of the targets, the risks have appeared also for 2030.

The Spanish Integrated National Energy and Climate Plan (NECP) also includes an adequacy assessment for target year 2030 following the ERAA methodology, although without applying an EVA. This allows to compare, for this key target year, adequacy in three different scenarios and extract some key messages:

- NECP shows that with 2030 target capacities no adequacy risks are observed, meaning the generation portfolio is sufficient to reach the electrification level.
- ERAA shows that in NECP scenario a part of the thermal fleet may not be economically viable and that their decommissioning would imply nonzero adequacy risks, although below the considered reliability standard.
- NRAA shows that if national specificities are considered in more detail and especially if the storage targets set in the NECP are not achieved in the expected time, adequacy risks would rise above the reliability standard even if the scenario is at theoretical economic equilibrium.

A combined look of these three assessments allows us to understand that the energy market itself will not suffice to achieve proper system adequacy in Spain, and the importance of implementing additional measures such as capacity mechanism, already considered in the NECP as a measure to reach the targets, that allow to achieve the desired level of decarbonization and electrification in time and with the required level of guarantee of supply.

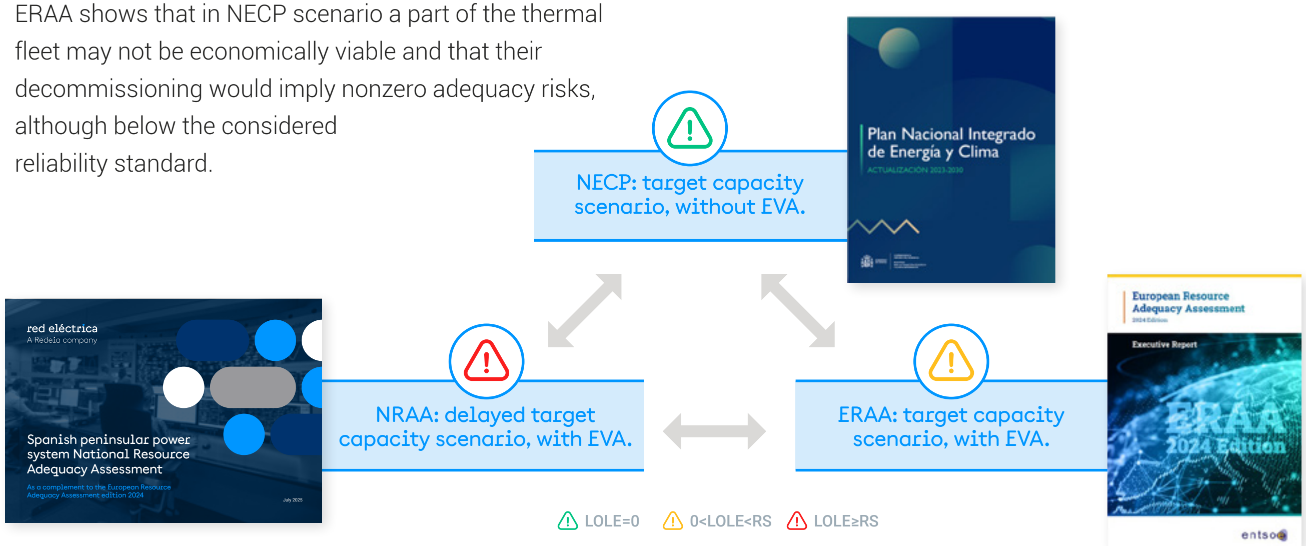


Figure 56. Complementary adequacy assessments for the Spanish peninsular power system in 2030.

8. Glossary of acronyms

A list of the acronyms used across the report is provided in order to ease its readability.

Table 31. Glossary of acronyms

Acronym	Stands for
ACER	Agency for the Cooperation of Energy Regulators
ADQ	Adequacy
BZ	Bidding Zone
CCGT	Combined Cycle Gas Turbine
CEP	Clean Energy Package
CM	Capacity Mechanism
CNMC	Comisión Nacional de los Mercados y la Competencia
CONE	Cost Of New Entry
CS	Curtailment Sharing
CY	Climate Year
DGPEM	Dirección General de Política Energética y Minas
DSR	Demand Side Response
ED	Economic Dispatch
EL	Economic Lifetime
EENS	Expected Energy Not Served
ENS	Energy Not Served
ENTSO-E	European Network of Transmission System Operators for Electricity
ERAA	European Resource Adequacy Assessment
EU	European Union
EVA	Economic Viability Assessment
FO	Forced Outage
FOM	Fixed Operation and Maintenance costs
FOP	Forced Outage Pattern

Acronym	Stands for
HMMCP	Harmonized Maximum and Minimum Clearing Prices
HP	Hurdle Premium
LLD	Load of Loss Duration
LOLE	Loss Of Load Expectation
MS	Member State
NE	National Estimates
NECP	National Energy and Climate Plan
NRA	National Regulatory Authority
NRAA	National Resource Adequacy Assessment
NT	National Trends
PECD	Pan European Climate Database
RCC	Regional Coordination Centre
RES	Renewable Energy Sources
RS	Reliability Standard
TEU	Treaty on European Union
TFEU	Treaty on the Functioning of the European Union
TSO	Transmission System Operator
TY	Target Year
UCED	Unit Commitment and Economic Dispatch
VOLL	Value Of Lost Load
VOM	Variable Operation and Maintenance costs
WACC	Weighted Average Cost of Capital
WS	Weather Scenario
XB	Cross Border

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