2018 Edition

Mid-term Adequacy Forecast

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Reliable Sustainable Connected

Contents

Section 1

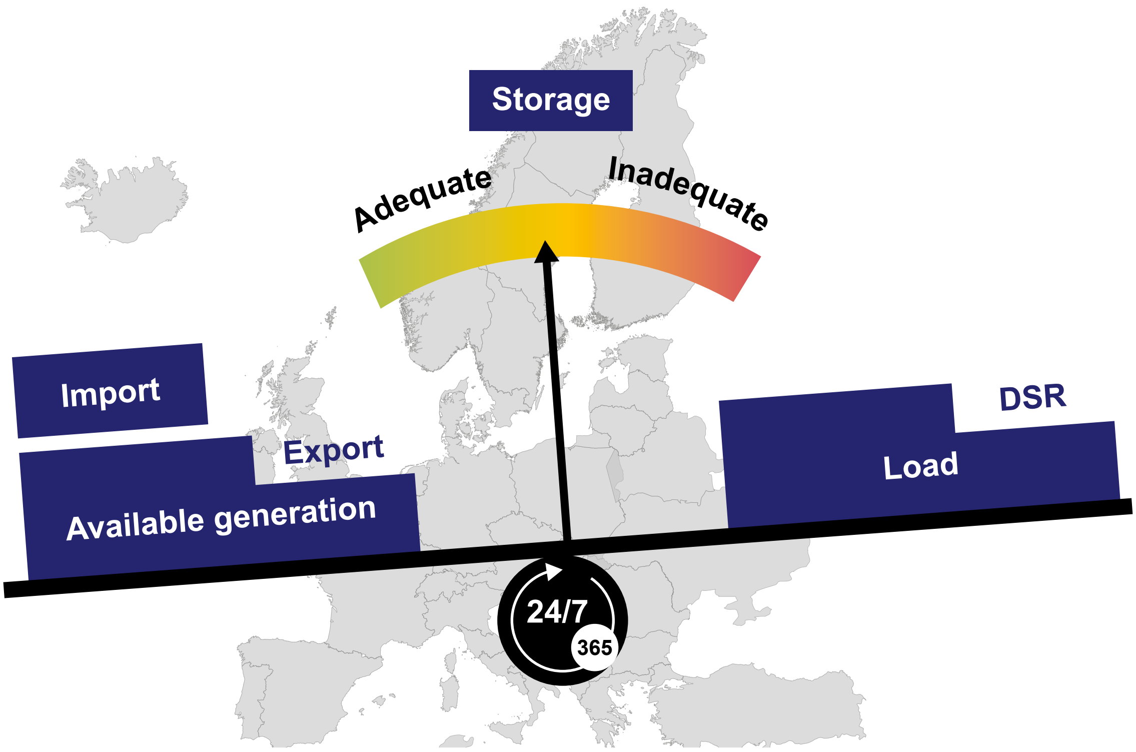
Introduction to the MAF

What is the purpose of the 'MAF'?

The Mid-term Adequacy Forecast (MAF) is a pan-European monitoring assessment of power system resource adequacy spanning the timeframe up to 10 years ahead. It is based upon a state-of-the-art probabilistic analysis conducted using sophisticated market-modelling tools. It aims to provide stakeholders with comprehensive support to take qualified decisions.

Resource adequacy is an increasingly prominent issue that requires advanced methodologies to capture and analyse rare events with adverse consequences for the supply of electric power. It describes the continuous balance between net available generation on the one hand and net load levels on the other, as shown in Figure 1.1.

Figure 1.1: 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 enhanced related challenges for system development and operation, a pan-European analysis of resource adequacy has become ever more important. Cooperation across Europe in developing such methodologies is necessary to accelerate methodological development processes and ensure common standards – i.e., a common 'language'.

Over the past decade, ENTSO-E has continuously improved its methodologies and forecasts, and will continue to ensure that further progress is made. The MAF already contributes to the harmonisation of resource adequacy methodologies across Europe, being a reference study among European TSOs and a targeted approach for TYNDP and Seasonal Outlook studies.

The MAF aims to provide stakeholders with comprehensive support to take qualified decisions, and will help to develop the European power system in a reliable, sustainable and connected way.

Stakeholders may find the prospective nature of the MAF, as well as its extensive pan-European coverage, particularly useful. In fact, the MAF is the most comprehensive pan-European assessment of adequacy so far attempted, using a market-based probabilistic modelling approach. It is a result of the collaborative effort of representatives from TSOs, covering the whole pan-European area under the coordination of ENTSO-E. Five different modelling tools have been calibrated with the same input data and benchmarked against each other to increase consistency, robustness and – fundamentally – trust in the complex analytical results presented in the report. Still, it should also be noted that the present pan-European assessment inevitably faces limitations. For instance, the MAF does not consider possible network constraints within a zone. The higher granularity of national/regional adequacy assessments might detect local resource or network constraints which are not identified by the present assessment, thus highlighting the complementarity of regional and pan-European analyses.

What are the main improvements compared to the MAF 2017?

Since the publication of last year's report, MAF activities have been consolidated, improved and standardised. Furthermore, the MAF database has been updated to consider the latest country adjustments, while new modelling features have been tested with an innovative flow-based modelling approach.

In terms of modelling assumptions and model alignment among all participating tools, the MAF 2018 builds on the accomplishments of previous MAF editions. The number of tools performing the adequacy study increased by one – i.e., five tools in total – and the efforts to align models were intensified. Furthermore, specific modelling improvements have been put into practice along with more detailed "what-if" sensitivity analyses, as listed below:

— **Low-carbon sensitivity analysis:** As an additional sensitivity scenario under the context of MAF 2018, information regarding potential reduction in installed capacity and decommissioning of units was collected, originating from accelerated low-carbon policies. The sensitivity analysis focuses on the target year 2025 and explores the impact on adequacy of accelerated low-carbon (environmental) national policies. For example, this may correspond to capacity reduction stemming either directly from environmental legislations – e.g., a coal phase-out – or indirectly by the impact of environmental actions on the profitability of generating units. Data for this sensitivity analysis was provided by TSOs, in addition to the base case (best estimate) data set for the year 2025.

— **Flow-based innovative analyses:** To improve the representation of the network on the simulations, two new approaches were investigated and tested under the framework of the MAF 2018 for the respective 2020 and 2025 horizons. For the target year 2020, the corresponding simulation model is built in line with the rules of the Continental Western Europe (CWE) flow-based market coupling model, adopting the same implementation approach performed by TSOs in the latest PLEF study[1]. The results of this study are compared with the base case scenario and give a view on the impact of network consideration on the market simulations. For the target year 2025, a test has been made of the capability to handle the complexity of a detailed representation of the extra-high-voltage transmission grid complemented with MAF data. The detailed grid model for Continental Europe has been built in the framework of TYNDP 2018.

— **Import levels during simultaneous scarcity situations:** Interconnections between countries are of importance to ensure adequacy in tight situations. In hours of scarcity, a country relies on imports from neighbouring power systems in order to recover adequacy, provided there is available power in the neighbouring power system as well as sufficient transfer capacities to allow imports. In the current version of the MAF 2018, an in-depth detailed analysis of the base case results was performed, evaluating the import levels of a country in hours of scarcity as well as the impact of simultaneous scarcity situations on multiple countries – i.e., scarcity observed in a single country and scarcity observed in multiple neighbouring countries in the same hour. To this end, a restricted geographical region was considered (France, Belgium, Great Britain) in order to showcase the results of this analysis. The results are presented in "Appendix 1: Methodology and detailed results".

— **Hydro modelling:** Hydro modelling is a topic of high complexity that has considerable impact on market-modelling simulations. Therefore, it has been given special attention in the current version of the MAF by performing specific experiments aimed at aligning and understanding the impact of relevant assumptions and optimisation horizons on the adequacy results. Methodologies for optimising hydro generation vary considerably among modelling tools, and exploring its impact on the simulations is an arduous task. For this reason, a comparative analysis has been performed with different modelling tools. The results are presented in "Appendix 1: Methodology and detailed results".

[1] Pentalateral Energy Forum, Support Group 2, "Generation Adequacy Assessment", January 2018, http://www.benelux.int/nl/kernthemas/holder/energie/pentalateral-energy-forum

What are the lessons learnt?

Our report highlights the importance of cross-border cooperation in fostering adequacy throughout the pan-European power system. There are complex interdependencies between supply, demand, storage and interconnection capacities. With a sensitivity analysis on accelerated phase-out of high carbon-emitting supply, the MAF sets the framework for detailed regional/national studies to investigate in-depth, specific solutions, including, among others, technological advances on demand-side response (DSR), renewable energy sources (RES), storage, flexibility and interconnections.

Based upon activities and simulations conducted for the MAF, several insights were gained:

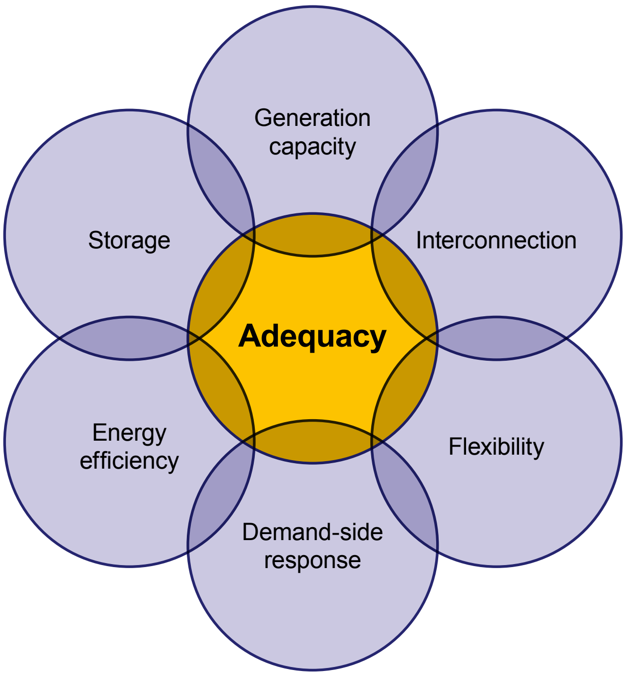
— **Improvement of adequacy results compared to the previous MAF edition:** The moderate adjustments of input data brought notable improvements on adequacy results. The MAF hereby shows its important monitoring role. Improved MAF 2018 results may also be attributed to existing capacity mechanisms as well as those recently approved by the European Commission (early 2018 for Belgium, France, Germany, Greece, Italy and Poland). Further investigation of the impact of capacity mechanisms on adequacy, by MAF and complementary regional/national studies, requires increased modelling granularity, including unit-by-unit modelling with sensitive economic data, the consensus of the relevant stakeholders, and significant commitment of the necessary resources by TSOs.

— **Increased resolution in modelling indicates potential problems in the periphery:** An additional zone has been considered in the MAF 2018 – namely, Tunisia – while in an effort to increase modelling granularity, the islands of Corsica and Crete have been explicitly modelled. Thus, a better representation of the isolated areas was achieved, leading to more reliable results.

— **Estimated reliability levels throughout Europe are heterogeneous:** Limited transmission capacities between some areas obstruct the full deployment of complementary support throughout Europe. Consequently, adequacy risks could be expected for small islands and, in some cases, at the periphery of the simulated power system.

— **Strong system interdependencies call for a pan-European perspective:** Our analysis demonstrates complex and strong system interdependencies, and highlights their impact on system adequacy, schematically shown in Figure 1.2. Specifically, we find temporal and spatial dependencies in load and generation patterns from variable renewable energies, as well as in the availability of hydro and thermal power (e.g., driven by hydrological inflows or maintenance schedules). However, beneficial balancing effects for support systems in times of scarce generation capacity may only be deployed if sufficient grid infrastructure is present. Measures to overcome adequacy problems may be allocated to the supply, demand or the grid sector. Therefore, decision makers will need to coordinate their activities to ensure efficient deployment of (partially) complementary measures. For instance, additional interconnection may supersede the need to enhance generation capacity within a country.

Figure 1.2: Interdependencies between measures that impact resource adequacy



— **Substantial generation capacities that could be decommissioned by 2025 due to environmental reasons would require some increase in resources to secure system adequacy:** A low-carbon stress test for 2025 of around 23 GW capacity reduction compared to the 2025 base case indicates increased adequacy risks and highlights the need for preventive actions, which could leverage on resources and technologies described in Figure 1.2. At the same time, due to the system interdependencies, it is not clear whether this capacity reduction would take place simultaneously, as modelled in the MAF. Further regional and national sensitivities might be needed to assess the evolution of such a 'low-carbon' scenario.

— **The crucial role of interconnectors, especially in periods of scarcity:** Our studies indicate that countries import extensively during periods of scarcity. Moreover, in cases of simultaneous scarcity in neighbouring countries, countries import as much as possible from the available power in all neighbouring regions to which they are interconnected. This confirms the crucial role of interconnectors in maintaining adequacy.

— **A common standard is needed for data, models and reliability metrics:** The MAF 2018 demonstrates important improvements regarding data collection and alignment of the modelling tools. This process revealed that results can be considerably sensitive to modelling approaches, optimisation methods and, generally, different tools' specificities, as highlighted by the results' sensitivity to the hydro optimisation process. In addition, large variations may be observed in the reliability standards and thresholds applied by the various Member States (for a detailed discussion, see ACER/CEER Market Monitoring Report 2015[2]). Therefore, additional efforts should be directed towards the development of common standards for data models, as well as setting homogeneous definitions and usage of reliability metrics across Europe, which is strongly desirable for coherent and comparable adequacy assessments. Discussion is also required regarding whether the national values and thresholds of these reliability metrics might still differ.

— **Adequacy assessments require substantial coordinated efforts:** To conduct and improve the complex probabilistic assessment of power system adequacy, continuous and coordinated activities and efforts are necessary. Specifically, adequacy assessments require a substantial amount of resources to collect reliable data from multiple stakeholders, validate them and build complex models with the appropriate level of precision and reliability. This is not only relevant for the pan-European assessment, but naturally extends to regional and national studies. Future efforts should thus be streamlined and supported by all stakeholders in an effort to ensure consistent and reliable results for qualified decision-making.

[2] ACER – Annual Report on the Results of Monitoring the Internal Electricity Markets in 2015, page 61.

Upcoming challenges and future steps

Capitalising on its achievements, the MAF's future activities will continue to target four dimensions: data, modelling, common standards and complementarity with national and regional studies.

The MAF is progressively becoming a reference for adequacy studies in Europe. Nevertheless, further efforts are still needed to ensure that it provides an elaborated pan-European view for adequacy-related decision-making in Europe. Specifically, further improvements should be directed towards the following four dimensions:

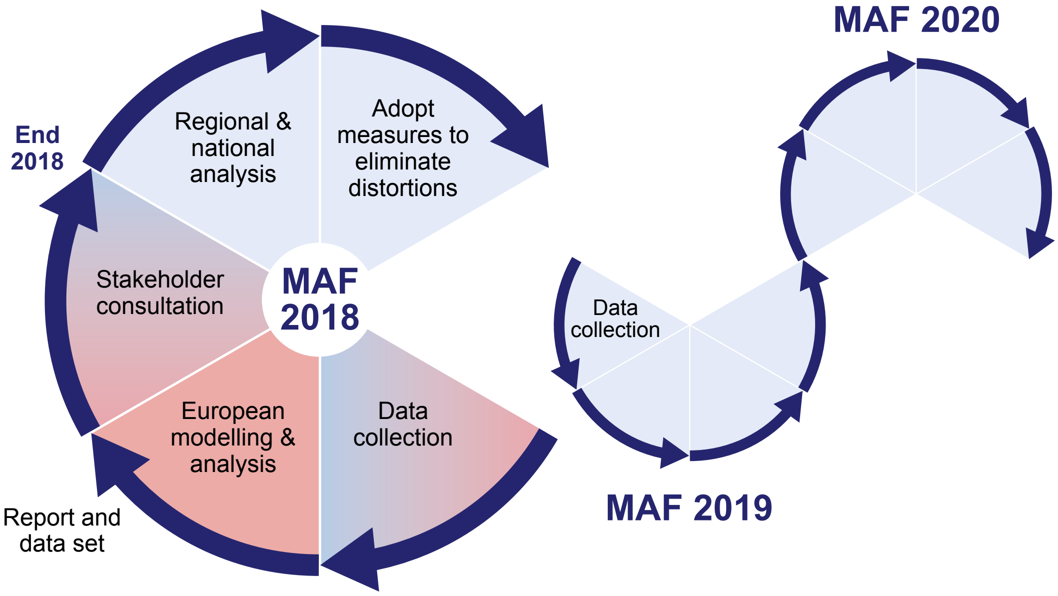
First, data collection and consolidation should maintain a high level of quality and, in some cases, improve further. Additional **data collection** will lead to an even better representation of the full complexity of adequacy in the power system. The greatest potential for further improvement is seen in the context of hydro-power modelling and flexibility of generation assets, as well as economic parameters of the system. Finally, the study of the uncertainty associated with each data/parameter as well as the propagation of the uncertainty in the input of the results will be investigated.

Second, the **models** need to be further developed to address the full complexity of adequacy. For future editions of the MAF, the focus will be on a more detailed representation and analysis of interdependencies within the system – e.g., regarding the (partial) substitutability of demand, storage and supply-side measures and interconnectors. The representation of grid infrastructure will be further developed towards a more accurate flow-based representation, as already implemented as a sensitivity analysis in the current edition. Lastly, flexibility products and ramping are also areas of intended future improvements.

Third, convergence of **common standards in terms of data and methodology** constitutes a major challenge. ENTSO-E strives to establish the MAF methodology as a reference for other studies (e.g., in relation to the TYNDP, seasonal outlooks, regional or national adequacy studies, etc.). This includes enhanced and more standardised interaction with TSOs and other stakeholders regarding data and modelling interfaces. In line with the proposals in the EU Clean Energy Package, the outcome will be reported in a 'Methodology Guidelines' report, including a stakeholder consultation phase and corresponding amendments. This document will significantly contribute towards establishing a standardised framework for adequacy assessments in Europe.

Last but not least, the MAF will be **embedded in a broader set of stakeholder activities**. Within a continuous forward-moving cycle, the yearly process mainly consists of five steps, as shown in Figure 1.3. The MAF itself mainly covers the first three parts – i.e., data collection, European modelling and analysis, and stakeholder consultation. However, to realise the full potential of the MAF, these steps need to be complemented by regional and national analyses, thus providing a sound basis for adopting measures to eliminate regulatory distortions hindering the realisation of an adequate system state. Learnings and new developments will then be fed into the next edition of the MAF to ensure continuity and consistent improvements.

Figure 1.3: Process of activities in the adequacy domain



Regional and national studies should aim to ensure the highest degree of consistency (i.e., data, time horizons, assumptions) with the MAF in order to enable comparison. Moreover, they should challenge the MAF with regards to enhancements of methodology and use of the highest granularity of data possible.

How can erroneous takeaways be avoided?

The calculated reliability indicators are not a forecast of future outages. Specifically, the adequacy analysis presented in this report is (and can only be seen as) a best possible estimate of future developments, considering the information available today.

It must be noted that the conclusions in this report cannot be seen in isolation from the hypotheses described, and they can only be read in reference to them. The hypotheses were gathered by the TSOs according to their best knowledge at the time of the data collection and were validated by ENTSO-E's relevant committees.

MAF 2018 GPS:
Navigating through the MAF 2018 report

The MAF 2018 is divided into three different parts in an effort to assist different stakeholders in easily identifying relevant information.

Executive Report:
presents the motivation of the MAF 2018, followed by the main adequacy results, including:

— The base case results for 2020 and 2025

— The low-carbon sensitivity analysis results for 2025.

Appendix 1:
presents a more detailed description of the MAF study, including:

— methodology and assumptions

— detailed results of the different studies

— analysis of the import/export levels during single and simultaneous scarcity situations

— impact analysis of hydro constraints and their relaxation

— description of the market-modelling tools used for the MAF 2018.

Appendix 2:
contains the country-specific comments and the relevant references to national and regional studies.

Section 2

Main findings of the MAF 2018

For the MAF 2018, five European electricity market models were calibrated and run based on comprehensive data sets for 2020 and 2025. The main findings are presented in this section, while more detailed results are contained in the Appendices. As a preliminary remark, it should be noted that although the same time horizon as that in last year's MAF has been studied, the careful reader will find several differences between the results.

There are two main sources of such differences: (1) the updated input data set provided by TSOs, which showcases the monitoring role of the MAF, and (2) improvements in hydro modelling assumptions. While a one-to-one comparison is difficult due to the large number of interdependent assumptions and complex models, the results presented hereafter should be seen as an updated and improved best estimate of future adequacy conditions. To this end, the MAF 2018 generally anticipates lower risks of inadequacy in Europe, as a result of the aforementioned data update, but foresees a scarcer adequacy situation between 2020 and 2025 for some bidding zones.

In addition to the base case scenarios 2020 and 2025 depicted in the following two chapters, a large number of additional analyses were carried out while preparing the MAF 2018. The main insights are presented hereafter, while the detailed model results are displayed in the Appendices.

2.1 Adequacy in base case 2020

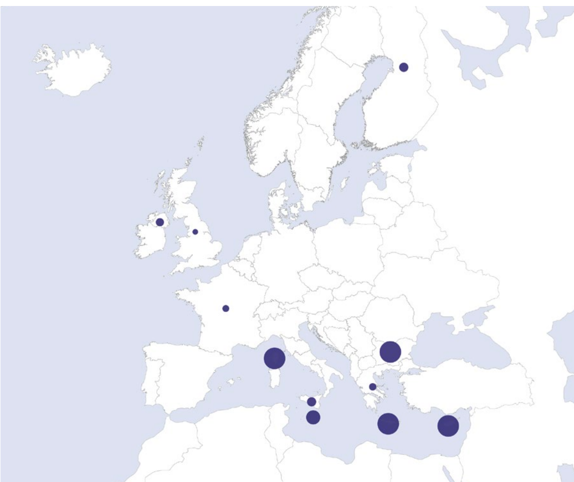
The estimated levels of resource adequacy for the year 2020 in the base case scenario are shown in Figure 2.1 by means of country-by-country loss of load expectation (LOLE) – i.e., a risk indicator derived from probabilistic market-modelling tools. It should be noted that LOLE indicated in this report refers to the market resource adequacy, without considering the energy not served (ENS) due to transmission or distribution faults. More specifically, for each zone, Figure 2.1 plots the LOLE (left side) and the 95th percentile of results (right side)[3]. For more information about the methodology and probabilistic indicators, please see "Appendix 1: Methodology and detailed results". Moreover, readers should also consider the country comments presented in Appendix 2: "Country comments on the MAF 2018" in order to better understand particular characteristics and modelling assumptions that might apply to different countries, before deriving any conclusions.

In Figure 2.1, a circle's radius increases along with LOLE values. Furthermore, a colour range is also applied to illustrate the different LOLE values among different areas, as well as their magnitude (colour darkens with increasing values of LOLE).

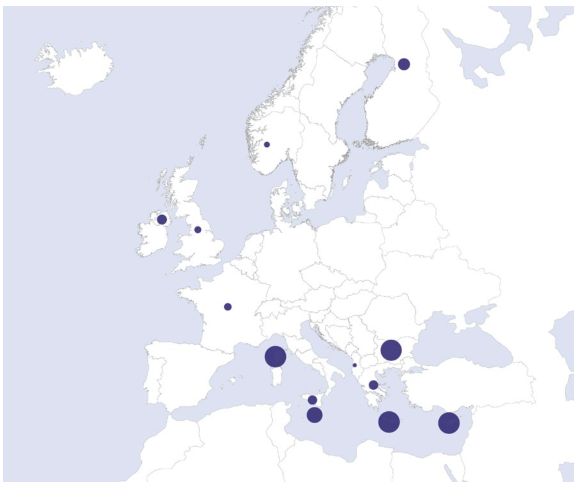
The market-modelling results for the year 2020 do not indicate considerable adequacy issues in most countries, even considering the 95th percentile. On the contrary, the risk of resource scarcity appears for only a few countries, including Bulgaria and some islands – e.g., Cyprus, Malta, Corsica and Crete – while for the rest of the countries, the observed values of LOLE are below 4 hours. However, results for islands should be consulted with care, since they are more sensitive to updates in modelling assumptions. Besides structural developments on the demand and supply sides, these findings confirm the role of interconnection in helping countries to get support in critical situations.

In Figure 2.2, we present the corresponding result from the previous edition of the MAF – i.e., the MAF 2017. In the MAF 2018, Corsica and Crete were explicitly modelled. This has led to the observed difference in Figure 2.1 and Figure 2.2, where severe risk is identified for the islands this year. Apart from these two islands, it can be observed that results in the MAF 2018 are comparatively more optimistic than the previous edition of the MAF, identifying less risks of resource scarcity – for example, see the cases of Ireland, Poland and Finland. The explanation behind this improvement of adequacy results between the two editions lies mainly on the updated data set in the MAF 2018 and highlights the monitoring role of this assessment.

Figure 2.1: Market resource adequacy – loss of load expectation (LOLE) – 2020 base case scenario (MAF 2018). The circles and the corresponding values used in the legends are only indicative and do not cover the whole range of circle radius and LOLE values that are presented in the maps – e.g., in the map circles exist that correspond to values between 1 and 5 h.



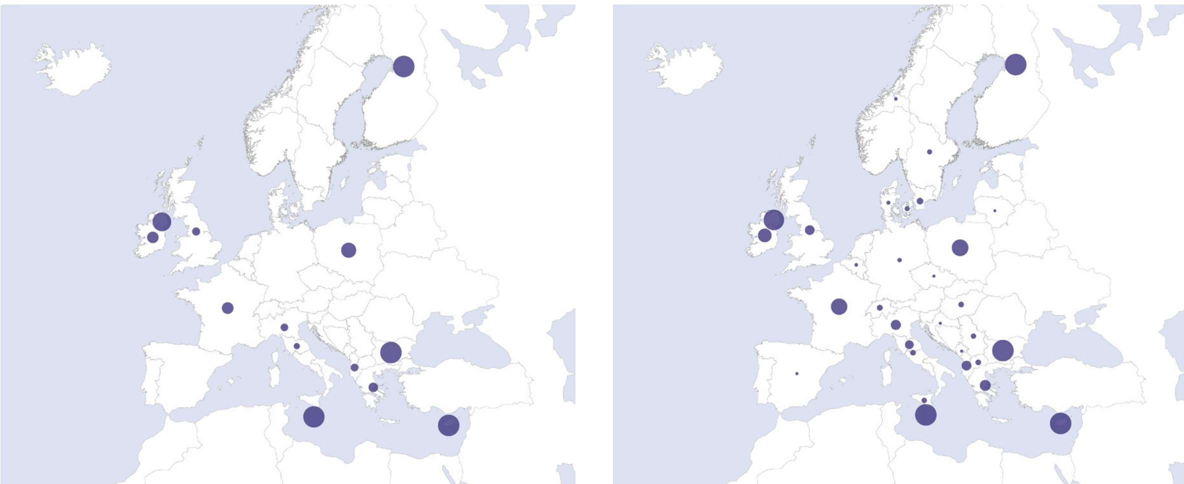
LOLE (h) – Base Case 2020
1 · 5 · 10 · 15 · ≥20



95th Percentile (h) – Base Case 2020
1 · 20 · 40 · ≥60

[3] The 95th percentile is equal to the value that is higher than 95% of all results. This corresponds to a probability of occurrence of 1 in 20 years.

Figure 2.2: Market resource adequacy – loss of load expectation (LOLE) – 2020 base case scenario (MAF 2017). The circles and the corresponding values used in the legends are only indicative and do not cover the whole range of circle radius and LOLE values that are presented in the maps – e.g., in the map circles exist that correspond to values between 1 and 5 h.



LOLE (h) – Base Case 2020 (MAF 2017)
1 5 10 15 ≥20

95th Percentile (h) – Base Case 2020 (MAF 2017)
1 20 40 ≥60

Figure 2.3: Monte Carlo approach to assessing resource adequacy in a nutshell

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

The modern Monte Carlo method was developed by scientists working on the atomic bomb in the 1940s. They named it after the city in Monaco famed for its casinos and games of chance. Its core idea is to use random samples of parameters or inputs to explore the behaviour of a complex system or process. Since that time, Monte Carlo methods have been applied to an incredibly diverse range of problems in science, engineering and finance, as well as business applications in virtually every industry.

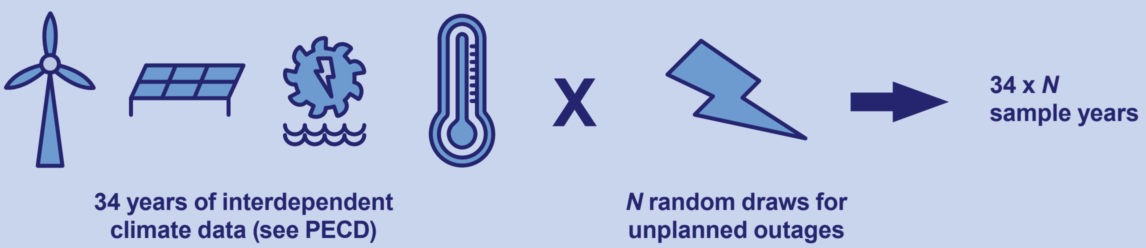
The high number of aleatory input variables which influence the outcomes of an adequacy assessment in power systems makes the Monte Carlo method very suitable for the current study. Specifically, it is a state-of-the-art technique used to represent probabilistic variables such as climate data and unplanned outages in electricity market models, as illustrated below.

For each hour of our simulations, a reliability indicator is calculated, namely the energy not served (ENS), indicating whether there is an adequacy problem or not.

This value can be either:

ENS = 0 (no adequancy problem)
or
ENS ≠0 (adequacy problem found)

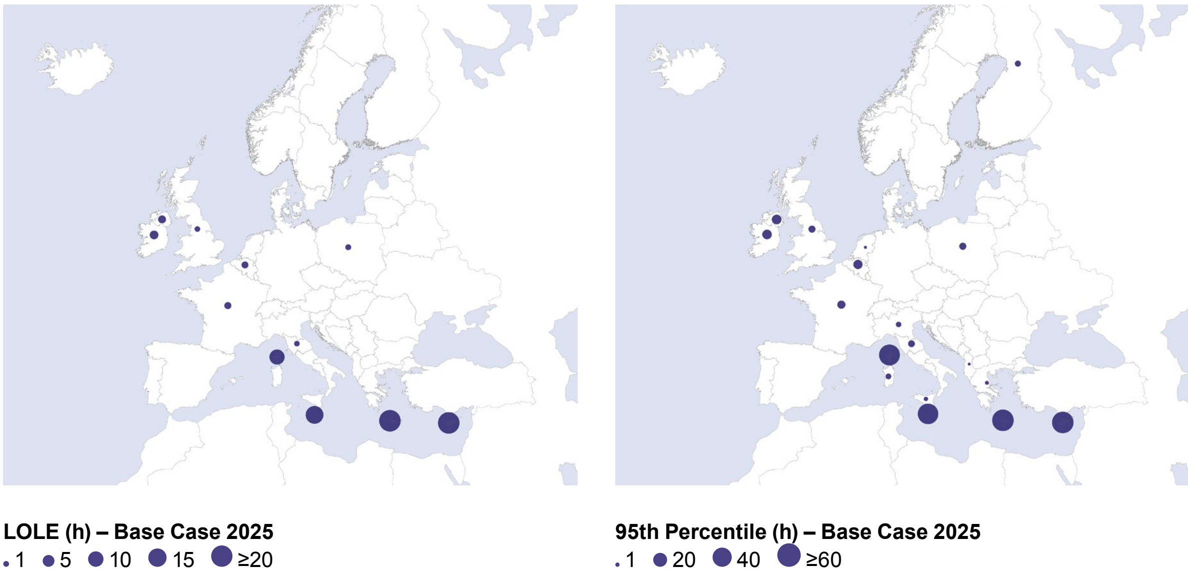
For each area of interest, the number of times with non-zero ENS is counted and stored. This number divided by the total number of simulations provides an estimate of the probability of adequacy issues. Bookkeeping of the number of counts of ENS allows us to construct the so-called probability distribution (PD) function and to derive the LOLE – i.e., the expected number of hours with adequacy issues within a certain area during a year. It is important to recall that our analysis must not be understood as a forecast of actual scarcity situations. The actual realisation of scarcity events in a particular hour in the future will, of course, depend upon the actual realisation of all the variables impacting a power system, and could be very different compared to our analysed situations. Meanwhile, our analysis provides a sound indication for the range of possible realisations (see next infobox).



2.2
Adequacy in base case 2025

The same analysis conducted for 2020 was performed for the base case 2025 scenario. Figure 2.4 presents the key resource adequacy indicator – i.e., LOLE – which was extracted from the probabilistic market modelling of the pan-European system.

Figure 2.4: Market resource adequacy – loss of load expectation (LOLE) – 2025 base case scenario (MAF 2018). The circles and the corresponding values used in the legends are only indicative and do not cover the whole range of circle radius and LOLE values that are presented in the maps – e.g., in the map circles exist that correspond to values between 1 and 5 h.



Comparing the maps in Figure 2.4 to those in Figure 2.1, some additional circles appear. A limited number of hours of LOLE could be considered as proof of equilibrium between net available generation and net load, on average, and it highlights the need to deploy the planned investments in the systems towards 2025. Figure 2.4 also shows comparatively higher LOLE values for the islands compared to the rest of the countries. Similarly to the 2020 results, the results for the islands are sensitive to updates and the implementation of interconnection projects, especially for longer time horizons – i.e., 2025. Lastly, it should be noted that a smaller system, if not sufficiently interconnected with the power systems of Continental Europe, is more exposed to possible outage of generation assets on the island.

How is LOLE calculated?

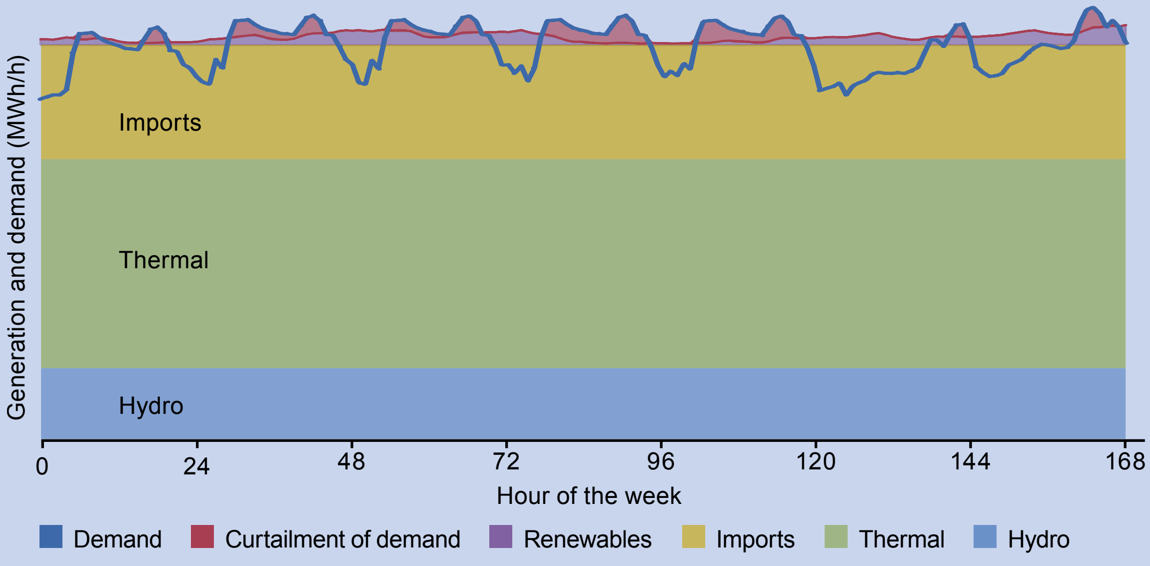
Simulations of a target year (e.g., 2020) are run multiple times, so that random forced-outage events can occur at any time (according to available statistics). Indeed, from a big number of simulations, many correspond to cases without particularly stressful outages. On the other hand, some can also correspond to patterns of forced outages that are particularly stressful – i.e., demand cannot be met by available generators and/or imports over available interconnectors. In these situations, the amount of demand that is not served is counted as 'energy not served' (ENS), measured in GWh. The average number of hours among all simulation runs during which this event occurs is recorded as 'loss of load expectation' (LOLE).

The amount of ENS and LOLE is recorded for each region and for each simulation. After performing multiple simulations, the expected ENS (EENS) and LOLE can be calculated (per region, and for the pan-European system), as can the P95 (95th percentile) values. The P95 values are particularly useful to demonstrate the type of severe events that could happen once in 20 years.

The MAF incorporates a number of different scenarios where different outlooks are studied – namely, different levels of generation, demand and climatic conditions. Through this, we hope to give a picture of how the adequacy situation might develop depending on which path each region chooses to follow. Of course, the actions of one region might affect its neighbours. Being a pan-European model, the MAF is designed to capture these interdependencies.

Does LOLE being greater than zero indicate risk of blackout?

Figure 2.5: Illustration of partial inadequacy to cover demand with the available resources



If the LOLE for a region is not zero, then there exists a theoretical risk of partial lack of resources to meet 100% of demand. This region can expect a number of hours in the year where the demand cannot be met, considering that all generation means and available imports have been utilised (e.g., red area in Figure 2.5 representing curtailment of demand). Some regions have national adequacy standards of a number of hours of LOLE. This means that they strive (through a capacity or other mechanism) to ensure that their LOLE remains at or below this standard.

However, while the MAF focuses on and only observes the day-ahead situation with respect to adequacy, TSOs have various tools to resolve situations of scarcity in the intraday. Thus, for example, if the LOLE is 10 hours and the EENS=1 GWh, then even in a very severe situation, load-shedding risk would be only partial (e.g., 100,000 households for 10 hours), if not avoided by operational measures or contracted industrial load shedding. Furthermore, diverse remedial actions and out-of-the-market resources, like strategic reserves, can be used as a last resort to prevent load shedding.

From a theoretical economic point of view, having 1 h with 1 GW of load shedding and having 10 hours with 100 MW of load shedding are the same. However, from a practical viewpoint, in most situations, a TSO would favour having smaller demand shortages for a longer period, rather than a short, sharp shock with large outages.

2.3
Low-carbon sensitivity analysis

In addition to the base case scenarios, data was collected about the number and size of generation units which may be at risk of being closed by 2025 due to an acceleration of "low-carbon (environmental) policies". For example, such capacity reduction could stem either directly from environmental legislations – e.g., a coal phase-out – or indirectly by the impact of environmental actions on the profitability of generating units. This is considered as a stress test, since the decommissionned generation considered in this assessment is not replaced by any other resource. The input was provided by TSOs, and the reduced capacity in comparison with the base case 2025 is presented in absolute numbers (MW) in Figure 2.6. In total, around 23 GW of generating capacity was removed from the 2025 base case scenario. Figure 2.7 shows a map of the relative capacity reduction for each area along with the updated adequacy result for 2025, as depicted by circles of increasing radius (a more detailed description of the numerical data can be found in "Appendix 1: Methodology and detailed results"). The relative values (%) presented in Figure 2.7 represent the capacity reduction as a ratio of the peak demand for each area.

Figure 2.6: Generation capacity flagged as at risk of being decommissioned by 2025, and consequently removed in the low-carbon sensitivity analysis

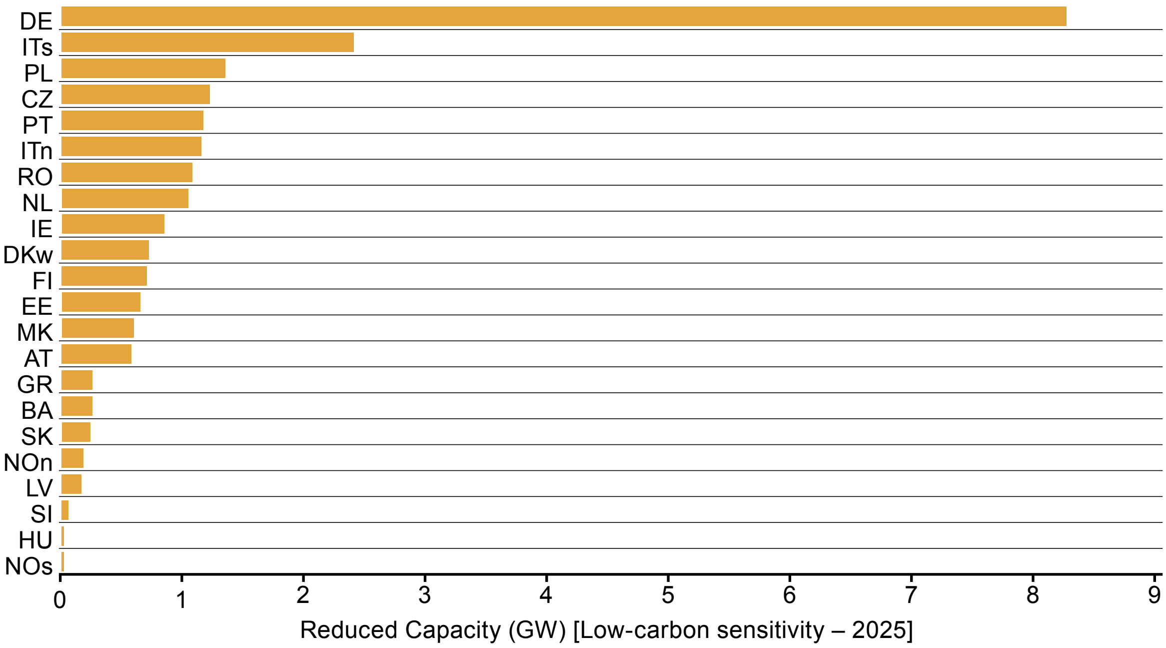
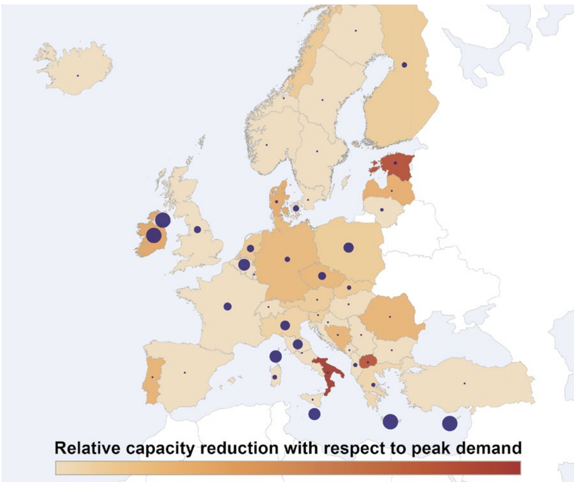


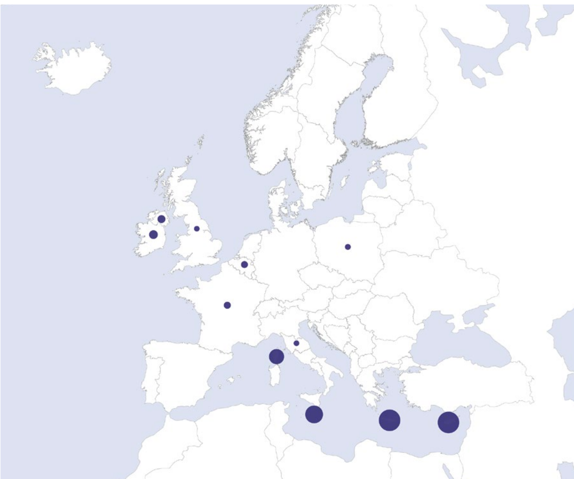
Figure 2.7: Country colour shows the ratio between decommissioned capacity (see Fig. 2.6) and peak demand. The blue circles indicate the LOLE at each region after the capacity reduction according to the “low-carbon sensitivity” input.



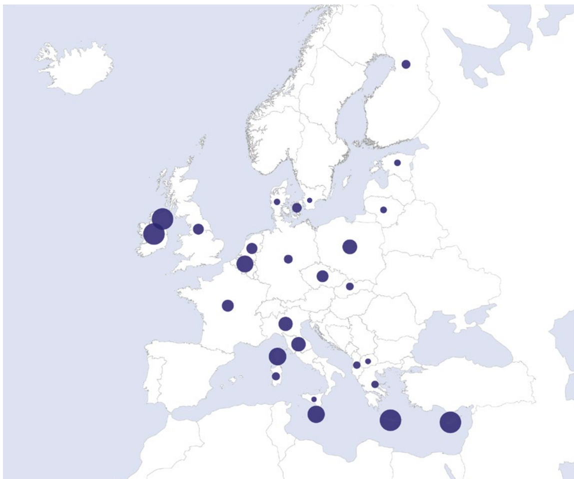
LOLE (h) – Low-Carbon Sensitivity 2025
≤1 5 10 15 ≥20

The regional dimension of adequacy is confirmed by this stress test analysis: Figure 2.8 shows an increase of hours of LOLE in Belgium and France, although the assumptions in these countries for this sensitivity have not changed.

Figure 2.8: Comparison of LOLE between the base case and the low-carbon sensitivity in 2025. The circles and the corresponding values used in the legends are only indicative and do not cover the whole range of circle radius and LOLE values that are presented in the maps – e.g., in the map circles exist that correspond to values between 1 and 5 h.



LOLE (h) – Base Case 2025
1 5 10 15 ≥20



LOLE (h) – Low-Carbon Sensitivity 2025
1 5 10 15 ≥20

This sensitivity analysis should be understood as a stress test on generating capacity, and can, by definition, only result in inferior adequacy levels. In order to better understand the impact of such a reduction on the installed capacity, results are compared in Figure 2.8 with the corresponding results of the base case 2025: the results confirm that the decommissioning of polluting generation capacity should be accompanied by the development of the systems in different terms (e.g., development of DSR[4]; storage; generation; interconnection). Higher granularity of national/regional adequacy assessments could complete the picture by assessing possible resource adjustment and by detecting any local resource or network constraints which might not be identified by the MAF. Also, the next edition of the MAF strives to monitor the situation further through possible updates of the assumptions in each country.

Finally, to ensure reliable predictions of future adequacy levels, it is crucial to obtain reliable and consistent data from the supply side of the system. To this end, a potential approach would be that European utilities are asked to announce the (de-) commissioning as well as mothballing plans for 3–5 years ahead. This would result in a clearer picture of the future system conditions and power system evolutions.

[4] DSR potential in Europe has been estimated at more than 60 GW (Hans Christian Gils, Assessment of the theoretical demand response potential in Europe, Energy, Vol. 67, 2014). The DSR considered in the present study for 2025 is 19 GW.

2.4
Flow-based sensitivities

One important simplification in the MAF 2018 simulations is in the representation of the network. In the base case simulations, the results of which have been presented above, the impedance of the network is not explicitly considered in the simulations and is only taken into account in the values of the transmission constraints imposed as constant net transfer capacity (NTC) between zones.

A more detailed representation of the network is attempted under the framework of this sensitivity analysis following two different approaches for each of the target years investigated in the MAF 2018 – i.e., years 2020 and 2025.

The flow-based (FB) approach implemented for the year 2020 follows the implementation of FB-market coupling (FB-MC) performed at the regional level by the PLEF study. In this approach, representative historical FB domains, including the effect of grid reinforcements until 2019, are implemented for CWE countries (BE, FR, DE, NL) as the basis for the modelling of cross-border capacity. The different types of FB domains used represent several situations with different levels of congestions in the grid. Their implementation in the model is further correlated to expected climate and consumption conditions for each day of the simulations, which are the main drivers for congestions in the grid. An important methodological improvement compared to the PLEF study is the implementation of the so-called minimum remaining available margin (MinRAM), equal to 20% of the maximum allowed power flow on each critical network element and contingency (CNEC).

For the target year 2025, one tool tested the capability to handle the complexity of a detailed representation of the grid model for Continental Europe, built into the framework of TYNDP 2018 using the CGMES[5] format, with the representation of voltage levels from 100 kV up to 400 kV. The model demonstrates the following features:

— TYNDP 2018 full grid network (20,000 buses, 21,000 generators) complemented by the MAF 2018 data

— Flow-based approach based directly on network power flows, considering the impedance and the location of loads and generators

— Applicable to all countries represented in the grid model

— Network reinforcement included in the TYNDP is considered.

More details on the 2020 and 2025 flow-based approaches can be found in Appendix 1.

[5] Common Grid Model Exchange Specification.

2.5
Flexibility requirements

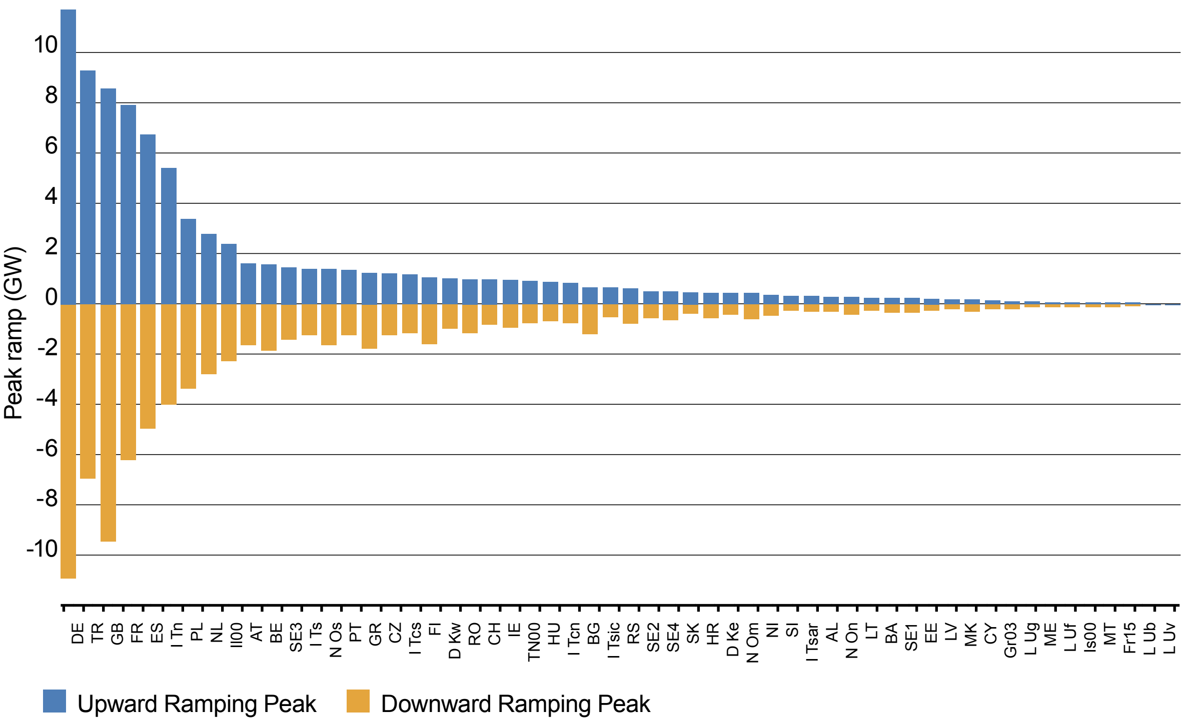
Adequacy is not only related to the total amount of capacity being installed in the system, but also to the ability of the installed capacity to adjust to the ever-increasing dynamics of dispatch events in the system. The latter is defined as flexibility adequacy and it becomes evermore important, mainly due to the increasing amount of variable renewable energy present in the power system. Several flexibility services will be required in order to ensure a smooth transition to high RES penetration. In particular:

— **Ramping needs:** Notably with the growing PV penetration, flexible resources will become essential to meet the fast change of residual demand – for instance, the steep upward ramp created by the decline in solar output due to the sun setting when demand increases in the evening.

— **Balancing fast reserves:** The increase of variable generation along with the forecast error of wind and PV should be overcome with reserve deployment in order to secure the supply. Modelling of balancing reserves in the current MAF is performed assuming that a fixed amount of supply is kept available at any time. Despite the considerable improvements in forecasting variable power generation, for both wind and solar, in practice, forecasting can never be perfectly accurate, with decreasing forecast errors as real-time operation approaches. Thus, forecasts are very likely to be updated hours ahead of real time, and the system will require fast starting and controllable resources (interconnectors, DSR, storage and fast response generators).

Figure 2.9 shows the hourly residual load ramps (i.e., the hourly changes in load minus variable renewable energy generation) that are requested from dispatchable generation units when considering each market node independently.

Figure 2.9: Hourly residual load ramps on a national basis (99.9th percentile)



The ramping needs shall be addressed through all available means. The interconnections can contribute up to around one third of the flexibility needs in 2025[6]. The remaining needs shall be addressed by generation, demand response and/or storage. Recent studies in Europe and around the world confirm that flexibility is becoming a crucial point for system adequacy. Flexibility services and products are growing in importance and are progressively being integrated into the market. ENTSO-E aims to extend further insights on flexibility in coming MAF reports.

[6] Cf. MAF 2017 chapter 2.4.

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