

*2019 Edition*

# Mid-term Adequacy Forecast Executive Summary

**DISCLAIMER:**

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ENTSO-E emphasises that ENTSO-E and the TSOs involved in this study are not responsible in the event that the hypotheses presented in this report or the estimations based upon these hypotheses are not realised in the future.

## MAF 2019: Navigating through the report

MAF 2019 is divided into four sections in an effort to assist stakeholders in identifying relevant information.

### **Executive Summary:**

Presents the motivation of the MAF 2019, followed by the main adequacy results for the Base-Case scenarios for the target years 2021 and 2025.

### **Appendix 1 – Detailed results, sensitivities and input data:**

Presents a closer look at the input data and the results of MAF 2019, including:

- An overview of the main input data and the changes compared to MAF 2018;
- Detailed tables of results for the Base-Case scenarios and results per each modelling tool;
- Results of additional sensitivity studies, i.e., Low-Carbon and Flow-Based studies.

### **Appendix 2 - Methodology:**

Presents the main methodology followed in MAF 2019, which consists of:

- Geographical scope;
- Probabilistic methodology for assessing adequacy;
- Input data and granularity;
- Introduction to methodologies used for preparing demand and hydro datasets;
- Future evolution of the methodology.

### **Appendix 3 – Country views on MAF 2019:**

Contains country-specific comments and relevant references to national and regional studies provided directly by the TSOs.

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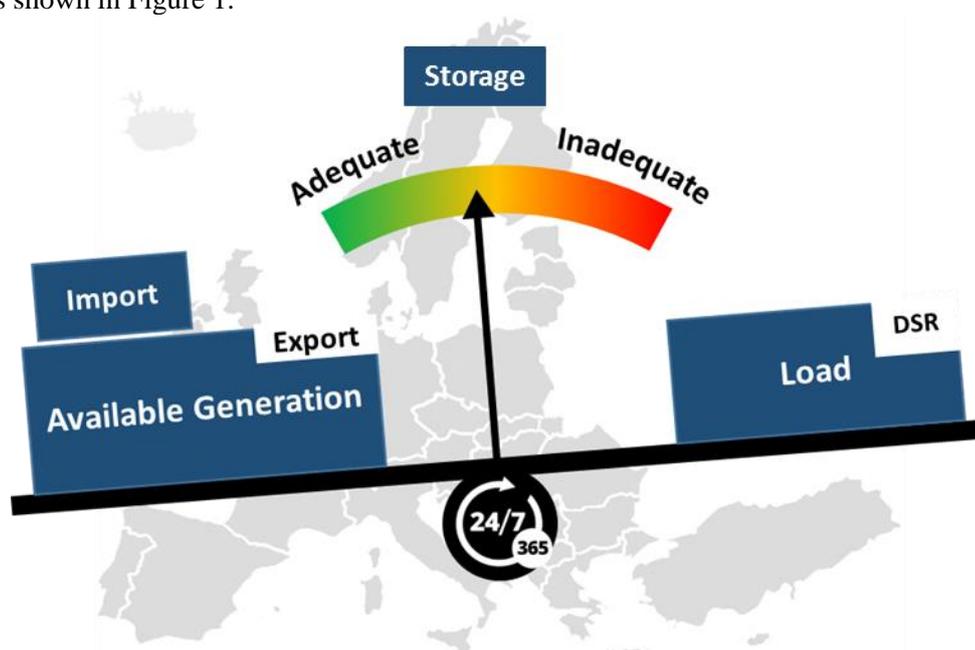
## 1 Introduction

### 1.1 Purpose and Motivation

*What is the purpose of the Mid-term Adequacy Forecast?*

*The Mid-term Adequacy Forecast (MAF) is a pan-European monitoring assessment of power system resource adequacy spanning a timeframe from one to ten years ahead. It is based upon a state-of-the-art probabilistic analysis, aiming to provide stakeholders with comprehensive support to take qualified decisions.*

Resource adequacy assessments are increasingly prominent studies that use advanced methodologies to model and analyse rare events with potentially adverse consequences for the supply of electric power. They capture the continuous balance between net available generation, on the one hand, and net load levels, on the other, as shown in Figure 1.



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

Due to the increasing level of variable renewable energy sources in the European power system and the associated challenges for system development and operation, a pan-European analysis of resource adequacy has become ever more important. Cooperation across Europe is necessary to accelerate the development of common methodological standards, i.e., a common ‘language’ is needed for performing these studies.

Over the past decade, the European Network of Transmission System Operators for Electricity (ENTSO-E) has been improving its methodologies and forecasts continuously and will continue to ensure that further progress is made. MAF contributes to the harmonisation of resource adequacy methodologies across Europe by being a reference study for European Transmission System Operators (TSO) and a target approach for the Ten-Year Network Development Plan (TYNDP) and Seasonal Outlook studies. The MAF

aims to provide stakeholders with the data necessary to make informed, quality decisions and promote the development of the European power system in a reliable, sustainable and connected way.

Stakeholders should find the MAF and its extensive pan-European coverage particularly useful. In fact, MAF is the most comprehensive pan-European assessment of adequacy attempted to date, as it is based on a market-based probabilistic modelling approach undertaken in a collaborative effort with representatives from TSOs across the entire pan-European area. Five different modelling tools have been calibrated with the same input data and benchmarked against one another to increase consistency, robustness, and – fundamentally – confidence in the complex analytical results presented in the report.

It should be noted that the present pan-European assessment inevitably faces limitations. For instance, MAF does not consider all possible network constraints within a defined modelling zone. The higher granularity of national/regional adequacy assessments might be able to detect local resource or network constraints which cannot be identified by the present pan-European assessment, thus highlighting the complementary nature of regional/national and pan-European analyses. While such studies may rely on the same methodology and reference scenarios, they can assess additional sensitivities<sup>1</sup>. National and regional studies can use tools and data granularity that are complementary to those used by ENTSO-E.

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*What are the main improvements compared to the MAF 2018?*

Data granularity and quality have improved significantly in MAF 2019. For example, for the first time, unit-by-unit information concerning thermal generation was collected and implemented in the models. In addition, the climate database was extended to include 35 years of hydrological data, and a new, improved methodology was introduced to construct hourly demand time series.

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## 1.2 Improvements in MAF 2019

Five modelling tools were used to performing the adequacy assessment in MAF 2019, and efforts to align models were intensified. Specific modelling improvements have also been implemented:

Data and Modelling Improvements:

- **Thermal generation:** One of the most prominent innovations of MAF 2019 is undoubtedly the increased granularity of the thermal generation data. A major milestone for ENTSO-E studies has been reached in the collection of thermal generation data with the highest granularity (unit-by-unit), including a wide range of information for each power plant property in the pan-European system. For MAF 2019, a hybrid implementation approach was followed: two models were built based on the new, more granular database, while the remaining three models were built on an aggregated version of the database using the same clustering used in MAF 2018, i.e., clustering by technology type.
- **Hydro modelling:** Available hydropower generation is an important factor for assessing adequacy in power systems. It can have significant impact on results, which highlights the importance of

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<sup>1</sup> Regulation (EU) 2019/943 of the European Parliament and of the Council on the internal market for electricity, Chapter IV, Art. 20.1.

choosing the appropriate level of detail, evaluating distinct hydrological conditions, applying harmonized assumptions and better reflecting the interdependence of hydro generation and climate conditions. Thus, a new hydro database was constructed for use in MAF 2019 which encompasses the full ENTSO-E perimeter with a complete set of distinct hydrological conditions for all climate years. The new hydro database guarantees homogeneous data, a common methodology for hydro modelling and a better reflection of the correlation of hydro output with other climate variables. This is a major improvement compared to MAF 2018, in which the weather's impact on hydro generation was only considered through clustering climate years as wet, dry or normal.

- **Demand time series:** An advanced demand modelling tool is introduced in MAF 2019 which builds on statistical modelling of historical data. The model of each zone is trained based on a sufficient number of historical demand time series in order to better capture the dependency of demand on parameters such as temperature and to construct the target time series for all available climate scenarios. The new methodology leads to more reliable projections of demand time series for the target years and better reflects the impact of climate variables and new technologies (e.g., electric vehicles) on demand.

Sensitivities:

- **Flow-Based Sensitivity:** To improve the representation of the network in the simulations, a sensitivity analysis has been performed for target year 2021. This sensitivity analysis builds on the methodology introduced in PLEF<sup>2</sup> and presented in MAF 2018 but uses updated input data (Flow-Based domains). The corresponding simulation model was built to follow the rules of the Central Western Europe (CWE) Flow-Based Market Coupling and has been applied to the CWE perimeter. The results of this study are compared with the Base-Case scenario and provide additional insights into the impact of network considerations on market simulations. The results of this sensitivity analysis are presented in Appendix 1.
- **Low-Carbon Sensitivity:** The transition towards a European power system with high shares of renewable sources and decreased thermal capacities is driven by low-carbon emission policies (including carbon pricing). These policies have a significant impact on the availability and profitability of fossil-fuel thermal generation technologies in the power system. While this impact on installed capacity is already included in the Base-Case scenarios for MAF 2019, for most countries, a sensitivity study was added that reflects a more ambitious trajectory for the phase-outs of fossil-fuel-generation capacities. The sensitivity study was based on the inputs of 11 countries. In line with the well-received Low-Carbon sensitivity study presented in MAF 2018, data were collected from TSOs for a scenario corresponding to a decrease in the installed capacity of coal and lignite for 2025. The input data and the results of this analysis are presented and compared to the Base-Case results in Appendix 1.

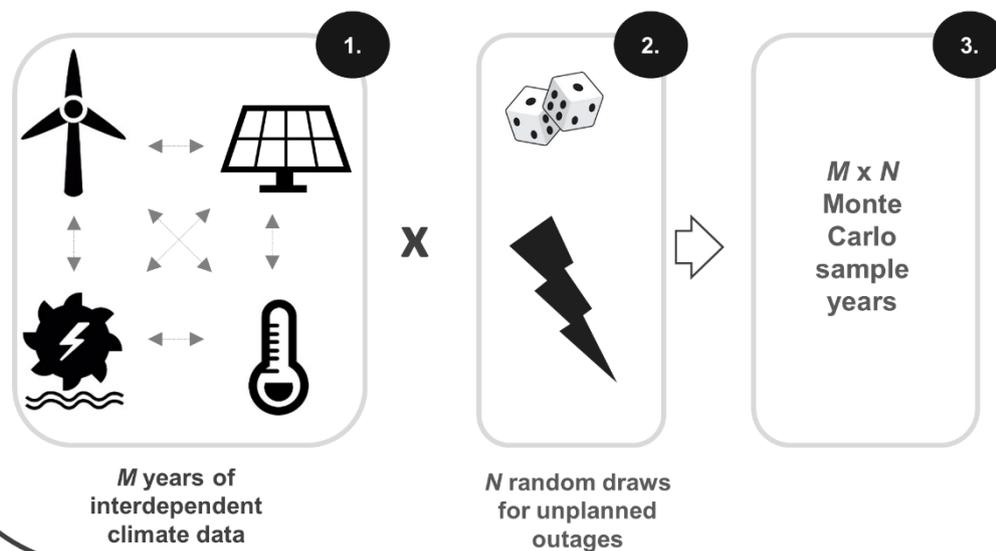
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<sup>2</sup> Pentilateral Energy Forum, Support Group 2, "Generation Adequacy Assessment", January 2018, <http://www.benelux.int/nl/kernthemas/holder/energie/pentalateral-energy-forum>

### Monte Carlo: State-of-the-art technique to assess resource adequacy

The core idea of the Monte Carlo (MC) method is to use random samples of parameters or inputs to explore the behavior of a complex system or process.

The high number of aleatory input variables which influence the outcomes of an adequacy assessment in power systems makes MC very suitable for the current study, where it is used to represent probabilistic variables such as unplanned outages in electricity market models. The process is illustrated below.



### 1.3 The “Clean Energy for all Europeans” package and evolution of MAF

Along with the coupling of European energy markets, integration of renewable energy sources and efforts to decarbonize energy systems, adequacy monitoring needs to be intensified. Within the current fast-paced landscape, the European resource adequacy assessment, i.e., the annual screening of adequacy in Europe for the upcoming decade, must provide input for strategic decisions regarding, for instance, the introduction of capacity mechanisms. Therefore, the methodology for assessing adequacy in Europe will need to undergo significant changes in order to address the challenges the energy sector faces.

*What are the upcoming challenges and future steps for resource adequacy?*

Economic viability, capacity mechanisms, increased temporal granularity, more sensitivities: undoubtedly, the “Clean Energy Package” aims high, introducing significant challenges and improvements for future pan-European and Regional adequacy assessments.

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The recent legislative package on Clean Energy for all Europeans, specifically Regulation 2019/943 of 5 June 2019 on the internal market for electricity, has placed resource adequacy in a central position in European energy policy. Under this regulation (Article 23), European resource adequacy assessments are required to consider, amongst others, the following aspects:

- Time horizons of 10 years with annual resolution;
- Flow-Based modelling of the power network (when applicable);
- An economic viability assessment of generation assets;
- Analysis of additional scenarios, including the presence or absence of capacity mechanisms;
- Consideration of energy sectoral integration.

In addition, and to complement the European resource adequacy assessment, ENTSO-E shall develop a methodology for the definition of the value of lost load, the cost of a new entry in generation and/or demand response and a methodology used to establish the reliability standard.

## 2 Main findings of MAF 2019

Five different market modelling tools were used for the current adequacy assessment. The five models were built to encompass the entire European perimeter based on comprehensive data for two target years: 2021 and 2025. The main findings of the assessment are presented in this section, while more detailed results can be found in Appendix 1. As a preliminary remark, it should be noted that the first target year, i.e., 2021, was chosen due to its temporal proximity as well as its ability to anticipate the system's adequacy situation in the short term without overlapping with the Seasonal Outlooks. The MAF 2019 updates, and provides a comparison to, the results of MAF 2018, which focused on the target year 2020. The second target year, i.e., 2025, was chosen as a pivotal year for evaluating adequacy due to significant reductions in coal and nuclear capacity expected between 2021 and 2025. Hence, this target year is evaluated again with updated input data.

Generally, the results of MAF 2019 indicate low risks of inadequacy in the system, if input assumptions of the assessment materialize, with the exception of islands and a few continental market zones. To this end, several differences can be observed in these results and those for MAF 2018. Before elaborating on these differences in the following subsections, it is necessary to highlight the two main sources of these differences: (1) the updated input dataset provided by TSOs, which partially showcases the monitoring role of the MAF, and (2) improvements in ENTSO-E databases, i.e., in the thermal generation granularity, demand time series, hydro dataset and hydro modelling assumptions. While a one-to-one comparison is difficult due to the large number of interdependent assumptions and the complexity of the models, the results presented hereafter should be considered to be an updated and improved best estimate of the future adequacy landscape. More information on the updates in the input data and methodology can be found in Appendices 1 and 2, respectively.

### How is LOLE calculated?

Simulations of each target year (e.g., 2021) are run multiple times with different Monte Carlo combinations of climate situations and random forced outage events based on available statistics and climate data.

For a large number of simulations, many hours correspond to cases without particularly stressful outages and climate conditions, i.e., situations in which all demands are met. On the other hand, some hours correspond to patterns of forced outages and climate conditions that are particularly stressful, i.e., situations in which demand cannot be met by the available supply or imports via interconnectors. In these situations, the demand that is not served is registered as Energy Not Served (ENS), measured in GWh over the course of a year.

The number of hours during which ENS occurs is recorded as Loss of Load Duration (LLD). The values for ENS and LLD are recorded for each region and for each Monte Carlo year. After performing multiple Monte Carlo simulations, the Expected ENS (EENS) and Loss Of Load Expectation (LOLE) are calculated per region and for the pan-European system. Additionally, the 95<sup>th</sup> percentile (P95) values are calculated. The P95 values are particularly useful for demonstrating the types of severe events that could happen once every 20 years.

### 2.1 Results of Base-Case scenarios

The development of different scenarios permits a comparison of multiple potential future states of the European power system. In the MAF, bottom-up scenarios collected from TSOs result in Base-Case

scenarios for the analysed time horizons. They will be complemented consecutively by sensitivities (e.g., further reductions in carbon-emitting generating capacities). This section presents the results of the MAF 2019 adequacy assessment while focusing on the Base-Case scenarios for the target years 2021 and 2025. In this executive summary, only LOLEs and the 95<sup>th</sup> percentiles<sup>3</sup> are presented on maps of the simulated area in order to provide the main aspects of the adequacy situation within the MAF perimeter. However, more detailed results, including EENS values, can be found in Appendix 1, along with the results of the sensitivities performed within the framework of this MAF edition.

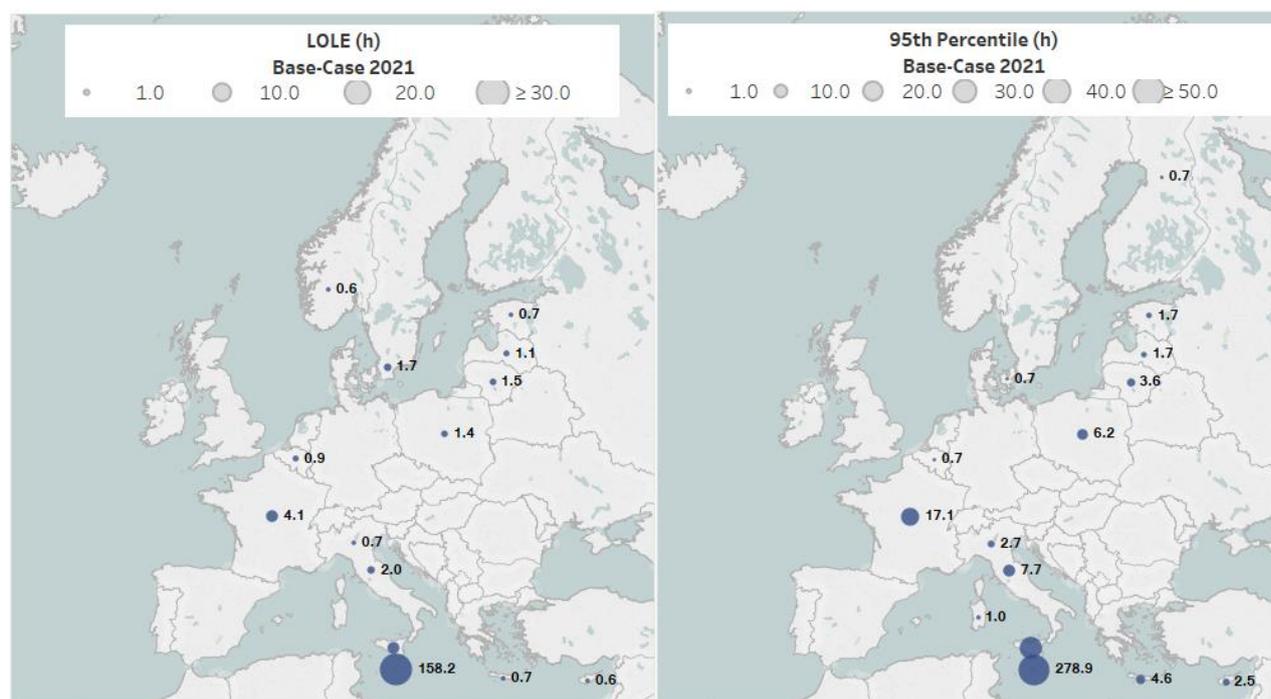
The results presented in the following paragraphs correspond to the resulting LOLE values per zone for the Base-Case scenario, which are the averages of the results of five different models. The models were built by different software tools and using two different levels of data granularity with respect to the thermal power plants (unit-by-unit and aggregated per technology). A non-zero value of LOLE in this report indicates only a resource inadequacy in the market. Any ENS due to transmission and distribution faults or demand and RES forecast errors is not accounted for. For more information on the methodology and probabilistic indicators, please see Appendix 2. Moreover, there are cases in which the results depend on the specificities of each country or zone. Thus, the reader should also consult Appendix 3, which contains country comments that will help the reader better understand the specific results for some countries and derive more accurate conclusions.

### 2.1.1 Base-Case results for 2021

Figure 2 shows the estimated levels of resource adequacy for the target year 2021. More specifically, for each zone, Figure 2 plots the LOLE (left-hand side) and the 95<sup>th</sup> percentile of the LLD that occurred among all simulated Monte Carlo years (right-hand side). The market-modelling results for the year 2021 do not indicate significant adequacy issues in most countries. As was the case in previous adequacy assessments, islands are vulnerable to loss of load. Thus, in Figure 2, Malta has high values for both LOLE and the 95<sup>th</sup> percentile of the LLD. Adequacy issues are also observed in Sicily, where the LOLE reaches 4 hours, on average, and the 95<sup>th</sup> percentile of the LLD is 25 hours. In continental Europe, a LOLE of around 4 hours was identified in France. The remaining zones follow, all with LOLE results below 2 hours per year. These results show that continental Europe's interconnected system is expected to be adequate in 2021.

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<sup>3</sup> The 95<sup>th</sup> percentile (P95) of the LLD is the value above which lie only 5% of all observations and corresponds to a probability of occurrence of 1 in 20 years. Note that in some cases, observations may include very few but extreme values, resulting in P95 values lower than average (LOLE).



**Figure 2: Loss of load expectation (LOLE) values for the 2021 Base-Case scenario. Circle radii reflect the magnitudes of the LOLE values for the corresponding zones. Zones with missing circles have LOLE values of less than 0.5 h. \*In these maps, outliers were removed before averaging the results of all tools for the zones consisting of France, Sicily, Malta and South Norway. Input data for Iceland have not been updated since MAF 2018, thus the outcomes remain the same.**

Even though MAF 2018 focused on the target year 2020, while MAF 2019 focuses on 2021, it can still be insightful to compare the results for these two scenarios due to their temporal proximity. Comparing the results of MAF 2018 with this edition (Figure 3), it is observed that the adequacy situation is quite different in some zones. For the zones consisting of the United Kingdom (UK; both Northern Ireland and Great Britain), Finland, Greece (including the explicitly modelled zone of Crete), Bulgaria and Cyprus, the adequacy issues found in MAF 2018 have disappeared. Regarding the UK and Greece, increased thermal capacity is anticipated for target year 2021 as opposed to the 2020 scenario, explaining the positive results in Figure 2. Furthermore, Finland anticipates a higher penetration of Renewable Energy Sources (RES), i.e., wind and solar, in 2021. In addition, the new hydro database had a considerable impact on the hydro capacity in Bulgaria. Lastly, in the case of Cyprus, the anticipated increase in thermal capacity, along with its updated demand profile, eliminated the expected adequacy risks for this island country.

On the other hand, it is worth noting that the LOLE increased in France by approximately 2 hours between MAF 2019 and MAF 2018. This result is linked to the planned decommissioning of two nuclear units by mid-2020 and to the postponed commissioning of a new nuclear plant to a later date, i.e., 2023. Furthermore, Sweden's LOLE values increased by 1.7 hours in the 2021 Base-Case scenario compared to 2020.

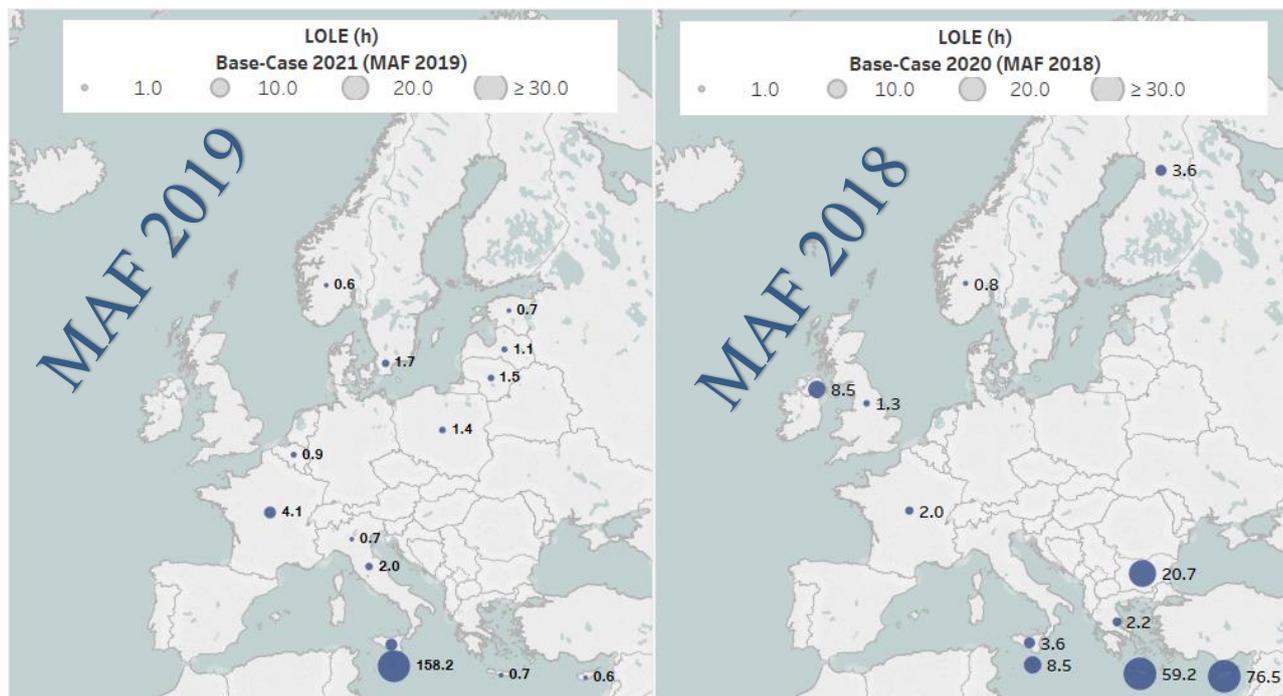
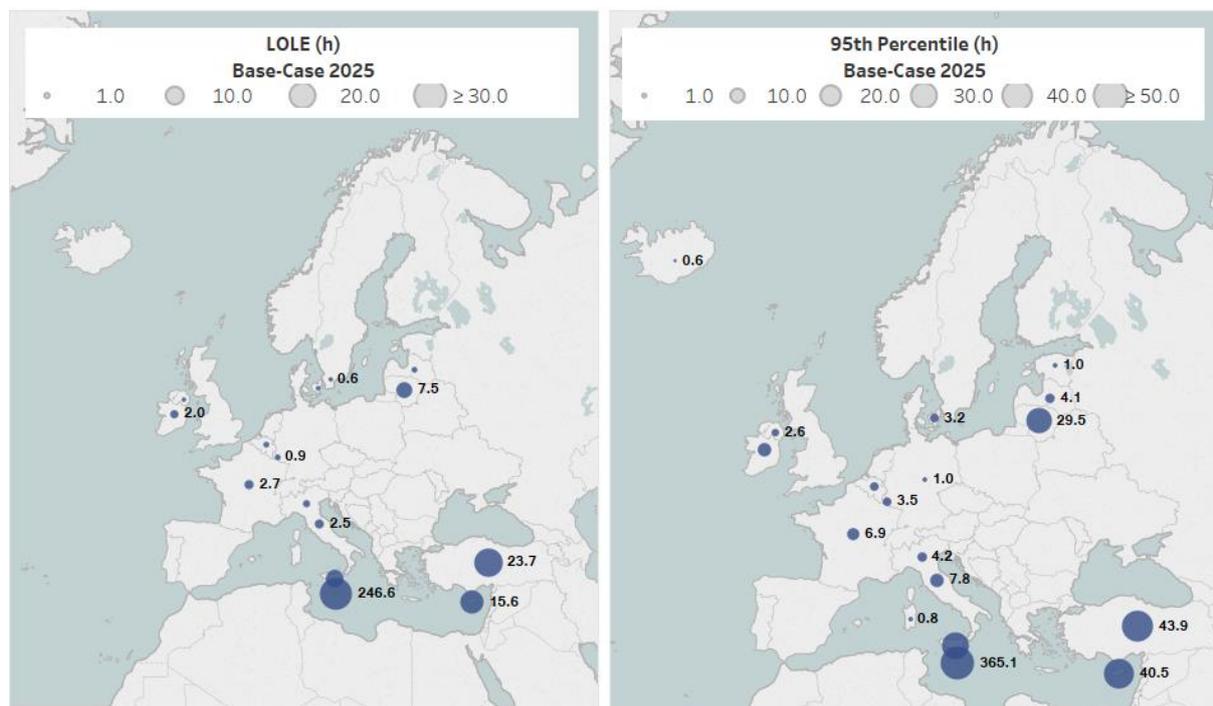


Figure 3: Comparison of LOLE values between MAF 2018 and MAF 2019 for target years 2020 and 2021, respectively. Circle radii reflect the magnitudes of the LOLE values for the corresponding zones. Zones with missing circles have LOLE values of less than 0.5 h. \*In the MAF 2019 maps, outliers were removed before averaging the results of all tools for the zones consisting of France, Sicily, Malta and South Norway. Input data for Iceland have not been updated since MAF 2018, thus outcomes remain the same.

### 2.1.2 Base-Case results for 2025

Figure 4 presents the results for Base-Case target year 2025. As noted above, the magnitude of a LOLE value is indicated by the radius of the circle on the map. Observing the map, one notices that only a few zones have LOLE values greater than 3 hours. More precisely, in the 2025 scenario Malta presents high adequacy risks, followed by Cyprus and Sicily. In continental Europe, very limited adequacy risks are predicted for the 2025 target year, provided that the input assumptions taken for the different countries materialize. With the exception of Turkey and Lithuania<sup>4</sup>, all zones have LOLE values of less than 3 hours, including France, which had a higher LOLE value in the 2021 scenario. The latter result for France is linked to the planned commissioning of a new nuclear power plant and the development of RES, Demand Side Response (DSR) and interconnectors. Naturally, in terms of the P95 values on the map (Figure 4, right-hand side), the number and radii of the circles is expected to increase but still remain insignificant, with the exception of the islands.

<sup>4</sup> Due to a data issue, net generating capacity for Lithuania includes an additional 400 MW of hydro turbine capacity, which should have been removed and reserved for providing Frequency Restoration Reserves (FRR). In MAF 2019, reserved capacity should not be considered as being available for assessing adequacy.



**Figure 4: Loss of load expectation (LOLE) values for the 2025 Base-Case scenario. Circle radii reflect the magnitudes of the LOLE values for the corresponding zones. Zones with missing circles have LOLE values of less than 0.5 h. \*In these maps, outliers were removed before averaging the results of all tools for the zones consisting of Cyprus, Sicily, Lithuania and Turkey. Input data for Iceland have not been updated since MAF 2018, thus outcomes remain the same.**

Plotting the results of the two investigated scenarios, 2021 and 2025, side-by-side (Figure 5) allows a better exploration of the evolution of adequacy, as anticipated by the MAF models. For a few zones, it is observed that changes between 2021 and 2025 have impacts on ensuring adequacy. This is the case for Lithuania, Turkey and Cyprus, where LOLE values show increases of over 6 hours. Other examples with lower LOLE value increases are Ireland, Belgium and Italy. The reader is invited to read Appendix 1 as well as the country comments in Appendix 3 to better understand the specific results.

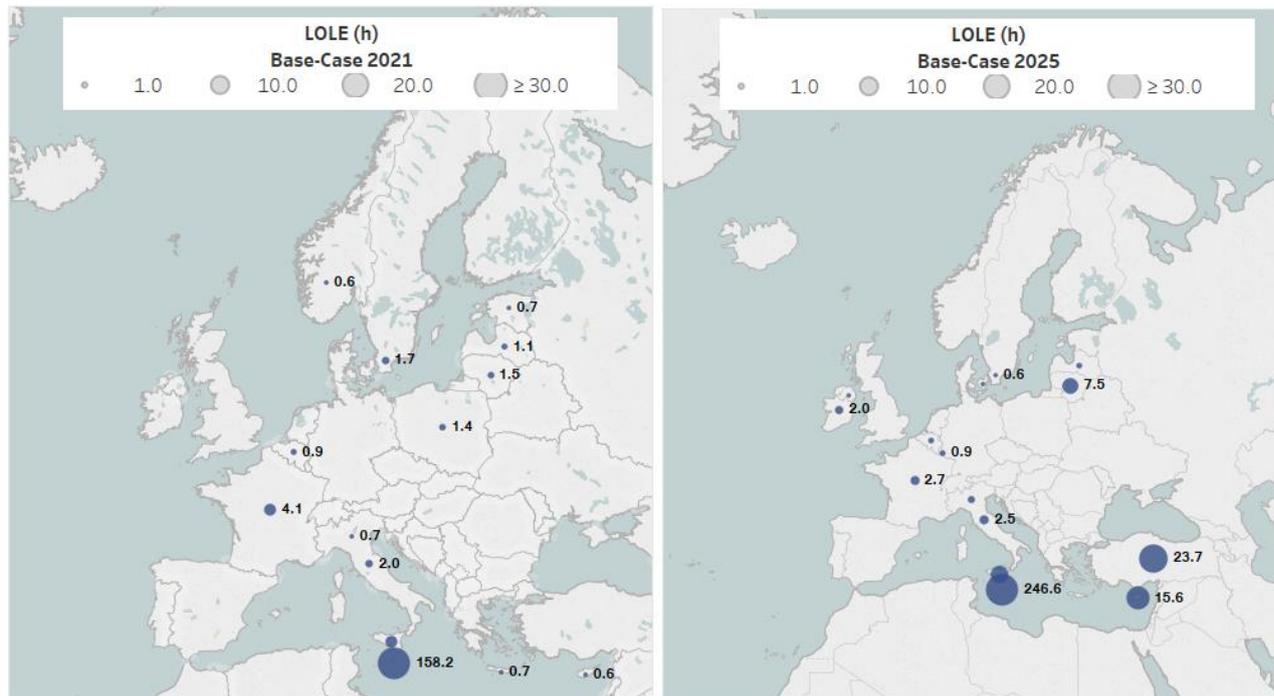


Figure 5: Comparison of LOLE values between the two target years, i.e., the 2021 and 2025 Base-Case scenarios. Circle radii reflect the magnitudes of LOLE values for the corresponding zones. Zones with missing circles have LOLE values of less than 0.5 h. *\*In these maps, outliers were removed before averaging the results of all tools for the zones consisting of Cyprus, Sicily, Lithuania and Turkey. Input data for Iceland have not been updated since MAF 2018, thus outcomes remain the same.*

As mentioned in the introduction, the target year 2025 is currently of specific interest for adequacy assessments due to the number of changes that are anticipated with respect to thermal decommissioning in numerous countries. For this reason, 2025 was evaluated in both MAF 2018 and 2019. The results for both MAF versions are presented in the maps in Figure 6.

One of the first observations one can make is that the results look mixed. A number of countries are in better situations, according to the latest findings in MAF 2019, including Poland, Ireland, the UK, Cyprus and the island of Crete. On the other hand, for some zones, e.g., Latvia, continental Italy and Lithuania, there are increases in the expected LOLE hours. The reader can consult the country comments in Appendix 3 for detailed national comments on the results for some of the zones.

The most significant improvements concern Ireland, which falls below the 3 h threshold, as well as Cyprus and Crete, where improved demand modelling and increased interconnection capacities had clear impacts on results.

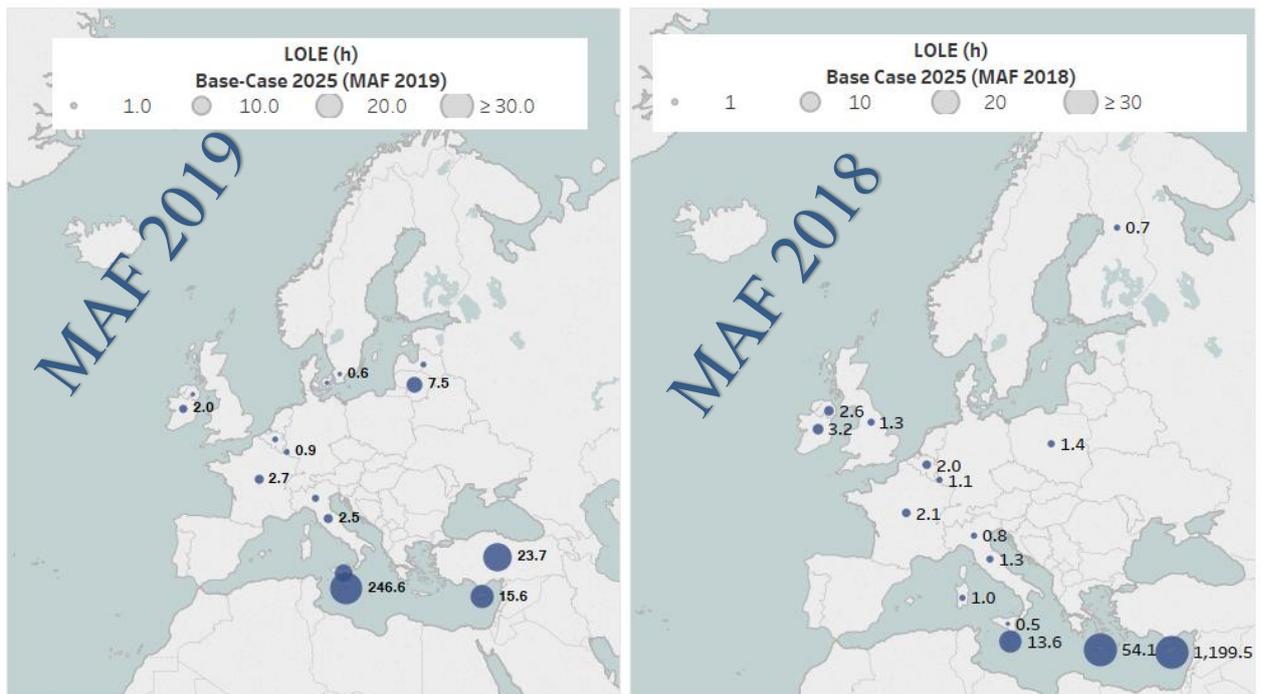


Figure 6: Comparison of LOLE values between MAF 2018 and MAF 2019 for the target year 2025 Base-Case scenario. Circle radii reflect the magnitudes of the LOLE values for the corresponding zones. Zones with missing circles have LOLE values of less than 0.5 h. \*In these maps, outlying results were removed before averaging the results of all tools for the zones consisting of Cyprus, Sicily, Lithuania and Turkey. Input data for Iceland has not been updated since MAF 2018, thus outcomes remain the same.