APE

APPUNTI DI ENERGIA

ADEQUACY

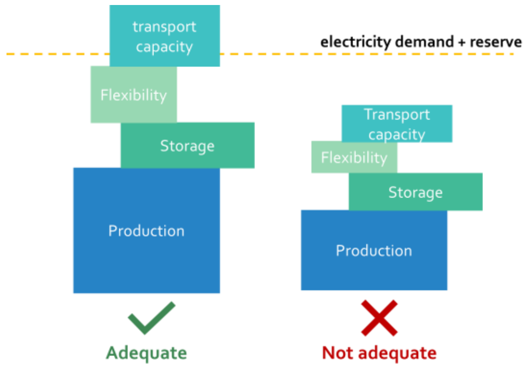
September 2025

What is it about?

Adequacy consists in ensuring that **the available production capacity**, including imports from abroad, storage, and flexibility, **is sufficient to meet energy demand at all times** and in all zones of the country, including an appropriate reserve margin to cope with potential contingencies (such as errors in demand and production forecasting and possible generator failures).

TSO – Transmission System Operator. The Italian TSO is Terna.

Transmission System Operators (TSOs) must ensure, at every moment, that the energy demanded by consumers is always balanced by the energy produced. If the resources available to an electrical system are not adequate, load shedding may occur, which, in the worst-case scenario, can lead to blackouts.



ENTSO-E - European Network of Transmission System Operators, rappresenta 40 TSO di 36 paesi in tutta Europa.

ENTSO-E

ERAA

Using the definition adopted by ENTSO-E, within the framework of the pan-European methodology ERAA - European Resource Adequacy Assessment:

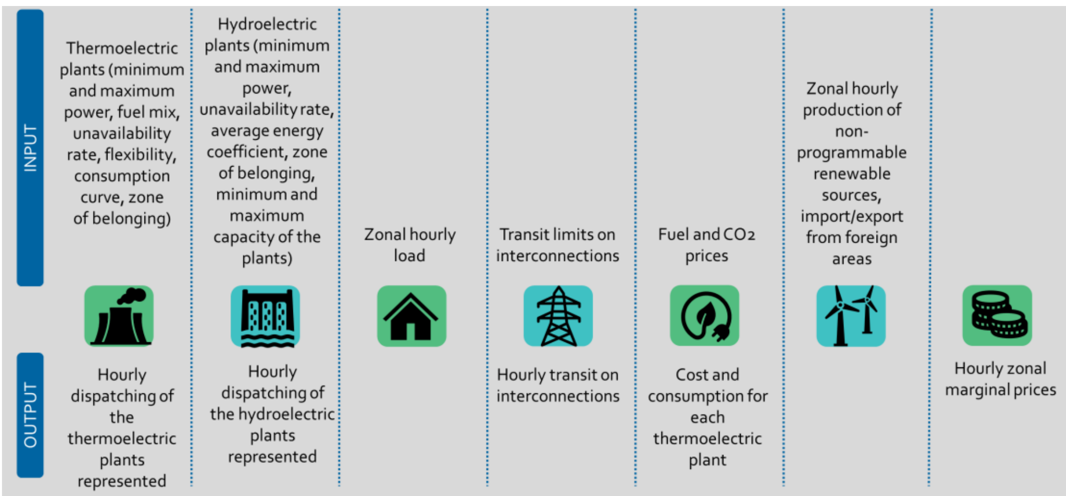
> *Adequacy is a measure of the power system's ability to maintain security of supply across a very large number of possible future system states, due to various plausible weather conditions and random failures of conventional power plants and related network elements.*

The topic of adequacy is becoming increasingly relevant as some thermoelectric plants are reaching the end of their lifecycle or will go out of service due to policy forecasts, and non-programmable renewable sources, by their nature, cannot ensure the same level of availability as programmable generation.

Evaluate the electrical system

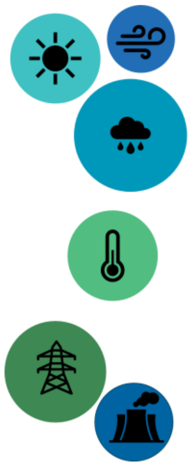
Adequacy is assessed by simulating the operation of the electricity system for a given energy scenario, in order to assess the number of hours in a year in which the system fails to cover the demand. The main inputs and outputs of a scenario are as follows.

Energy scenarios are the main tools able to represent the complexity of the interconnections of the energy system with the economic and environmental dimensions, as well as to evaluate the impacts of objectives and policies according to multiple aspects and at different levels of detail.



Calculation methods

For adequacy assessments there is a need for a methodology that is robust to those specific sources of uncertainty that may alter available generation or electricity demand.



Weather and climate variables, such as wind and radiation, determine production from Non-Programmable Renewable Sources

Temperature mainly influences energy demand

Unplanned failures of thermoelectric production units and transmission lines reduce the programmable generation and the exchange capacity between market zones, respectively.

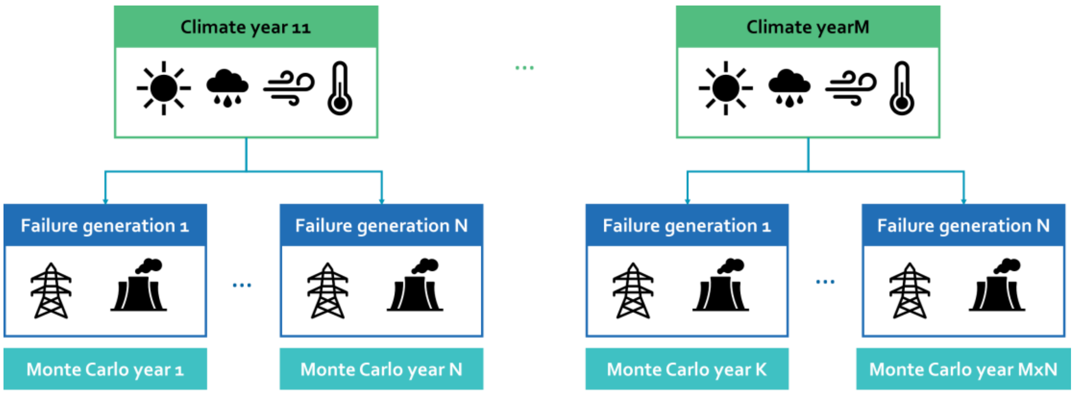
To carry out a correct assessment of the adequacy it is necessary to take into account the uncertain variables in the system and their possible realizations through probabilistic indicators. The state of the art on the methodologies for adequacy studies refers to the **Monte Carlo** simulation approach to take into account the uncertain variables of the system.

The Monte Carlo simulation consists in considering a high number of possible scenarios of the electrical system different from each other, each characterized by specific values of uncertain variables, such as weather data and unplanned failures.

The process starts by defining *M* climate scenarios, which represent historical coherent climate years. In ERAA, for example, each climate year represents a set of demand time series, wind and solar load factor time series, hydro generation time series, climate dependent time series for other renewable and non-renewable sources. Each climate year is then combined with *N* random realizations of plant failures. Each run for a climate year and all its failure realizations is called a "Monte Carlo year". Consequently, if *M* climate years are considered and for each climate year *N* random realizations of generator and interconnection failures are considered, this will result in *MxN* Monte Carlo years.

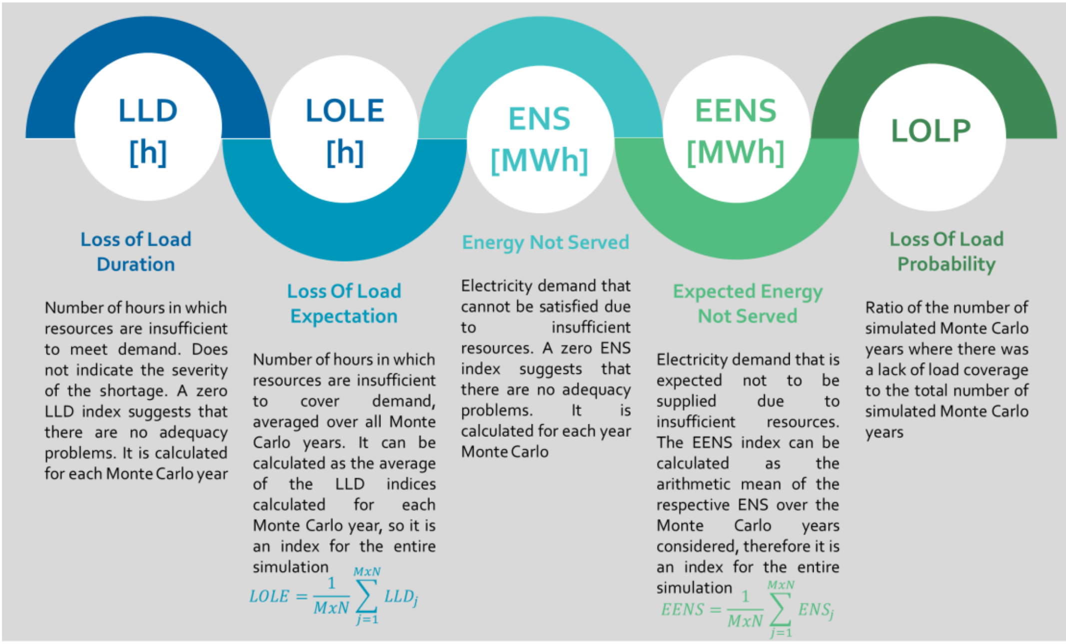
For the purpose of assessing adequacy, the Monte Carlo years constructed in this way are all considered equally probable, since the probability of occurrence of one year compared to another is independent of the variables considered.

For each Monte Carlo year, the operation of the electrical system is simulated and the adequacy indicators are calculated. Once all the Monte Carlo years have been simulated, statistical values of the indicators obtained can be calculated, such as the annual average.



How to measure

There are several indices that can be used to measure the adequacy of an electrical system. Many of the adequacy indices are essentially expected values of random variables. The expected value is the long-term average of the variable under examination.
For the assessment of adequacy, the indices most used in the literature are the following:



Decree 28/10/2021

The LOLE index does not indicate the severity of the shortage, nor the frequency of the load loss. Despite the absence of this information, it is currently the most used probabilistic criterion in capacity planning studies. The MiTE[1] itself, with the Ministerial Decree of 28/10/2021, in order to guarantee the adequacy of the Italian electrical system, has defined the **maximum value of LOLE equal to 3 h/year**.

The higher the capacity installed in the system, the lower the LOLE will be. A system with a LOLE equal to zero is defined as adequate, with a LOLE less than or equal to 3 hours it is defined as not adequate within the target value, a system with a LOLE greater than 3 hours is defined as not adequate

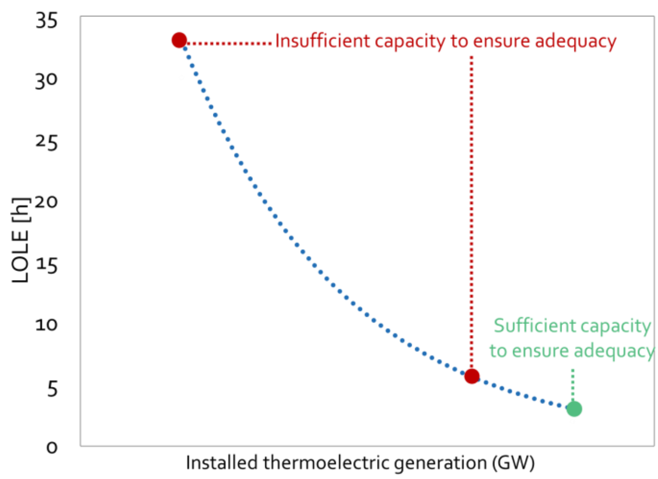


Figure 1 – LOLE for installed capacity. Image from LightBox of Terna[2]

[1] *Ministero della Transizione Ecologica, today MASE (Ministero dell'Ambiente e della Sicurezza Energetica)*
[2] *https://lightbox.terna.it/it/insight/adeguatezza-sistema-elettrico*

Where to find the adequacy reports

Seasonal Outlook of ENTSO-E

Rapporto Adeguatezza Terna

ENTSO-E, at European level, and Terna, at Italian level, annually draw up Adequacy Reports to fulfil regulatory obligations.

ENTSO-E, as can be read on its website, "*analyses possible risks for the security of supply in Europe twice a year: for the summer and winter periods. Because of possible very high/low temperatures and other 'extreme' weather conditions, winters and summers are the most critical periods for the power grid. The role of the* ***Seasonal Outlooks*** *is to identify when and where system adequacy is at risk and to identify potential vulnerabilities for the upcoming season which can be addressed proactively with preparation or mitigation measures. The Outlooks are the product of cooperation between 40 European electricity TSOs. Because of their pan-European scope, the Outlooks complement the analysis carried out in national and regional assessments, which provide a more detailed picture of adequacy at local level. They promote cooperation across Europe and between regional and national stakeholders*."

In addition to the seasonal outlooks, ENTSO-E has been annually drawing up the **ERAA - European Resource Adequacy Assessment** report since 2021. "T*he ERAA is a pan-European monitoring assessment of power system resource adequacy of up to 10 years ahead. Building on the work done with the Mid-term Adequacy Forecast (MAF), the ERAA is a leap forward in system modelling. It is based upon state-of-the-art methodologies and probabilistic assessments, aiming to model and analyse possible events which can adversely impact the balance between supply and demand of electric power. It will be an important element for supporting qualified decisions by policy makers on strategic matters such as the introduction of capacity mechanisms (CMs)".*

Therefore, while seasonal outlooks verify adequacy in the short term, ERAA analyses it in the medium-long term, reaching 10 years of analysis.

Terna's Adequacy Report is based on the same time horizon as the ERAA, analyzing Italian adequacy in the medium-long term (ten-year horizon), "*taking into account the positive effects deriving from the development of networks and interconnections with foreign countries, the scenarios and analyses of adequacy at regional and European level developed by the ENTSO, the evolution of generation from renewable sources, distributed generation, demand resources and storage systems, in line with the objective of developing the integrated electricity market*".

Main results

Terna Adequacy report 2024

To better understand what an adequacy assessment entails, the main results from Terna's latest **Adequacy Report drawn up in 2023** are reported below, from which the following data and graphs are taken and which we invite you to read for all the details. To carry out the analyses, the system was simulated in two different states: a medium-term one (2028) and a long-term one (2033). The main results of the 2028 and 2033 scenarios are as follows.

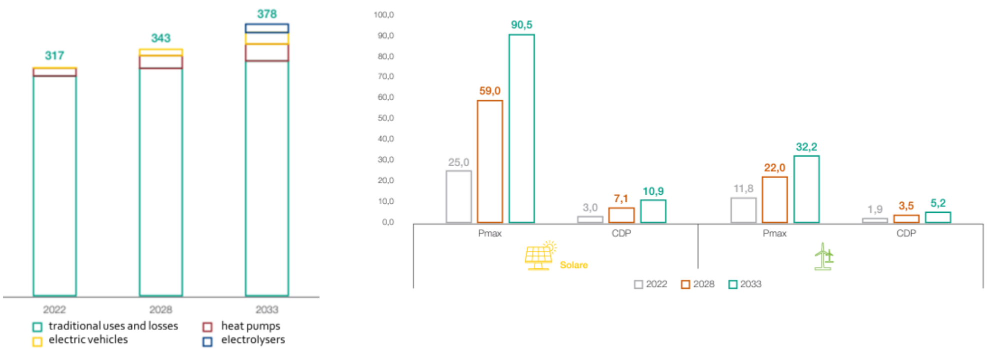


Figura 2 - Evolution of demand (TWh, on the left) and evolution of RES (GW, on the right). ***Source: Terna Adequacy Report 2023***

APE on Capacity Market

Electricity demand is the sum of electricity consumed for final uses, energy uses and network losses. In the scenario analyzed, electricity demand reaches 343 TWh in 2028 and 378 TWh in 2033. Since solar and wind production is uncertain and random, to better estimate the impact that these resources will have on the adequacy of the system, the available capacity in probability (CDP) is used, calculated by multiplying the installed power by specific de-rating coefficients that take into account the actual availability of each source to cover the electrical load (as is the case for the Capacity Market). The medium-term scenario (2028) sees 59 GW of solar and 22 GW of wind, while the long-term scenario to 2033 sees 90 GW of solar plants and approximately 32 GW of wind plants.

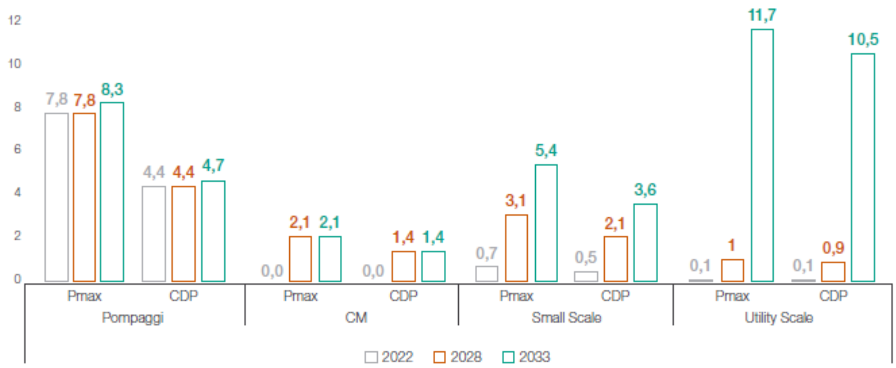


Figura 3 – Evoluzione capacità di accumulo (GW). *Fonte: Rapporto Adeguatezza Terna 2023*

In the NECP Policy 2030 scenario, the storage capacity needed to integrate renewables and manage the electricity system is approximately 122 GWh.

The storage capacity present in the scenario is given by the sum of existing storages, such as pumped hydroelectric plants ("*pompaggi*"), storages contracted in the Capacity Market auctions, new small-scale storages, typically aimed at increasing self-consumption from renewable sources, and new large-scale utility-scale storages. In particular, the horizon years 2028 and 2033 present a total storage capacity of 13,9 GW and 27,4 GW respectively.
Similarly to solar and wind, the CDP is also considered for storages as they are plants that can continuously feed energy into the grid only for a limited period of time, depending on their capacity and state of charge.

Terna's Development Plan

As regards thermoelectric plants, in the coming years it will be necessary to take into account the decommissioning of coal and oil plants and the new plants that will enter the market (whether contracted or not on the Capacity Market).
In 2022, the thermoelectric capacity actually available for adequacy stood at 55,6 GW. In 2028, in the absence of further and unforeseen decommissioning, the maximum available thermoelectric capacity will be reduced to just over 54 GW. Instead, in the longer term (2033), the thermal capacity that can contribute to the adequacy of the system will be just over 53 GW due to the planned decommissioning of the remaining coal plants.
The development of the network follows Terna's Development Plan, therefore foreseeing the entry into operation of the Tyrrhenian link as early as 2028.

---------------------------------- 2028 MAIN RESULTS ----------------------------------

Adequate system

Taking into account the generation contracted in the previous Capacity Market auctions; the growth in demand, RES and Storage systems; an evolution of the exchange capacity and, in particular, the entry into operation of the Tyrrhenian Link and Adriatic Link connections and not considering further decommissioning beyond those already planned, the system is adequate, with a national average LOLE value of less than 3 h/year.

Avoidable fixed costs are understood as all costs incurred by the owner of the plant regardless of its production. These costs include:

- *the maintenance portion: this item includes all costs related to ordinary, preventive and predictive maintenance (during the normal operation of the plant);*
- *the labor portion: it contains the costs related to the personnel employed and the maintenance of the plant;*
- *the insurance portion, i.e. the economic amount of the insurance stipulated by the plant manager.*

The Economic Viability Assessment (EVA) of the plants highlighted the presence of approximately 14,8 GW of thermal power not able to cover their avoidable fixed costs. The decommissioning of these plants for economic reasons would determine a LOLE value well above the adequacy standard and with critical issues distributed across all areas of the system. Appropriate mechanisms are therefore necessary to maintain the capacity in operation in order to bring the LOLE back to adequate levels.

Inadequate system

Adequate but risky system

There remain risks due to the occurrence of extreme weather conditions such as those that occurred in 2022 (extreme and prolonged drought, high temperatures and too low river levels). A similar situation would lead to risks for adequacy based on unavailability linked to extreme weather conditions. It will therefore be necessary to identify solutions to improve the availability of the current generation park in extreme conditions of high temperatures and drought of the canals.

2033 MAIN RESULTS

Adequate system

From the analyses of the reference scenario it emerges that the long-term horizon year, considering the increases in RES capacity and the increase in storage capacity and maintaining all the thermoelectric capacity expected in 2033, appears fully adequate with a LOLE value close to 0 h/year and in any case less critical than the medium term with regards to the adequacy of the system.

The EVA analysis in the long term has highlighted greater critical issues than in the medium term regarding the risk associated with the closure and decommissioning of thermoelectric plants due to economic unsustainability. In the event of decommissioning of all the production units in the EVA perimeter, only Sicily appears to be able to guarantee coverage of its zonal load without compromising the adequacy standard mainly thanks to the large expansion of RES in the territory and the low impact that decommissioning due to economic unsustainability has on this market area.

Inadequate system

Notes by:

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He currently applies his Master's Degree in Electrical Energy Engineering to the study of networks, also by applying innovative techniques.

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