red eléctrica
A Redeia company

Spanish peninsular power system National Resource Adequacy Assessment

As a complement to the European Resource Adequacy Assessment edition 2022

October 2023

Contents

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 2022 taking into account additional sensitivities.

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 may consider 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 have been considered compared to the ERAA, by aligning the assumptions on storage to be coherent with the National Energy and Climate Plan (NCEP) trend scenario.

As a complement to the ERAA, this NRAA has been performed in first place for the first target year of the horizon, 2024, which was not assessed by the ERAA. The Loss Of Load Expectation (LOLE) indicator identifies adequacy risks of 5.63 h/y, above the reliability standard used as reference (0.94 h/y). This, in addition to the LOLE results obtained by ERAA 2022 for target year 2025 of 6.7 h/y, confirms that the Spanish peninsular power system could face adequacy risks in the short-term in case of decommissioning of certain level of combined cycle gas power plants.

In second place, this NRAA focuses on the mid-term. For target year 2027, ERAA also identifies adequacy risks, that could double the considered reliability standard, in case of decommissioning of certain level of combined cycle gas power plants. This NRAA aims to explore additional scenarios by introducing some sensitivities to the ERAA for the underlaying hypothesis that have a higher degree of uncertainty. With this respect, alternative scenarios have been considered in which a delay of the presumed additional storage commissioning in the Spanish peninsular system is assumed.

Under this hypothesis and reassessing the economic viability of Spanish peninsular combined cycle gas turbines, new adequacy risks are identified for target year 2027 with LOLE values in the range of 4.76 h/y. These risks are also detected for target year 2027 if, as an addition to the economic scenario identified in the ERAA, either the delay in storage commissioning is assumed (7.14 h/y) or even by applying a different economic viability assessment methodology that considers a higher number of climatic years (3.83 h/y) and has national focus.

Regarding the longer-term horizon, 2030, adequacy risks are also detected by ERAA, which are further explored in this NRAA under the hypothesis of a delay of the presumed additional storage commissioning and reassessing the economic viability of Spanish peninsular combined cycle gas turbines, resulting in higher risks than the ones identified by ERAA.

As a conclusion, under the given scenarios and methodological framework following the considerations set out by the Regulation EU 2019/943, 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. Both the ERAA and this NRAA show that this generation is needed to ensure proper adequacy levels.

A summary of the adequacy indicators, Loss Of Load Expectation (LOLE) and Expected Energy Not Served (EENS), produced both by ERAA 2022 and this NRAA for the different target years (TY) is listed in Table 1 and shown graphically in Figure 33 and Figure 34.

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

TY	Scenario	LOLE (h/y)	EENS (GWh/y)
2024	post-EVA ERAA 2022 (Red Eléctrica)	5.63	9.38
2025	post-EVA ERAA 2022 (ENTSO-E)	6.7	11.10
	post-EVA ERAA 2022 (Red Eléctrica)	6.26	12.90
2027	post-EVA ERAA 2022 (ENTSO-E)	1.9	3.08
	post-EVA ERAA 2022 (Red Eléctrica)	1.86	3.63
	post-EVA ERAA 2022 and reassessment of CCGT viability	3.83	8.24
	post-EVA ERAA 2022 with no new storage commissioning	7.14	15.68
	post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability	4.76	10.12
2030	post-EVA ERAA 2022 (ENTSO-E)	1.5	2.3
	post-EVA ERAA 2022 (Red Eléctrica)	1.66	4.25
	post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability	2.34	5.65

*In the figures and tables along this document, LOLE values above the considered reliability standard (0.94 h/y) are colored in red.

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 2022. taking into account additional sensitivities.

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, 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. According to ERAA 2022, 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 “Central scenario without Capacity Mechanisms” (also known as post-EVA scenario) shows concerning adequacy results for the year 2025 after a significant capacity reduction due to lack of economic viability, consisting of the decommissioning of 9.6 GW of combined cycle gas turbines and 540 MW of coal, and commissioning of 1 GW of demand-side response, which all together implies a net capacity reduction of 9.1 GW. In fact, the results show high levels of loss of load expectation, 6.7 h/y, more than 6 times the reliability standard used as reference (0.94 h/y). In terms of the energy not served, the average expected unserved energy is 11 GWh.

According to the ERAA 2022, looking at the results for 2027 and 2030, adequacy concerns are less probable as new investments in renewable generation and storage are expected, although still well above the reliability standard. However, the timely materialization of these investments is subject to uncertainties and delays due to economic, logistic or socioenvironmental difficulties.

The 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.

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. 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.

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 Resource Adequacy Assessment (ERAA) is described. Then, a detailed description of the methodology that is used for the assessment is included. As a next step, the assumptions that shape the different scenarios that are assessed are presented. 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 Hypotheses	This chapter summarizes the hypothesis and assumptions used both in the ERAA 2022 and in this NRAA. The ERAA 2022 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 2022 and in this NRAA, and then offers a detailed analysis of the results produced under this assessment, also assessing the impact of some methodological decisions taken for this NRAA.
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 1. 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 occurs:

   2.a. Certain risk for the provision of electric power supply.

   2.b. Situations of shortage of any or some of the primary energy sources.

   2.c. 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.d 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.a. Temporary limitations or modifications to the electricity market referred to in Article 25 or to the existing generation dispatch in isolated electricity systems.

3.b. Direct operation of generation, transmission and distribution facilities.

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

3.d. 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.e. Modification of the general conditions of regularity of supply in general or referring to certain categories of consumers.

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

3.g. Limitation or allocation of primary energy supplies to electricity producers.

3.h. 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.a. To indicatively forecast and control the level of guarantee of electricity supply of the system in the short-term and med-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.b. 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 occur within the forecast period, both in the peninsular system and in the non-peninsular systems.

2.g. 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.), hypotheses of new and retired generating 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 Propuesta de resolución de la Dirección General de Política Energética y Minas, 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 proposal for Resolution on VOLL/RS[4] sets the value of lost load, cost of new entry and reliability standard 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 22,978 €/MWh. The CONE/CORP set for the existing CCGTs is 20,000 €/MW/y, and a derating factor of 93% is applied. This results in a LOLE threshold for this reference technology of 0.94 h/y.

Under this NRAA, calculations with all existing CCGT units in service show that the expected LOLE in all the scenarios respects this threshold, and therefore the LOLE threshold for CCGT is set as the reliability standard.

3. https://www.ree.es/sites/default/files/01_ACTIVIDADES/Documentos/ProcedimientosOperacion/PO_resol_24may2006_2.2.pdf
4. https://energia.gob.es/es-es/Participacion/Paginas/DetalleParticipacionPublica.aspx?k=641

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)[5] is one of 2 primary treaties of the European Union (EU), alongside the Treaty on European Union (TEU)[6]. 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.

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

3.2.2 Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity

This Regulation[7] (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, 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

To eliminate residual resource adequacy concerns MSs may, as a last resort 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.

7. https://eur-lex.europa.eu/eli/reg/2019/943/2022-06-23

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 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)[8] 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, newbuild 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.

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

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.

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)[9] 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 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.

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

4 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). In second place, specific methodological implementations of this NRAA, different to the ERAA ones, are also explained.

4.1 European Resource Adequacy Assessment

A full detailed description of the current ERAA methodology implementation can be found at the ERAA 2022 report (Annex 2 – Methodology)[10], 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 2 illustrates the general methodological framework.

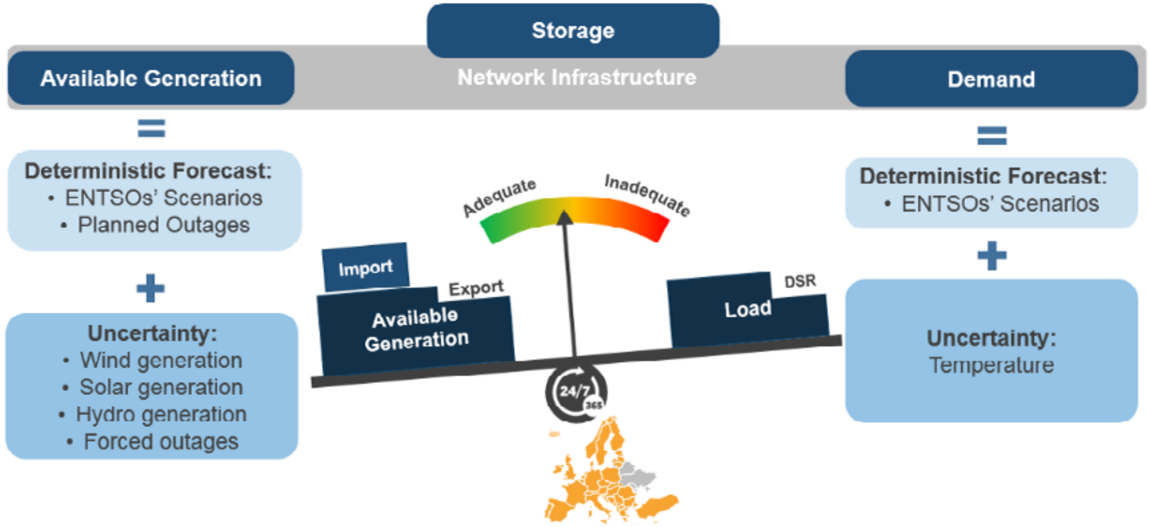


Figure 2. Overview of the ERAA methodological approach. Prepared by ENTSO-E.

10. Link to ERAA 2022 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 3.

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.

Figure 3. The interconnected European power system modelled in the ERAA 2022. Prepared by ENTSO-E.

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, 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 without capacity mechanisms. This scenario is assessed by the UCED model and, by applying the probabilistic methodology, the adequacy indicators are obtained. After, a Central reference scenario with capacity mechanisms is produced by iteratively adding capacity to the countries that have an approved capacity mechanisms until all of them meet their reliability standard.

As described above and shown in Figure 4, the ERAA process is a multistep and iterative, which is very time intensive.

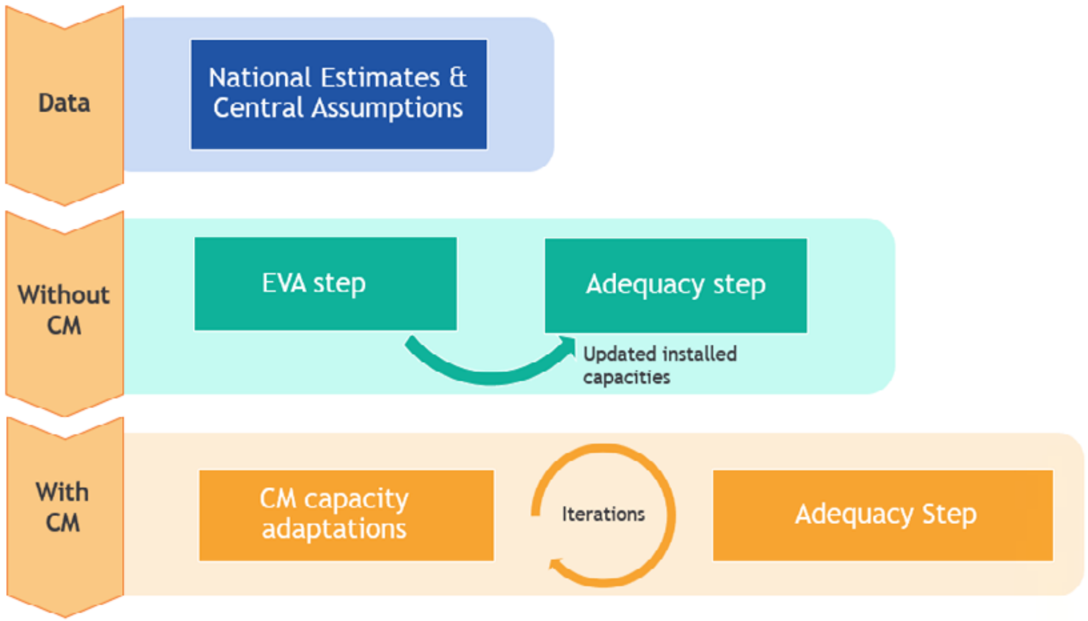


Figure 4. Overview of the ERAA process. Prepared by ENTSO-E

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. This assessment therefore delivers insight on the resource capacities that are likely to be retired, invested in, (de)mothballed or extended in lifetime. At the moment, only some of the investment decisions are applied to some of the technologies, as shown in Figure 5.

Technologies	Decommissioning	(De-)mothballing	Life Extension	New Entry
Gas	✓	✓	✓	✓
Lignite/Hard Coal/Oil	✓	✓	✓	
DSR				✓
Battery				✓

Figure 5. EVA decision variables. 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.

Solving the entire horizon of the EVA problem in a single optimization step is a bulk and numerically complex task that requires advanced solver settings and important computational power. To ensure numerical stability and computational feasibility of the EVA simulations, the horizon is divided in five steps with one overlapping year, as shown in Figure 6.

Target Year	Step 1	Step 2	Step 3	Step 4	Step 5
2024	✓ (Final)				
2025	✓ (Final)				
2026	✓ (Re-optimised)	✓ (Final)			
2027		✓ (Re-optimised)	✓ (Final)		
2028			✓ (Re-optimised)	✓ (Final)	
2029				✓ (Re-optimised)	✓ (Final)
2030					✓ (Final)

Legend	
Re-optimised	✓ (grey)
Final	✓ (black)

Figure 6. EVA step overview. Prepared by ENTSO-E.

Given a collection of climatic 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 climatic 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 2022) of Climate Years (CYs). No Forced Outage (FO) patterns were included in this model, instead derating of units was used.

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 intertemporal 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 (climate year) consists of a realistic combination of demand (taking into account temperature dependence), wind, solar and hydro inputs. They are based on historical data. Each set of climate 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 CY will be the number necessary to achieve convergence of the adequacy indicators. The convolution of the climate scenarios and random outage patterns defines the final number of Monte Carlo scenarios analyzed. Figure 7 illustrates this process.

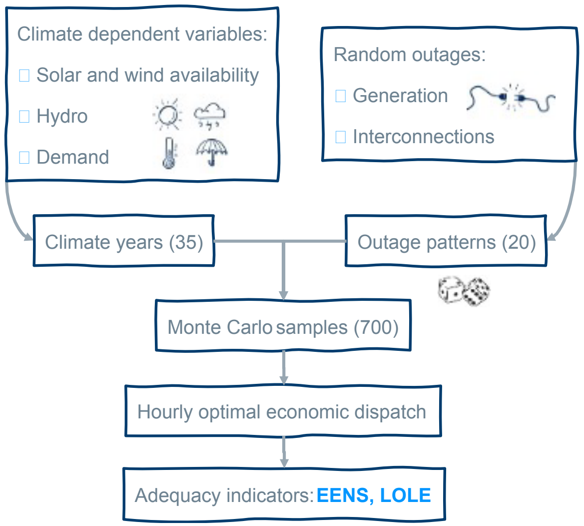


Figure 7. ERAA probabilistic methodology.

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[11] 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. In the EVA model, the NTC approach is used for all Europe.

11. 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 Methodology applied in this National Resource Adequacy Assessment

As specified in Article 24 of Regulation EU 2019/943, the same probabilistic methodology as the one used in the ERAA 2022 has been applied for this NRAA. Nonetheless, there are some methodological differences applied to the EVA as explained in this chapter.

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.

Presently, ERAA is applying the system cost minimization approach. However, for this NRAA a methodology based on the revenues versus costs approach has been applied as only one economic decision (retirement) for one single technology (Combined Cycle Gas Turbine, CCGT) in one single bidding zone (peninsular Spain) is assessed.

This EVA approach has been chosen to be able to take into account a larger number of climatic years when assessing the viability of the current fleet. It also requires reduced computational resources than the ERAA 2022 EVA model and brings as close as possible the adequacy risks perceived by the investment step and the adequacy monitoring step. Please note that the stochastic EVA model run for ERAA 2022 has high computational requirements that required the simplification of certain methodological elements to allow for numerical convergence.

Therefore, the EVA methodology used in this NRAA is based on a single model for the investment decisions and the adequacy monitoring, which is used in an iterative way taking into account 35 climatic years instead of 3 to estimate the net revenues of the generators and this way carry out their economic viability assessment and then re-executed with higher precision over the final iteration (the one found to be in economic equilibrium) to assess the adequacy risks. Due to the scope of this NRAA, for all the scenarios that have been explored, the non-Spanish perimeter has been fixed at the post-EVA ERAA 2022 scenario, and only changes in the Spanish peninsular system have been performed.

4.2.1 Methodological differences with respect to ERAA 2022

In order to conduct the economic viability assessment for this NRAA a simplified iterative process based on the revenues and costs calculated by the UCED model has been used. The main methodological differences with regards to the EVA carried out on ERAA 2022 are the following:

1. The EVA in this NRAA is performed under the "capacity resources revenues versus costs" approach, rather than the "system cost minimization" approach used in ERAA 2022. The same revenues and cost references as in the ERAA 2022 are considered.

2. Inside the Spanish perimeter only CCGTs are assessed. The post-EVA ERAA 2022 proposed the commissioning of DSR and the decommissioning of CCGT for Spanish peninsular system. DSR expansion has not been assessed in this NRAA because the Fixed Operation and Maintenance (FOM) levels are very different: 8.76 €/kW/y for DSR band 1, 20.00 €/kW/y for CCGT, 81.22 €/kW/y for DSR band 2 and 105.43 €/kW/y for DSR band 3. It is assumed that DSR band 1 would be profitable if an economic equilibrium (with the lowest price cap of 5,000 €/MWh DSR would be profitable with a LOLE=1.75 h scenario) is found for CCGTs, but still DSR band 2 and 3 would not be profitable unless all CCGT was previously found to be profitable.

3. The target year for which the adequacy situation is analyzed is used for the iterative approach. A second loop for those units found to be unprofitable in a certain year could be carried out to check whether they would be profitable in the mid-term. However, this multiyear analysis requires a very demanding process and was not implemented for this NRAA, as it was also limited in ERAA 2022. On the other hand, it can be argued that economic decisions are also influenced by the historical information of each unit, which is not considered either in this assessment. During the last years, CCGT running hours in Spain has been considerably low. Therefore, it is considered as acceptable for the purpose of this assessment to assume the investment decisions for a specific target year (TY) based on the expected results for that TY, as unguaranteed foreseen revenues in the future could be an insufficient reason for units to withstand additional losses for several years.

4. For the iterative process, only 1 forced outage pattern has been used, in order to allow an acceptable simulation time. On the other hand, the 35 CY have been run, as it is expected that climatic variables can have a higher impact on system adequacy and generators' profitability than the outage patterns, especially in systems where the size of the generators is much smaller than the size of the system which is the case for the Spanish peninsular system and in which smaller renewable generators provide large shares of the electricity supply. This is also considered to be an important strength with respect to the consistency between the EVA and the UCED as it allows to run exactly the same model in both processes instead of running a simplified one in the EVA. The impact of this methodological difference is assessed focusing on the Spanish peninsular system in chapter 6.2.

5. The model considers all interconnections in NTC mode, meaning that Flow Based (FB) is not considered for the CORE region. This simplification is acceptable for evaluating adequacy in the Spanish peninsular system, as its serial topology with Portugal and France is not directly involved in FB. The impact of this methodological difference is assessed focusing on the Spanish peninsular system in chapter 6.2.

6. When transferring the EVA results to the UCED, ERAA 2022 did it with a linear derating of all the units that in the UCED model were part of the aggregated unit in the EVA model. This is not necessary when assessing unit profitability based on the UCED model, where a unit-by-unit assessment is done. The impact of this assumption on the Spanish peninsular system is assessed in chapter 6.2 when analyzing the results.

4.2.2 Revenues versus cost simplified EVA and adequacy assessment process

The process followed for determining the economic equilibrium of the Spanish CCGT units is the following:

1 Scenario definition:

1.a. The post-EVA ERAA 2022 scenario is considered as fixed for the non-Spanish perimeter in the UCED model.

1.b The national assumptions are introduced in the UCED model.

2 Economic viability assessment:

2.a The UCED model is run for each of the climatic conditions with reduced random outage samples.

2.b The net revenues of the generators are extracted and compared to the minimum profitability. Net revenues should be sufficient to recover the Fixed Operation and Maintenance costs (FOM), affected by the Weighted Average Cost of Capital (WACC) and the Hurdle Premium (HP):

Net revenues - FOM x (1+(WACC+HP)>0.

2.c If any generator is non-profitable, the next iteration is performed by reducing 1 additional unit.

2.d The iterative process ends when all units are profitable (no units are non-profitable) → The changes in capacity are the result of the iterative revenues vs costs EVA process.

3 Adequacy assessment:

3.a The UCED model is run on the iteration in economic equilibrium for each of the climatic conditions with all the outage pattern samples → Adequacy indicators (LOLE, EENS) are extracted as the result of the adequacy assessment.

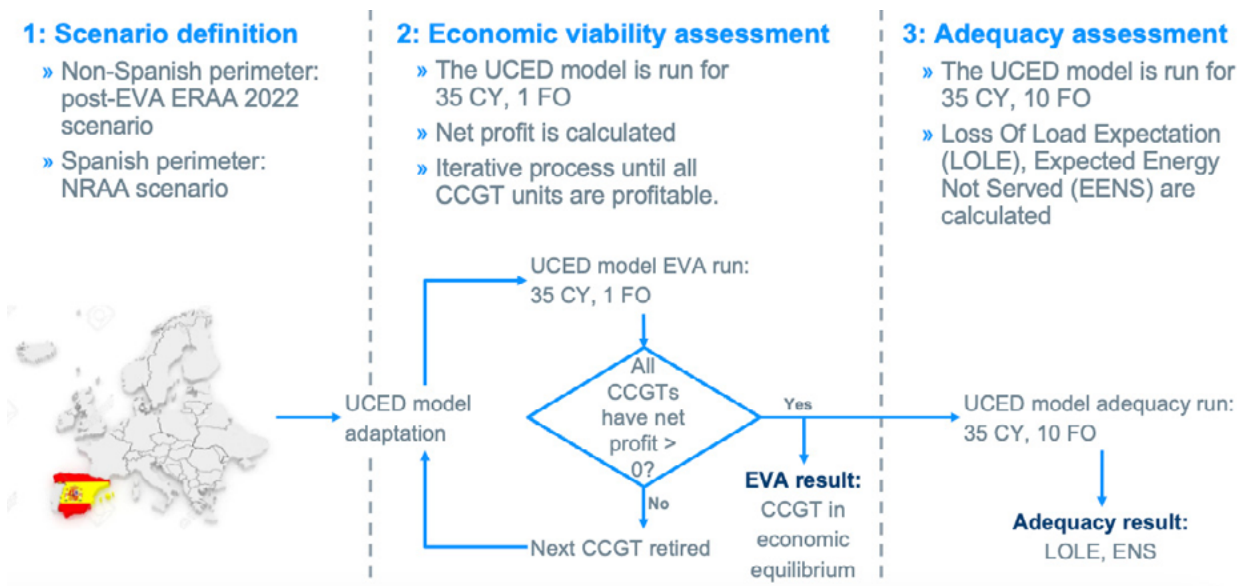


Figure 8. Revenues versus cost simplified EVA and adequacy assessment process.

5 Hypotheses

This chapter summarizes the hypothesis and assumptions used both in the European Resource Adequacy Assessment (ERAA 2022) and in this National Resource Adequacy Assessment (NRAA). The ERAA 2022 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 2022

A full detailed description of the input data and assumptions that were used for European Resource Adequacy Assessment (ERAA 2022) can be found at the report (Annex 1 - Input data & Assumptions)[12], but a summary of the main assumptions for the European and Spanish perimeter are included. Also, economic parameters are listed.

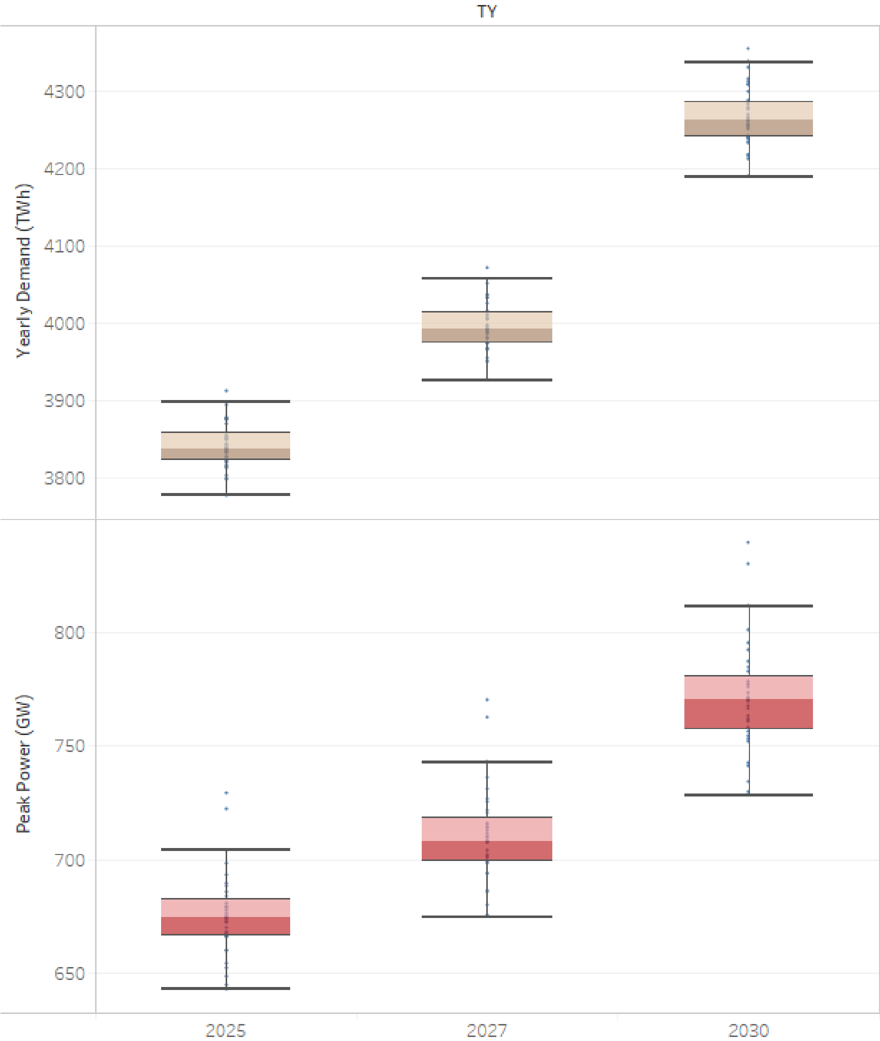
5.1.1 European perimeter

A short summary of the pan-European data considered in the ERAA 2022 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 2022 webpage, includes: demand; Resource capacities under 'National Estimates' and 'Post-EVA' scenarios; 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.

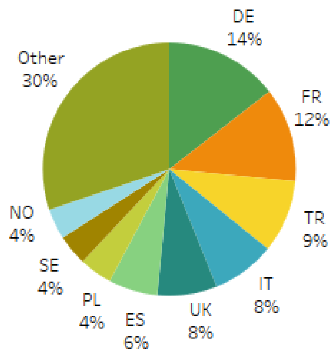
12. Link to ERAA 2022 report (Annex I - Input data & Assumptions): https://eepublicdownloads.azureedge.net/clean-documents/sdc-documents/ERAA/2022/data-for-publication/ERAA2022_Annex_1_Assumptions.pdf

Demand

Aggregated Yearly and Peak Demand



Yearly demand share per country
(Values in pie chart taken as average of all CY and TY)



Map

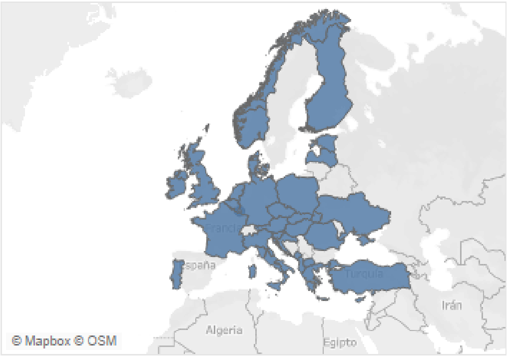


Figure 9. ERAA 2022 assumptions. Pan-European yearly and peak demand. Prepared by ENTSO-E.

Resource capacities under 'National Estimates' and 'Post-EVA' scenarios

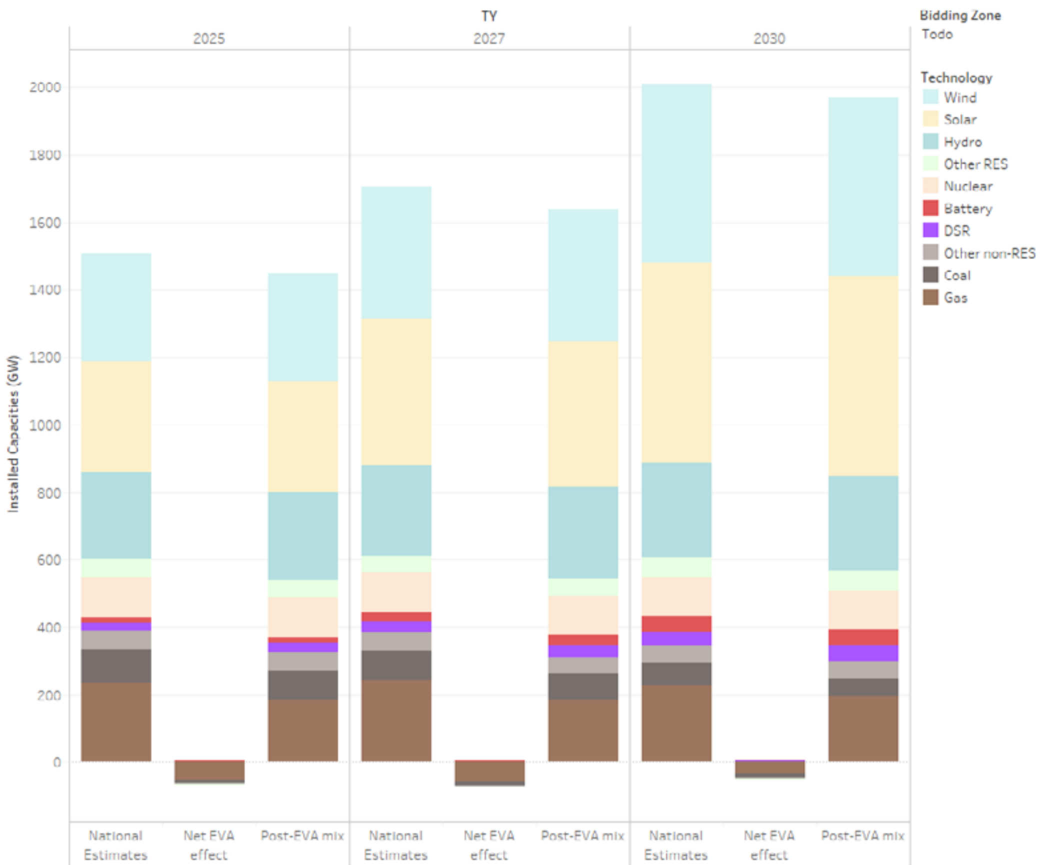


Figure 10. ERAA 2022 assumptions. Pan-European resource capacities under 'National Estimates' and 'Post-EVA' scenarios. Prepared by ENTSO-E.

Storage capacities

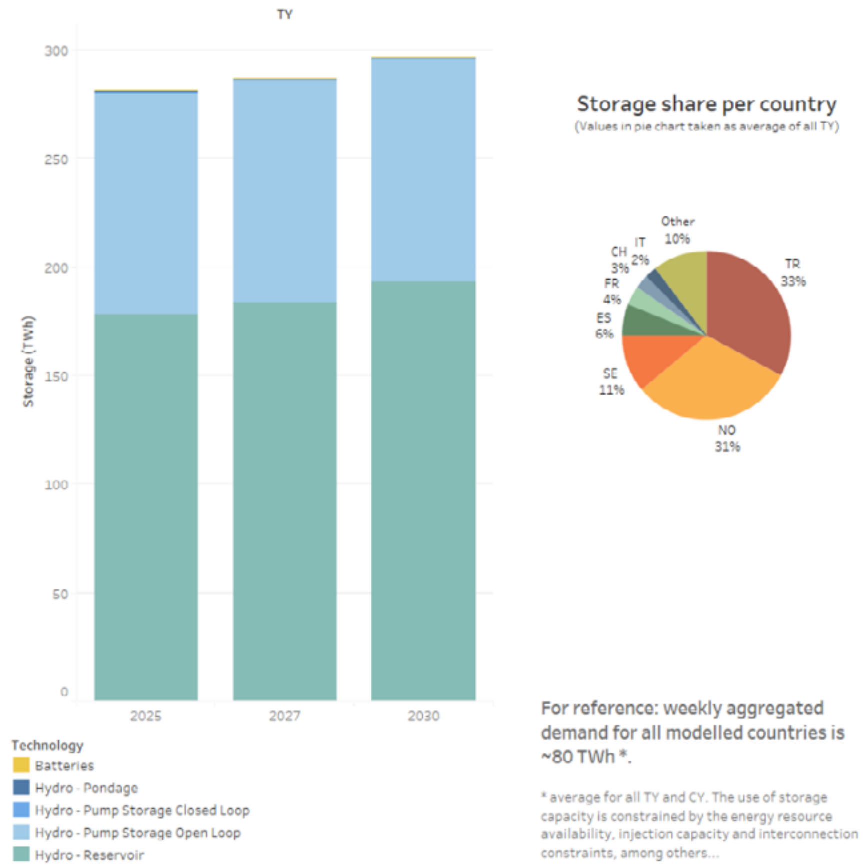


Figure 11. ERAA 2022 assumptions. Pan-European storage capacities. Prepared by ENTSO-E.

PECD energy variables and hydro inflows

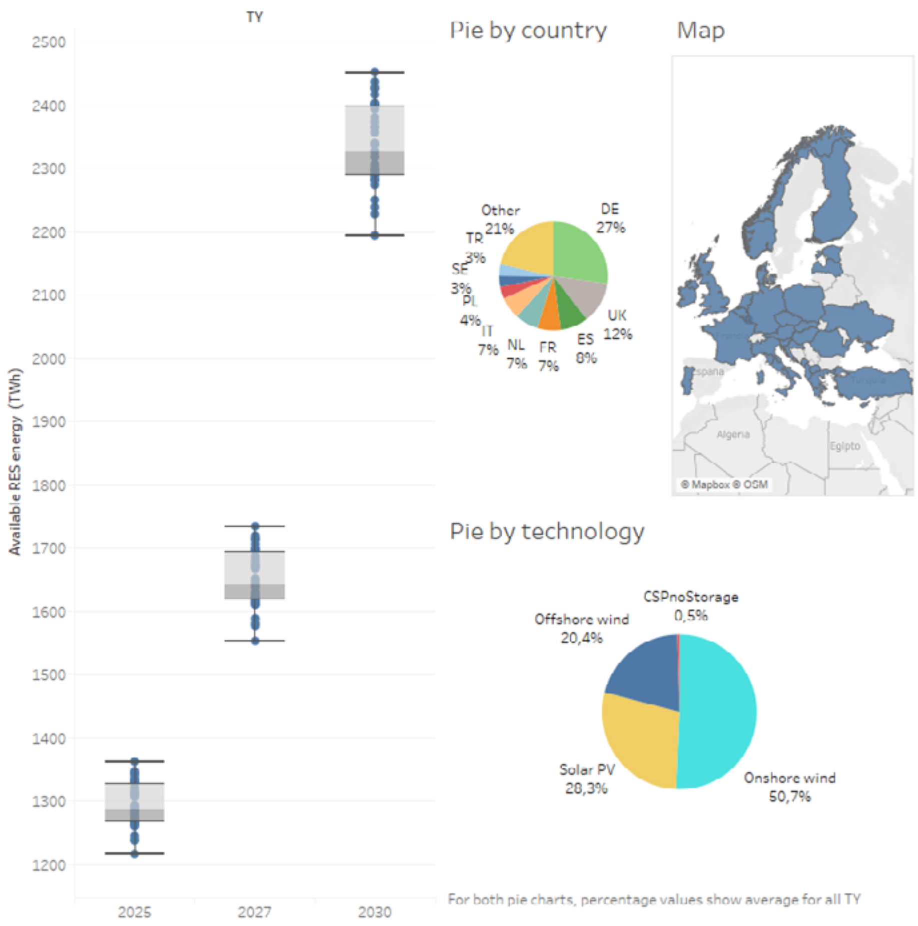


Figure 12. ERAA 2022 assumptions. Aggregated available RES energy. Prepared by ENTSO-E.

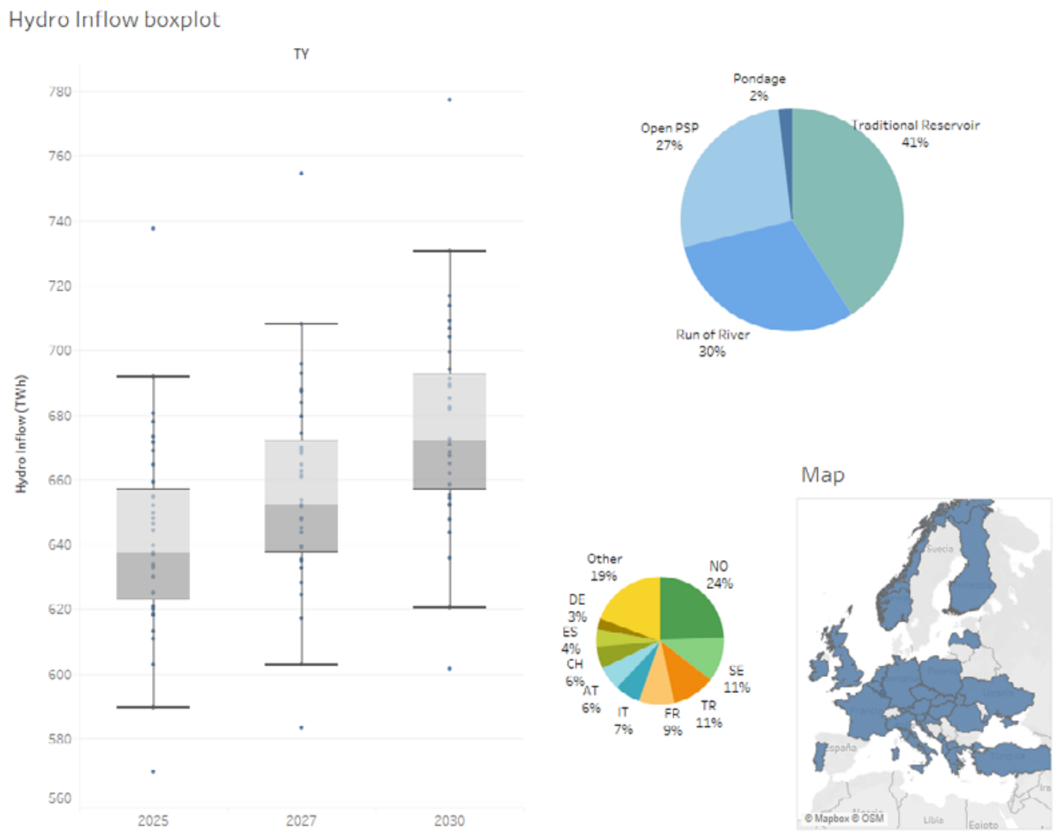


Figure 13. ERAA 2022 assumptions. Aggregated hydro inflow. Prepared by ENTSO-E.

Reserve requirements

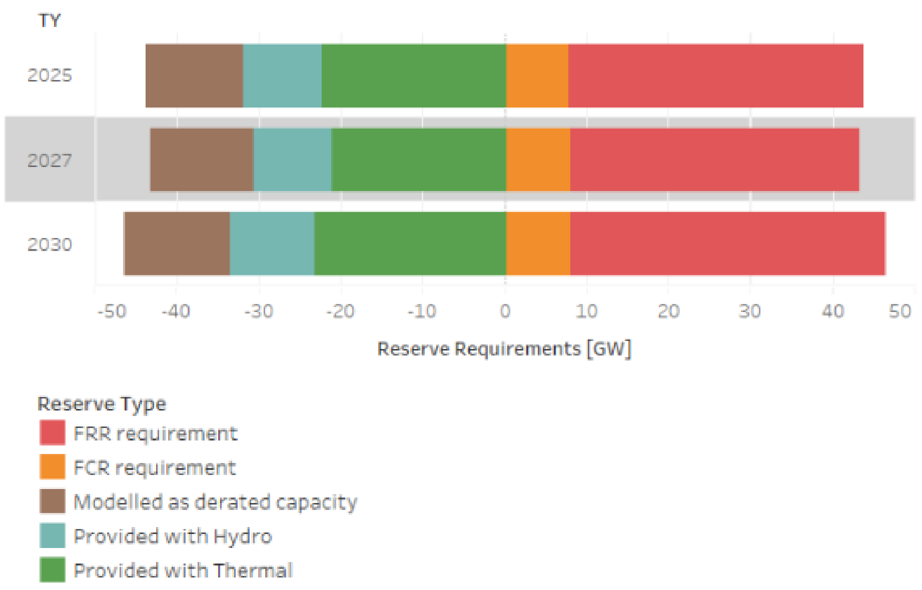


Figure 14. ERAA 2022 assumptions. Aggregated reserve requirements. Prepared by ENTSO-E.

Planned maintenance

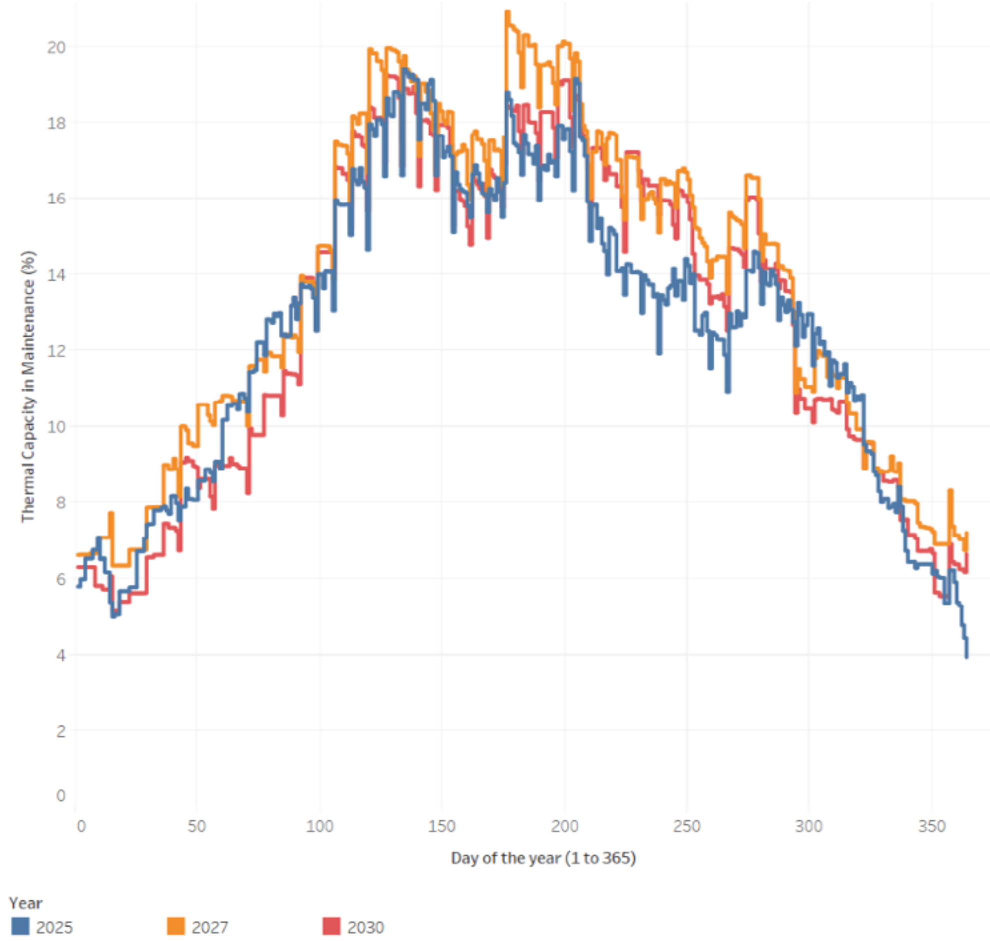
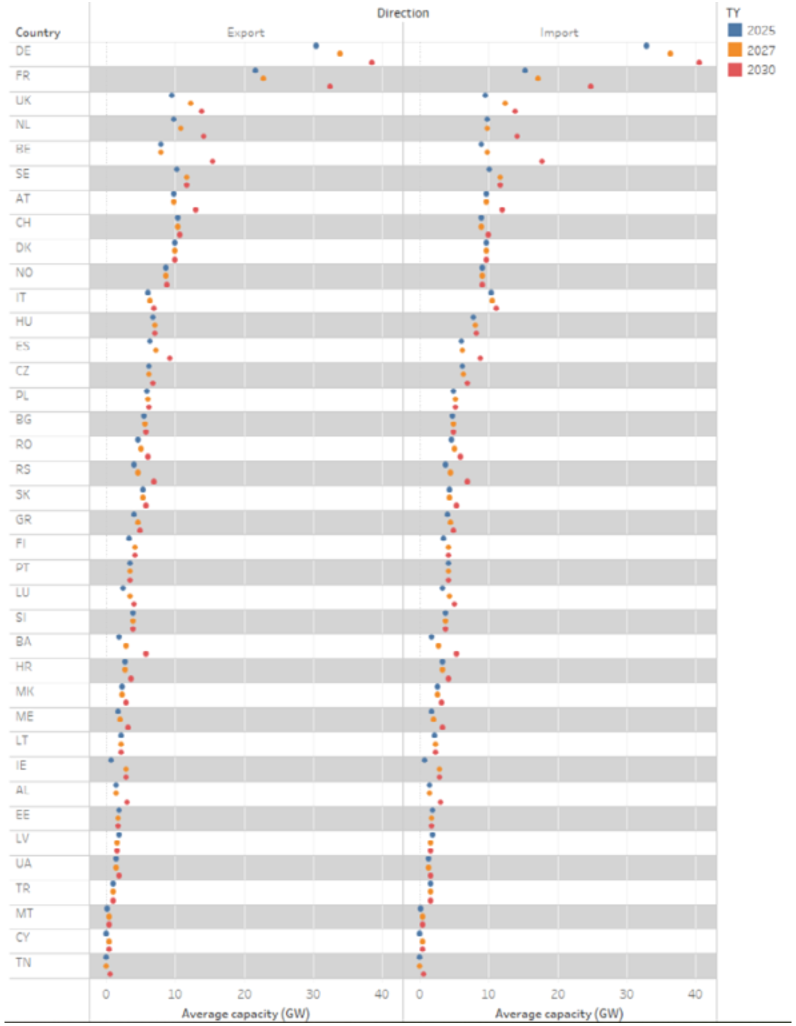


Figure 15. ERAA 2022 assumptions. Aggregated thermal planned maintenance profile. Prepared by ENTSO-E.

Net import/export capacities and exchanges with implicit regions



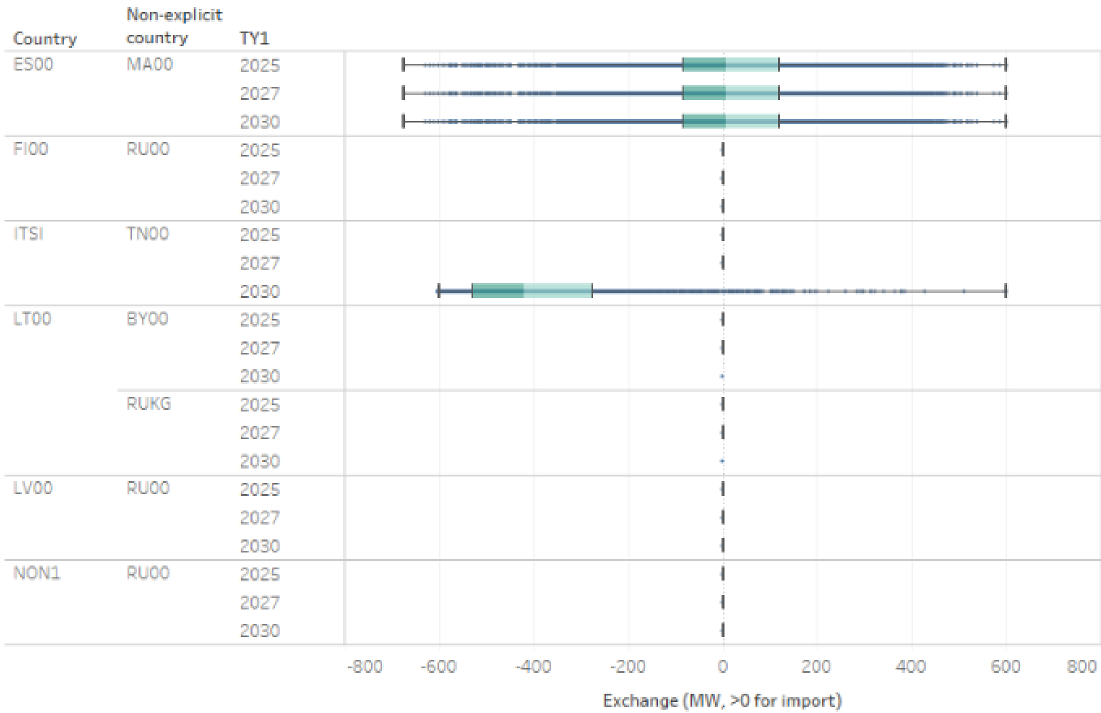


Figure 17. ERAA 2022 assumptions. Exchanges with implicit regions. Prepared by ENTSO-E.

Figure 16. ERAA 2022 assumptions. Aggregated net import/export capacities. Prepared by ENTSO-E.

5.1.2 Spanish perimeter

A short summary of the Spanish data considered in the ERAA 2022 is included: total system demand; Resource capacities under 'National Estimates' and 'Post-EVA' scenarios; 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 2. ERAA 2022 assumptions. Spanish Yearly and Peak total system demand.

	TY2024		TY2025		TY2027		TY2030	
Attribute	Power (GW)	Yearly Demand (TWh)	Power (GW)	Yearly Demand (TWh)	Power (GW)	Yearly Demand (TWh)	Power (GW)	Yearly Demand (TWh)
Min	41.79	250.69	43.06	254.79	43.74	256.61	44.61	259.32
P25	44.23	253.66	45.45	257.76	45.90	259.51	46.50	262.03
Avg	45.16	254.59	46.45	258.68	47.07	260.40	47.77	262.91
P50	44.90	254.83	46.22	258.91	46.88	260.59	47.54	263.04
P75	46.06	255.60	49.44	261.66	50.01	263.28	50.62	265.59
Max	49.00	257.76	50.31	261.85	50.76	263.50	51.17	265.87

Resource capacities under 'National Estimates' and 'Post-EVA' scenarios

Table 3. ERAA 2022 assumptions. Spanish resource capacities under 'National Estimates' scenario.

Installed capacities (MW)	TY2024	TY2025	TY2027	TY2030
Hydro	**20,440**	**20,460**	**22,627**	**24,144**
Run of river	3,453	3,474	3,528	3,589
Reservoir	10,972	10,972	10,972	10,972
Pumped storage - Open	2,683	2,683	2,683	2,683
Pumped storage - Closed	3,331	3,331	5,444	6,900
Renewables	**51,030**	**58,370**	**74,840**	**95,984**
Wind - Onshore	31,058	33,916	39,690	48,350
Wind - Offshore	0	0	0	200
Solar thermal - Current	2,300	2,300	2,300	2,300
Solar thermal - Future	0	0	3,500	5,000
Solar photovoltaic - Rooftop	1,931	2,435	3,286	4,903
Solar photovoltaic - Farm	14,651	18,629	24,714	33,501
Other renewables	1,090	1,090	1,350	1,730
Thermal	**37,083**	**36,978**	**36,107**	**31,520**
Coal	536	536	0	0
Combined cycle gas turbines	24,500	24,500	24,500	24,500
Nuclear	7,117	7,117	7,117	3,040
Other non-renewables	4,930	4,825	4,490	3,980
Batteries y DSR	**50**	**100**	**1,000**	**2,500**
Batteries	50	100	1,000	2,500
DSR	0	0	0	0
TOTAL CAPACITY	**108,603**	**115,908**	**134,574**	**154,148**

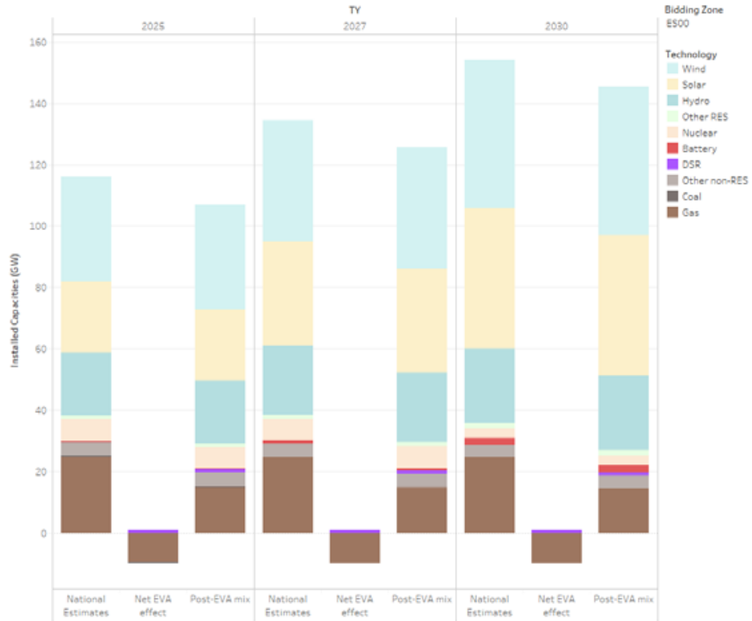


Figure 18. ERAA 2022 assumptions. Spanish capacities in 'National Estimates' and 'Post-EVA' scenarios.

Table 4. ERAA 2022 EVA results. Changes in Spanish resource capacities.

Changes in installed capacities (MW	TY2024	TY2025	TY2027	TY2030
Coal	0	-540	0	0
Combined cycle gas turbines	-9,570	-9,570	-9,890	-9,910
DSR	1,000	1,000	1,000	1,000
TOTAL CAPACITY	**-8,570**	**-9,110**	**-8,890**	**-8,910**

Storage capacities

Table 5. ERAA 2022 assumptions. Spanish storage capacities.

	TY2024		TY2025		TY2027		TY2030	
Attribute	Injection capacity (GW)	Storage (GWh)	Injection capacity (GW)	Storage (GWh)	Injection capacity (GW)	Storage (GWh)	Injection capacity (GW)	Storage (GWh)
Reservoir	10.97	11,650	10.97	11,650	10.97	11,650	10.97	11,650
Pump Storage Open	2.68	5,962	2.68	5,962	2.68	5,962	2.68	5,962
Pump Storage Closed	3.33	95.4	3.33	95.4	5.44	101.2	6.90	175.2
Batteries	0,050	0.01	0,100	0.2	1	2	2.5	5

PECD energy variables and hydro inflows

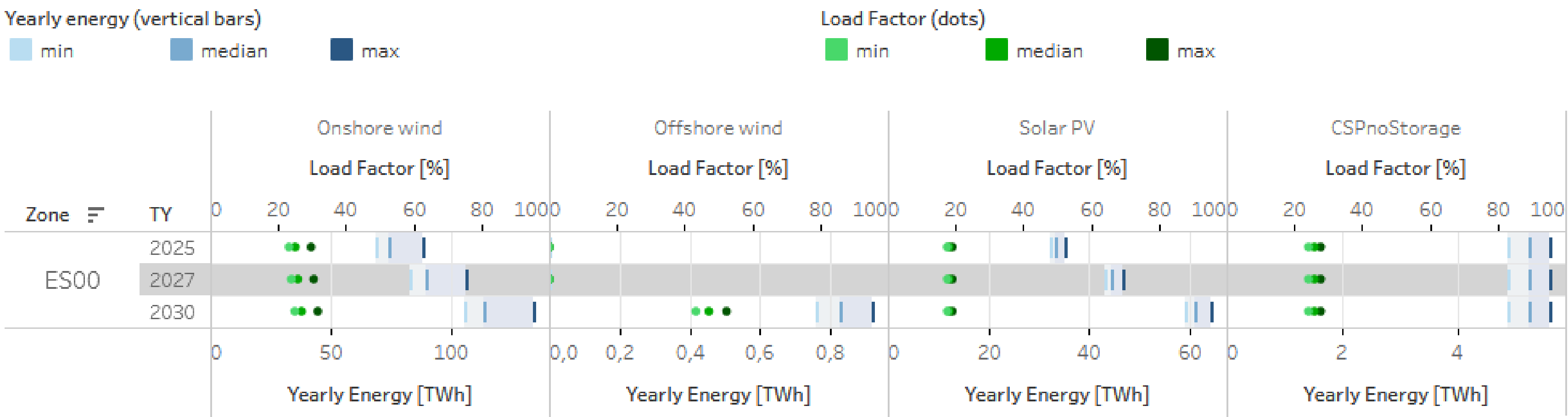


Figure 19. ERAA 2022 assumptions. Spanish available RES energy.

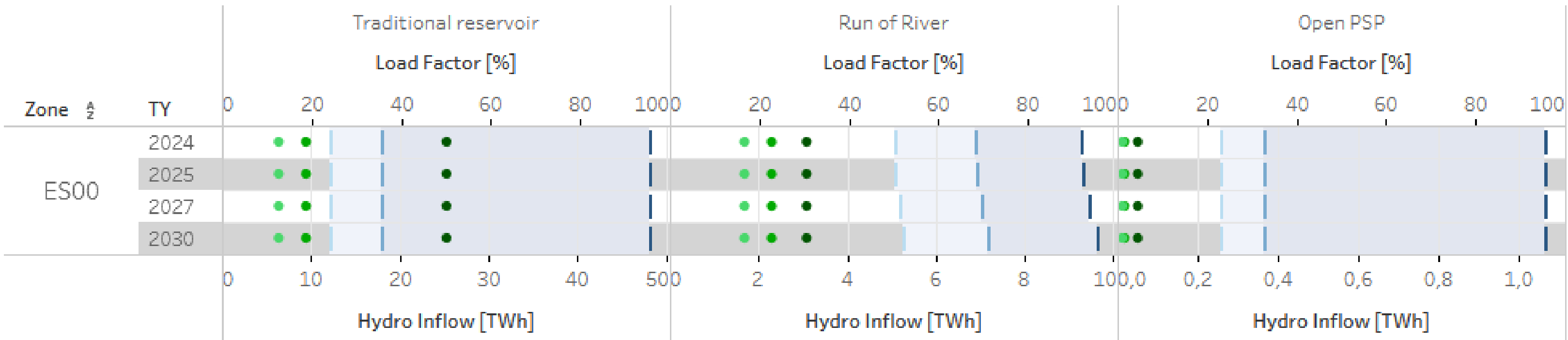


Figure 20. ERAA 2022 assumptions. Spanish hydro inflow.

Reserve requirements

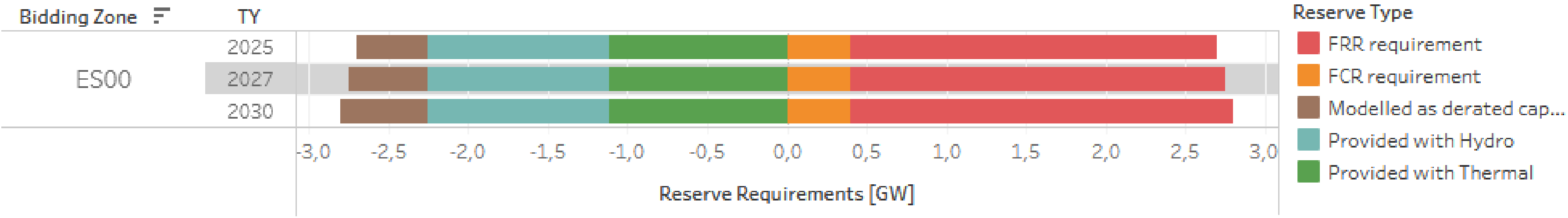


Figure 21. ERAA 2022 assumptions. Spanish reserve requirements.

Planned maintenance

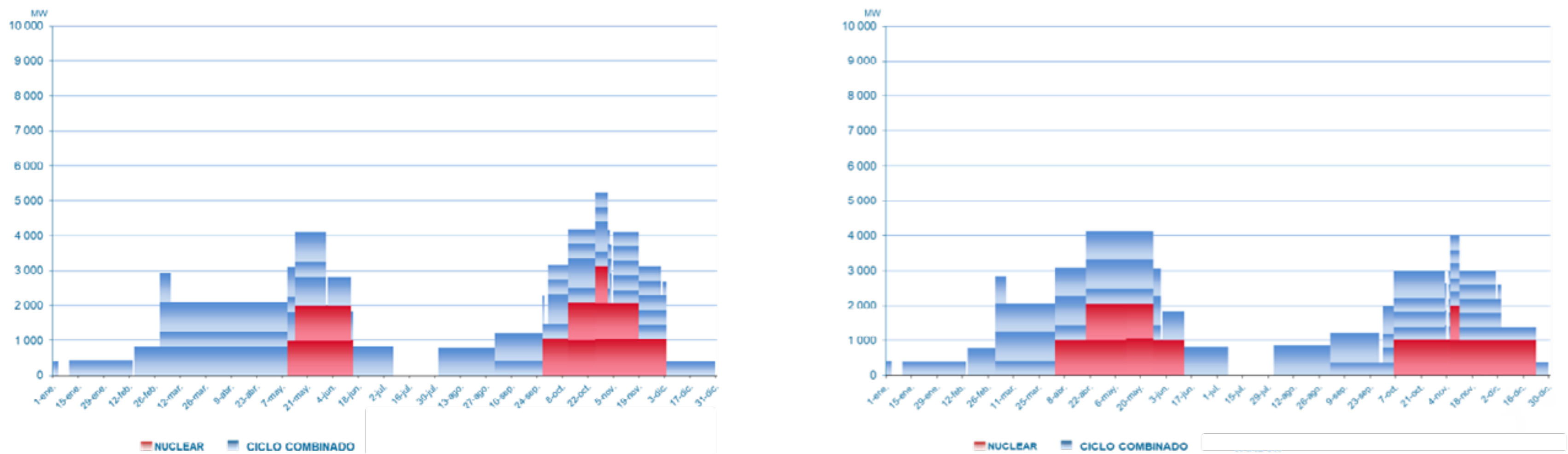


Figure 22. ERAA 2022 assumptions. Spanish planned maintenance profile for TY2024, 2025.

Net import/export capacities and exchanges with implicit regions

Table 6. ERAA 2022 assumptions. TY2024, 2025, 2027, 2030. Spanish NTC and exchanges.

Spain-France interconnection	2024, 2025				2027				2030			
	Winter		Summer		Winter		Summer		Winter		Summer	
	O-P	P	O-P	P	O-P	P	O-P	P	O-P	P	O-P	P
ES00 → FR00 (exp)	2,500	2,200	2,200	1,900	3,400	3,000	3,100	2,700	5,670	5,400	4,700	3,600
FR00 → ES00 (imp)	2,700	2,900	2,200	2,300	2,800	3,000	2,400	2,500	5,300	5,200	5,300	5,250
Spain-Portugal interconnection	2024						2025, 2027, 2030					
ES00 → PT00 (exp)	2,700						4,200					
PT00 → ES00 (imp)							3,500					
Spain-Morocco interconnection	2024, 2025, 2027, 2030											
ES00 → MA00 (exp)	Fixed exchange. Max 675 MW.											
MA00 → ES00 (imp)	Fixed exchange. Max 600 MW.											

For each target year, interconnections whose planned commissioning date is, at the latest, the previous year are considered available. In other words, interconnections are not considered available in their planned year of entry into service, but from the following year. In the ERAA 2022 and in this national study, the future Beariz-Ponte de Lima interconnection is considered available from the target year 2025 and the future Gulf of Biscay interconnection is considered available from the year 2028.For the future Navarra-Landes and Aragón-Atlantic Pyrenees interconnections, the expected commissioning date considered is December 2030, and therefore they have not been considered available for the 2030 target year.

Explicit DSR potential for EVA expansion

Table 7. ERAA 2022 assumptions. TY2024, 2025, 2027, 2030. Spanish DSR potential for EVA.

Band	CAPEX (€/kW)	FOM (€/kW/year)	Potential (MW)	Activation Price (€/MWh)	Activation limit (h)
Industry 1	0.556	8.764	1,000	65	2 h/d, 10 h/y
Industry 2	0.24	81.22	1,340	65	2 h/d, 10 h/y
Industry 3	0.225	105.429	260	83	2 h/d, 10 h/y

5.1.3 Technoeconomic parameters

A short summary of the technoeconomic parameters considered both in the UCED and in the EVA in the ERAA 2022 is graphically shown in order to give a general idea of the whole scenario framework. Data, extracted from the ERAA 2022 report, includes: Economic dispatch parameters of thermal units; Price cap; Hydrogen price; Also, additional economic parameters for the EVA investment decisions are shown.

Economic dispatch parameters

Fuel Type	2024	2025	2026	2027	2028	2029	2030	Reference
Nuclear	0.47							TYNDP 2022[2]
Lignite	1.4–3.1							TYNDP 2022
Hard coal	2.99	2.99	3.00	3.01	3.02	3.03	3.05	RePowerEU[3]
Natural gas	14.28	12.95	12.80	12.65	12.50	12.35	12.20	RePowerEU
Light oil	19.25							RePowerEU
Heavy oil	15.79							RePowerEU
Shale oil	1.56	1.56	1.62	1.68	1.74	1.80	1.86	TYNDP 2022

Figure 23. ERAA 2022 assumptions. Fuel cost per fuel and target year. Prepared by ENTSO-E.

TY	2024	2025	2026	2027	2028	2029	2030	Reference
Price	90.50	93.75	97.00	100.25	103.50	106.75	110.00	WEO 2021

Figure 24. ERAA 2022 assumptions. CO_2 price per target year. Prepared by ENTSO-E.

Generation Unit Category	2024	2030
CCGT	1.96–2.31	1.9–2.31
OCGT	2.8	2.8
Lignite	2.76–3	2.76–3
Hard Coal	2.4–3.59	2.4–3.51
Oil	2.76	2.8
Nuclear	6.8	7.4

Figure 25. ERAA 2022 assumptions. Variable operation and maintenance cost per generation category and target year. Prepared by ENTSO-E.Elaboración 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
Lignitew	101
Hard Coal	94
Oil	78–100
Nuclear	0

Figure 26. ERAA 2022 assumptions. Efficiency and CO_2 emission factor per generation category. Prepared by ENTSO-E.

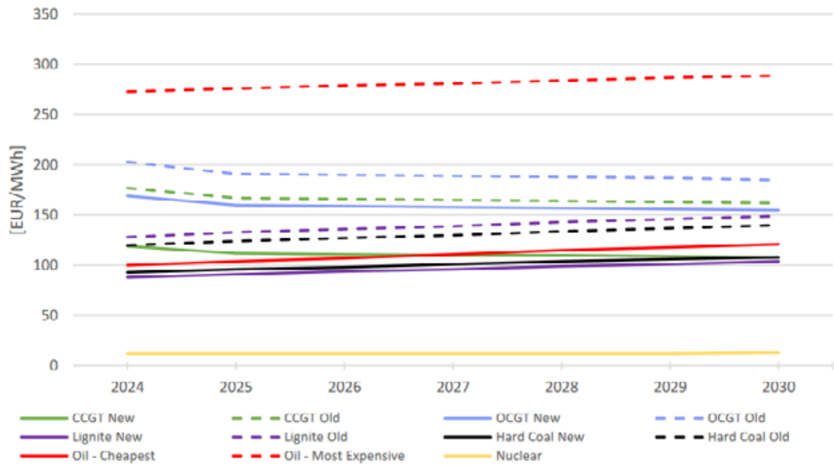


Figure 27. ERAA 2022 assumptions. Marginal cost of thermal units per generation category and target year. Prepared by ENTSO-E.

2024	2025	2026	2027	2028	2029	2030
5,000	5,000	6,000	6,000	7,000	8,000	8,000

Figure 28. ERAA 2022 assumptions. Price cap per target year. Prepared by ENTSO-E.

red eléctrica

Economic parameters for the economic viability assessment

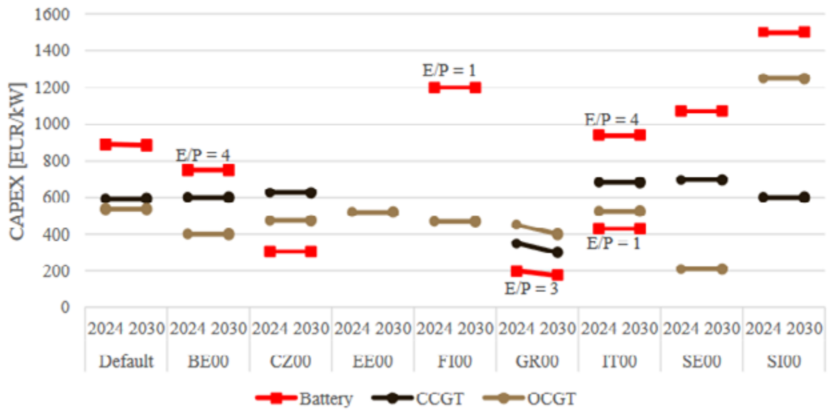


Figure 11: Default values and CONE values for CAPEX

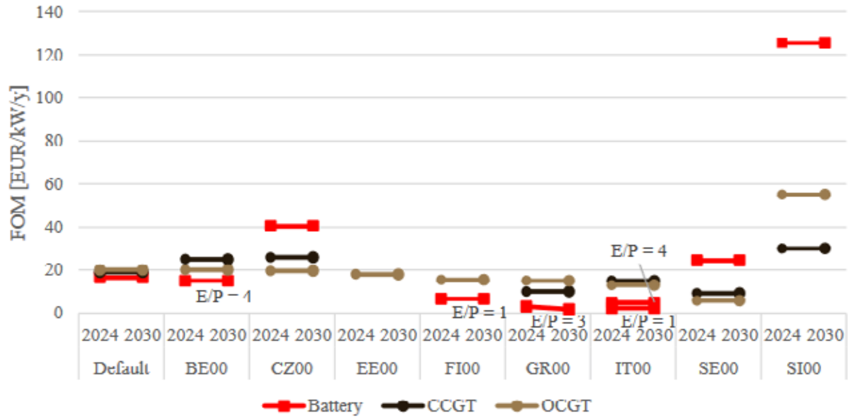


Figure 12: Default values and CONE values for FOM

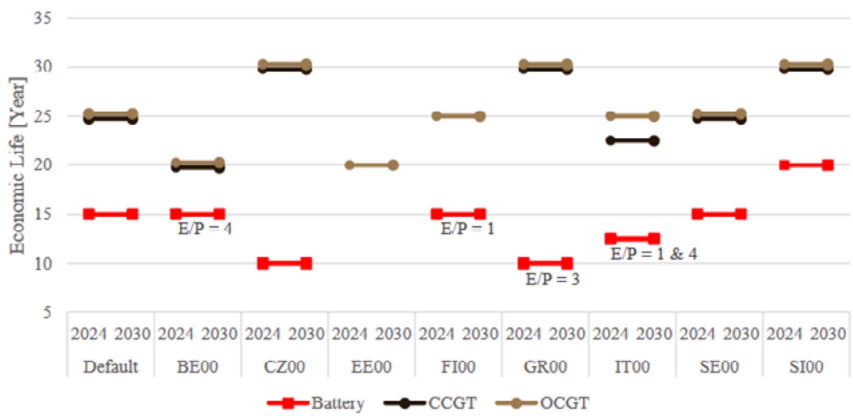


Figure 13: Default values and CONE values for economic life

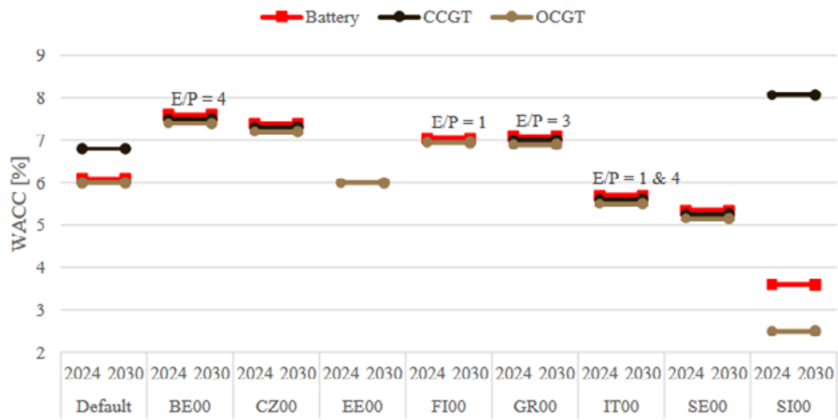


Figure 14: Default values and CONE values for WACC

Table 5: Default values for the hurdle premium [%]

Battery	CCGT	OCGT
8.5	6.5	8.5

Figure 29. ERAA 2022 assumptions. Parameters for economic commissioning candidates. Prepared by ENTSO-E.

Resource Unit Category	FOM cost [€/kW/y]	WACC [%]	Hurdle Premium [%]	Source of the Fixed Cost Value
Hard Coal	25–40	6	1.5	EU reference scenario 2020[4]/ASSET 2018[5]
Lignite	32–46	6	1.5	EU reference scenario 2020/ASSET 2018
CCGT	19	6.8	1.5	Average of CONE
OCGT	20	6	1.5	Average of CONE
Light Oil	21	6.8	1.5	EU reference scenario 2020/ASSET 2018
Heavy Oil	21	6.8	1.5	EU reference scenario 2020/ASSET 2018
Oil Shale	21	6.8	1.5	EU reference scenario 2020/ASSET 2018

Figure 30. ERAA 2022 assumptions. Economic parameters for economic decommissioning candidates. Prepared by ENTSO-E.

Resource Unit Category	CAPEX [EUR/kW]	Life Extension [years]	Hurdle Premium [%]	WACC [%]	Sources
CCGT	100	15	4	10.8	Elia[6]
OCGT	80				Elia
Lignite	275				Extrapolation
Hard Coal	241				Extrapolation
Oil	187				Extrapolation

Figure 31. ERAA 2022 assumptions. Economic parameters for lifetime extension. Prepared by ENTSO-E.

Resource Unit Category	Mothballing CAPEX [EUR/kW]	De-mothballing CAPEX [EUR/kW]	Fixed cost [EUR/kW/y]	Hurdle premium [%]	WACC [%]	Source
CCGT	2.50	18.75	0.60	1.5	8.3–9.3	TenneT
OCGT	2.30	17.26	0.55	2.5	8.3	Extrapolation
Lignite	6.87	51.55	1.6	1.5	8.3	Extrapolation
Hard Coal	6.01	45.10	1.4	1.5	8.3	Extrapolation
Oil	4.69	35.15	1.1	1.5	8.3	Extrapolation

Figure 32. ERAA 2022 assumptions. Economic parameters for mothballing. Prepared by ENTSO-E.

5.2 Hypotheses for this National Resource Adequacy Assessment

The regulatory framework concerning the NRAA establishes that they may be carried out for the purpose of complementing the ERAA.

NRAA may consider 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 only different assumptions over the generation have been considered compared to the ERAA, by aligning the assumptions on storage to be coherent with the National Energy and Climate Plan (NCEP) trend scenario.

As it is explained in the ERAA 2022 report, in overall the ERAA 2022 data has been based on the Spanish NECP. The values given for 2030 in the ERAA 2022 dataset are those defined in the NECP approved by the Spanish government. However, for 2024 and 2025, some differences have been included in light of the best information available from the stakeholders and the evolution of the installed capacities and permits issued. The growth foreseen for thermal solar, wind and hydropump capacity in those years is slower than expected in the NECP. Data for 2027, including storage, was mainly interpolated between 2025 and 2030 data.

Therefore, the scenario for target years 2024 and 2025 is not revaluated in this NRAA. However, as the horizon gets away from the present moment, uncertainty on all the hypothesis that build up the scenario grows. With this in mind, and regarding the scope of this national assessment, additional scenarios have been produced for 2027 and 2030.

The number of possible scenarios is high, depending on the capacity resource combinations. Considering the impact on resource adequacy, the robustness and understandability of the assumptions, and argumentation of the changes respect to ERAA, one single new assumption has been made: consider the delay or no new commissioning of the NECP-target scenario expected storage in the Spanish power system. This is also coherent with the NECP trend scenario, which is the scenario that would result if no energy politics were introduced to achieve the NECP target scenario, being capacity mechanisms one of those politics.

The system operator considers this to be a reasonable assumption for this NRAA due to the fact that currently no pumped storage nor solar thermal units are under construction. It is normally accepted that these types of units need several years for construction. As an example, Royal Decree-Law 23/2020 approving measures in energy and other areas for economic reactivation[13], establishes that pumped-storage projects may request an extension of the grid access permission expiration of up to 7 years

13. Link to Royal Decree-Law 20/2022: https://www.boe.es/buscar/act.php?id=BOE-A-2022-22685

since the permission is granted for obtaining the definitive administrative authorization for operation. In addition, the economic viability of stand-alone batteries is still not proved, as the ERAA 2022 EVA showed (no batteries commissioning was foreseen). There is a high interest in storage projects in Spain and many projects are being studied by promoters, however their estimated profitability is not sufficient and is acting as a barrier. As an example, at the moment only 50 MW of new solar thermal capacity have requested grid access. It is possible that, new mechanisms supporting storage and demand side response could help in developing storage projects. However, they still have to be approved for the construction of storage capacity to begin. Therefore, it is reasonable to assume for this NRAA that, in the absence of a capacity mechanism, grid scale storage capacity will most probably not be commissioned in the next years and is considered as a robust assumption for sensitivity analysis under this NRAA.

In addition, in order to be aligned with the national CONE estimations, a Fixed Operation and Maintenance cost (FOM) of 20,000 €/kW/y has been considered in this NRAA for Spanish Combined Cycle Gas Turbines instead of the default 19,000 €/kW/y considered in the ERAA. This does not change the economic equilibrium point of the iterations performed in the different scenarios assessed in this NRAA. The values of WACC and Hurdle Premium are kept as in ERAA 2022 (Figure 30).

6 Results

This chapter firstly includes a summary of the results obtained across all the different scenarios available both in European Resource Adequacy Assessment (ERAA) 2022 and in this National Resource Adequacy Assessment (NRAA), and then offers a detailed analysis of the results produced under this assessment, also assessing the impact of some methodological decisions taken for this NRAA.

6.1 Summary of scenarios and results

Under this assessment, a total of 8 full set adequacy simulations have been produced. Firstly, the same model as ERAA 2022 has been run in order to cross check the results, and also to estimate the results that ERAA 2022 could have delivered for target year (TY) 2024. As a second step, an iterative revenues-based economic viability assessment (EVA) methodology has been applied to the post-EVA ERAA 2022 scenario for TY2027, as Spanish CCGTs were found to be in a non-economical equilibrium. Then, two additional sensitivities on TY2027 have been carried out revising the hypothesis on new storage capacity commissioning, one of them revising the economic viability of the Spanish Combined Cycle Gas Turbines (CCGTs) by iteratively estimating their revenues and adapting the available CCGT capacity. This same sensitivity has been carried out also for TY2030. A summary of the adequacy indicators, Loss Of Load Expectation (LOLE) and Expected Energy Not Served (EENS), produced both by ERAA 2022 and this NRAA is listed in Table 8 and shown graphically in Figure 33 and Figure 34.

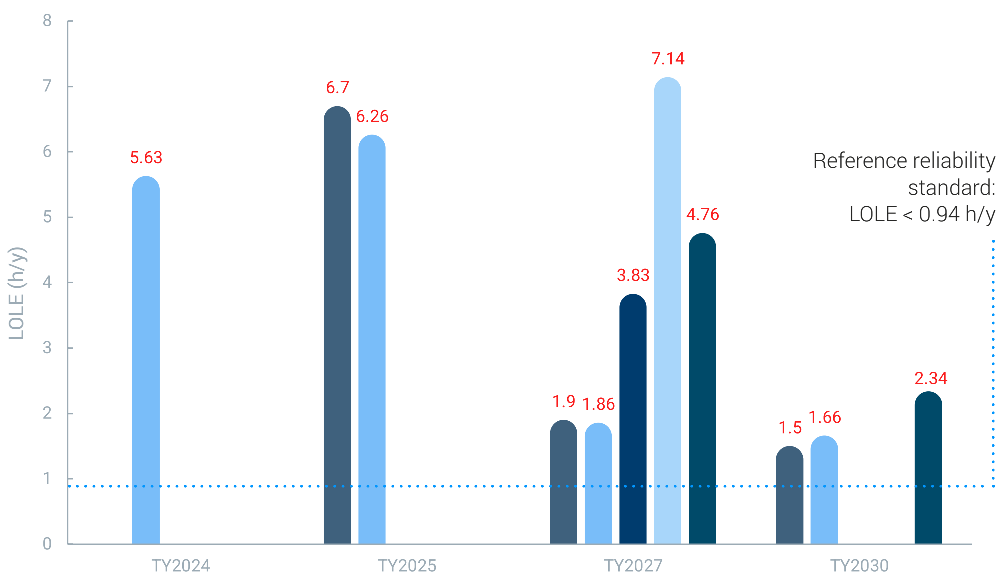
As a result of this NRAA, the assessment of the scenarios which would result from the decommissioning of the economically unviable units shows a significant risk of adequacy issues in the following years in the Spanish peninsular system if additional incentives are not put in place.

Table 8. Summary of target years, scenarios and adequacy indicators.

TY	Scenario	LOLE (h/y)	EENS (GWh/y)
2024	post-EVA ERAA 2022 (Red Eléctrica)	5.63	9.38
2025	post-EVA ERAA 2022 (ENTSO-E)	6.7	11.10
	post-EVA ERAA 2022 (Red Eléctrica)	6.26	12.90
2027	post-EVA ERAA 2022 (ENTSO-E)	1.9	3.08
	post-EVA ERAA 2022 (Red Eléctrica)	1.86	3.63
	post-EVA ERAA 2022 and reassessment of CCGT viability	3.83	8.24
	post-EVA ERAA 2022 with no new storage commissioning	7.14	15.68
	post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability	4.76	10.12
2030	post-EVA ERAA 2022 (ENTSO-E)	1.5	2.3
	post-EVA ERAA 2022 (Red Eléctrica)	1.66	4.25
	post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability	2.34	5.65

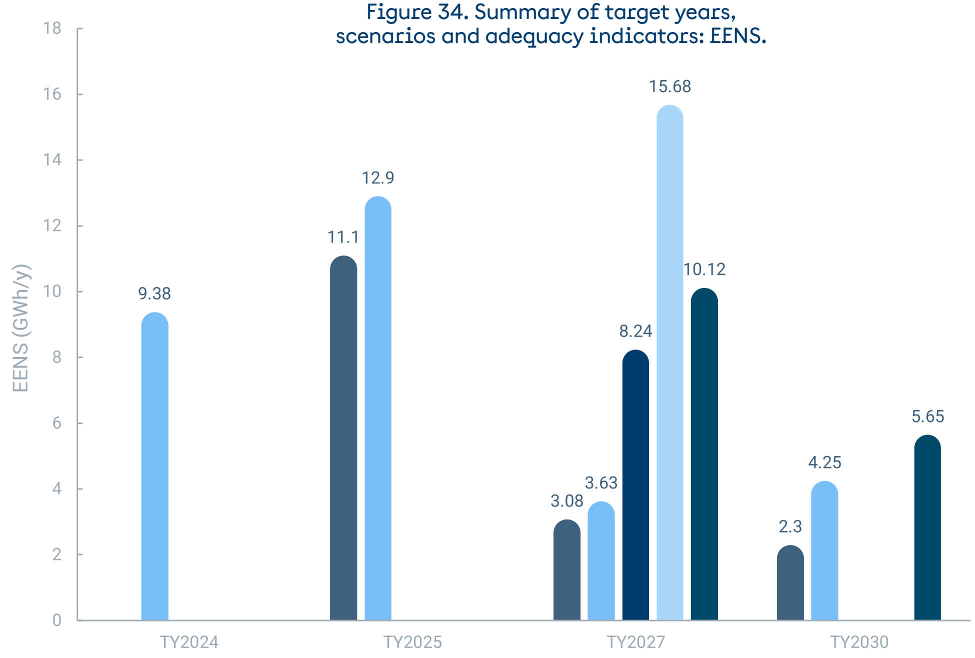
Please note the large amount of information produced under this assessment, due to the number of probabilistic simulations (both on climate years and forced outage patterns), with hourly detail for the whole European system on a multitude of variables. The values presented in this report are all mean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

Figure 33. Summary of target years, scenarios and adequacy indicators: LOLE.



- post-EVA ERAA 2022 (ENTSO-E)
- post-EVA ERAA 2022 (Red Eléctrica)
- post-EVA ERAA 2022 and reassessment of CCGT viability
- post-EVA ERAA 2022 with no new storage commissioning
- post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability

Figure 34. Summary of target years, scenarios and adequacy indicators: EENS.



- post-EVA ERAA 2022 (ENTSO-E)
- post-EVA ERAA 2022 (Red Eléctrica)
- post-EVA ERAA 2022 and reassessment of CCGT viability
- post-EVA ERAA 2022 with no new storage commissioning
- post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability

6.2 Analysis of results

In first place, the post-EVA scenario produced in ERAA 2022 is analyzed in chapter 6.2.1. A benchmark of the results presented by ENTSO-E for the ERAA 2022 edition and those produced by Red Eléctrica for this NRAA is provided, explaining the small differences observed between these two different runs. Then, more detailed analysis of the results for the Spanish peninsular system are provided.

In second place, chapter 6.2.2 includes a full analysis of the different scenarios considered in this NRAA. During the analysis, the methodological differences between this NRAA in respect to the ERAA are also explained when they are first observed, as also specific methodological decisions taken in this NRAA are assessed.

In the two cases, the analysis is focused on the results obtained for the Spanish peninsular system in terms of adequacy indicators, cross border contribution and economic viability of Spanish CCGTs.

6.2.1 Scenario 0: post-EVA ERAA 2022 scenario. Focus on the short-term

As a starting point of the NRAA, the latest ERAA models[14] were run for the four target years (TY) analyzed in ERAA 2022 (TY2024, TY2025, TY2027 and TY2030) in order to check the models and the results, and properly benchmark the rest of the results produced under the NRAA. Once the Red Eléctrica runs of the ERAA 2022 model are declared as valid, more detailed results are shown.

6.2.1.1 ENTSO-E and Red Eléctrica runs: model benchmarking

Red Eléctrica actively participated in ERAA 2022 edition, which has allowed for the understanding of the hypothesis, tools and models used for the process and to contribute to the stepwise implementation of ERAA. With the latest available models, the four (one per target year) adequacy models were run on the full set of climatic years although with the following operational differences that were perceived as necessary in order to produce this assessment within a reasonable amount of time, without reducing the quality of the outcomes, allowing to test a different approach for the economic viability analysis part and to perform several sensitivities that could show the expected behavior of the Spanish peninsular system in different possible future scenarios.

With this in mind, when benchmarking the results of the two set of runs the following operational differences have to be taken into consideration:

Table 9. Operational differences between ENTSO-E and Red Eléctrica runs.

Topic	Reason for difference	ENTSO-E	Red Eléctrica
PLEXOS engine	Availability of newer version	9.0 R05	9.1 R01
Interconnections	Simulation time and being the Spanish borders out of the CORE region	Flow-based market coupling (FB)	Net transfer capacities (NTC)
Curtailment sharing (CS)	Implemented in FB model	Yes	No
Forced outage pattern samples	Simulation time and reduced impact expected if system size is much bigger than generator size	20	10

14. Please note that TY2024 was not finally delivered as an outcome of ERAA 2022. Please consider the results produced under this NRAA for this specific TY as indicative, since at some moment of the ERAA 2022 this model could have been left out of priority and certain updates or checks may have not been implemented. Only LOLE and EENS results are provided.

As it can be inferred from the following table, the impact of these operational differences is very important in terms of simulation time, which was one of the biggest barriers for ERAA 2022 to produce results for all target years and all scenarios, and also undermining its purpose of providing several sensitivities.

Table 10. Approximate simulation time per TY and per CY (when only 1 model running at Red Eléctrica servers).

Model type	Interconnections	Forced outage pattern samples	Simulation time (h)
ERAA 2022	FB	20	40
NRAA (Test)	NTC	20	20
NRAA (ED step)	NTC	10	10
NRAA (EVA steps)	NTC	1	3

Please note that the current implementation of the curtailment sharing methodology requires running twice each FB model, thus duplicating the amount of needed time. Using FB with CS in this NRAA would have limited very much its scope and was discarded due to the limited impact on Spanish results (see Table 11).

Table 11. Benchmark of ENTSO-E and Red Eléctrica runs of the post-EVA ERAA 2022 model.

TY	Scenario	LOLE (h/y)	EENS (GWh/y)
2024	Post-EVA ERAA 2022 (Red Eléctrica)	**5.63**	9.38
2025	Post-EVA ERAA 2022 (ENTSO-E)	**6.7**	11.10
	Post-EVA ERAA 2022 (Red Eléctrica)	**6.26**	12.90
2027	Post-EVA ERAA 2022 (ENTSO-E)	**1.9**	3.08
	Post-EVA ERAA 2022 (Red Eléctrica)	**1.86**	3.63
2030	Post-EVA ERAA 2022 (ENTSO-E)	**1.5**	2.3
	Post-EVA ERAA 2022 (Red Eléctrica)	**1.66**	4.25

In terms of impact in results, these operational differences do not introduce big deviations in Spanish peninsular results. It can be noted that differences in results are rather small, and not always in the same direction. This is, for TY2025 and TY2027, the LOLE values estimated by ERAA 2022 are higher than the ones estimated by NRAA, but for TY2030 the values calculated by ERAA 2022 are slightly lower than the ones obtained in the NRAA. Also, the differences are smaller when comparing LOLE than when comparing EENS, probably driven by the reduction on forced outage patterns. However, the time simulation reduction is considerable and therefore these slight differences are considered as acceptable.

A first conclusion is that the benchmark models used in this NRAA for TY2025, TY2027, TY2030 produce results aligned with those produced by the ERAA 2022 models. A second conclusion is that if ERAA 2022 would have been able to deliver results for TY2024, adequacy risks above the reliability standard would have been identified, as the results produced under the NRAA show.

Therefore, 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.

Figure 35. Benchmark of the post-EVA ERAA 2022 scenario: LOLE.

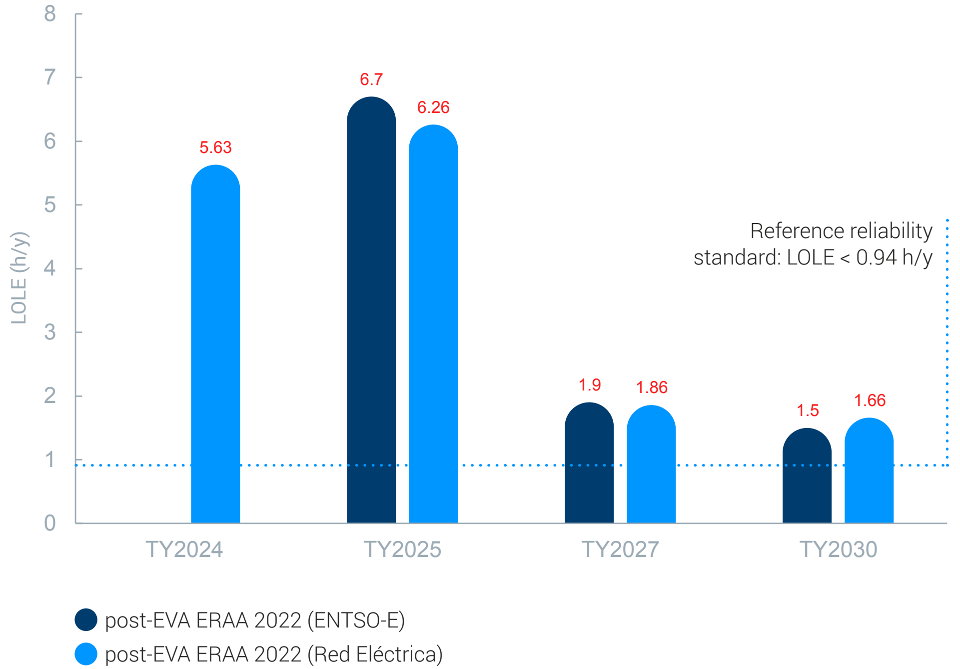
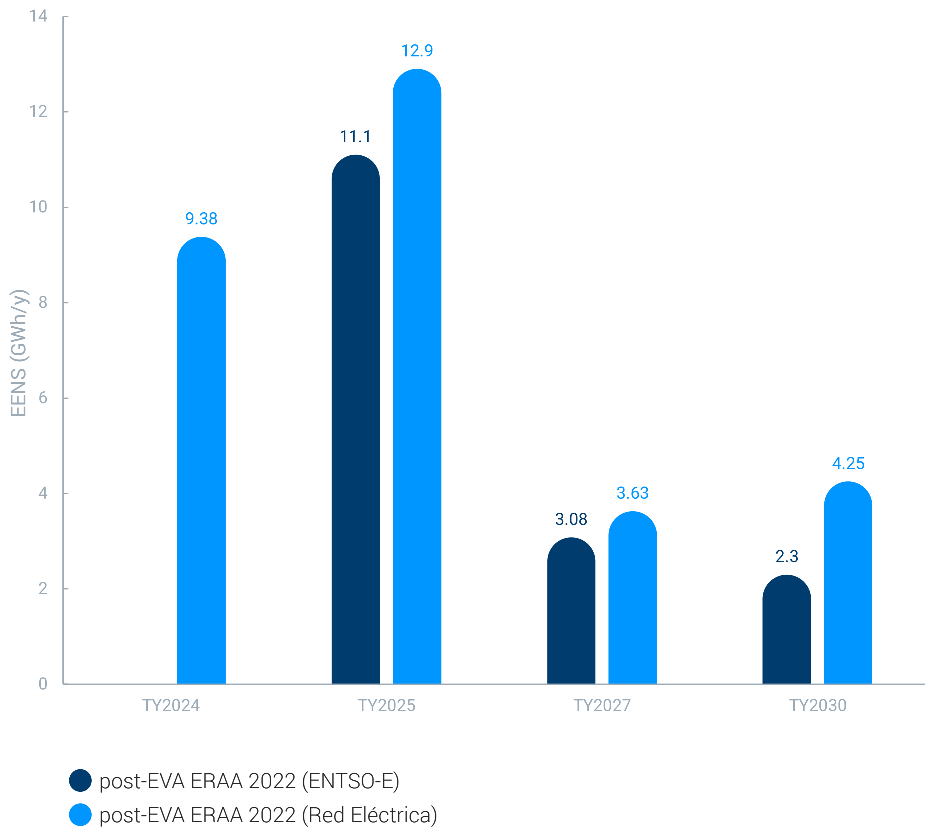


Figure 36. Benchmark of the post-EVA ERAA 2022 scenario: EENS.



6.2.1.2 Red Eléctrica runs: detailed results

The following figures and tables provide further detail on adequacy indicators for the Spanish peninsular system in the post-EVA ERAA 2022 scenario, giving the chance to assess more deeply the Spanish peninsular system in this scenario and give in this NRAA additional insights to the ones already in the ERAA 2022 report.

The main statistical metrics are included in Table 12. For more detail on adequacy indicators per climate year please refer to Table 14.

Due to the high variability observed across the different climate years in the adequacy indicators, Figure 37 y la Figure 38 con más detalle.

For all target years the adequacy risks are mainly observed during the late autumn and the winter period (November, December, January, February), and mainly in the evening hours.

This fact, which is common to other countries in the European system, is due to a variety of reasons. Besides the demand values, it's worth noting the lower or absent resource of solar infeed (either PV, rooftop or thermal) during the peak hours. Another point worth mentioning is the evolution of the hydro reserves during the year. The hydro reserves usually hit their minimum in Spain in October or November, affecting the amount of hydro resources in the end of the Autumn and the beginning of Winter. This effect is more significant for the system during dry years, which are happening more often in the latest decade and are expected to be more frequent in the future. Besides these reasons, the simultaneous unavailability of thermal power plants, due to planned or unplanned outages, increases the risk of insufficient resources to cover the demand.

The adequacy risks which are assessed in the calculations are aligned with the operational situations which have been observed in the last two years in Spain. Although no adequacy issues were met, the available capacity margins to keep exports got tight in situations of low renewable energy infeed, combined with low availability of thermal power plants.

Table 12. TY2024, 2025, 2027, 2030. Scenario 0: post-EVA ERAA 2022. Adequacy indicators statistics across different climate years.

	TY2024		TY2025		TY2027		TY2030	
Attribute	LOLE (h/y)	EENS (GWh/y)	LOLE (h/y)	EENS (GWh/y)	LOLE (h/y)	EENS (GWh/y)	LOLE (h/y)	EENS (GWh/y)
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max	**26.70**	60.08	**26.90**	87.02	**11.30**	40.47	**10.20**	44.11
Avg	**5.63**	9.38	**6.26**	12.90	**1.86**	3.63	**1.66**	4.25
P50	**3.60**	5.22	**3.50**	6.54	0.20	0.18	0.10	0.08
P95	**18.35**	41.27	**22.74**	55.37	**7.75**	15.84	**8.32**	23.08

When estimating the mean value of the hourly energy volumes that would not be met during scarcity events, volumes of 1.66 GWh, 2.06 GWh, 1.95 GWh and 2.56 GWh are found for TY2024, TY2025, TY2027 and TY2030, respectively. However, in the most critical hour of the most critical climate conditions, the following hourly volumes of unserved energy are observed as an average of the 10 forced outage samples: 7.03 GWh in TY2024, 9.44 GWh in TY2025, 8.01 GWh in TY2027 and 11.39 GWh in TY2030. Both magnitudes, mean and maximum, would imply important demand disruptions that would cause important damages in socioeconomic activity.

In addition to the adequacy indicators, as the revenues of Spanish CCGTs are going to be used in order to assess their viability, an analysis of their revenues in the post-EVA ERAA 2022 scenario has also been performed and is reflected in Figure 38, showing that the amount of decommissioning estimated by EVA is close to the economic equilibrium but slightly underestimated specially for TY2025 and TY2027, this meaning that if the national economic equilibrium was achieved even higher adequacy risks would be observed.

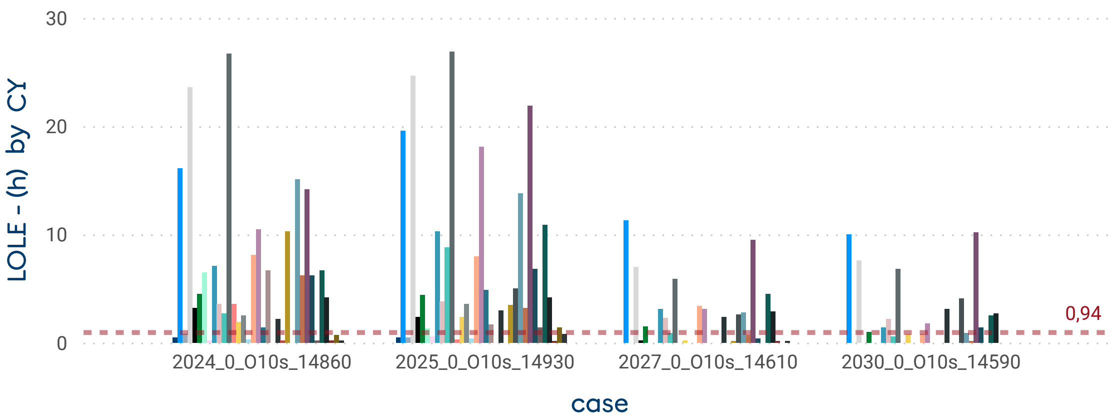
Regarding the cross-border contribution, Figure 38 shows the impact of interconnectors in adequacy. Please recall this is the representation of the average values of 10 forced outage patterns samples. It can be observed that in some situations unserved energy happens without fully using the interconnections, this means that the neighboring systems are also facing a scarcity situation. However, the volume of unserved energy grows rapidly when cross-border capacity is exhausted, and most of the scarcity situations take place with fully used interconnections.

Taking this into account, it can be inferred that the risks are highly conditioned by the effective support that can be received from neighboring countries. The results obtained in this assessment should be interpreted considering that, according to the reality observed in system operation, this support is not always guaranteed.

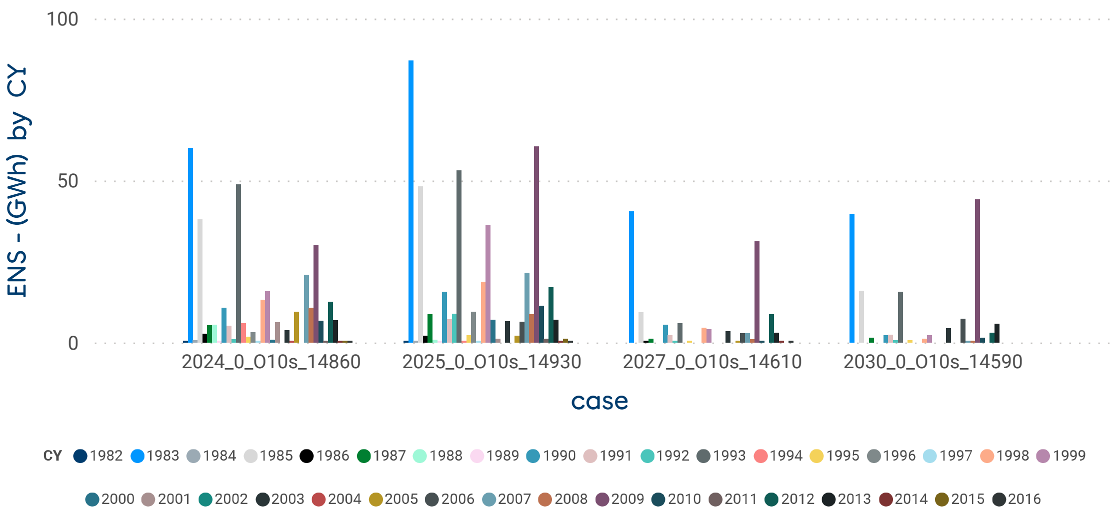
This leads to the conclusion that the Spanish peninsular system remains close to an energy island in terms of adequacy, meaning that mainly national resources would be needed to meet the reliability standard. Expanding the cross-border capacity would allow both to provide support to other countries and to access capacity providers located in other countries, but with the current expected cross-border capacities this would not be enough to fulfill the reliability standard as capacity is exhausted in most of the scarcity situations.

Figure 37. TY2024, TY2025, TY2027, TY2030. Scenario 0: post-EVA ERAA 2022. Economic dispach results.

Adequacy indicators: LOLE by CY



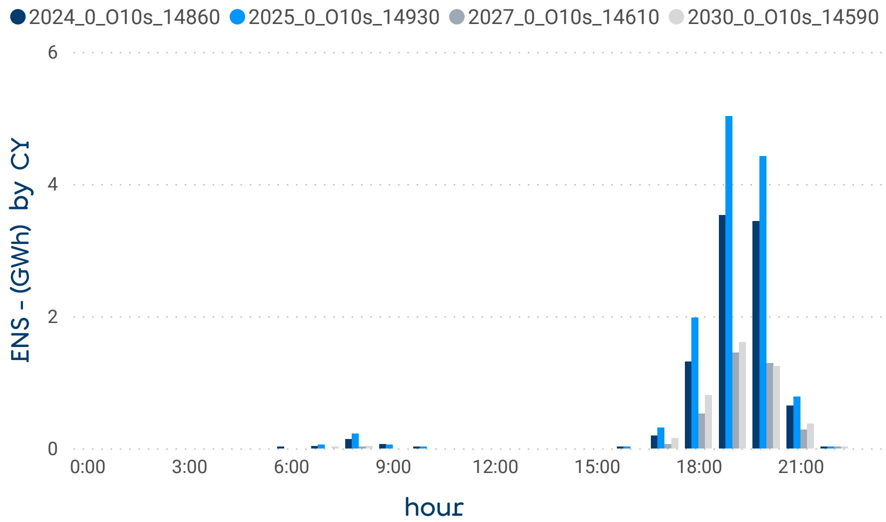
Adequacy indicators: EENS by CY



Adequacy indicators: LOLE monthly distribution (h)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2024_0_010s_14860	1,15	0,56	0,24					0,00			1,50	2,18	**5,63**
2025_0_010s_14930	1,78	0,86								0,07	2,11	1,43	**6,26**
2027_0_010s_14610	0,63	0,44									0,20	0,58	**1,86**
2030_0_010s_14590	0,74	0,43									0,22	0,27	**1,66**

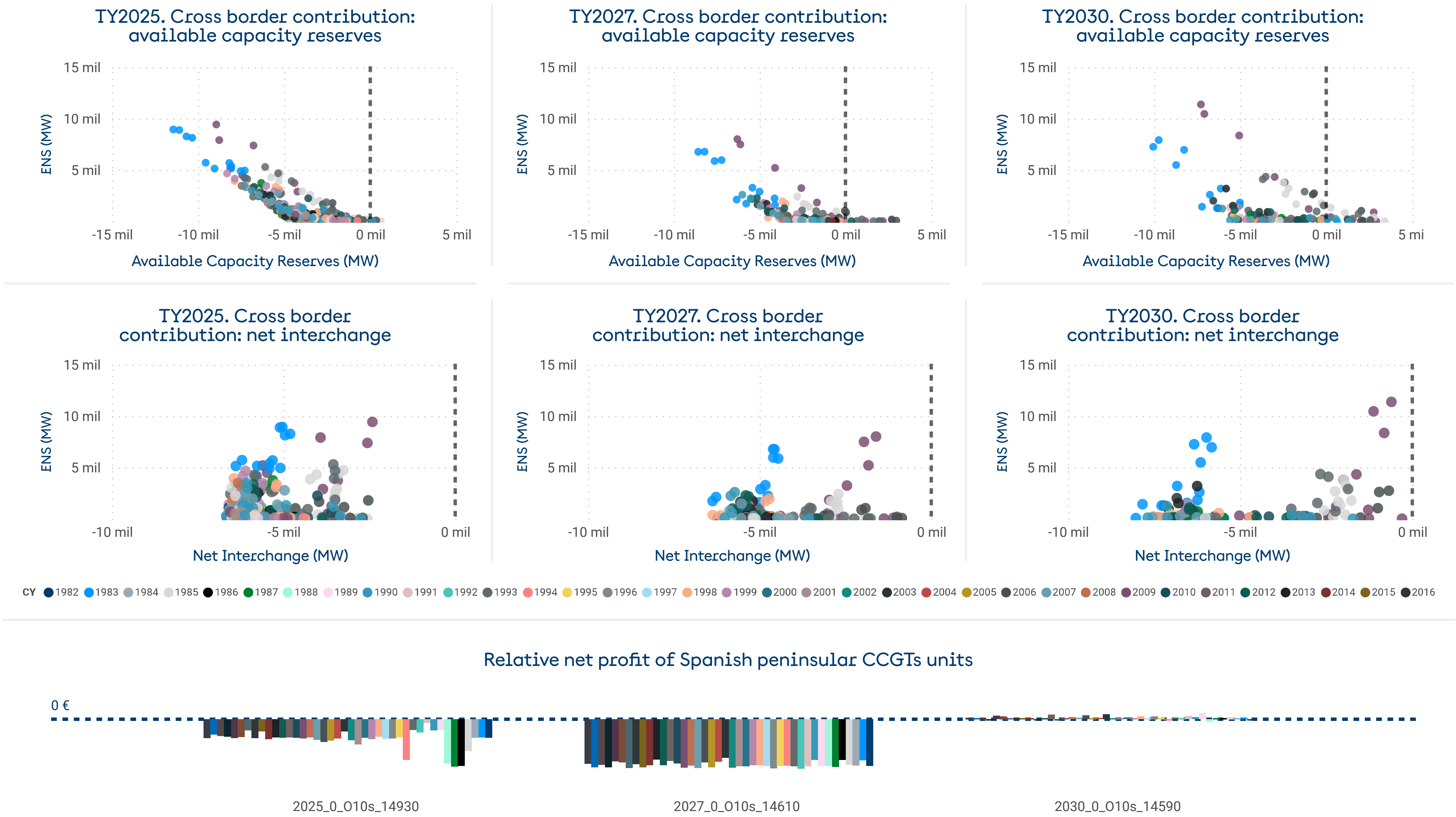
Adequacy indicators: EENS daily distribution



Adequacy indicators: EENS monthly distribution (GWh)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2024_0_010s_14860	2,08	1,86	0,28					0,00			2,41	2,75	**9,38**
2025_0_010s_14930	3,69	2,94								0,07	3,95	2,24	**12,90**
2027_0_010s_14610	1,33	1,27									0,22	0,82	**3,63**
2030_0_010s_14590	1,99	1,39									0,48	0,40	**4,25**

Figure 38. TY2025, TY2027, TY2030. Scenario 0: post-EVA ERAA 2022. Cross border contribution and net profits of Spanish peninsular CCGT units.



As a reminder, the post-EVA ERAA 2022 scenario figures are summarized in Table 13. Capacities affected by EVA (only coal, CCGT and DSR) are highlighted.

Table 13. TY2024, 2025, 2027, 2030. Scenario 0: post-EVA ERAA 2022. Installed capacities.

Installed capacities (MW)	TY2024	TY2025	TY2027	TY2030
Hydro	**20,440**	**20,460**	**22,627**	**24,144**
Run of river	3,453	3,474	3,528	3,589
Reservoir	10,972	10,972	10,972	10,972
Pumped storage - Open	2,683	2,683	2,683	2,683
Pumped storage - Closed	3,331	3,331	5,444	6,900
Renewables	**51,030**	**58,370**	**74,840**	**95,984**
Wind - Onshore	31,058	33,916	39,690	48,350
Wind - Offshore	0	0	0	200
Solar thermal - Current	2,300	2,300	2,300	2,300
Solar thermal - Future	0	0	3,500	5,000
Solar photovoltaic - Rooftop	1,931	2,435	3,286	4,903
Solar photovoltaic - Farm	14,651	18,629	24,714	33,501
Other renewables	1,090	1,090	1,350	1,730
Thermal	**27,513**	**26,872**	**26,217**	**21,610**
Coal	536	**0**	0	0
Combined cycle gas turbines	**14,930**	**14,930**	**14,610**	**14,590**
Nuclear	7,117	7,117	7,117	3,040
Other non-renewables	4,930	4,825	4,490	3,980
Batteries y DSR	**1,050**	**1,100**	**2,000**	**3,500**
Batteries	50	100	1,000	2,500
DSR	**1,000**	**1,000**	**1,000**	**1,000**
TOTAL CAPACITY	**100,033**	**106,802**	**125,684**	**145,238**

Finally, detailed results are provided for LOLE and EENS for each CY and TY in Table 14.

Table 14. TY2024, 2025, 2027, 2030. Scenario 0: post-EVA ERAA 2022. Adequacy indicators per climate year.

	TY2024		TY2025		TY2027		TY2030	
CY	LOLE (h/y)	EENS (GWh/y)	LOLE (h/y)	EENS (GWh/y)	LOLE (h/y)	EENS (GWh/y)	LOLE (h/y)	EENS (GWh/y)
1982	0.50	0.42	0.50	0.29	0.00	0.00	0.00	0.00
1983	16.10	60.08	19.60	87.02	11.30	40.47	10.00	39.73
1984	0.80	0.66	0.50	0.08	0.00	0.00	0.00	0.00
1985	23.60	38.01	24.70	48.12	7.00	9.27	7.60	15.94
1986	3.20	2.72	2.40	2.01	0.20	0.18	0.00	0.00
1987	4.50	5.39	4.40	8.78	1.50	1.12	1.00	1.46
1988	6.50	5.41	1.30	0.92	0.00	0.00	0.00	0.00
1989	0.20	0.10	0.60	0.16	0.00	0.00	0.00	0.00
1990	7.10	10.73	10.30	15.58	3.10	5.54	1.40	2.24
1991	3.60	5.22	3.80	7.24	2.30	2.21	2.20	2.34
1992	2.70	0.98	8.80	8.90	0.90	0.23	0.60	0.64
1993	26.70	48.87	26.90	53.18	5.90	5.98	6.80	15.68
1994	3.60	5.87	0.30	0.33	0.00	0.00	0.00	0.00
1995	1.90	1.74	2.40	2.28	0.20	0.29	0.80	0.69
1996	2.50	3.19	3.60	9.45	0.00	0.00	0.00	0.00
1997	0.30	0.28	0.40	0.14	0.00	0.00	0.00	0.00
1998	8.10	13.21	8.00	18.73	3.40	4.62	0.80	1.12
1999	10.50	15.75	18.10	36.30	3.10	4.03	1.80	2.17
2000	1.40	0.81	4.90	7.00	0.00	0.00	0.00	0.00
2001	6.70	6.20	1.70	1.22	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	2.20	3.77	3.00	6.54	2.40	3.46	3.10	4.35
2004	0.20	0.08	0.00	0.00	0.00	0.00	0.00	0.00
2005	10.30	9.55	3.50	2.09	0.10	0.03	0.00	0.00
2006	0.00	0.00	5.00	6.39	2.60	2.86	4.10	7.31
2007	15.10	20.94	13.80	21.49	2.80	2.85	0.90	0.59
2008	6.20	10.75	3.20	8.64	0.70	0.94	0.10	0.08
2009	14.20	30.19	21.90	60.49	9.50	31.18	10.20	44.11
2010	6.20	6.68	6.80	11.31	0.40	0.16	1.40	1.53
2011	0.20	0.36	1.40	1.23	0.00	0.00	0.00	0.00
2012	6.70	12.51	10.90	17.01	4.50	8.65	2.50	3.04
2013	4.20	6.86	4.20	6.95	2.90	3.06	2.70	5.76
2014	0.20	0.25	0.10	0.01	0.10	0.01	0.00	0.00
2015	0.70	0.58	1.40	1.11	0.00	0.00	0.00	0.00
2016	0.20	0.11	0.80	0.47	0.10	0.08	0.00	0.00
Avg	**5.63**	**9.38**	**6.26**	**12.90**	**1.86**	**3.63**	**1.66**	**4.25**

6.2.2 National adaptations of the post-EVA ERAA 2022 scenario. Focus on the mid-term

As the results in chapter 6.2.1, show, in the post-EVA ERAA 2022 scenario TY2027 and TY2030 show adequacy risk above the reliability standard, under the given scenarios and methodology framework. In this NRAA both elements, methodology and scenario, are investigated in order to evaluate different possible future situations and the derived adequacy risks.

As a first exercise, a different methodological approach for assessing the economic viability of certain units is carried out, due to the fact that in ERAA 2022 edition the EVA part and the Adequacy part were performed by different models. Being the EVA model very complex and demanding in computational resources, some simplifications were introduced to allow for numerical convergence, meaning that the results are the best estimation possible but probably not totally aligned with the adequacy model and bringing close but different results than the ones that a single model would estimate. In fact, in chapter 6.2.1.2 the revenues of the Spanish CCGT generators that were found to be economically viable for the system by the EVA model in ERAA 2022 are shown to have a lack of economic viability problem. Knowing that this approach would be very demanding if introduced in the ERAA process, it has been applied only at national scale in this NRAA to produce a first scenario.

In addition, the conclusions of any analysis are conditioned to the fulfilment of the main assumptions over which they are built. As the horizon gets away from the present moment, uncertainty on all the hypothesis that build up the scenario grows. With this in mind, and regarding the scope of this national assessment, two different scenarios have been produced for TY2027. Both scenarios consider that no additional storage is installed in the Spanish power system, which is a reasonable assumption as no pumped storage nor solar thermal units are under construction and economic viability of stand-alone batteries is still not proved, as the ERAA 2022 EVA showed (no batteries commissioning was foreseen). One scenario gives an idea of the adequacy risks if the post-EVA ERAA 2022 scenario materialized (9 GW of decommissioning if no incentives are put in place) after 2025 and then the commissioning of the storage capacity was delayed or canceled. The other scenario then reassesses the economic viability of the Spanish CCGTs considering that the base case does not include new storage capacity.

The three previously referred scenarios were assessed for TY2027, being the third scenario “post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability” the one considered as central reference scenario and also assessed for TY2030. The results obtained are analyzed in this chapter.

6.2.2.1 TY2027. Scenario 1: post-EVA ERAA 2022 and reassessment of CCGT viability

According to what has been shown in chapter 6.2.1.2, remaining Spanish CCGT after the EVA performed in ERAA 2022 would be slightly unprofitable. If the iterative approach is applied, the economic equilibrium is reached at an amount of 12,978 MW instead of 14,610 MW. With this additional 1.6 GW decommissioning, LOLE in TY2027 would rise from 1.86 h/y to 3.83 h/y, both values already above the considered reliability standard. It is common that when power systems face adequacy issues they grow in a non-linear way, this meaning that a small change in resource capacities can highly impact the adequacy indicators, as proven in this scenario.

Figure 39 shows the evolution of the net profit of the Spanish CCGT units in the different iterations that have been performed. The first iteration (2027_1_O1s_14600) aims to benchmark the reliability standard and the profitability of units when trespassing the EVA results in a unit-by-unit basis, instead of homogeneous capacity derating performed in ERAA 2022 (2027_0_O10s_14610). Very similar results can be observed, both in terms of adequacy and profitability, confirming that the unit-by-unit investment decision can be used for this assessment, probably being more representative in this iterative EVA approach than the linear derating applied in ERAA since the EVA model was technology-aggregated. This is specifically reflected in Table 15.

After this successful benchmark, several iterations were performed gradually reducing the available number of CCGT units, based on the profitability obtained in the first iteration. The economic equilibrium (all available generators are profitable) is reached between iterations 13,400 MW (2027_1_O1s_13400) (some are non-profitable) and 13,000 MW (2027_1_O1s_13000) (none are non-profitable), resulting in 12,978 MW of CCGT.

When iteration 13,000 MW is rerun using 10 forced outage patterns (2027_1_O10s_13000) instead of the single pattern used for the iterative process, it can be observed that results are quite similar in terms of profitability, LOLE and ENS, thus confirming the validity of the chosen approach regarding the use of a single forced outage pattern for the iterative process. This is specifically reflected in Table 16.

In the remaining scenarios the original post-EVA simulation will not be shown. Also, for the sake of simplicity, the final iteration rerun with 10 samples will not be shown when assessing the economic equilibrium, but only when adequacy is analyzed. However, in Figure 39 they are shown for full comprehension of the process followed. An additional iteration with all existing CCGTs capacity available (24,500 MW) is always shown to confirm that if all the units were available the Spanish peninsular power system would not have adequacy risks above the reliability standard.

Regarding the adequacy indicators of this scenario, the main statistical metrics are included in Table 17. For more detail on adequacy indicators per climate year please refer to Table 19.

Table 15. Impact of using unit-by-unit approach for NRAA

Property	Linear derating (ERAA)	Unit-by-unit (NRAA)
LOLE (h/y)	1.86	1.74
ENS (GWh/y)	3.63	3.6

Table 16. Impact of using 1 forced outage pattern for iterative process.

Property	1 forced outage pattern (economic assessment)	10 forced outage pattern (adequacy assessment)
LOLE (h/y)	4.14	3.83
ENS (GWh/y)	8.06	8.24

Table 17. TY2027. Scenario 1: post-EVA ERAA 2022 and reassessment of CCGT viability. Adequacy indicators statistics.

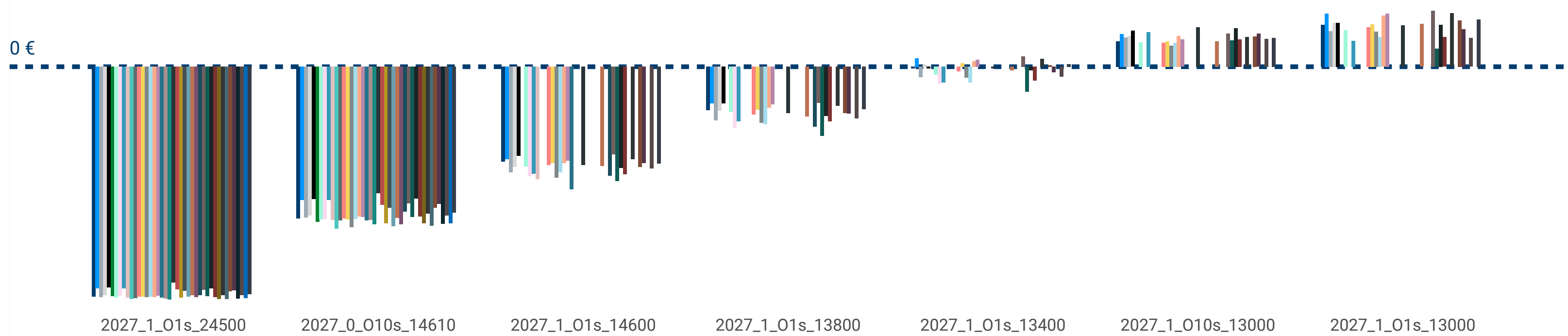
Attribute	LOLE (h/y)	EENS (GWh/y)
Min	0.00	0.00
Max	15.20	60.90
Avg	3.83	8.23
P50	2.00	2.30
P95	14.30	32.40

Figure 39. TY2027. Scenario 1: post-EVA ERAA 2022 and reassessment of CCGT viability. Iterative EVA results.

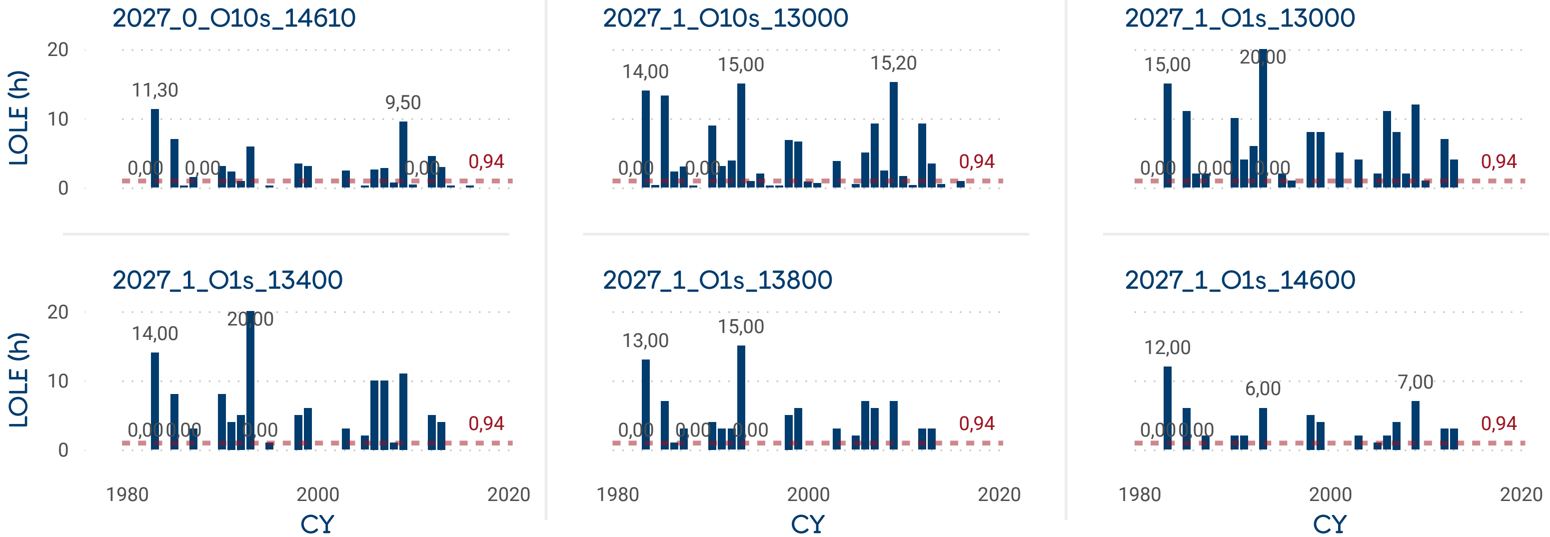
Installed capacity (MW)

case	CCGT
2027_0_O10s_14610	14.610
2027_1_O10s_13000	12.978
2027_1_O1s_13000	12.978
2027_1_O1s_13400	13.388
2027_1_O1s_13800	13.801
2027_1_O1s_14600	14.624
2027_1_O1s_24500	24.499

Relative net profit of Spanish peninsular CCGTs units



Adequacy indicators: LOLE by CY

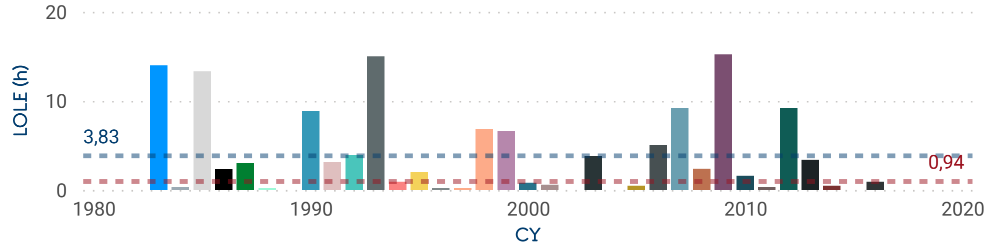


Adequacy indicators: LOLE and EENS

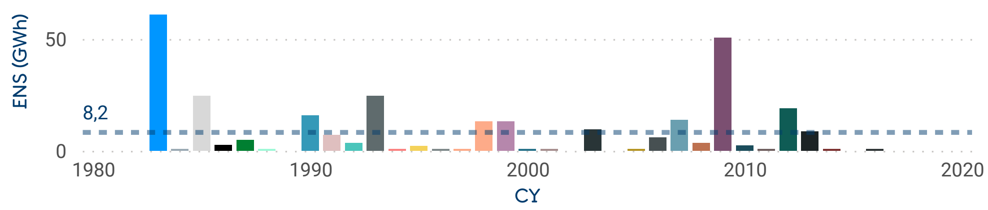
case	LOLE - (h) by CY	ENS - (GWh) by CY
2027_0_O10s_14610	1,86	3,63
2027_1_O10s_13000	3,83	8,24
2027_1_O1s_13000	4,14	8,06
2027_1_O1s_13400	3,43	6,42
2027_1_O1s_13800	2,60	5,22
2027_1_O1s_14600	1,74	3,60
2027_1_O1s_24500		0,00

Figure 40. TY2027. Scenario 1: post-EVA ERAA 2022 and reassessment of CCGT viability. Economic dispach results.

Adequacy indicators: LOLE by CY



Adequacy indicators: EENS by CY



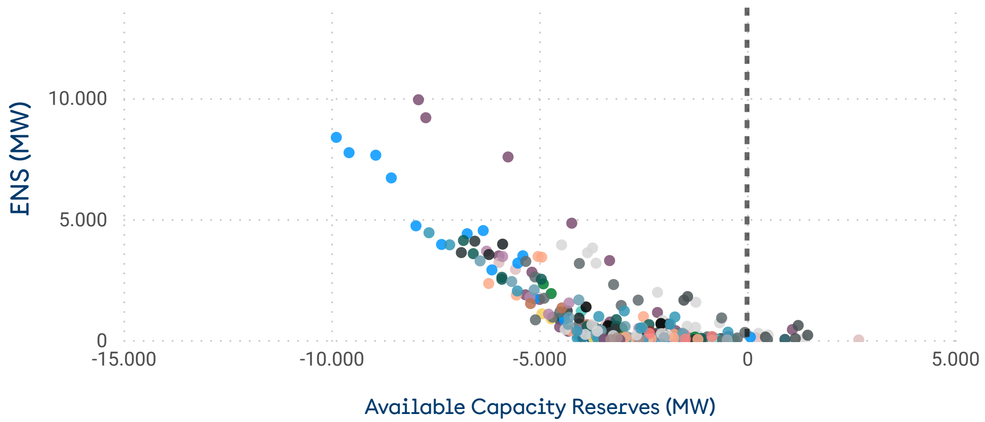
Adequacy indicators: LOLE monthly distribution (h)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2027_1_010s_13000	1,28	0,62						0,01			0,64	1,29	3,83

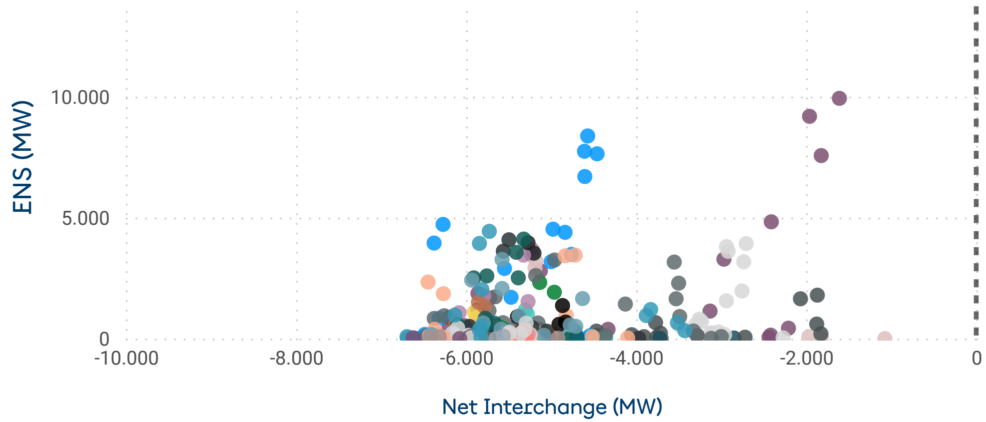
Adequacy indicators: EENS monthly distribution (GWh)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2027_1_010s_13000	2,86	2,04						0,00			1,00	2,34	8,24

Cross border contribution: available capacity reserves



Cross border contribution: net interchange



CY 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

Due to the high variability observed across the different climate years in the adequacy indicators Figure 40 with more details is included and analyzed. It shows the distribution of total yearly LOLE and ENS indicators by climate year, their monthly distribution and also the hourly distribution of the ENS depending on the available capacity reserves and the net interchange.

When analyzing the adequacy indicators of the iteration defining the final scenario (2027_1_010s_13000), LOLE reaches 3.83 h/y and EENS is 8.24 GWh/y, being winter (November, December, January, February) the riskiest period from an adequacy perspective, although non-zero very low values are observed in August for a specific climatic year. When estimating the mean vale of the hourly energy volume that would not be met during those 3.83 hours, a volume of 2.15 GWh is obtained. However, looking at the hourly details for the different climatic years (average of 10 forced outage patterns) there are specific hours in which a maximum of 9.93 GWh could be at risk.

Looking at the impact of the interconnections and cross border contribution, the Spanish system is always importing when there is energy not served, and it also can be noted that in general the volume of ENS grows considerably when the total cross border contribution is exhausted.

As a conclusion, in TY2027 adequacy risks would rise well above the reliability standard in the case that economic equilibrium for CCGTs was slightly different from the one found in the post-EVA ERAA 2022 scenario because the situation already showed adequacy risks, that would grow in a non-linear way.

The differences with the post-EVA ERAA 2022 scenario in terms of installed capacities are shown in Table 18. Capacities affected NRAA (only CCGT) are highlighted.

Table 18. TY2027. Scenario 1: post-EVA ERAA 2022 and reassessment of CCGT viability. Installed capacity.

Installed capacities (MW)	post-EVA ERAA 2022	NRAA Scenario 1
Hydro	**22,627**	**22,627**
Run of river	3,528	3,528
Reservoir	10,972	10,972
Pumped storage - Open	2,683	2,683
Pumped storage - Closed	5,444	5,444
Renewables	**74,840**	**74,840**
Wind - Onshore	39,690	39,690
Wind - Offshore	0	0
Solar thermal - Current	2,300	2,300
Solar thermal - Future	3,500	3,500
Solar photovoltaic - Rooftop	3,286	3,286
Solar photovoltaic - Farm	24,714	24,714
Other renewables	1,350	1,350
Thermal	**26,217**	**24,585**
Coal	0	0
Combined cycle gas turbines	14,610	12,978
Nuclear	7,117	7,117
Other non-renewables	4,490	4,490
Batteries y DSR	**2,000**	**2,000**
Batteries	1,000	1,000
DSR	1,000	1,000
TOTAL CAPACITY	**125,684**	**124,052**

Finally, detailed results are provided for LOLE and EENS for each CY and TY in Table 19.

Table 19. TY2027. Scenario 1: post-EVA ERAA 2022 and reassessment of CCGT viability. Adequacy indicators per climate year.

CY	LOLE (h/y)	EENS (GWh/y)
1982	0.00	0.00
1983	14.00	60.90
1984	0.30	0.10
1985	13.30	24.60
1986	2.30	2.70
1987	3.00	4.80
1988	0.20	0.00
1989	0.00	0.00
1990	8.90	15.80
1991	3.10	7.00
1992	3.90	3.40
1993	15.00	24.60
1994	0.90	0.50
1995	2.00	2.00
1996	0.10	0.00
1997	0.20	0.20
1998	6.80	13.10
1999	6.60	13.00

CY	LOLE (h/y)	EENS (GWh/y)
2000	0.80	0.30
2001	0.60	0.10
2002	0.00	0.00
2003	3.80	9.50
2004	0.00	0.00
2005	0.50	0.40
2006	5.00	6.00
2007	9.20	13.70
2008	2.40	3.50
2009	15.20	50.60
2010	1.60	2.30
2011	0.30	0.10
2012	9.20	19.00
2013	3.40	8.60
2014	0.50	0.60
2015	0.00	0.00
2016	0.90	0.80
Avg	**3.83**	**8.23**

6.2.2.2 TY2027. Scenario 2: post-EVA ERAA 2022 with no new storage commissioning

In this scenario, all the assumptions are the same as the ones of the post-EVA ERAA 2022 scenario, except for the storage capacities in the Spanish peninsular system. The scenario gives an idea of the adequacy risks if the post-EVA ERAA 2022 scenario materialized (9 GW of decommissioning if no incentives are put in place) by 2025 and then the commissioning of the NECP target scenario storage capacity was delayed or canceled.

In this scenario, the adequacy indicators show a very high level of unserved energy reaching 7.14 h/y of LOLE and 15.68 GWh/y of EENS. This scenario shows unacceptable for the Spanish peninsular system, as the reliability standard would be trespassed in 86% of the climatic years (30 out of 35).

Regarding the adequacy indicators of this scenario, the main statistical metrics are included in Table 20. For more detail on adequacy indicators per climate year please refer to Table 22.

Table 20. TY2027. Scenario 2: post-EVA ERAA 2022 swith no new storage commissioning.

Attribute	LOLE (h/y)	EENS (GWh/y)
Min	0.20	0.00
Max	27.40	84.60
Avg	7.14	15.68
P50	4.00	6.70
P95	23.62	58.33

Due to the high variability observed across the different climate years in the adequacy indicators, Figure 41 with more details is included and analyzed. It shows the distribution of total yearly LOLE and ENS indicators by climate year, their monthly distribution and the hourly distribution of the ENS depending on the available capacity reserves and the net interchange.

When analyzing the adequacy indicators of this scenario, LOLE reaches 7.14 h/y and EENS is 15.68 GWh/y, being winter (November, December, January, February) the riskiest period from an adequacy perspective although non-zero values that start to be meaningful are observed in August, July and October for two climatic years. When estimating the mean value of the hourly energy volume that would not be met during those 7.14 hours, a volume of 2.19 GWh is obtained. However, looking at the hourly details for the different climatic years (average of 10 forced outage patterns) there are specific hours in which a maximum of 10.56 GWh could be at risk.

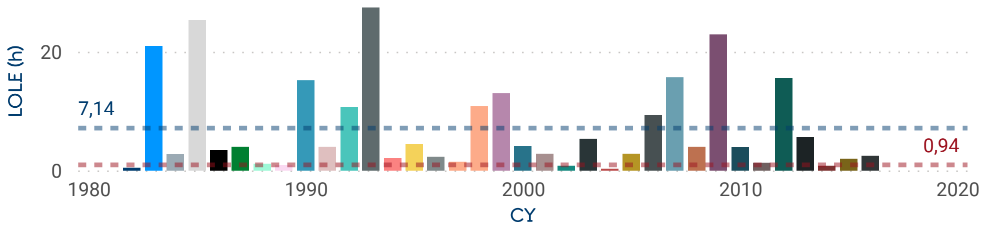
Looking at the impact of the interconnections and cross border contribution, the Spanish system is always importing when there is energy not served, and it also can be noted that in general the volume of ENS grows considerably when the total cross border contribution is exhausted.

From the results obtained for this scenario, the decommissioning of 9 GW of capacity indicated by the EVA and, in addition, the delay or non-commissioning of new storage facilities foreseen in the NECP would be totally unacceptable from a security of supply point of view. Please note that the risks would be even higher if the volume of decommissioned CCGT is the one found in scenario 1 via the iterative approach (11.5 GW), although this situation has not been assessed under this NRAA as the current scenario 2 already shows an extreme risk for adequacy.

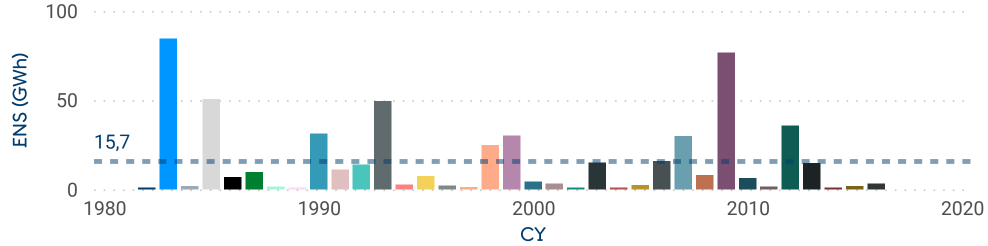
As a conclusion, in TY2027 adequacy risks would totally overstep the reliability standard in the case that the post-EVA ERAA 2022 scenario materialized (9 GW of decommissioning if no incentives are put in place) by 2025 and then the commissioning of the NECP-target scenario storage capacity was delayed or canceled.

Figure 41. TY2027. Scenario 2: post-EVA ERAA 2022 with no new storage commissioning. Economic dispach results.

Adequacy indicators: LOLE by CY



Adequacy indicators: EENS by CY



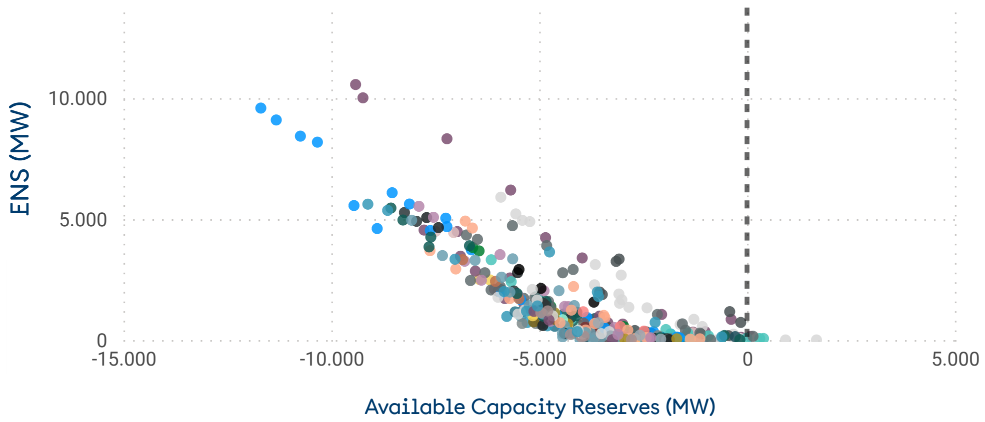
Adequacy indicators: LOLE monthly distribution (h)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2027_2_010s_14610	2,35	0,96					0,01	0,04		0,01	1,25	2,52	**7,14**

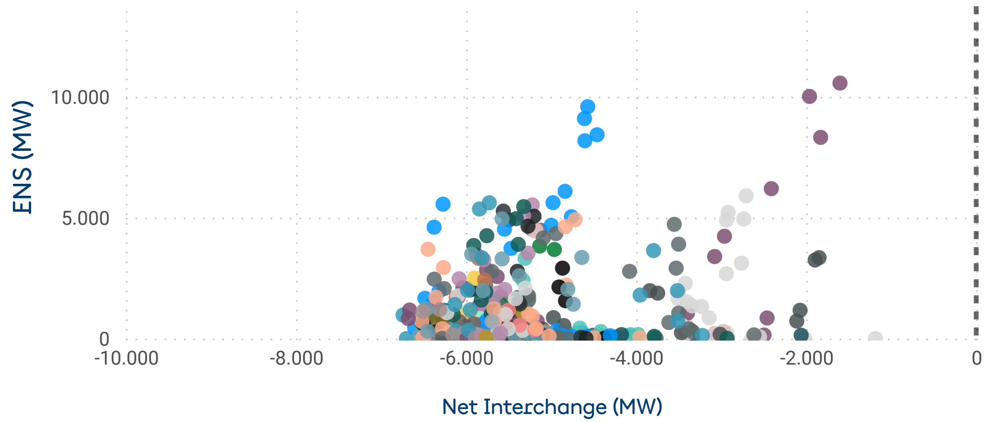
Adequacy indicators: EENS monthly distribution (GWh)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2027_2_010s_14610	5,24	3,11					0,00	0,04		0,01	2,25	5,02	**15,68**

Cross border contribution: available capacity reserves



Cross border contribution: net interchange



CY 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

The differences with the post-EVA ERAA 2022 scenario in terms of installed capacities are shown in Table 21. Capacities affected NRAA (only pumped storage-closed, solar thermal-future and batteries) are highlighted.

Table 21. TY2027. Scenario 2: post-EVA ERAA 2022 with no new storage commissioning. Installed capacity.

Installed capacities (MW)	post-EVA ERAA 2022	NRAA Scenario 2
Hydro	**22,627**	**20,514**
Run of river	3,528	3,528
Reservoir	10,972	10,972
Pumped storage - Open	2,683	2,683
Pumped storage - Closed	5,444	**3,331**
Renewables	**74,840**	**71,340**
Wind - Onshore	39,690	39,690
Wind - Offshore	0	0
Solar thermal - Current	2,300	2,300
Solar thermal - Future	3,500	**0**
Solar photovoltaic - Rooftop	3,286	3,286
Solar photovoltaic - Farm	24,714	24,714
Other renewables	1,350	1,350
Thermal	**26,217**	**26,217**
Coal	0	0
Combined cycle gas turbines	14,610	14,610
Nuclear	7,117	7,117
Other non-renewables	4,490	4,490
Batteries y DSR	**2,000**	**1,000**
Batteries	1,000	**0**
DSR	1,000	1,000
TOTAL CAPACITY	**125,684**	**119,071**

Finally, detailed results are provided for LOLE and EENS for each CY and TY in Table 22.

Table 22. TY2027. Scenario 2: post-EVA ERAA 2022 with no new storage commissioning. Adequacy indicators per climate year.

CY	LOLE (h/y)	EENS (GWh/y)	CY	LOLE (h/y)	EENS (GWh/y)
1982	0.5	0.3	**2000**	**4.1**	4.2
1983	**21**	84.6	**2001**	**2.8**	3.3
1984	**2.7**	1.7	**2002**	0.8	0.5
1985	**25.3**	50.5	**2003**	**5.3**	15
1986	**3.4**	6.7	**2004**	0.2	0
1987	**4**	9.6	**2005**	**2.8**	2.3
1988	**1.1**	1.4	**2006**	**9.4**	15.8
1989	0.9	0.4	**2007**	**15.7**	30
1990	**15.2**	31.3	**2008**	**4**	8
1991	**4**	11.2	**2009**	**22.9**	76.6
1992	**10.7**	13.8	**2010**	**3.9**	6.2
1993	**27.4**	49.4	**2011**	**1.3**	1.6
1994	**2.1**	2.8	**2012**	**15.6**	35.6
1995	**4.4**	7.4	**2013**	**5.6**	14.7
1996	**2.3**	2	**2014**	0.8	0.9
1997	**1.5**	1.2	**2015**	**2**	1.7
1998	**10.8**	24.8	**2016**	**2.5**	3.2
1999	**13**	30	**Avg**	**7.14**	**15.68**

6.2.2.3 TY2027. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability

This third scenario is produced in order to have a scenario in economic equilibrium after assuming the delay or non-commissioning of new storage capacity and should be taken as the central reference scenario for TY2027 in this NRAA. A different economic viability assessment methodology from the one used in the ERAA 2022 edition is used, as already explained in chapters 4.2 and 6.2.2.1. This iterative EVA is carried out only for Spanish peninsular system, considering the post-EVA ERAA 2022 scenario in the rest of the geographical perimeter due to the scope of this assessment, and only used to assess the economic viability of the existing Spanish CCGTs.

The economic equilibrium (all available generators are profitable) is reached between iterations 15,900 MW (2027_3_O1s_15900) (some are non-profitable) and 15,500 MW (2027_3_O1s_15500) (none are non-profitable). In this situation, LOLE in TY2027 would rise to 4.76 h/y, well above the considered reliability standard of 0.94 h/y, and EENS would be 10.12 GWh/y.

Figure 42 shows the revenues of each CCGT generator depending on the volume of CCGT installed capacity. As an example, when all CCGTs are considered (which corresponds to 24,499 MW of installed capacity), none of them are profitable. By reducing the units available, the final value in economic equilibrium is found to be at 15,530 MW (9 GW decommissioned), corresponding to iteration labelled as 2027_3_O1s_15500.

Regarding the adequacy indicators of this scenario, the main statistical metrics are included in Table 23. For more detail on adequacy indicators per climate year please refer to Table 25.

Table 23. TY2027. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Adequacy indicators statistics.

Attribute	LOLE (h/y)	EENS (GWh/y)
Min	0.00	0.00
Max	18.50	65.80
Avg	4.76	10.12
P50	2.60	3.70
P95	17.33	39.45

Due to the high variability observed across the different climate years in the adequacy indicators Figure 43 with more details is included and analyzed. It shows the distribution of total yearly LOLE and ENS indicators by climate year, their monthly distribution and the hourly distribution of the ENS depending on the available capacity reserves and the net interchange.

When analyzing the adequacy indicators of this final iteration (15,530 MW), LOLE reaches 4.76 h/y and EENS is 10.12 GWh/y, being winter (November, December, January, February) the riskiest period from an adequacy perspective although non-zero values that start to be meaningful are observed in August and October for two climatic years. When estimating the mean value of the hourly energy volume that would not be met during those 4.76 hours, a volume of 2.13 GWh is obtained. However, looking at the hourly details for the different climatic years (average of 10 forced outage patterns) there are specific hours in which a maximum of 9.91 GWh could be at risk.

Looking at the impact of the interconnections and cross border contribution, the Spanish system is always importing when there is energy not served, and it also can be noted that in general the volume of ENS grows considerably when the total cross border contribution is exhausted.

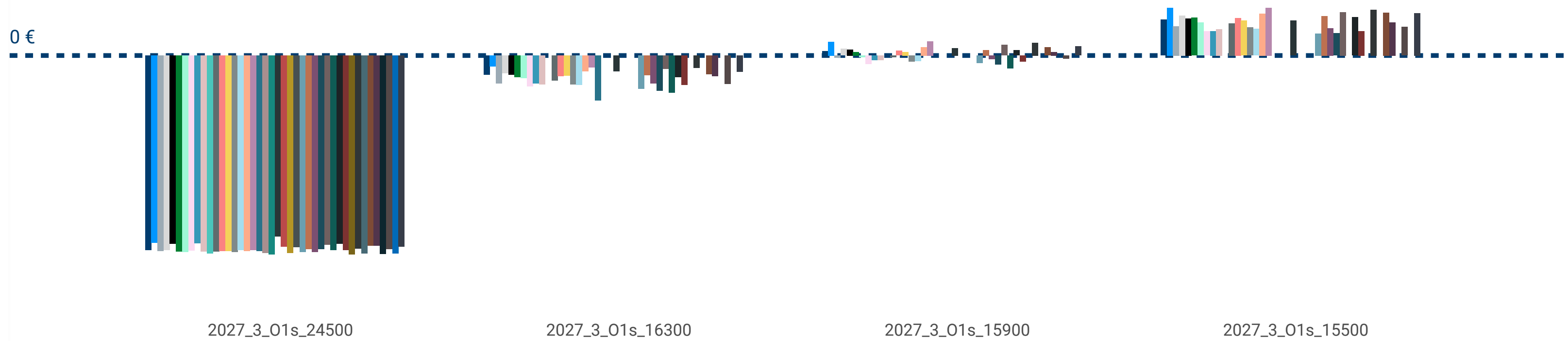
As a conclusion, in TY2027 adequacy risks would rise well above the reliability standard in the case that the commissioning of the NECP-target scenario storage capacity was delayed or canceled even if CCGTs would be at their economic equilibrium capacity.

Figure 42. TY2027. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Iterative EVA results.

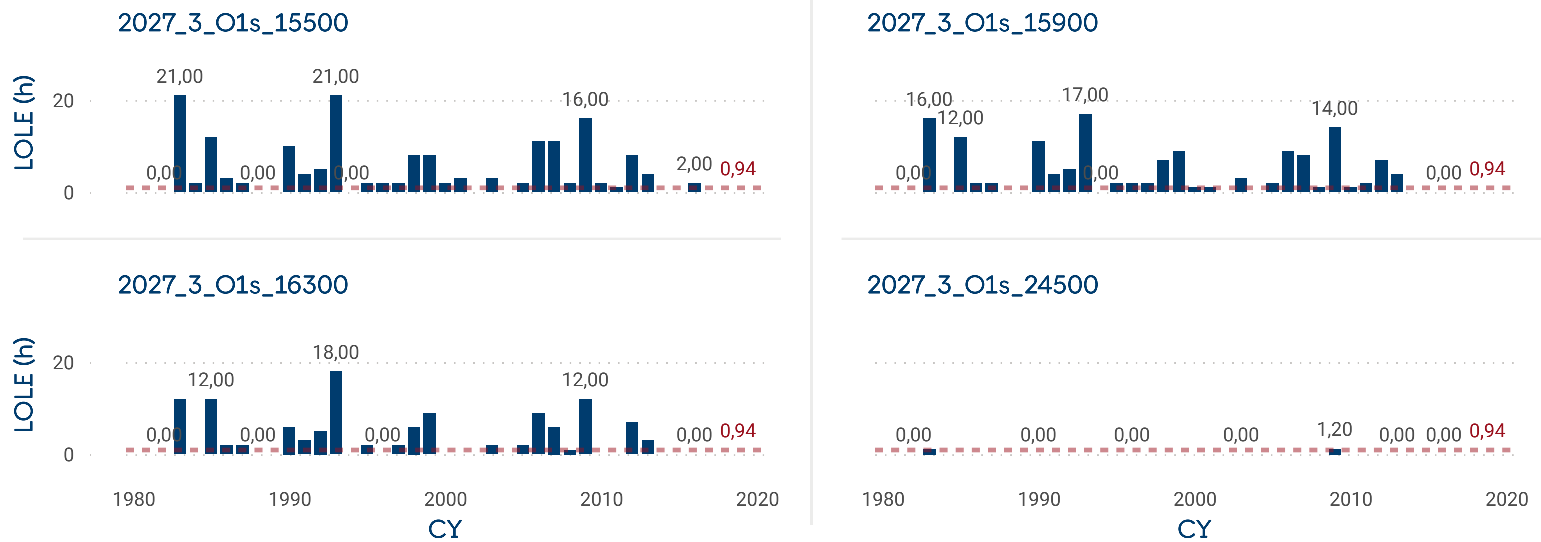
Installed capacity (MW)

case	CCGT
2027_3_O1s_15500	15.530
2027_3_O1s_15900	15.921
2027_3_O1s_16300	16.324
2027_3_O1s_24500	24.499

Relative net profit of Spanish peninsular CCGTs units



Adequacy indicators: LOLE by CY



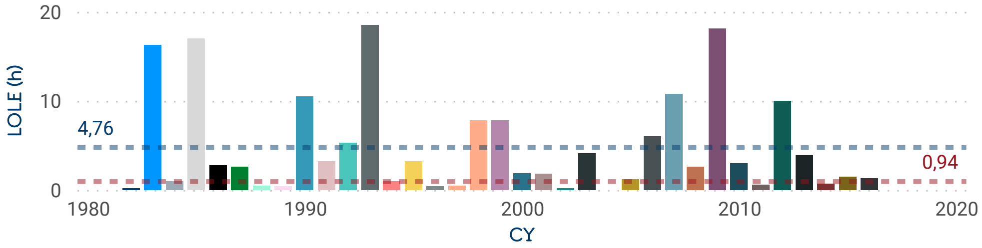
Adequacy indicators: LOLE and EENS

case	LOLE - (h) by CY	ENS - (GWh) by CY
2027_3_O1s_15500	4,83	9,79
2027_3_O1s_15900	4,11	8,28
2027_3_O1s_16300	3,46	6,92
2027_3_O1s_24500	0,07	0,06

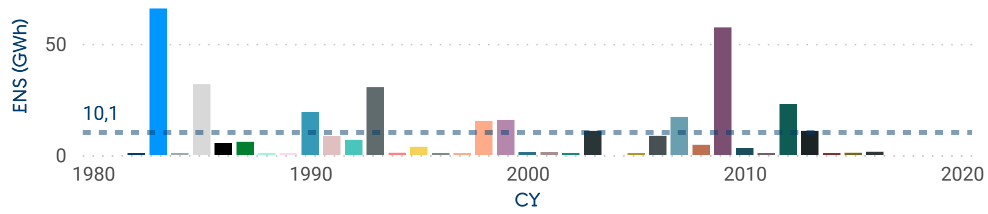
red eléctrica

Figure 43. TY2027. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Economic dispach results.

Adequacy indicators: LOLE by CY



Adequacy indicators: EENS by CY



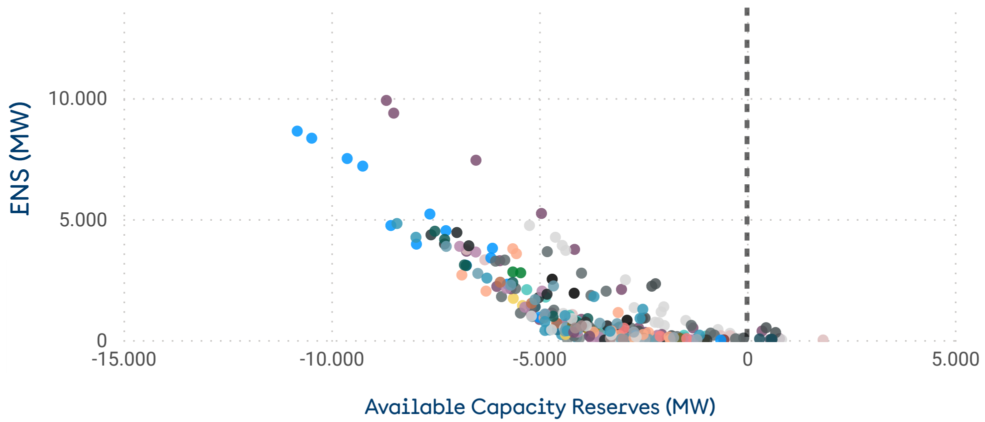
Adequacy indicators: LOLE monthly distribution (h)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2027_3_010s_15500	1,61	0,68						0,02		0,01	0,77	1,67	**4,76**

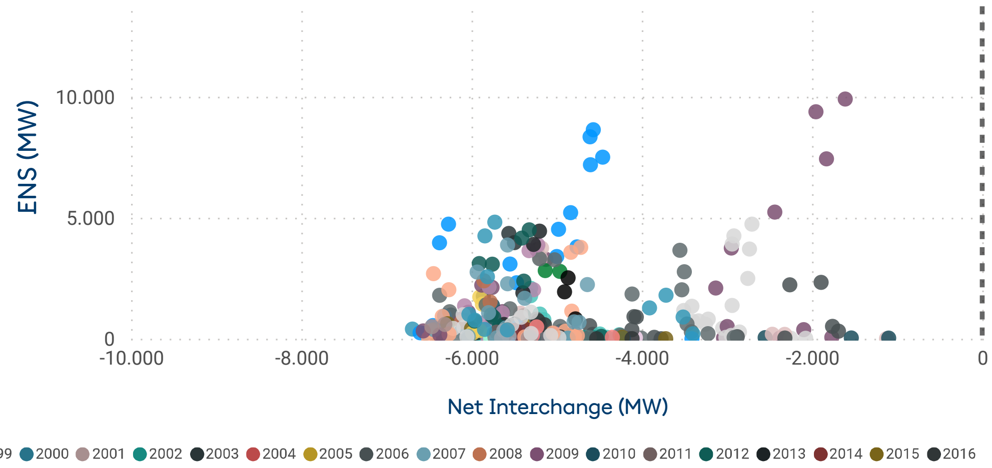
Adequacy indicators: EENS monthly distribution (GWh)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2027_3_010s_15500	3,54	2,27						0,01		0,00	1,30	2,99	**10,12**

Cross border contribution: available capacity reserves



Cross border contribution: net interchange



The differences with the post-EVA ERAA 2022 scenario in terms of installed capacities are shown in Table 24. Capacities affected NRAA (only pumped storage-closed, solar thermal-future, batteries and CCGT) are highlighted.

Table 24. TY2027. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Installed capacities.

Installed capacities (MW)	post-EVA ERAA 2022	NRAA Scenario 2
Hydro	**22,627**	**20,514**
Run of river	3,528	3,528
Reservoir	10,972	10,972
Pumped storage - Open	2,683	2,683
Pumped storage - Closed	5,444	**3,331**
Renewables	**74,840**	**71,340**
Wind - Onshore	39,690	39,690
Wind - Offshore	0	0
Solar thermal - Current	2,300	2,300
Solar thermal - Future	3,500	**0**
Solar photovoltaic - Rooftop	3,286	3,286
Solar photovoltaic - Farm	24,714	24,714
Other renewables	1,350	1,350
Thermal	**26,217**	**27,137**
Coal	0	0
Combined cycle gas turbines	14,610	**15,530**
Nuclear	7,117	7,117
Other non-renewables	4,490	4,490
Batteries y DSR	**2,000**	**1,000**
Batteries	1,000	**0**
DSR	1,000	1,000
TOTAL CAPACITY	**125,684**	**119,991**

Finally, detailed results are provided for LOLE and EENS for each CY and TY in Table 25.

Table 25. TY2027. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Adequacy indicators per climate year.

CY	LOLE (h/y)	EENS (GWh/y)	CY	LOLE (h/y)	EENS (GWh/y)
1982	0.1	0	**2000**	**1.9**	1.3
1983	**16.3**	65.8	**2001**	**1.8**	1.2
1984	**1**	0.5	**2002**	0.2	0.1
1985	**17**	31.8	**2003**	**4.1**	10.8
1986	**2.8**	5.3	**2004**	0	0
1987	**2.6**	5.9	**2005**	**1.2**	0.7
1988	0.5	0.2	**2006**	**6**	8.7
1989	0.4	0.2	**2007**	**10.8**	17.2
1990	**10.5**	19.5	**2008**	**2.6**	4.7
1991	**3.2**	8.5	**2009**	**18.1**	57.3
1992	**5.3**	6.9	**2010**	**3**	3
1993	**18.5**	30.4	**2011**	0.6	0.4
1994	**1**	1	**2012**	**10**	23
1995	**3.2**	3.7	**2013**	**3.9**	10.8
1996	0.4	0.2	**2014**	0.7	0.8
1997	0.5	0.6	**2015**	**1.5**	1.1
1998	**7.8**	15.3	**2016**	**1.3**	1.4
1999	**7.8**	15.8	**Avg**	**4.76**	**10.12**

6.2.2.4 TY2030. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability

The same assumption (delay or non-commissioning of new storage capacity) and methodology (economic equilibrium) used to produce scenario 3 for TY2027 have been also applied for TY2030.

The economic equilibrium (all available generators are profitable) is reached between iterations 20,300 MW (2030_3_01s_20300) (some are non-profitable) and 19,500 MW (2030_3_01s_19500) (none are non-profitable). In this situation, LOLE in TY2030 would keep at 2.34 h/y, above the reliability standard of 0.94 h/y, and EENS would be 5.65 GWh/y.

The following figure shows the revenues of each CCGT generator depending on the volume of CCGT installed capacity. By reducing the units available, the final value in economic equilibrium is found to be at 19,516 MW (5 GW decommissioned), corresponding to iteration labelled as 2030_3_01s_19500.

Regarding the adequacy indicators of this scenario, the main statistical metrics are included in Table 26. For more detail on adequacy indicators per climate year please refer to Table 28.

Table 26. TY2030. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Adequacy indicators statistics.

Attribute	LOLE (h/y)	EENS (GWh/y)
Min	0.00	0.00
Max	12.70	49.40
Avg	2.34	5.65
P50	0.40	0.40
P95	10.85	28.57

Due to the high variability observed across the different climate years in the adequacy indicators, Figure 45 with more details are included and analyzed. It shows the distribution of total yearly LOLE and ENS indicators by climate year, their monthly distribution and the hourly distribution of the ENS depending on the available capacity reserves and the net interchange.

When analyzing the adequacy indicators of this final iteration (19,516 MW), LOLE reaches 2.34 h/y and EENS is 5.65 GWh/y, being winter (November, December, January, February) the only risky period from an adequacy perspective. When estimating the mean value of the hourly energy volume that would not be met during those 2.34 hours, a volume of 2.41 GWh is obtained. However, looking at the hourly details for the different climatic years (average of 10 forced outage patterns) there are specific hours in which a maximum of 10.96 GWh could be at risk.

Looking at the impact of the interconnections and cross border contribution, the Spanish system is always importing when there is energy not served, and it also can be noted that in general the volume of ENS grows considerably when the total cross border contribution is exhausted, which is less remarked in this scenario, which accounts for the expected commissioning of the Gulf of Biscay project.

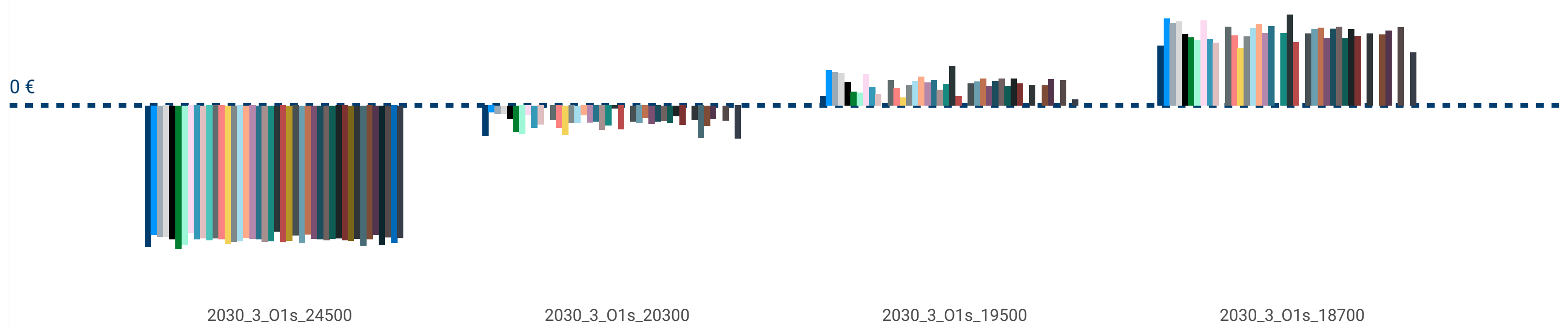
As a conclusion, in TY2030 adequacy risks would also be above the reliability standard in the case that the commissioning of the NECP-target scenario storage capacity was delayed or canceled and if CCGTs would be at their economic equilibrium capacity.

Figure 44. TY2030. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Iterative EVA results.

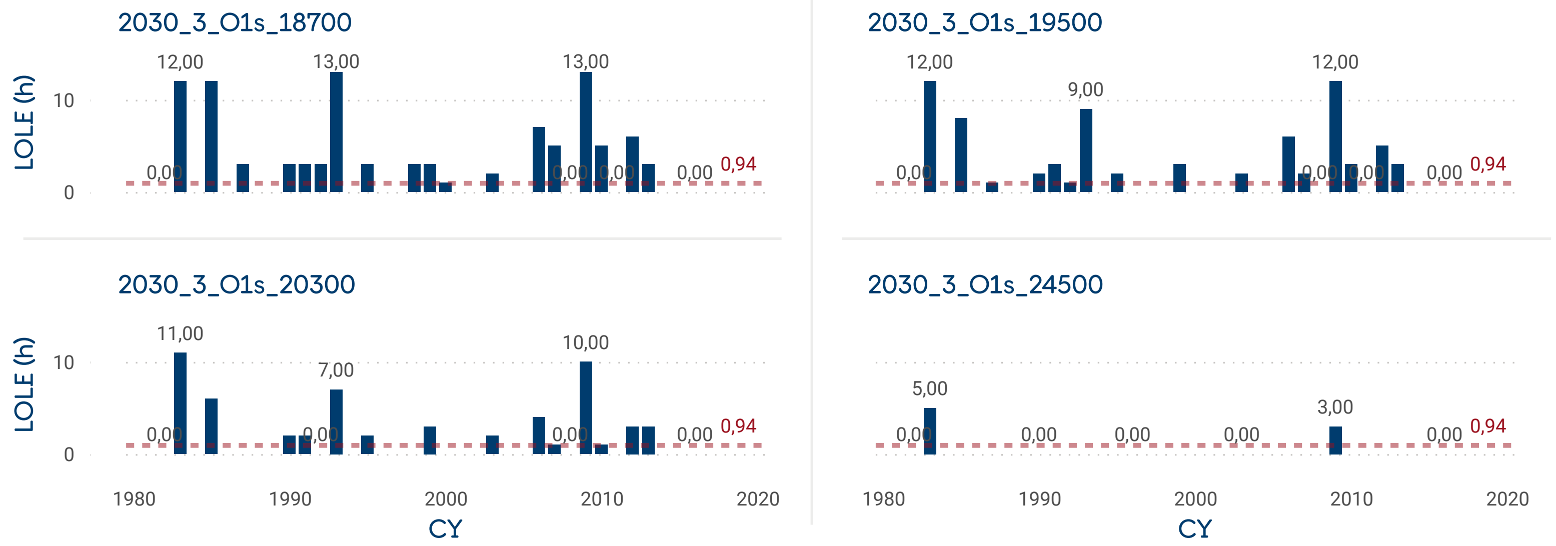
Installed capacity (MW)

case	CCGT
2030_3_O1s_18700	18.700
2030_3_O1s_19500	19.516
2030_3_O1s_20300	20.301
2030_3_O1s_24500	24.499

Relative net profit of Spanish peninsular CCGTs units



Adequacy indicators: LOLE by CY

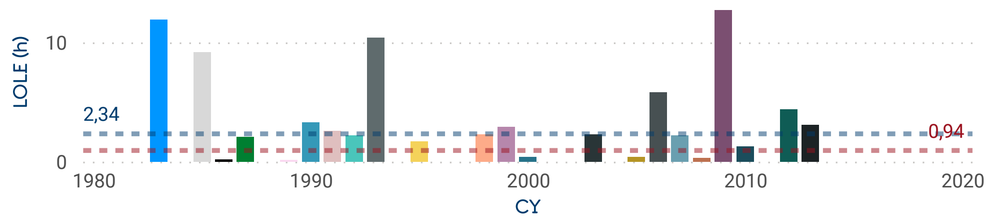


Adequacy indicators: LOLE and EENS

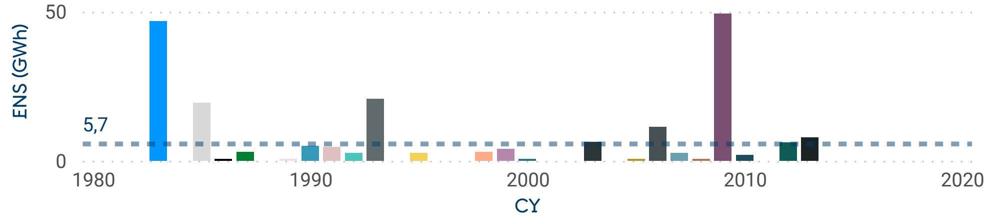
case	LOLE - (h) by CY	ENS - (GWh) by CY
2030_3_O1s_18700	2,86	7,10
2030_3_O1s_19500	2,11	4,93
2030_3_O1s_20300	1,63	3,58
2030_3_O1s_24500	0,23	0,60

Figure 45. TY2030. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Economic dispach results.

Adequacy indicators: LOLE by CY



Adequacy indicators: EENS by CY



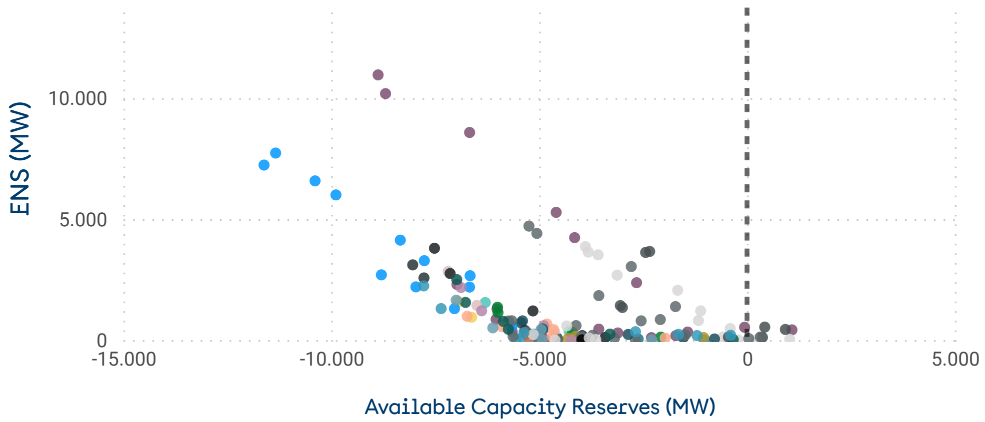
Adequacy indicators: LOLE monthly distribution (h)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2030_3_010s_19500	0,94	0,58									0,29	0,54	2,34

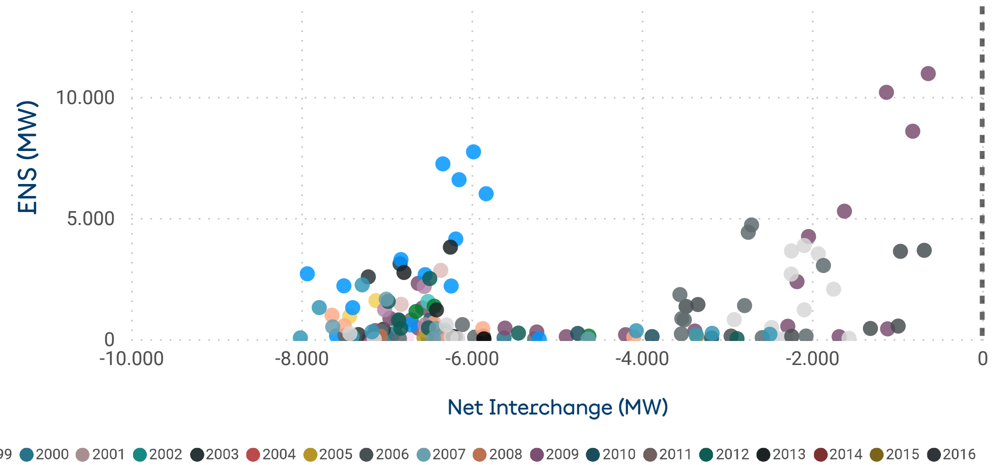
Adequacy indicators: EENS monthly distribution (GWh)

case	1	2	3	4	5	6	7	8	9	10	11	12	Total
2030_3_010s_19500	2,50	1,75									0,61	0,79	5,65

Cross border contribution: available capacity reserves



Cross border contribution: net interchange



The differences with the post-EVA ERAA 2022 scenario in terms of installed capacities are shown in Table 27. Capacities affected NRAA (only pumped storage-closed, solar thermal-future, batteries and CCGT) are highlighted.

Table 27. TY2030. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Installed capacities.

Installed capacities (MW)	post-EVA ERAA 2022	NRAA Scenario 2
Hydro	**24,144**	**20,575**
Run of river	3,589	3,589
Reservoir	10,972	10,972
Pumped storage - Open	2,683	2,683
Pumped storage - Closed	6,900	3,331
Renewables	**95,984**	**90,984**
Wind - Onshore	48,350	48,350
Wind - Offshore	200	200
Solar thermal - Current	2,300	2,300
Solar thermal - Future	5,000	0
Solar photovoltaic - Rooftop	4,903	4,903
Solar photovoltaic - Farm	33,501	33,501
Other renewables	1,730	1,730
Thermal	**21,610**	**26,536**
Coal	0	0
Combined cycle gas turbines	14,590	19,516
Nuclear	3,040	3,040
Other non-renewables	3,980	3,980
Batteries y DSR	**3,500**	**1,000**
Batteries	2,500	0
DSR	1,000	1,000
TOTAL CAPACITY	**142,738**	**139,095**

Finally, detailed results are provided for LOLE and EENS for each CY and TY in Table 28.

Table 28. TY2030. TY2030. Scenario 3: post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability. Adequacy indicators per climate year.

CY	LOLE (h/y)	EENS (GWh/y)	CY	LOLE (h/y)	EENS (GWh/y)
1982	0.00	0.00	**2000**	0.40	0.40
1983	11.90	46.70	**2001**	0.00	0.00
1984	0.00	0.00	**2002**	0.00	0.00
1985	9.20	19.40	**2003**	2.30	6.30
1986	0.20	0.00	**2004**	0.00	0.00
1987	2.10	2.90	**2005**	0.40	0.30
1988	0.00	0.00	**2006**	5.80	11.30
1989	0.10	0.00	**2007**	2.20	2.60
1990	3.30	5.00	**2008**	0.30	0.10
1991	2.60	4.60	**2009**	12.70	49.40
1992	2.20	2.70	**2010**	1.30	1.90
1993	10.40	20.80	**2011**	0.00	0.00
1994	0.00	0.00	**2012**	4.40	6.10
1995	1.70	2.50	**2013**	3.10	7.90
1996	0.00	0.00	**2014**	0.00	0.00
1997	0.00	0.00	**2015**	0.00	0.00
1998	2.30	2.90	**2016**	0.00	0.00
1999	2.90	4.00	**Avg**	**2.34**	**5.65**

6.2.3 CCGT LOLE threshold as reliability standard

Finally, the results of the simulations performed considering as available all the currently existing CCGT capacity (24,500 MW) in the scenarios assessed in this NRAA are summarized in the following table. For TY 2027 and 2030, these simulations were carried out as the starting point of the iterative EVA process. For TY 2024 and 2025, the simulations have been performed in the post-EVA ERAA 2022 scenario. All the simulations were carried out using 1 forced outage pattern.

These results show that currently existing CCGT capacity (24,500 MW) is sufficient to guarantee the LOLE threshold set for this reference technology (0.94 h/y) under the given VOLL and CONE/CORP values, confirming that this LOLE threshold is valid as the target reliability standard for the Spanish peninsular power system.

Table 29. Summary of target years, scenarios and adequacy indicators when all the currently existing CCGT capacity (24,500 MW) is considered to be available

TY	Scenario	LOLE (h/y)	EENS (GWh/y)
2024	post-EVA ERAA 2022 (Red Eléctrica)	0	0
2025	post-EVA ERAA 2022 (Red Eléctrica)	0.06	0.09
2027	post-EVA ERAA 2022 and reassessment of CCGT viability	0	0
	post-EVA ERAA 2022 with no new storage commissioning	0.07	0.06
	post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability	0.07	0.06
2030	post-EVA ERAA 2022 with no new storage commissioning and reassessment of CCGT viability	0.23	0.6

*LOLE values below the considered reliability standard (0.94 h/y) are colored in green.

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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.

Under the given scenarios and methodology framework following the considerations set out by the Regulation EU 2019/943, 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. Both the ERAA and this NRAA show that this generation is needed to ensure proper adequacy levels.

Target year 2024:

- If ERAA 2022 would have been able to deliver results for 2024, adequacy risks above the reliability standard would have been identified for the Spanish peninsular system, as shown in the results included in this NRAA (LOLE of 5.63 h/y, being the reliability standard LOLE < 0.94 h/y).

Target year 2025:

- ERAA 2022 already shows adequacy risks for 2025 in the theoretical scenario which would result from the decommissioning of the economically unviable units, fully supported by the Spanish system operator in this NRAA (LOLE of 6.26 h/y).

Target year 2027:

- In 2027 adequacy risks rise above the reliability standard. The ERAA results already showed adequacy risks, that would grow in a non-linear way with slightly different capacities (LOLE of 3.83 h/y).
- In 2027 adequacy risks surpass by several times the reliability standard in the case that the post-EVA ERAA 2022 scenario materialized (9 GW of decommissioning if no incentives are put in place) by 2025 and then the commissioning of the NECP target scenario storage capacity was delayed or canceled (LOLE of 7.14 h/y).
- In 2027 adequacy risks would rise well above the reliability standard in the case that the commissioning of the NECP target scenario storage capacity was delayed or canceled even if CCGTs would be at their economic equilibrium capacity (LOLE of 4.76 h/y).

Target year 2030:

- ERAA 2022 already shows adequacy risks for 2030 above the reliability standard.
- In 2030 adequacy risks are above the reliability standard also in the case that the commissioning of the NECP target scenario storage capacity was delayed or canceled and if CCGTs would be at their economic equilibrium capacity (LOLE of 2.34 h/y).

The benchmark models used in this NRAA for 2025, 2027 and 2030 produce results aligned with those produced by the ERAA 2022 models.

In all the scenarios the variability of the expected LOLE for different climatic year is very high, with several individual values well above the reliability standard.

The Spanish peninsular 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.

8. Glossary of acronyms

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

Table 30. Glossary of acronyms.

Acronym	Stands for
ACER	Agency for the Cooperation of Energy Regulators
BZ	Bidding Zone
CCGT	Combined Cycle Gas Turbine
CEP	Clean Energy Package
CM	Capacity Mechanism
CONE	Cost Of New Entry
CS	Curtailment Sharing
CY	Climate Year
DSR	Demand Side Response
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
HMMCP	Harmonized Maximum and Minimum Clearing Prices
HP	Hurdle Premium
LLD	Load of Loss Duration

Acronym	Stands for
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
XB	Cross Border

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