METIS Studies

Study S04

Generation and System Adequacy Analysis

METIS Studies
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EXECUTIVE SUMMARY

System adequacy in modern power systems

The primary goal that is sought when designing a power system is to ensure it is able to meet the demand in all but very exceptional situations. Historically, the system adequacy assessment was performed at the national level by comparing the available generation and peak demand for a small number of typical situations. However, modern power systems are characterized by a growing share of variable renewable power generation, which translates into uncertain power output and hence into the ineffectiveness of the way we used to assess system adequacy. New numerical techniques have been developed, in particular by TSOs, to precisely simulate the operations of the power system for a number of weather scenarios and are the basis of this report.

The growing share of variable power generation not only requires new techniques to assess system adequacy, but also questions the geographical scale that should be considered when making this assessment. If the assessment keeps being performed at the national scale, there will be redundant investment in back-up capacities. Indeed these capacities would only be running when renewables cannot deliver enough power. Instead, if the assessment is performed at a regional level, the investment in back-up capacities would be lower since the back-up capacities would be running a greater number of hours due to the fact that renewable power generation and peak demand do not happen at the same time in different countries. This report exhibits the benefits of a regional or European approach to system adequacy.

The benefit of using a probabilistic approach to system adequacy

One way to measure the quality of a power system is to estimate its adequacy, i.e. its ability to meet the demand in all but very exceptional situations. Historically, system adequacy has been assessed by comparing the generation capacity to the peak demand for a small number of points in time. While simple to handle, this approach has a number of drawbacks since it does not allow for a proper representation of the dynamics of the system. This report presents a number of situations in which the probabilistic approach allows to grasp security of supply stakes which could not be highlighted by the so-called deterministic approach (dynamic storage management, power exchanges).

For example, in order to estimate whether storage can help meeting the peak demand, one has to understand whether or not the system has allowed storage capacities to store enough power during previous periods: the dynamics of the system is crucial. Not taking them into account can lead to wrong conclusions. The same argument can be made for interconnectors: one cannot estimate their role in system adequacy by only considering their capacities, the ability of neighboring countries to deliver power is crucial too.

A more modern approach to system adequacy, known as the probabilistic approach, uses dynamical simulations of the power system operations taking into account the technical constraints of the power system assets. The ability of the power system to meet the demand may then be tested against a number of weather realizations that influence the demand (through temperature) and the production by renewables. The METIS software developed by Artelys for the European Commission uses the probabilistic approach to system adequacy.

The importance of regional coordination

A key parameter influencing the adequacy of the power system is the geographical scale at which the assessment is performed. If the assessment is performed at the country-level, one tries to understand whether or not the power system installed in the country is able to meet the country’s demand. If the assessment demonstrates that the country’s power system is not adequate, this is interpreted as a need for further investments in generation capacities.

However the country-level approach completely disregards the contribution of neighboring countries. A regional approach to system adequacy would result in a better utilization of power plants and hence in a lower level of investment required to reach security of supply.

This fact is due to the combined effect of the following three factors: (i) the variability of renewable production is partly smoothed out when one considers large geographical scales, (ii) the demands of different countries tend to peak at different times, and (iii) the power supply mix of different countries can be quite different, leading to synergies in their utilization.
Thanks to the variability of weather conditions (and consequently of RES generation profiles) across Europe, along with the different practices in terms of power consumption and generation, high capacity savings can be obtained by adopting a coordinated European approach to security of supply. The benefits of such a coordinated approach with respect to a country-level system adequacy assessment are estimated (in paragraph 5.2.1) to reach up to 90 GW in a high RES context (or 70 GW in a smaller progress context) of capacity savings (around 40 billion Euros of investments[1][2]).

Policy recommendations
Since the national approach underestimates the ability of the power system to adequately meet the demand (i.e. the value of the loss of load is overestimated), and given the level of savings induced by coordination, one should aim at a coordinated approach to system adequacy assessment. While a European coordination gives the best results in terms of the cost-effectiveness of security of supply, coordination on a regional level, which would be easier to organize, is shown to already be very beneficial in terms of avoided investments.
In order to reach such a goal, it is crucial that Member States share a common vision:

- By using the same metrics and methodology. For instance, the maximum loss of load per Member State, expressed as a percentage of its annual energy demand could be a robust metric. Moreover, adopting a probabilistic approach is recommended. A description of this methodology is proposed in paragraph 3.2.2.
- By defining a consistent set of assumptions (power demand projections, weather data, thermal capacities and availabilities).

[1] These values do not include fuel savings and the more efficient use of renewable resources that could be obtained by optimizing RES location from a European point of view.

[2] This figure of 40 billion Euros corresponds to an investment of 85 GW of OCGT (at 500 M€/GW, from IEA), which should be, as an initial approach, the plant type which could recover its investment when operating a small number of hours per year.

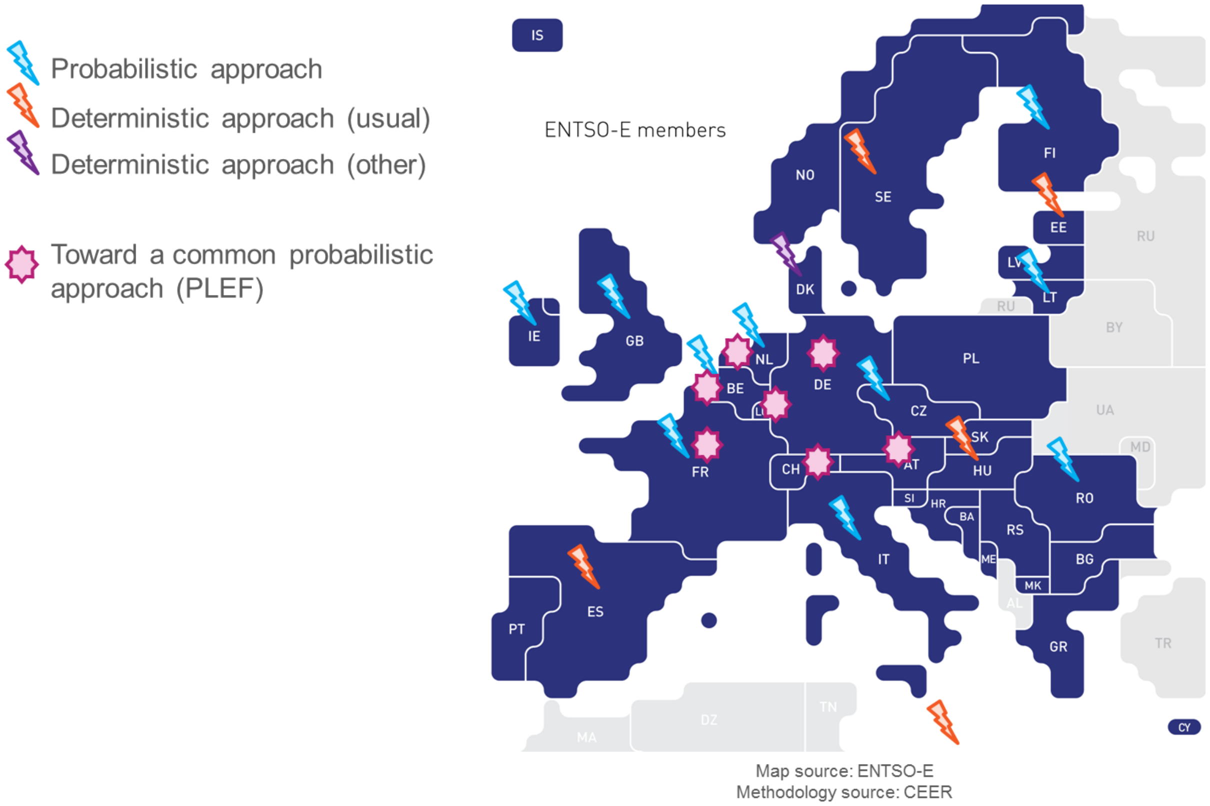

Figure 1: Current distributions of generation adequacy methodologies across Europe

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1. Abbreviations and definitions

1.1. Abbreviations

Abbreviation	Definition
ARM	Adequacy Reference Margin
CCGT	Combined Cycle Gas Turbine
CEER	Council of European Energy Regulators
EENS	Expected Energy not Served
ENTSO-E	European Network of Transmission System Operators
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
NTC	Net Transfer Capacity
OCGT	Open Cycle Gas Turbine
PHS	Pumped Hydro storage
PLEF	Pentalateral Energy Forum
RAC	Reliable Available Capacity
RC	Remaining capacity
RES	Renewable Energy System
SO&AF	Scenario Outlook & Adequacy Forecasts
TSO	Transmission System Operator
TYNDP	Ten Year Network Development Plan

Table 1 - Table of abbreviations

1.2. Definitions

Concept	Definition
Adequacy Reference Margin	Capacity that should be kept available at all times to ensure the security of supply.
Expected Energy not Served	Total volume of energy which was demanded but not supplied during a year.
Loss of Load Expectation	The expected number of hours per year for which the available generation capacity is insufficient to cover the demand.
Loss of Load Probability	Likelihood of encountering loss of load.
Reliable Available Capacity	Part of Net Generation Capacity which is actually available in the power system to cover the load at a respective Reference Point in normal (average) conditions.
Remaining capacity	Capacity left to cover any unexpected load variation and unplanned outages.

Table 2 - Table of definitions

2. Introduction and background

2.1. Foreword

The present document has been prepared by Artelys in response to the Terms of Reference included under ENER/C2/2014-639[3]. Readers should note that the report presents the views of the Consultant, which do not necessarily coincide with those of the Commission.

2.2. Introduction

Artelys is developing a software (METIS) for the European Commission which models and simulates the main aspects of the European energy systems and markets. At the same time Artelys has to gradually deliver a number of studies, which aim at enhancing the European Commission's understanding of the studied topics, as well as at to validate the capabilities of the METIS software modules.
This study, entitled "Generation and System Adequacy Analysis", uses METIS to analyze and compare several approaches to the evaluation of power security of supply in Europe.
Section 3 presents a literature review on how generation adequacy is defined and what are the current indicators used by main stakeholders. Section 4 compares the main methodologies and metrics used by European stakeholders to evaluate the adequacy of a power system. Section 5 concerns the stakes of the coordination between countries when assessing security of supply. To conclude, section 6 presents policy recommendations, advocating for a compromise between a global European coordination (which could entail some practical difficulties) and coordination on smaller scales (which could involve investment).
The study is the first application of the Power and Gas System Module, whose purpose is to simulate the optimal dispatch of energy (i.e. electricity and gas) in Europe. It fully exploits the main features of this module and especially the detailed representation of the power system infrastructure (generation, grids, dynamic storage management, etc.)[4], examining some of the issues associated with the assessment of security of supply and to evaluate the benefits of a common European approach. This study focuses on the power system.

[3] http://ec.europa.eu/dgs/energy/tenders/doc/2014/2014s_152_272370_specifications.pdf

[4] This study focuses on the power system only. Note that, even if demand response can have an important impact on system adequacy, it has not been considered in this report.

2.1. Modelling setup

The study has been performed with the use of METIS software using the following configuration.

Metis Configuration	
METIS VERSION	METIS v1.1
Modules	Power system
Scenarios	ENTSO-E TYNDP 2014 – Visions 1 and 3 - Year 2030 With current (2014) OCGT and CCGT installed capacities
Time granularity	Hourly (8760 consecutive time-steps per year)
Asset modelling	Fleet level at country granularity
Uncertainty modelling	*10 years of weather data*

Table 3 METIS Configuration used for study S4

3. Literature review: System and generation adequacy

3.1. Definition of generation adequacy

A major concern of national authorities is to ensure the *security of supply*, which is to say to make sure that the electric system is able to satisfy all consumers' needs. Such a characteristic is also referred to as *system adequacy*.
In order to assess security of supply, representative metrics are needed. Since the demand is less flexible than supply, system adequacy is usually interpreted as the ability of producers to supply a given load demand, often referred to as *generation adequacy*.[5]
The ENTSO-E defines *system adequacy* as follows:

> "*System adequacy of a power system is a measure of the ability of a power system to supply the load in all the steady states in which the power system may exist considering standard conditions. Within the ENTSOE Scenario Outlook and Adequacy Forecast, <u>system adequacy is assessed by means of Generation Adequacy Assessment</u>.*" (Chapter 7, section *System Adequacy*, p.126)

In other words, a system is considered *adequate* if the installed generation capacity is such that the demand can be met.

3.2. Two types of methodologies

One way to assess generation adequacy is to confront the required generation and capacity. The level of required generation obviously directly depends on the load level, while the available generation capacity in particular depends on planned and unplanned outages. Both generation requirements and available capacity are therefore varying with time, which implies that the ability to meet the demand can only be assessed at a given point in time.
The following paragraphs describe two types of classical methodologies, respectively known as "deterministic" and "probabilistic". The first one, often used at the country-level, computes capacity margins for a set of reference time slots; uncertainty is taken into account through an additional margin that represents seasonal peaks or extreme weather conditions (see Figure 2). Regional and European cooperation may be considered through a computation of capacity margins static dispatch.
The second approach, known as the probabilistic approach, involves the simulation of the annual operational management of all energy assets adopting an hourly time resolution, using several yearly realization of weather data to take into account the variable nature of RES power production and demand. The exchange of power between Member States is dictated by a network model.

3.2.1. Deterministic approach (ENTSO-E)

The deterministic approach has been adopted by ENTSO-E in their successive Scenario Outlook and Adequacy Forecasts (SO&AF) up to 2016. This section sums up the methodology used by ENSTO-E, as described in the Scenario Outlook and Adequacy Forecast 2014-2030. Note that ENTSO-E is progressively moving to the probabilistic approach.

3.2.1.1. Standard indicator: capacity margin

The following indicators are given to quantify both generation needs and capacities. They can only be computed at a given reference point. In practice, the ENTSO-E uses two representative reference points: one in winter (January), when the European load is the

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[5] Demand response can also play an important role for system adequacy. However, this is outside the scope of this report.

highest, and one in summer (July), when most of the maintenance works are scheduled and, as a result, when the available capacity on a European level is at its lowest.

- **Reliable Available Capacity (RAC):**

  Defined as "the part of Net Generation Capacity which is actually available in the power system to cover the load at a respective Reference Point in normal (average) conditions" (Chapter 7, p. 137).

  RAC = Net Generation Capacity (NGC) – Unavailable Capacity (UC)

  'Unavailable capacity' takes into account maintenance, overhauls, outages and system service reserves.

- **Remaining Capacity (RC):**

  Represents the capacity "left to (…) cover any unexpected load variation and unplanned outages" (Chapter 7, p.137)

  RC = RAC – (Load – Load management)

- **Generation adequacy under normal conditions**:

  At each reference point, the Remaining Capacity is directly used as a measure of generation adequacy under normal conditions. If positive, the installed capacity is sufficient, whereas if negative, it is not.

  Generation Adequacy Level = RC

This capacity margin can be compared to the Import Capacity to assess whether an eventual deficit in generation capacity may be compensated with imports**.**

3.2.1.2. Uncertainty considerations: additional margins

Two reference points are obviously not enough to represent all the possible situations that the electric system may face and that one should consider when assessing the security of supply. Moreover, even under normal conditions, a reference point does not depict the whole period it should be representing (summer and winter, in the case of SO&AF). In the deterministic approach, the variability of weather conditions and demand over a season, as well as unplanned events such as outages or extreme weather conditions, are therefore taken into account by setting additional margins.

- **Adequacy Reference Margin (ARM):**

  Represents the capacity that "should be kept available at all times to ensure the security of supply on the whole period each reference point is representative of" (chapter 7, p.137).

  In an individual country, it is defined as follows:

  ARM = Spare Capacity + Margin Against Seasonal Peak Load

  Where the *margin against seasonal peak load* is defined as the difference between load at a given reference point and load peak during the period (basically, one season) represented by the reference point.

  The spare capacity represents "the additional capacity that should be available to cope with any unforeseen extreme conditions" (chapter 7, p.135). For an individual country it is defined as the extra capacity needed to guarantee operations in 99% of possible situations (i.e. combinations of load and generation units' availabilities). For a set of countries, however, since extreme conditions are not likely to happen at the same time, spare capacity can be assessed as a fixed proportion of the Net Generation Capacity: 5% in the case of ENTSO-E's Adequacy Forecast.

- **Generation adequacy in most situations:**

To assess the system ability to cope extreme conditions or seasonal peaks, the Remaining Capacity is compared to the Adequacy Reference Margin – as opposed to 0, under normal conditions – which represents the capacity that should remain available at all times to ensure that the system is able to meet the demand in almost all situations.

Generation Adequacy Level = RC – ARM

The following graph illustrates the relation between the different indicators mentioned so far.

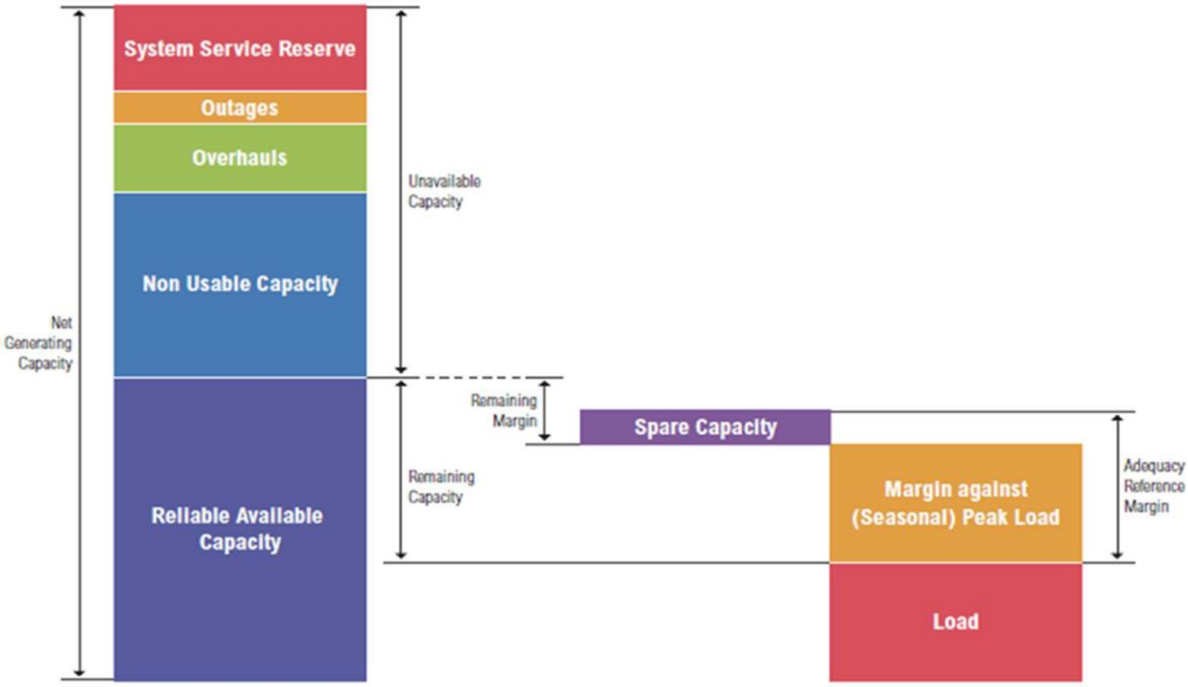

Figure 2: ENTSO-E's reference indicators
SOURCE: SO&AF 2014-2030, ENTSO-E

3.2.1.3. Regional analysis through national capacity margin or deficit

In its Scenario Outlook and Adequacy Forecast *(SO&AF)*, ENTSO-E assesses system adequacy of individual member countries, regions (that are blocks of several member countries), and the whole ENTSO-E. Indicators for a set of several countries are defined as sums of country-level indicators, except for the Spare Capacity (see previous section)[6]. On each scale, the different indicators (RC and RC - ARM) are used to quantify generation adequacy, for different security of supply requirements.
A regional analysis can then be performed to evaluate whether interactions between the different countries (or blocks of countries) can compensate for an eventual lack of generation capacity. A linear optimization is performed on the whole ENTSO-E: first each of the countries is characterized by its Remaining Capacity reduced by its Spare Capacity[7]. Exports and imports that minimize the total volume of flow are then determined, under maximum flow conditions, to assess whether some countries' lack of capacity can be balanced by other countries' extra capacity.

[6] Note that the Margin Against Seasonal Peak Load is thereby overestimated as seasonal peaks do not occur simultaneously in every country.

[7] Here, margins against seasonal peaks load are not taken into account since seasonal peaks are not likely to occur simultaneously in the ENTSO-E system.

3.2.2. PROBABILISTIC APPROACH (PLEF, ENTSO-E TARGET)

A more recent approach has been implemented by some TSOs and by the Pentalateral Energy Forum (known as the PLEF, gathering RTE, Elia, Amprion, Tennet, Swissgrid, APG, and Creos). The probabilistic consists in establishing a cost-minimizing production hourly dispatch such that all the national demands are met for several years of meteorological data. Various types of generation assets, as well as different storage technologies and interconnectors, are represented. Adequacy can then be assessed by analyzing the simulations' outputs. Different possible loads and renewable non-controllable generation conditions can be considered, e.g. using a Monte Carlo approach.
This is the target methodology for ENTSO-E future SO&AFs.

3.2.2.1. Considering different load and RES scenarios

Since the load, meteorological parameters (temperatures, wind, and solar expositions) and asset outages are characterized by a high level of uncertainty, different yearly realizations are defined for those parameters, and combined to build a range of historical weather years (220, in the case of the PLEF). Correlations between weather conditions in neighboring countries have to be taken into account when creating a yearly scenario.
The following graph shows how uncertainties regarding different parameters have been combined to define the set of hypothetical years in the PLEF adequacy study.

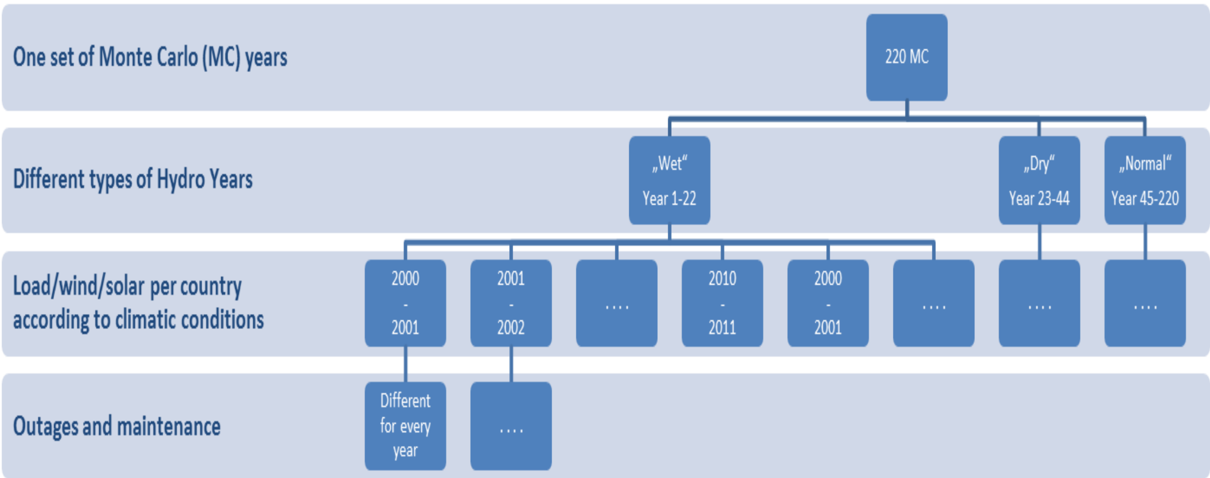

Figure 3: Graphical illustration of the amount of hypothetical years
SOURCE: Pentalateral Energy Forum's report on Adequacy Assessment

3.2.2.2. Modelling network (currently NTC, flow-based targeted)

Interconnectors are usually modelled as commercial flows with no network physical constraints, but constrained by maximum net transfer capacities (NTC). In practice NTC values can vary quite often, due to outages, maintenance and temperature affecting lines' physical properties. In this PLEF study, two values have been used: one for winter and one for summer. These values have been obtained by averaging the hourly NTC values.
Recently market coupling algorithms have adopted flow-based modelling instead of the NTC description[8]. Different institutions including the ENTSO-E and the PLEF are therefore considering including flow-based modelling as a future improvement.

3.2.2.3. Main metrics of security of supply

The following standard indicators, which are outputs of the simulations, can be used to assess the security of supply and generation adequacy:

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[8] For instance: https://www.epexspot.com/document/33019/CWE%20FB%20MC_Confirmation%20Go-live%2020%20May_24April.pdf

- **Loss of Load Expectation** (LOLE), which is defined as "the expected number of hours per year for which the available generation capacity is insufficient to cover the demand".
- **Expected Energy not Served** (EENS), which is total volume of energy which was demanded but not supplied during a year.
- **Loss of Load Probability** (LOLP), which represents the "likelihood of encountering loss of load". This is equal to LOLE / 8760 hours.
- **Probability density function** of the duration of the shortage expected when adverse operation conditions are met**.**
- **Remaining capacity** (that is capacity margins), which allows one to compare different situations with no loss of load by quantifying the margin left to the system.

Note that the number of hours during which a loss of load occurs could be misleading as an indicator of generation adequacy. Indeed, because of the dynamic use of power storage, a same loss of load volume could be concentrated on a small number of hours or spread over a longer period of time.

Besides, volumes indicators like EENS should be expressed as percentages of the national demands, in order to allow for consistent comparisons.

3.3. Historical assessments

The Council of European Energy Regulators (CEER) performed a survey[9] over European countries showing that security of supply is currently dealt with at national level, through quite different approaches. In particular, the two methodologies presented above ("probabilistic" and "deterministic") have been used, with different assumptions regarding the way the network is represented or the way storage dynamics and uncertainty are handled.
The following table sums up the methodologies discussed so far, and gives examples of major actors using it.

	PLEF (FR, DE, BENELUX, AT, CH), **RTE, ELIA**	**ENTSO-E**	
		Current	**Targeted**
APPROACH	« Probabilistic »	« Deterministic »	« Probabilistic »
SCALE	Regional (at least direct neighbors, up to second degree neighbors)	National – simplified regional	Pan European
NETWORK REPRESENTATION	**Current** NTC	**Targeted** PTDF	None on small scale, maximum flows on regional scale
SECURITY OF SUPPLY INDICATORS	Loss of Load (Energy, Duration, Probability, Frequency), Capacity margin	Capacity margin	Loss of Load
UNCERTAINTY CONSIDERATIONS	Monte Carlo simulations	Additional margins	Monte Carlo simulations

Table 4 - Main actors' historical methodologies

[9] Assessment of electricity generation adequacy in European countries, CEER, March 2014.

3.4. Towards a common methodology?

The CEER claims that "security of supply is no longer exclusively a national consideration, but it is to be addressed as a regional and pan-European issue" and that "generation adequacy needs to be addressed and coordinated at regional and European level in order to maximize the benefit of the internal market for energy"[10].

From that perspective, the network representation needs to be improved in order to properly take into account import/export possibilities, whose role in the assessment of the security of supply may be of primary importance. Furthermore, harmonized data - collected at the European level - must be used to take into account weather conditions' geographical correlation. This is especially important when considering RES generation profiles, water inflows, and residual demand. Current national methodologies do not satisfy these requirements.

As a conclusion of their survey, the CEER published recommendations[11] that emphasize the need for the implementation of a harmonized methodology. The PLEF has already used such a common approach (see previous section) in a recent security of supply study[12]. Additionally, the ENTSO-E's target methodology is announced to be "fully in line with the methodology developed by TSOs in PLEF"[13].

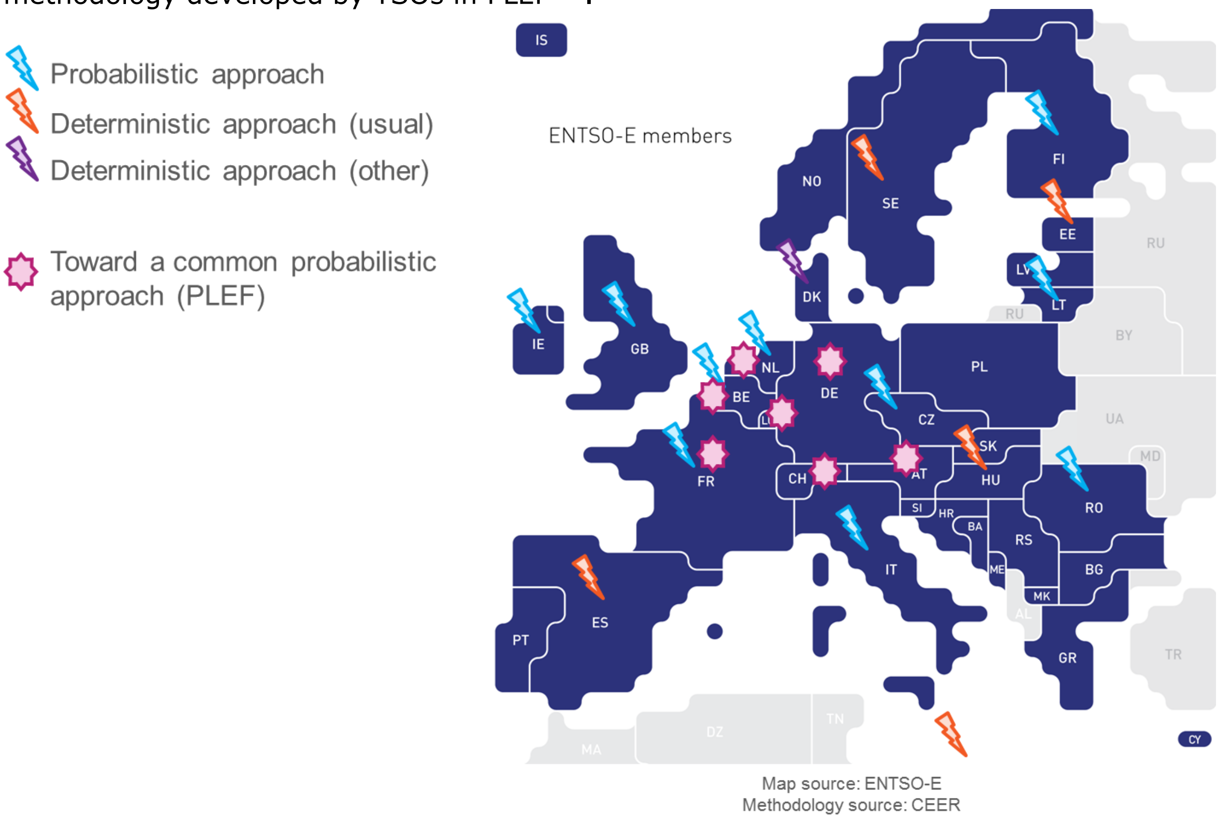

Figure 4: Current distributions of generation adequacy methodologies across Europe

[10] Assessment of electricity generation adequacy in European countries, CEER (p. 7), REF: C13 – ESS – 32 – 03 (03 Mars 2014).

[11] Recommendation for the assessment of electricity generation adequacy, CEER, REF: C13 – ESS – 33 – 08 (08 Oct 2014).

[12] Pentalateral Energy Forum [PLEF] – Support Group 2, Generation Adequacy Assessment.

[13] Energy Community Workshop : "Towards Sustainable Development of Energy Community", RES-integration : the ENTSO-E perspective.

4. COMPARING PROBABILISTIC AND DETERMINISTIC APPROACHES

The methodology implemented in METIS follows the probabilistic approach described by PLEF: it consists in performing dynamical simulations, on multiple weather realizations, with an hourly time resolution, taking into account storage dynamics and interconnection capacities between Member States. The metrics allowing one to assess the level of security of supply are globally the same as the ones presented in section 3.2.2.3.

4.1. STUDIED CASES

To illustrate both security of supply approaches (deterministic and probabilistic), study scenarios have been derived from ENTSO-E scenarios[14] (EU 2030 v1 and EU 2030 v3): all data on demand and generation mixes are driven from ENTSO-E scenarios but CCGT and OCGT installed capacities, which have been set to current values (values published by the ENTSO-E for 2014) in order to mimic situations of insufficient capacity in 2030[15]. Indeed, the integration of 500 to 1 000 TWh of additional RES[16] does not compensate for the coal, lignite and nuclear capacities decrease (- 65 GW of dispatchable capacity in total), and even less so in a context of power demand increase (+400 TWh for 2030 v1 and +1000 TWh for 2030 v3). These scenarios are used in the following to illustrate the results and the merits of the two approaches to security of supply (deterministic and probabilistic).
Two scenarios from the TYNDP 2014-2030 have been modelled in METIS:

- **Scenario 2030 v1:** "The first scenario is Vision 1 [developed by the ENTSO-E in their TYNDP], *Slow progress*. Vision 1 reflects slow progress in energy system development with less favorable economic and financial conditions. Vision 1 fails to meet the EU goals for 2030 […]. Compared to the present days, the consumption and generation mix have evolved by less than in other Visions entailing a lower pressure for more market integration and interconnection capacity"[17]. V1 is the scenario with the lowest RES development, although the main change in installed capacities is the increase of wind and solar, mostly in Germany. Besides, Germany, Belgium and Switzerland are assumed to plan a nuclear phase-out while other countries are expected to build new units.
- **Scenario 2030 v3:** "The third scenario is Vision 3, *green transition*. Vision 3 reflects an ambitious path towards the 2050 European energy goals, where every Member State develop its own effort achieving overall 50% of European load supplied by RES in 2030. Vision 3 meets the EU goals by 2030. However in this Vision, every country tends to secure its own supply independently from the other, resulting probably into a redundant investment in generation assets at European level."[18] This scenario is characterized by a large RES development.

[14] From the TYNDP 2014.

[15] To better grasp the differences between the different approaches to security of supply.

[16] Since RES units produce up to their expositions to wind, sun or water inflow, RES production is determined by the assumption on RES installed generation capacity. Flexible generating units' annual production volumes, on the other hand, depend on production planning choices. They are therefore not directly determined by assumptions on installed generating capacity but are outcomes from simulations.

[17] ENTSO-E's 10-year Network development plan.

[18] ENTSO-E's 10-year Network development plan.

	ENTSO-E 2030 v1	ENTSO-E 2030 v3
Wind onshore	190	260
Wind offshore	46	100
Solar	130	230
Nuclear	111	107
Lignite	50	50
Coal	77	65
Hydro (Total)	240	250
Oil	11	16

Table 5 - Assumptions on installed capacities in ENTSO-E scenarios (GW)

As mentioned above, the gas capacities have been assumed to be equal to the 2014 capacities.

4.2. COMPARISON BETWEEN THE TWO APPROACHES

4.2.1. DETERMINISTIC APPROACH

The main benefit of adopting a deterministic approach is that it requires less data, the collection of which is a considerable task since it should be done at the European scale with common and harmonized methodology.
On the other hand the deterministic approach does not grasp some of the main stakes of security of supply: dynamic management of storages, variability of RES generation and their complementarity at European scale, constraints of power exchanges between countries due to the satisfaction of their own security of supply.

4.2.2. PROBABILISTIC APPROACH

Unlike the deterministic approach, the probabilistic approach considers the supply-demand equilibrium at hourly time step on several years of weather data. This approach also allows taking into account the storage management and NTC constraints, as well as the variability of RES generation. It also grasps the benefits of complementarity between the European countries, in terms of RES generation and demand peak times.
However, implementing a probabilistic approach leads to some difficulties related to the data collection: a data set has to be constituted for each represented countries, which has to be geographically and temporally coherent (same level of details for every country, same historical years for reconstituting weather data realizations).

4.3. ILLUSTRATION OF THE MAIN STAKES GRASPED BY THE PROBABILISTIC APPROACH

4.3.1. BENEFITS OF HOURLY TIME STEP SIMULATION

The hourly time step resolution is important to capture short-term phenomena, such as storage dynamics, which influence the security of supply assessment. Indeed, storage

dynamics modelling is crucial to a proper representation of scarcity periods: the contribution of energy storage to the security of supply may be limited not only due to its power generation capacity, but also because of the dynamics of the system (i.e. the state of charge of storage).
On the following chart, representing the cumulative production in Belgium in December, the two circled days illustrate storage volume limitations. Energy storage is emptied (in blue) during the beginning of the day, and is therefore unable to use its output capacity for the rest of the day, which induces loss of load (in black).

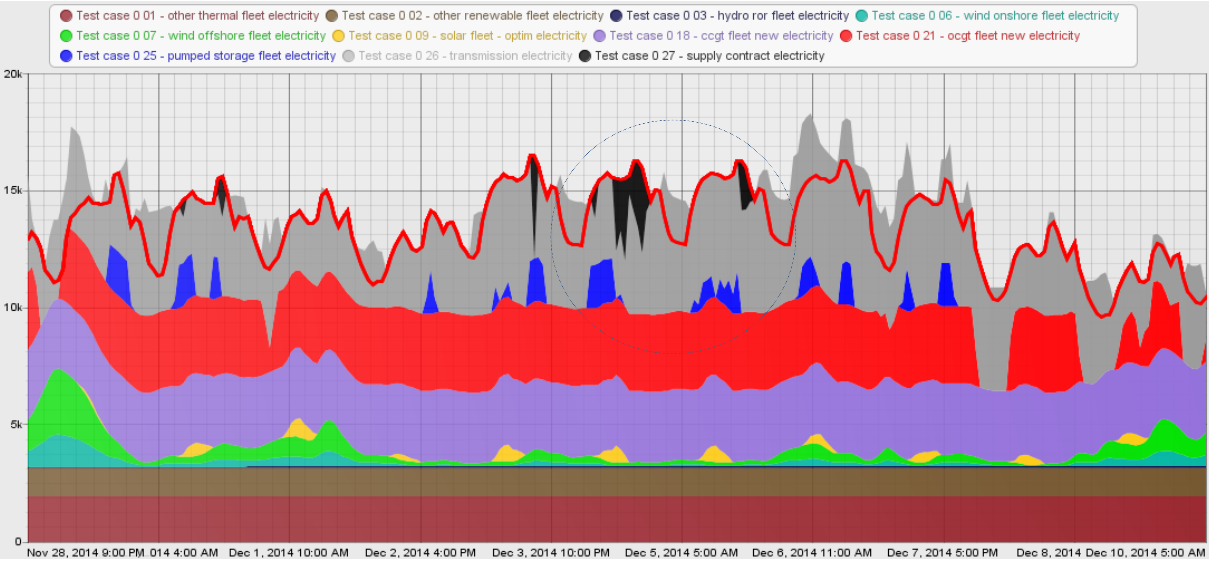

Figure 5: Importance of storage dynamics: cumulative production in December in Belgium (loss of load in black)
Scenario: ENTSO-E 2030 vision 3 with current CCGT/OCGT generation capacities

The Figure 5 shows that at 4 p.m. during the first circled day, the total available production/import capacity exceeds the demand by far, although loss of load occurs in dynamical simulations. The difference between available generation/import capacities and the actual production/import is due on one hand to the energy storage limitations, and on the other hand to neighboring countries' inability to provide extra production.

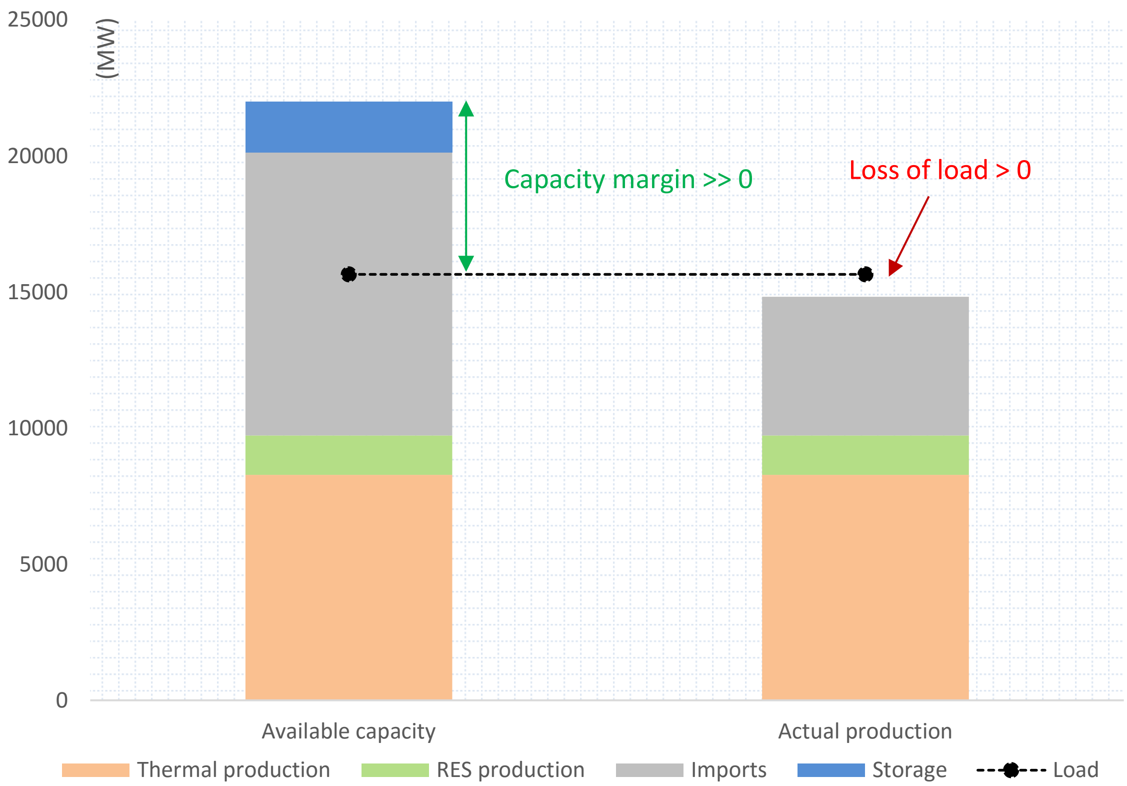

Figure 6: Production dispatch from simulation vs Capacity margin
Belgium, December 4th 4 p.m. – Scenario ENTSO-E 2030 v3 with current CCGT/OCGT generation capacities

It would not be possible to assess whether the system will be able to handle the demand using a deterministic approach in such a case. The deterministic approach would in fact consist in summing the available generation capacities at a given date to deduce a positive capacity margin, as shown by Figure 6, and would lead to a misleading conclusion.
Remark: To apply a deterministic approach, capacity credits should be defined and applied to storage output capacities so as to take into account the system's dynamical constraints. However, besides the obvious issue of evaluating such coefficients, this methodology would raise transparency issues.

4.3.2. Benefits of multiple climatic realizations

Taking into account the diversity of possible weather events and their representativeness is key to assess loss of load. Indeed, a given system might be adequate in some circumstances but not under tougher conditions. Therefore, since weather conditions (and, consequently, demand/RES production) are uncertain, system adequacy must be assessed using a wide range of different realizations of those conditions. The following graph illustrates the benefit one can derive from using multiple realizations.

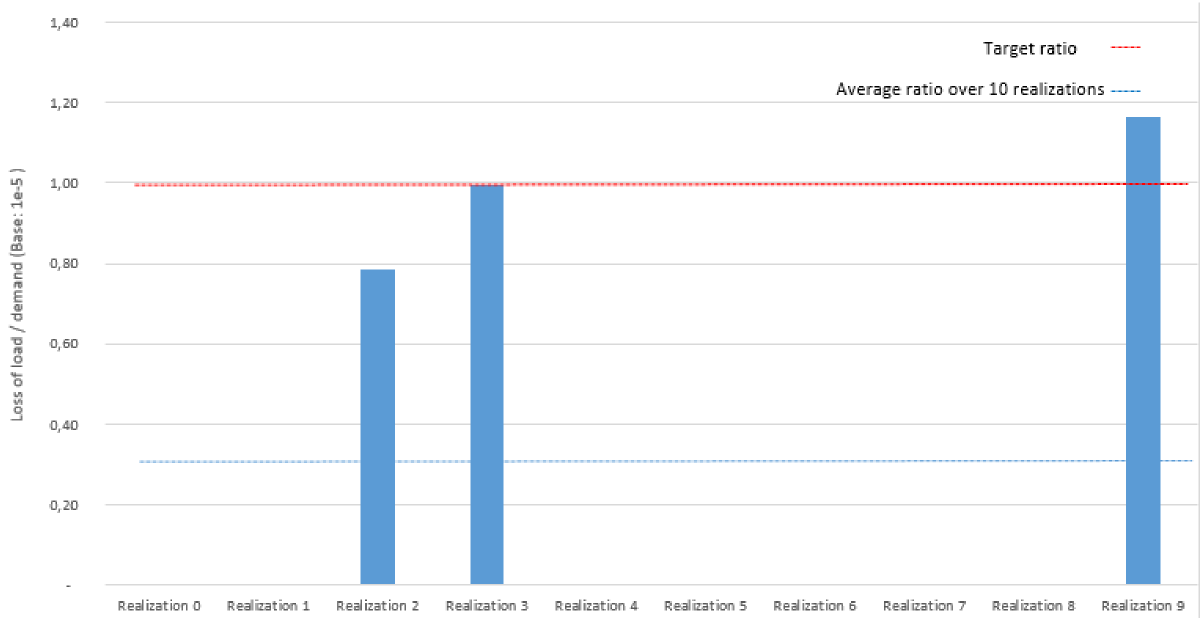

Figure 7: Security of supply sensitivity to weather conditions: EENS in Bosnia Herzegovina divided by the country energy demand. Scenario ENTSO-E 2030 v3 with current CCGT/OCGT generation capacities under 10 years of weather realizations

In this example, loss of load appears for the three years with the most severe weather conditions (cold days with low wind). The security of supply criteria is met *on average* since the average loss of load (dotted blue line) is below the target (dotted red line), suggesting that the system is adequate. If year 9 had been the only studied year, or if a deterministic approach had been applied with computation of margin against extreme load and RES conditions, as the one corresponding to year 9, the opposite conclusion would have been drawn.

4.3.3. MANAGEMENT OF THE CORRELATION BETWEEN COUNTRY WEATHER EVENTS

In addition to using a large history of weather data, it is important to take into account the fact that weather conditions are spatially correlated between neighboring countries. Indeed, extreme weather conditions may occur simultaneously, affecting a group of neighboring countries at the same time. It is illustrated by Figure 8, which shows wind power generation divided by the nominal generation capacity (also referred to as *capacity factor*) for Sweden, Norway and Finland from May 4th to July 1st (in scenario 8). Two wind falls are circled in black, both lasting a week. During the second one, the average wind power capacity factor is 7% in Finland and Sweden, and 9% in Norway whereas their respective annual are 20%, 30%, and 22%.

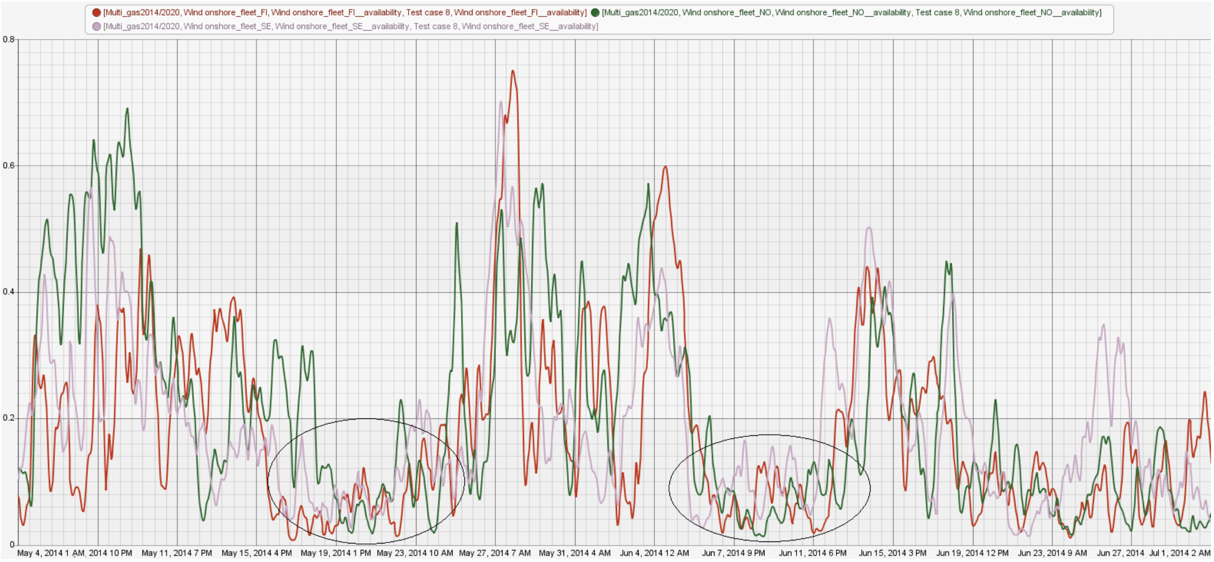

Figure 8: Wind energy generation time series for Sweden, Norway and Finland.

The deterministic approach, which handle data for each country separately, would also not be able to take into account the correlation between country weather events.

4.3.4. Benefits of a European network model

The way the network is represented is also of primary importance to assess the security of supply. Indeed, while some countries rely on imports to meet their national demands during scarcity periods, the actual level of imports also depends on the ability of neighboring countries to provide an extra generation capacity. Imports may therefore be unavailable even when transmission lines are not saturated.
The Figure 9 and Figure 10 illustrate these phenomena. Looking more precisely at January, 25th at 6 p.m., one may note that the available capacity margin (Figure 10) appears to be positive. However, loss of load occurs because of the inability of Germany's neighbors to provide power (Figure 9).

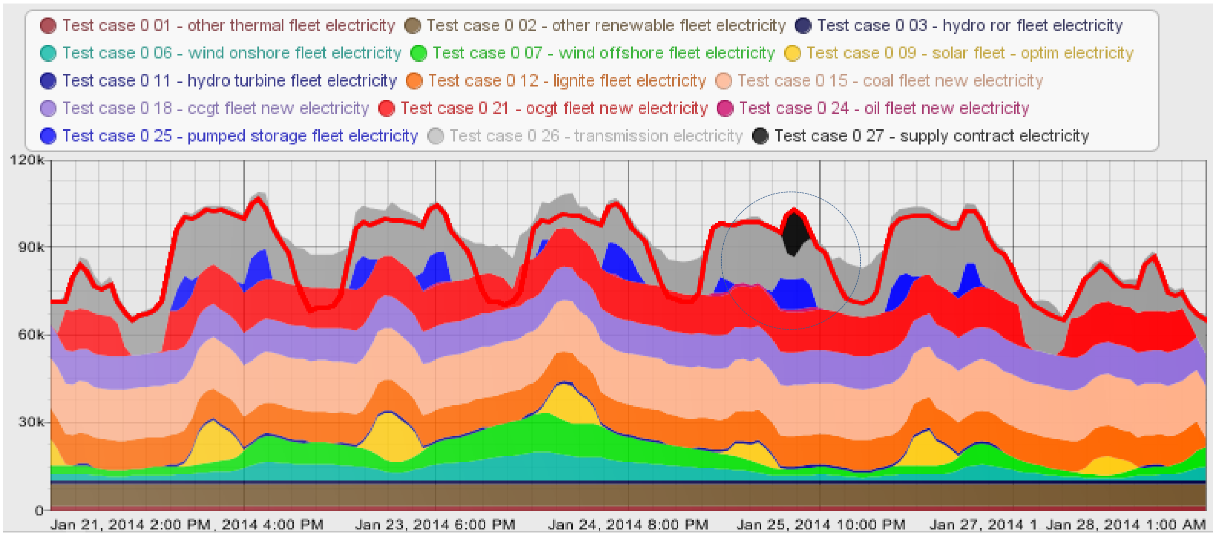

Figure 9: Importance of the network representation: cumulative production in Germany in January (loss of load in black). Scenario ENTSO-E 2030 v3 with current CCGT/OCGT generation capacities

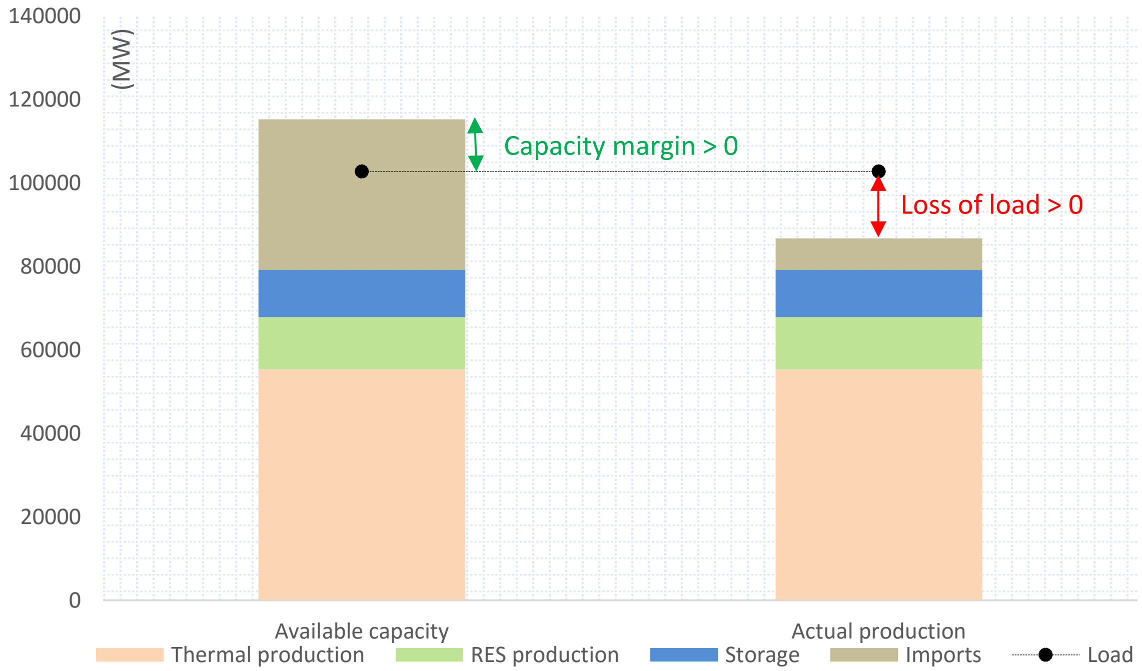

Figure 10: Production dispatch from simulations vs Capacity margin
Germany - January 25th, 6 p.m. – scenario ENTSO-E 2030 v3 with CCGT/OCGT current generation capacities

This example highlights that the deterministic approach, which computes capacity margin with a fixed import capacity (that is without taking into account any variable ability of the countries to help a neighbor to meet its own demand), is not suitable to assess the impact of the European coordination.

5. MAIN STAKES FOR A COMMON EUROPEAN APPROACH

The objective of this paragraph is to use the probabilistic approach to study the benefits of regional coordination when evaluating the power security of supply at the European level. For this purpose, three different levels at which security of supply can be assessed are compared using METIS.

- The first one is a "national level": the security of supply is independently assessed for each European country.
  - A power optimal dispatch is independently simulated in METIS for each country, disregarding the potential contribution of neighbor countries for security of supply (without any power exchanges between countries).
- Second, a "regional coordination" is assumed: the security of supply is evaluated at a regional level, taking into account the coordination within each of the regions (see figure below for the definition of the regions).
  - For each region, a power optimal dispatch is simulated in METIS, taking into account the NTC capacity constraints within the regions, but without any flows between regions.
- Finally, a global coordination at the European level is considered.
  - A power optimal dispatch is simulated at European level in METIS, taking into account the NTC capacity constraints between countries.

The goal of this section is to highlight the benefits of regional coordination when assessing the security of supply, and when designing the evolution of power systems. Indeed, since uncertainties tend to cancel out when considering larger areas (and peak demands tend not to happen at the same time), the need for capacity when assessing security of supply at the regional level is less than the sum of the needs for capacity obtained through a country-level assessment of generation adequacy. Regional coordination could therefore result in less redundant investment in power infrastructure.

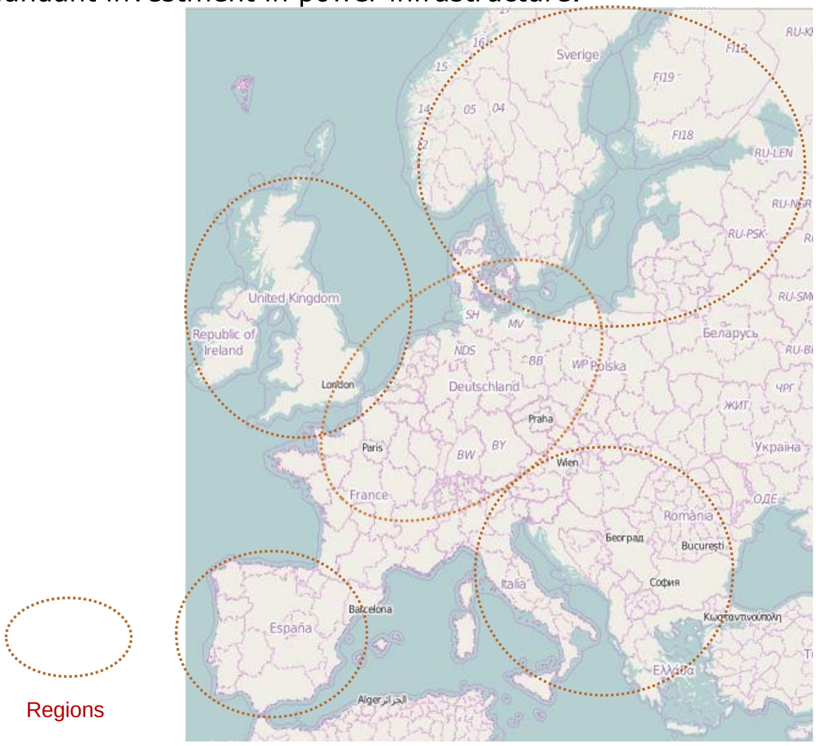

Figure 11: Definition of five regions for a regional coordination

5.1. EVALUATION OF THE BENEFITS OF REGIONAL COORDINATION

5.1.1. CONTEXT

Two 2030 scenarios, representing two ENTSO-E visions corresponding to different RES evolutions, are considered. Considering scenarios with different shares of RES will allow one to understand that regional coordination is especially beneficial when integrating high shares of RES. The scenarios were built considering ENTSO-E evolution assumptions in terms of RES and demand increase, and nuclear and coal decrease, but using today infrastructure for gas units. The reduced generation capacity creates a more stressed situation, which allows to better grasp the stakes of a coordinated generation adequacy assessment[19].
The adopted methodology, derived from ENTSO-E's one (probabilistic approach), considers hourly simulations over ten years of weather data realizations (2001-2010)[20]. The metrics used to compare the approaches are also based on ENTSO-E's: LOLE - Loss of Load Expectation (in hours) - and EENS - Expected Energy not Served (in GWh and in % of demand).

5.1.2. LOSS OF LOAD ASSESSMENT REQUIRES A COORDINATED APPROACH

The following table compares EENS (%) assessed for the three levels of coordination. It highlights an overestimation of the loss of load, when it is measured through a non- (or less-) coordinated approach, which does not (or less) take into account the mutual assistance between countries.

Level	EENS (% of annual load) - V1
National level	0,42 %
Regional level	0,02 %
European level	0,00 %

Table 6 - Global expected energy not served as part of global demand within the three approaches

The EENS for the three levels of coordination are represented on Figure 12. When the security of supply is assessed at the national level, a lot of countries of central Europe seem to present substantial levels of loss of load. However, since these countries are interconnected by the power grid, a regional assessment of security of supply (taking into account power exchanges within this region) significantly decreases the loss of load levels.

[19] The present analysis should be strictly seen as an assessment of a more regional methodological approach. Therefore the presented results are meaningful only when considered in comparison to each other (i.e. national vs regional vs European, and the improvements when enlarging the geographical scope).
[20] No very cold year at European scale (as 1956) captured.

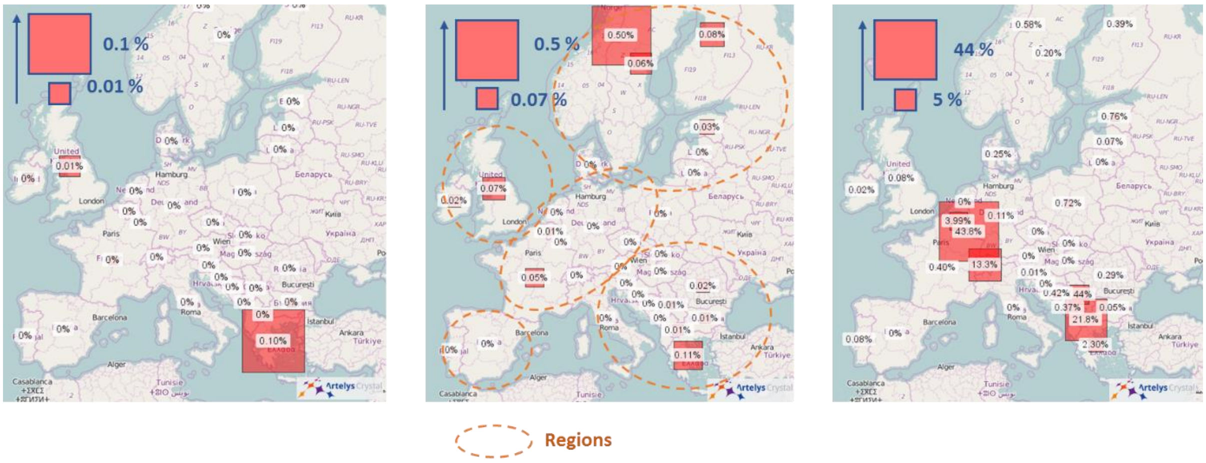

Figure 12: EENS (%) estimation by country for scenario ENTSO-E 2030 v1 with CCGT/OCGT current generation capacities From left to right: EENS estimated at European, regional and national levels

5.1.3. IMPACT OF A REGIONAL APPROACH

Even if the regional level allows to grasp most of the security of supply stakes, loss of load remains overestimated when it is independently assessed in each region, as shown in Table 7 and Figure 13.

Level	EENS assessment - V1
Regional level	1 500 GWh
European level	130 GWh
Level	EENS assessment - V1

Table 7 - Global loss of load assessment for European and regional levels

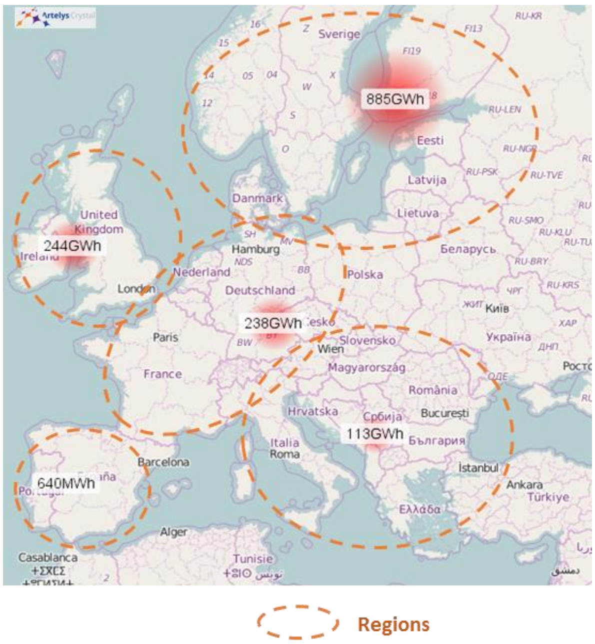

Figure 13: Regional loss of load for the regional-level approach (ENTSO-E 2030 v1 with CCGT/OCGT current generation capacities)

When assessing security of supply at the regional level, one cannot benefit from the fact that weather events (and hence RES generation) and demand peaks may be even better smoothened out at the European level compared with the regional level. This further cancelling out of spatial inhomogeneity explains the difference between the EENS when assessed at the European level and regional level.
An example of loss of load overestimation from a regional approach is presented on Figure 14. It illustrates a cold period with high load and low wind generation in the region UK. During this period, the European approach shows that the imports are sufficient to face the load peak. However, in the regional approach, it seems that there is not enough local production to meet the demand, which could lead to the misleading conclusion that the UK power capacity is insufficient.
When assessing the security of supply independently in each region, it would lead to some misleading additional capacity needs, and to some unnecessary investments, which could be avoided using power exchanges between regions. In conclusion, additional coordination between regions would allow for a better understanding of the capacity needs, and improve the security of supply assessment.

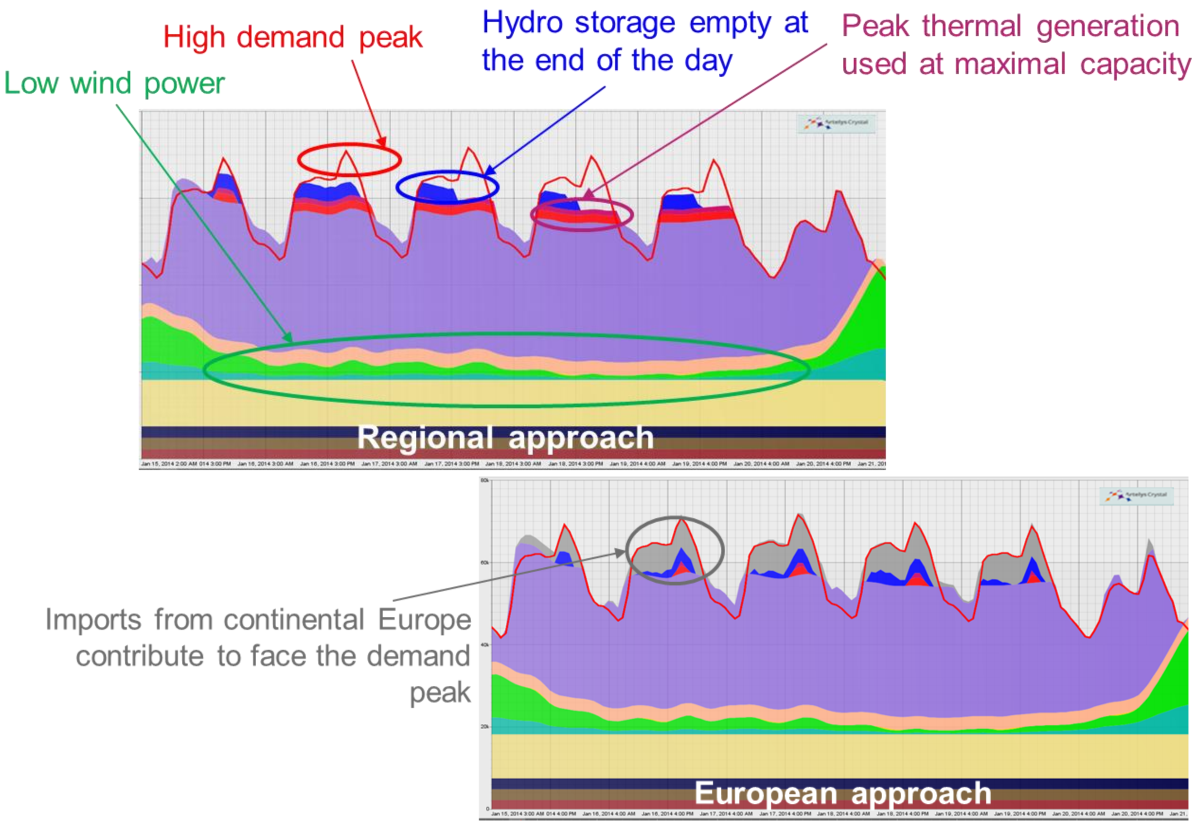

Figure 14: Comparison between regional and national approaches for one specific week in region UK

5.1.4. STAKES OF A EUROPEAN APPROACH IN HIGH RES INTEGRATION CONTEXT

In a context of high RES integration (such as in the V3 scenario), the overestimation of loss of load from a uncoordinated approach is especially significant, as shown on the next table, which presents respectively for the regional approach (second column) and for the national approach (third column) the difference with the European approach in terms of EENS.

ENTSO-E hypothesis (for RES, demand, nuclear & coal)	Overestimated EENS from regional-level assessment (TWh)	Overestimated EENS from national-level assessment (TWh)
2030 V1	0,6	13,5
2030 V3	8,6	50,7

Table 8 - European EENS estimated by regional and national approaches for both 2030 visions: difference between European approach and respectively regional and national approach. (European EENS estimation is 0,1 GWh for 2030 V1 and 2,9 TWh for 2030 V3.)

A national approach would thus lead to massive redundant investments, and a coordinated approach would better assess the capacity needs for generation adequacy.
In a high RES integration context, European coordination improves significantly the security of supply assessment. Even if a regional coordination allows to grasp the main stakes of security of supply, additional coordination between regions would be recommended, specifically in a high RES integration context.

5.1.5. SECURITY OF SUPPLY ISSUES FOR BORDER COUNTRIES

The following figure shows, for both 2030 visions, the EENS assessment from the European approach.

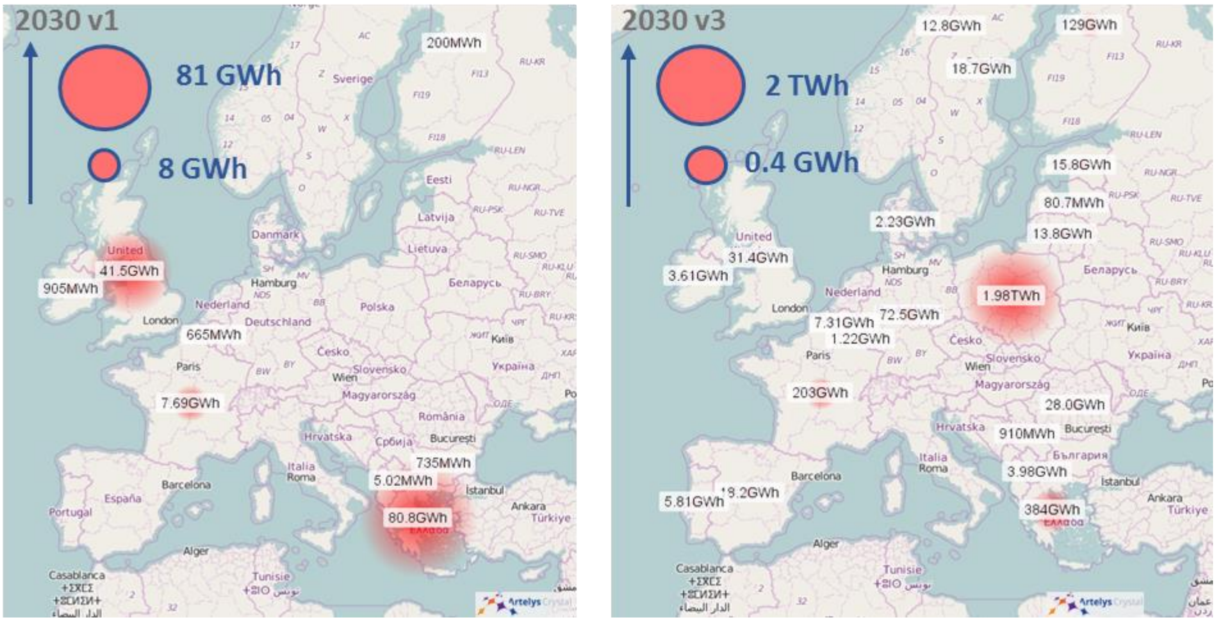

Figure 15: Expected energy not served assessed at the European level

These maps illustrate how significant the stakes of security of supply for border countries are. Indeed, even when assessing the EENS following the European approach, these countries are less interconnected and benefit from less power exchange possibilities than the countries located at the center of Europe.
The stakes of security of supply are higher in a high RES integration context[21]: EENS is higher in the V3 scenario, which includes a lot of variable and non-dispatchable generation, a higher consumption[22], and less base load capacities, without any evolution of the installed capacities of gas fleets.

[21] Except for some countries, like UK, which has a less demand increase between V1 and V3, and benefits from massive wind power generation (170 TWh) and an important part of nuclear (about 80 TWh).
[22] For instance, the Poland consumption is supposed to increase by 20% from V1 to V3.

5.2. ILLUSTRATION: REASONS OF THESE SAVINGS

5.2.1. VARIABILITY OF RES GENERATION ACROSS EUROPE

The variability is even more pronounced for RES generation. Despite geographical correlations at the regional scale, a bunch of different climatic regimes produce different weather conditions across the whole Europe, which often compensate one another.
Figure 16 shows the distribution of wind energy load factor for France, Germany and aggregated over Europe. Considering only France, wind energy generation is at 4% or less of the installed capacity 800 hours per year. In Germany, the load factors are even lower during the 800 worst hours. If we aggregate wind energy generation over Europe, the fluctuations compensate and the 10th percentile of wind energy load factor increases to 9%.

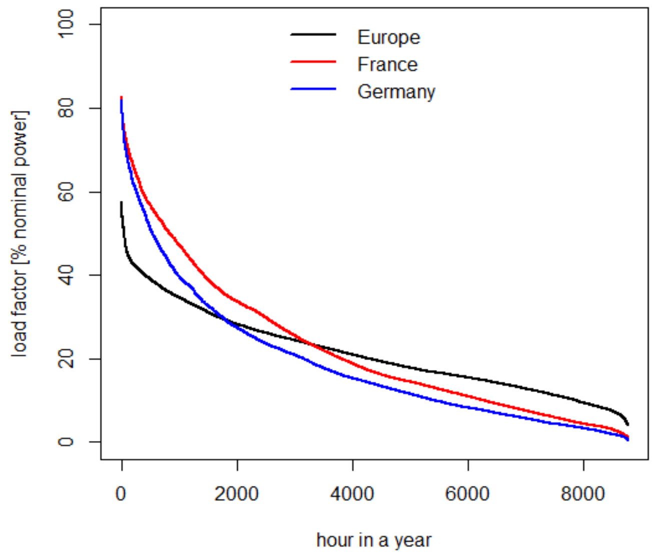

Figure 16: Wind load factor distribution for France, Germany and aggregated over Europe (current values)

This variability of RES load factors across Europe is a further motivation for a European approach to security of supply. The sum of national residual peak loads[23] minus the European residual peak load also corresponds to 70 GW for v1 and 90 GW for v3. These figures could be read as the maximal peak capacity which could be saved by a coordinated management of security of supply, assuming infinite interconnections, and in comparison to independent national managements.
Remark: these values are upper bounds, as they are based on peak net demand over 10 years and consider Europe as a cupper plate. The exact calculation of the savings would require to jointly optimize peak capacities for each Member State under interconnection constraints.

5.2.2. COMPLEMENTARITY OF ENERGY GENERATION MIXES

Another benefit for a coordinated approach is that European countries have historically developed different generation capacity mixes, with different techno-economic characteristics. The following table sums up the main stakes for the countries.

[23] The residual load or net demand is the power demand minus must-run renewable energy (wind energy, PV and hydro run-of-the-river).

Countries	Power mix key points	Main stakes for generation adequacy
Germany	High shares of RES	Periods with low wind and sun
France	75% nuclear	
25 GW hydro	Power demand sensitivity to temperature	
Poland	80% coal/lignite	Increasing power demand
Italy	15% imports	
Increasing PV capacity	Peak demand during summer	

Table 9 – Typical national mixes

6. Conclusion and open questions

This report highlights the substantial benefits which could be obtained from a coordinated approach to generation adequacy assessment. In fact, it demonstrates that the lack of coordination could lead to overestimate the risks for security of supply and thus could lead to redundant investment. Likewise, the analysis shows that the coordination benefits are even more significant in a high RES integration context.
It is also crucial to underline that such a coordination requires a common methodology shared by all European countries, preferably based on a probabilistic methodology, and a consistent set of data and assumptions (for power demand, weather data, etc.).
However, defining a coordinated policy for the assessment of generation adequacy opens a number of issues:

- Considering the differences in annual load and also in demand thermosensitivity, should the generation adequacy criteria be standardized or should it be different from one country to another?
- When loss of load occurs, how and under which criteria should it be shared between countries?

7. APPENDIX

7.1. NATIONAL LOAD LEVELS AT EUROPEAN LOAD PEAK

The following graphs show the mean demand level by country (power demand divided by the annual peak) at the hour of the European annual peak, averaged over the 10 studied meteorological years, for ENTSO-E scenarios 2030 v1 and v3.

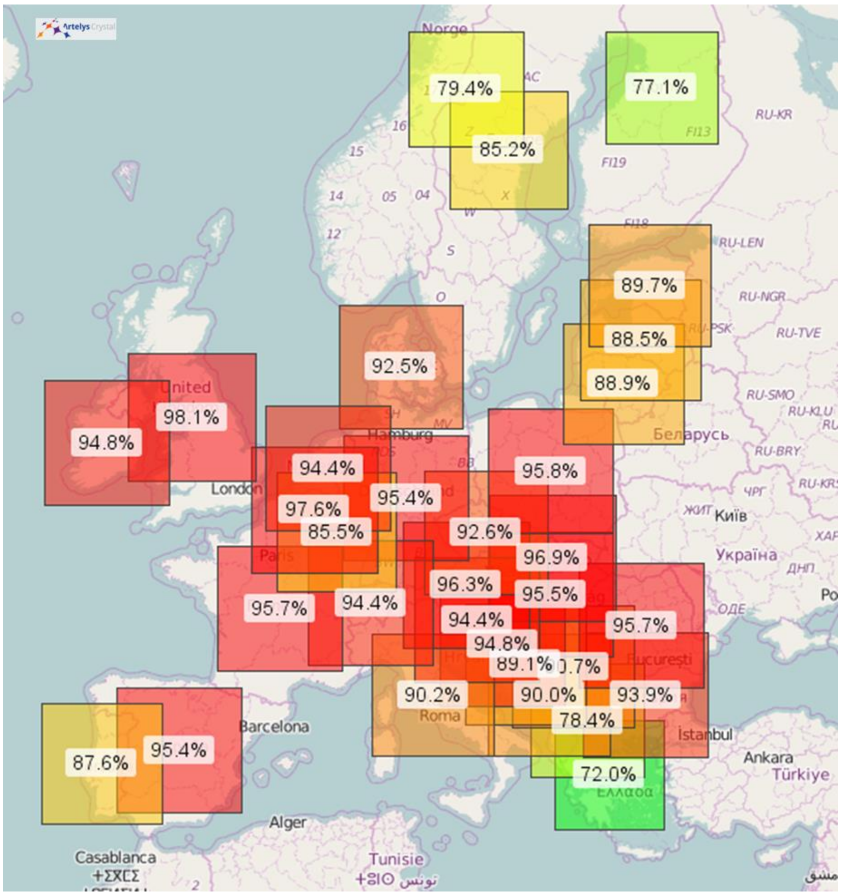

Figure 17: National load levels (in % of their national peaks) when the European load peak occurs in scenario ENTSO-E 2030 v1, averaged over 10 meteorological years

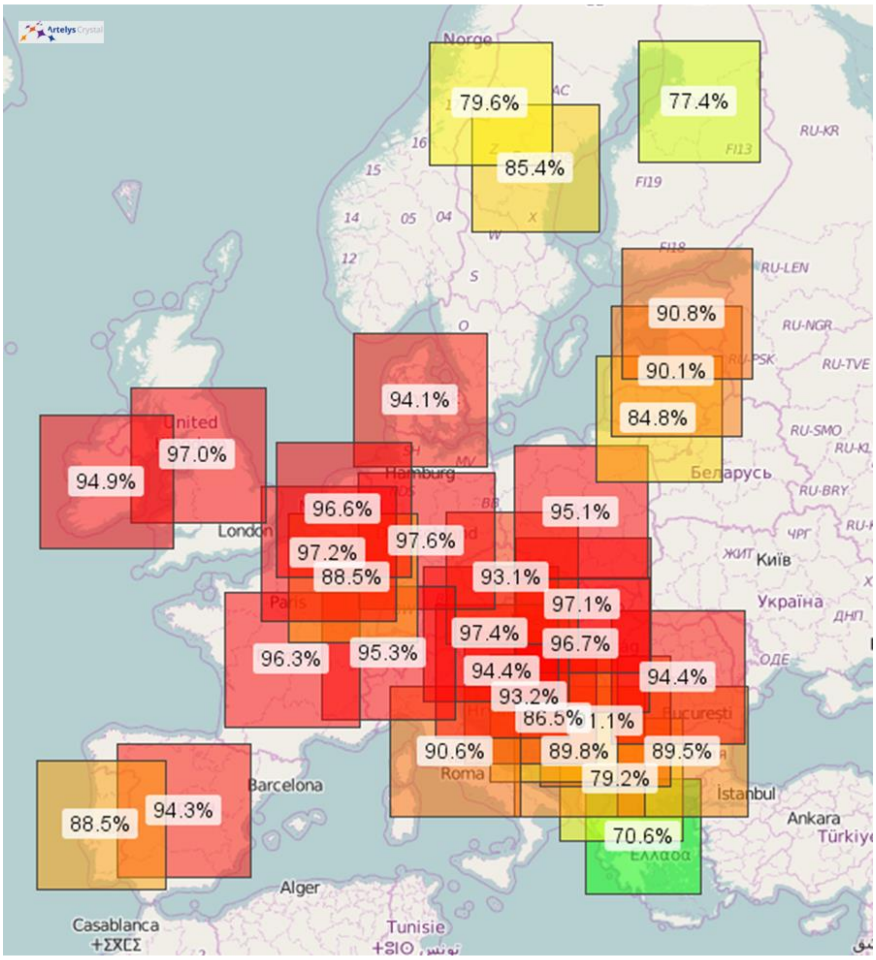

Figure 18: National load levels (in % of their national peaks) when the European load peak occurs in scenario ENTSO-E 2030 v3, averaged over 10 meteorological years

7.2. National residual load levels at European load peak

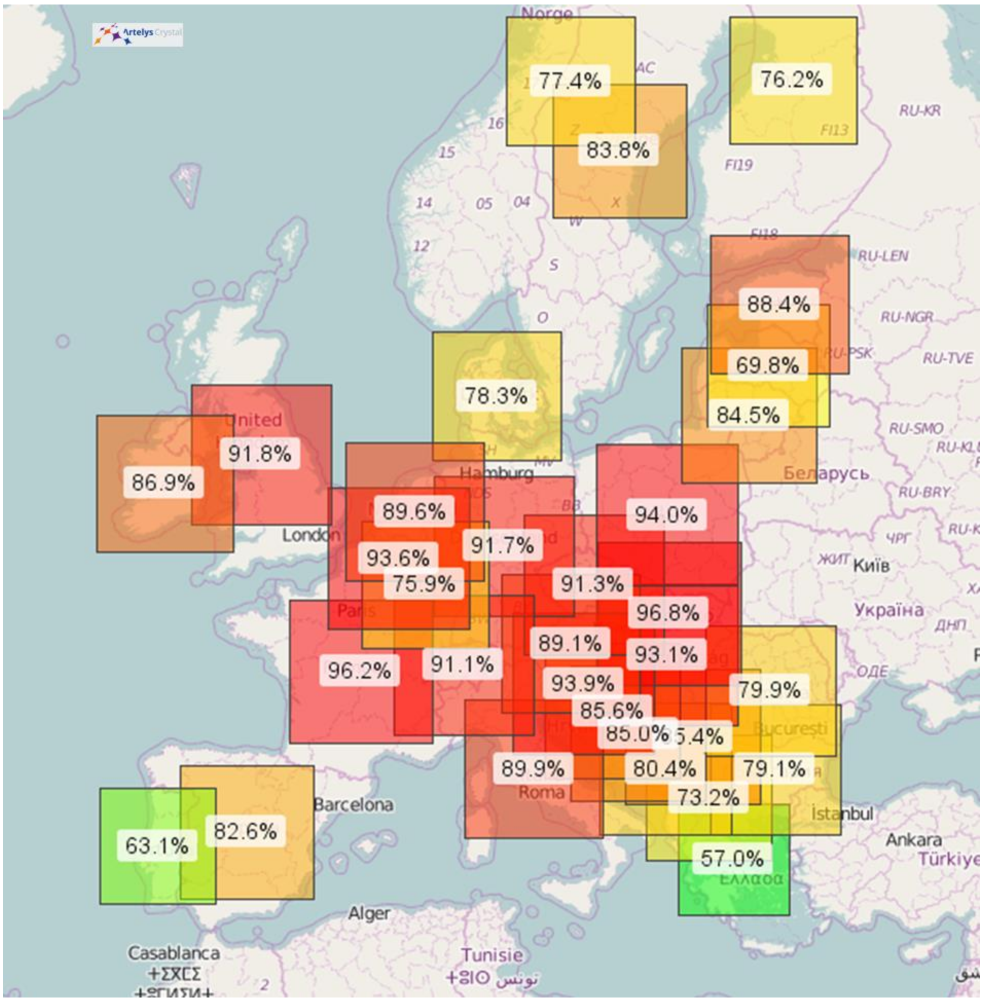

Figure 19: National residual load levels (in % of their national peaks) when the European residual load peak occurs in scenario ENTSO-E 2030 v1, averaged over 10 meteorological years

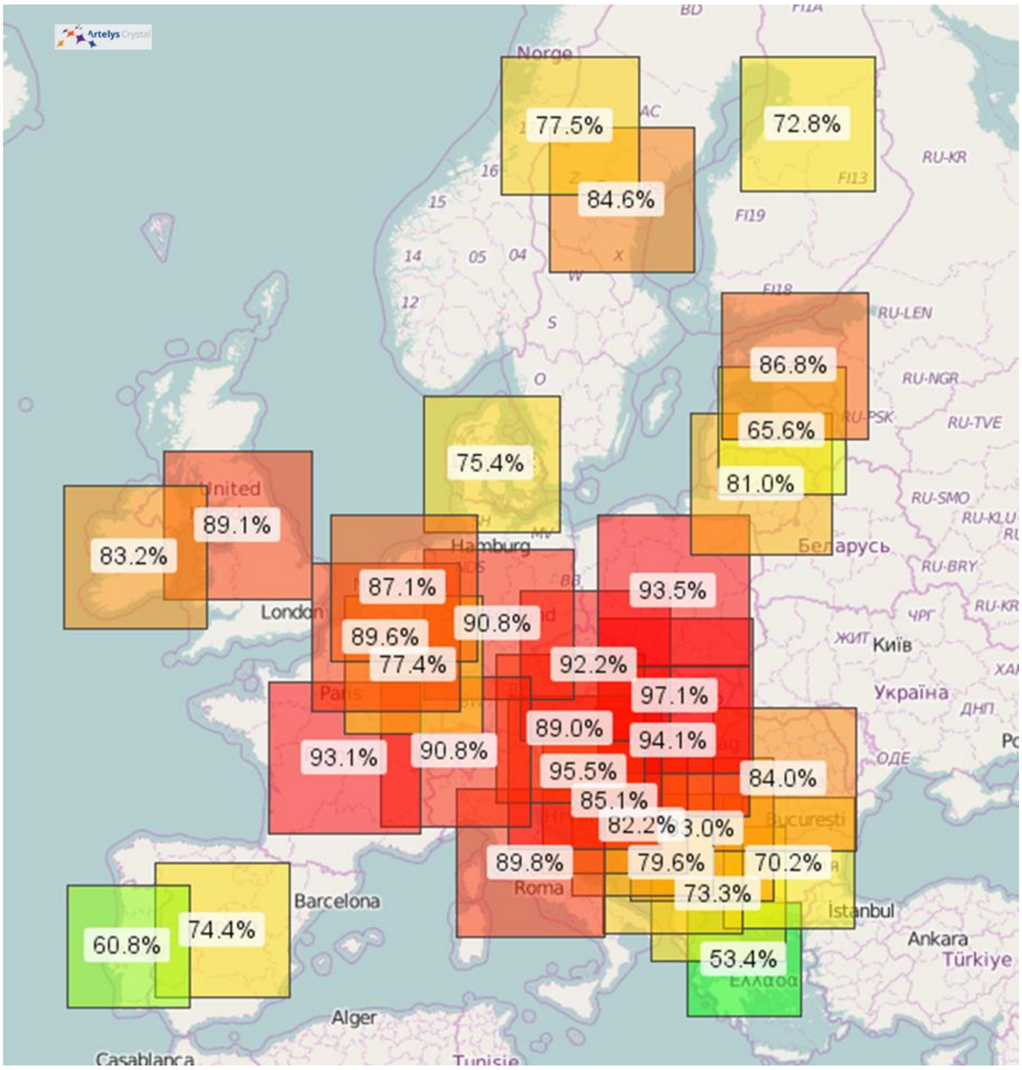

Figure 20: National residual load levels (in % of their national peaks) when the European residual load peak occurs in scenario ENTSO-E 2030 v3, averaged over 10 meteorological years

7.3. Focus on METIS models and datasets - Consistency with target methodology

This appendix describes the models and data used in METIS for generation adequacy assessments.

7.3.1. Global approach for climatic scenarios

As detailed in paragraph 4.3.2, to assess the security of supply at European level, it is crucial to use consistent weather data through Europe. For this reason, correlated RES generation data were integrated in METIS, as represented in Figure 21.

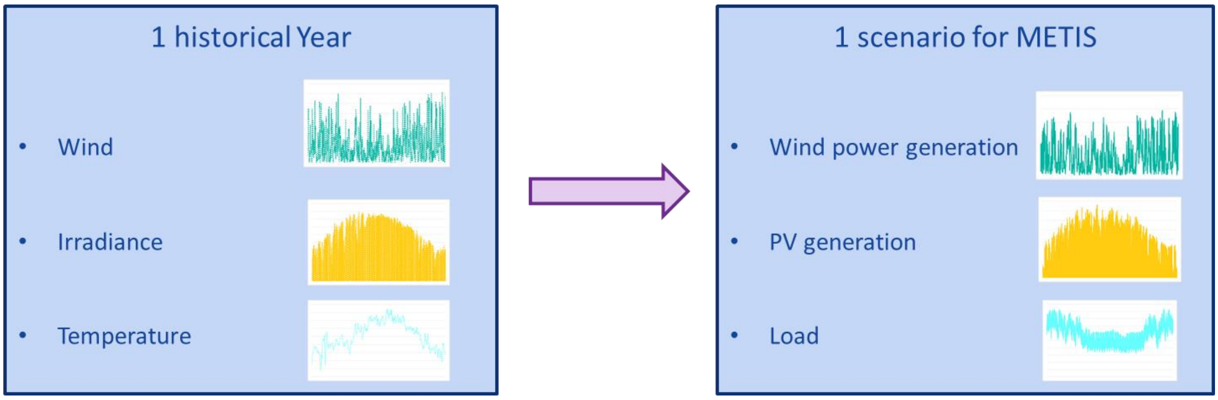

Figure 21: Correlated RES generation in METIS: for each year of weather data, one corresponding scenario is built.

The following paragraphs describe the methodology which was used to build the correlated demand time series and RES generation.
Remark: the use of several weather scenarios allows taking into account several weather occurrences and is also necessarily to compute probabilistic metrics, as LOLE or LOLP (see 3.2.2.3).

7.3.2. DEMAND SENSITIVITY TO TEMPERATURE

7.3.2.1. Description of the methodology

The objective is to generate fifty hourly scenarios of demand for each country by means of a statistical model fitted to the following data sources:

- year 1965 to year 2014 historical daily temperature data for all countries from the European Climate Assessment & Dataset project (ECA, see http://eca.knmi.nl/);
- historical hourly demand data for all countries provided by the ENTSO-E data portal (https://www.entsoe.eu/data/data-portal/Pages/default.aspx).

In this regard, each demand scenario is modeled as the sum of a thermo-sensitive component and the non-thermo-sensitive one. The thermo-sensitive component is computed by using a piecewise linear model. This model is set up with one threshold and two slopes[24] and calibrated by getting recourse to a *Multivariate Adaptive Regression Splines* method[25] that involves the computation of temperature gradients (MW of demand increase per °C increase) for each country. The calibrations are based on year 2030 vision 1 and vision 3 TYNDP[26] demand scenarios and the ECA fifty-years sample averaged temperature series for year 2030 scenarios.
As depicted Figure 22 for Spain, the temperature scenarios of each country drive its thermo-sensitive demand scenarios by using the country temperature gradients. Then, thermo-sensitive and non-thermo-sensitive demand scenarios are added so as to complete the generation of the country demand scenarios.

[24] The use of two slopes - one slope associated to low temperatures and one slope associated to high temperatures allows for applying the same approach for each country, with the same number of parameters, although three slopes could have been used for countries with both heating and cooling gradients.

[25] See J. H. Friedman, « *Multivariate Adaptive Regression Splines* », *Annals of Statistics*, vol. 19, nº 1, 1991 for the method and https://cran.r-project.org/web/packages/mda/mda.pdf for its R implementation.

[26] Data is given as hourly time series for one year and average seasonal temperatures.

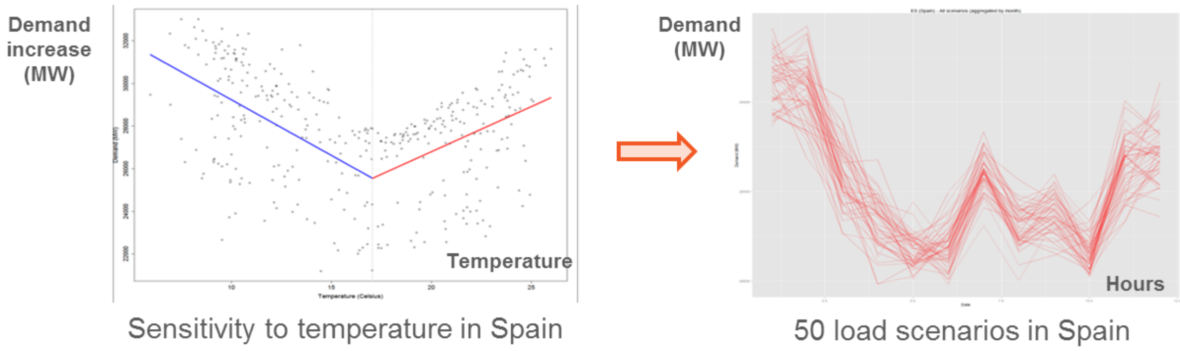

Figure 22: Two gradients and one threshold accounting for heating and cooling effects on Spain demand

7.3.2.2. Illustration

Figure 23 and Figure 24 represent the obtained heating and cooling gradient by country.

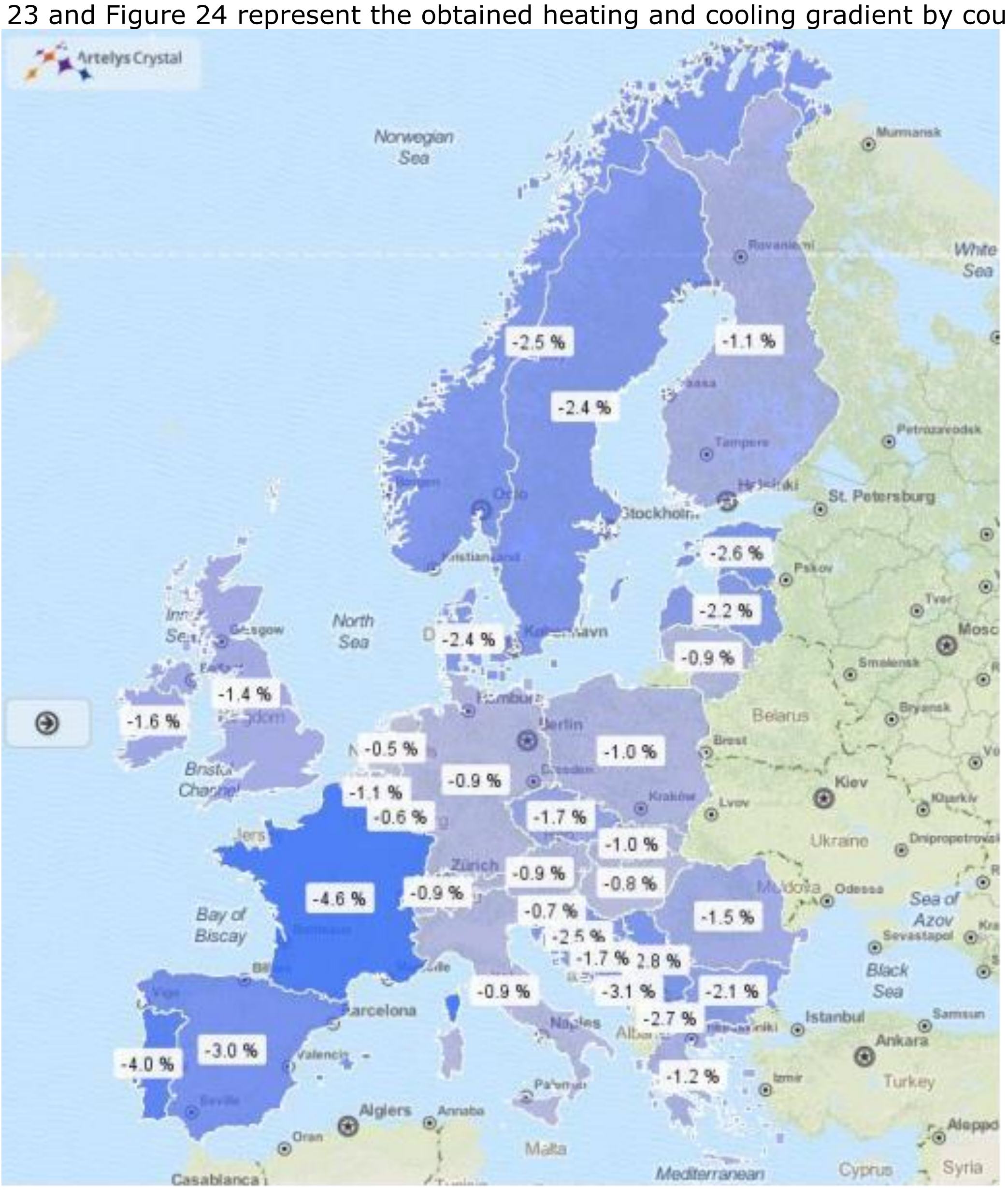

Figure 23: Current heating gradient by country (in % of the averaged demand)

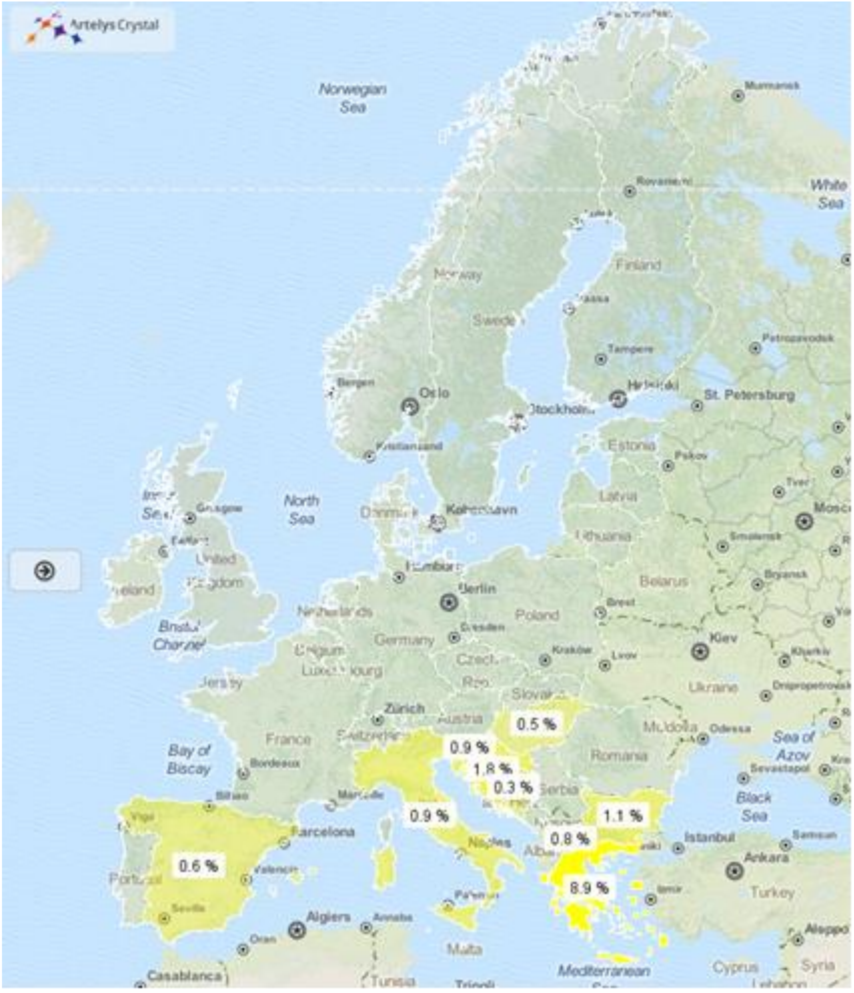

Figure 24: Current cooling gradient by country (in % of the averaged demand)

7.3.3. RES GENERATION PROFILES

7.3.3.1. Generation of solar and onshore wind power profiles

To generate profiles for wind power and solar power for ten historic years a model developed by IAEW has been used. The model uses historic meteorological data, units' power curves and historic generation data as input parameters to determine RES generation profiles and calibrate the results for each region in the models scope. The methodology is depicted in Figure 25.

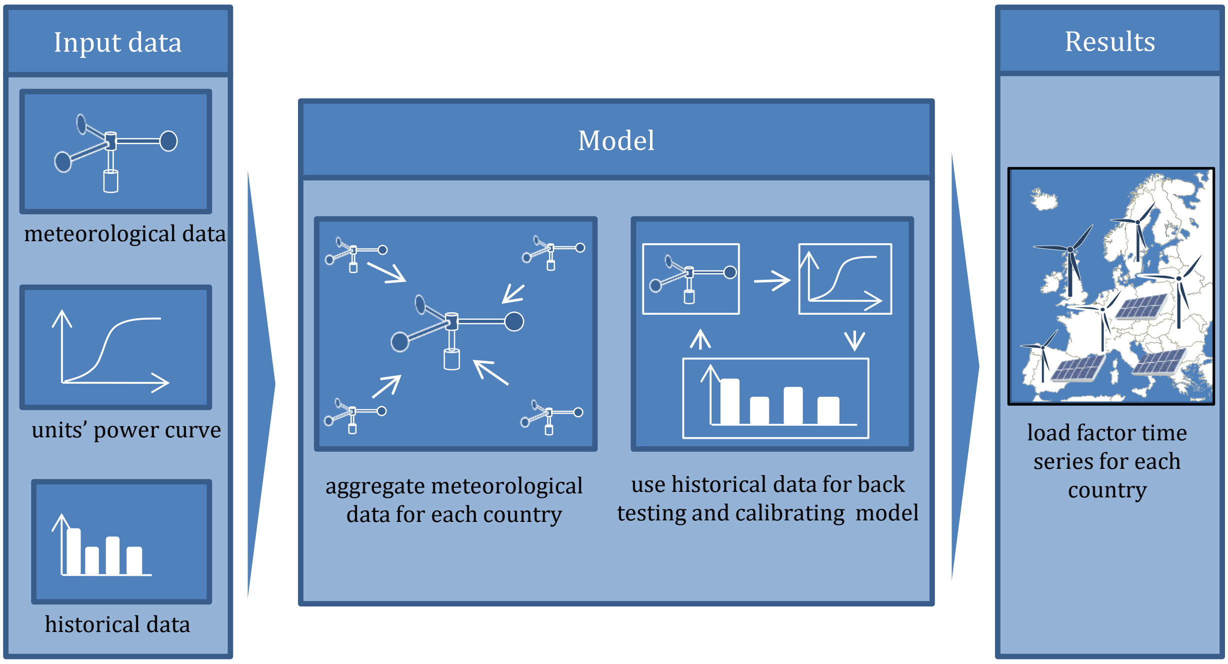

Figure 25: Methodology

7.3.3.2. Input Data

Meteorological Data

The delivered time series of renewables feed-in are based on fundamental wind, solar and temperature time series for 10 years (2001 to 2010) on a detailed regional level derived from the ERA-Interim data provided by Meteo Group Germany GmbH. From ERA-Interim model values for wind speed (m/s), global irradiation (W/m^2) and temperature (°C) are derived for every third hour and interpolated to hourly values by Meteo Group. The regional resolution of the data is one hourly input series (wind, solar, temperature) on a 0.75° (longitude) times 0.75° (latitude) grid model, which ensures an adequate modeling accuracy. The regional resolution is shown in Figure 26, in which each blue dot represents one data point.

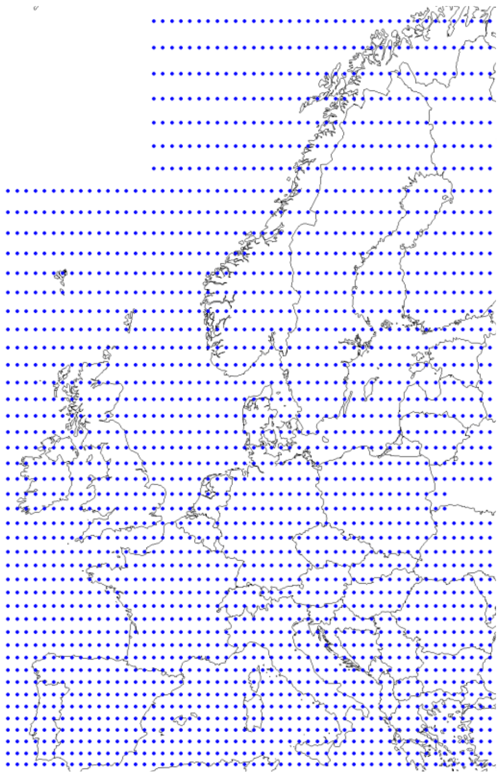

Figure 26: Regional resolution of meteorological data

Historical Data

To generate realistic time series a calibration of the models is inevitable. Therefore information regarding the yearly full load hours for wind and PV generation in each country is necessary. To derive the yearly number of full load hours the installed capacities of wind and PV generation as well as the yearly energy production have been investigated for each country.
In case of unavailable data the full load hours where derived based on the data of a neighboring country. As the availability for data regarding installed wind generation capacities and generated energy is satisfying in almost every country it is rather low for information regarding PV power. Only for a few countries reasonable full load hours could be derived from historical published data. For the other country data from the Photovoltaic Geographical Information System was used instead.

Model

In first step the high-resolution meteorological data are aggregated for each country and NUTS2 region. The aggregation is thereby based on the regional distribution of wind and PV capacities. The required distribution of wind and PV generation capacities is extracted from different databases and is aggregated at high voltage network nodes. In countries with no available information a uniform distribution is assumed.
Each high voltage network node gets the nearest meteorological data point assigned to and the data is weighted with the installed capacity at the network node. Thereby the wind-speed is weighted by the installed wind generation capacity whereas global irradiation and temperature are weighted with the installed PV generation capacity. The weighted time series for all nodes in each region are aggregated and divided by the overall installed wind respectively PV capacities. Subsequently, it is necessary to calibrate the generation models for each country by scaling the meteorological data accordingly. The process of calibration is display in Figure 27.

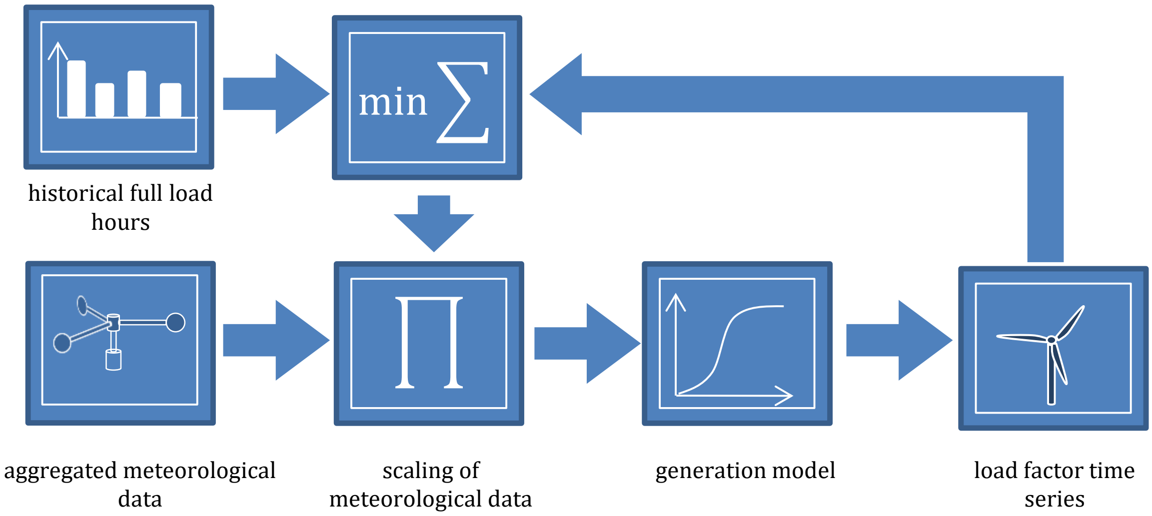

Figure 27: Model calibration

The meteorological data is fed into generation models for PV and wind generation. The resulting load factor time series are compared with the historical full load hours for the specific country and the deviation between load factor time series and the historic full load hours in each year *i* is to be minimized by scaling the meteorological data accordingly. In this minimization the yearly deviation between time series full load hours (*FLH*) and historical data is weighted with the installed capacity (*IC*) in the specific year according to formula 1.

$$\min \sum_{i=1}^{10} (FLH_{i,time\ series} - FLH_{i,historical\ data}) \cdot IC_i \tag{1}$$

The scaling factors are chosen independently for wind speed and global irradiation and are individual for each country.

Results

The resulting full load hours for both wind and PV are close to the historical data and results for exemplary countries are shown in Figure 28.

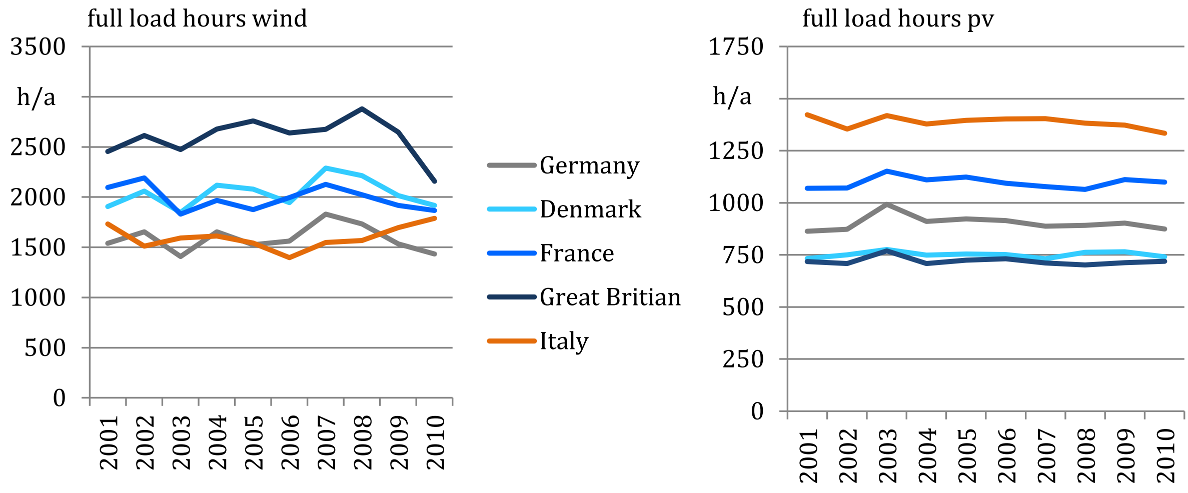

Figure 28: Wind and PV full load hours per year

Whereas the PV full load hours per year are not changing significantly from one year to the next, the resulting full load hours from wind generation vary considerably.
The resulting full load hours for wind and PV are respectively shown in Table 10 and Table 11.

Zone	year 2001	year 2002	year 2003	year 2004	year 2005	year 2006	year 2007	year 2008	year 2009	year 2010
AT	2 072 h	1 947 h	1 790 h	1 953 h	1 952 h	1 788 h	2 026 h	1 972 h	1 872 h	1 950 h
BA	2 382 h	2 230 h	2 095 h	2 189 h	2 001 h	1 941 h	2 106 h	2 166 h	2 097 h	2 290 h
BE	1 966 h	2 034 h	1 703 h	1 918 h	1 808 h	2 001 h	2 068 h	2 039 h	1 884 h	1 714 h
BG	1 988 h	1 745 h	1 697 h	1 775 h	1 853 h	1 692 h	1 765 h	1 672 h	1 542 h	1 786 h
CH	1 358 h	1 264 h	1 141 h	1 267 h	1 104 h	1 211 h	1 309 h	1 255 h	1 189 h	1 186 h
CZ	1 537 h	1 643 h	1 411 h	1 670 h	1 542 h	1 507 h	1 854 h	1 637 h	1 498 h	1 467 h
DE	1 538 h	1 652 h	1 406 h	1 647 h	1 524 h	1 561 h	1 828 h	1 730 h	1 533 h	1 430 h
DK	1 906 h	2 062 h	1 849 h	2 118 h	2 079 h	1 946 h	2 291 h	2 214 h	2 016 h	1 917 h
EE	1 947 h	1 915 h	2 002 h	1 910 h	2 026 h	1 990 h	2 128 h	2 325 h	1 798 h	1 838 h
ES	2 360 h	2 281 h	2 174 h	2 048 h	2 058 h	2 093 h	2 072 h	2 137 h	2 234 h	2 319 h
FI	1 946 h	1 669 h	1 986 h	1 807 h	2 102 h	1 903 h	2 028 h	1 958 h	1 785 h	1 710 h
FR	2 104 h	2 199 h	1 840 h	1 966 h	1 878 h	1 998 h	2 132 h	2 020 h	1 920 h	1 871 h
GR	2 778 h	2 110 h	2 708 h	2 541 h	2 492 h	2 618 h	2 452 h	2 578 h	2 507 h	2 406 h
HR	2 131 h	1 962 h	2 032 h	1 979 h	1 891 h	1 829 h	1 885 h	1 982 h	2 024 h	2 002 h
HU	2 283 h	2 097 h	1 968 h	2 034 h	2 039 h	1 819 h	2 038 h	2 097 h	1 955 h	2 121 h
IE	2 309 h	2 696 h	2 547 h	2 643 h	2 609 h	2 581 h	2 497 h	2 764 h	2 600 h	2 033 h
IT	1 733 h	1 512 h	1 592 h	1 604 h	1 542 h	1 398 h	1 548 h	1 566 h	1 695 h	1 788 h
LT	1 756 h	1 988 h	1 834 h	1 889 h	1 752 h	1 711 h	1 990 h	2 054 h	1 745 h	1 744 h
LU	1 681 h	1 713 h	1 442 h	1 623 h	1 487 h	1 649 h	1 756 h	1 656 h	1 560 h	1 436 h
LV	1 627 h	1 811 h	1 697 h	1 767 h	1 661 h	1 630 h	1 845 h	1 947 h	1 647 h	1 627 h
ME	2 348 h	2 125 h	2 182 h	2 245 h	2 034 h	1 927 h	2 101 h	2 118 h	2 102 h	2 295 h
MK	1 013 h	906 h	938 h	1 069 h	956 h	811 h	942 h	973 h	928 h	1 054 h
NL	1 888 h	1 945 h	1 649 h	1 958 h	1 869 h	1 987 h	2 120 h	2 147 h	1 906 h	1 683 h
NO	2 428 h	2 342 h	2 484 h	2 615 h	2 808 h	2 622 h	2 835 h	2 576 h	2 590 h	2 114 h
PL	1 860 h	1 992 h	1 822 h	1 991 h	1 792 h	1 709 h	2 141 h	2 047 h	1 772 h	1 860 h
PT	2 537 h	2 417 h	2 316 h	2 112 h	2 278 h	2 218 h	2 146 h	2 239 h	2 315 h	2 493 h
RO	1 294 h	1 237 h	1 143 h	1 220 h	1 181 h	1 088 h	1 219 h	1 183 h	1 040 h	1 189 h
RS	1 490 h	1 455 h	1 271 h	1 434 h	1 316 h	1 181 h	1 321 h	1 388 h	1 273 h	1 482 h
SE	1 899 h	1 898 h	1 950 h	2 010 h	2 033 h	1 921 h	2 173 h	2 104 h	1 893 h	1 823 h
SI	2 223 h	1 960 h	1 944 h	1 894 h	1 917 h	1 930 h	2 016 h	2 026 h	2 047 h	2 072 h
SK	1 582 h	1 621 h	1 452 h	1 591 h	1 496 h	1 381 h	1 632 h	1 628 h	1 445 h	1 522 h
UK	2 454 h	2 613 h	2 474 h	2 671 h	2 759 h	2 640 h	2 677 h	2 878 h	2 647 h	2 158 h

Table 10 - Wind onshore generation yearly full load hours

Zone	year 2001	year 2002	year 2003	year 2004	year 2005	year 2006	year 2007	year 2008	year 2009	year 2010
AT	996 h	989 h	1 111 h	1 019 h	1 035 h	1 028 h	1 033 h	996 h	1 008 h	963 h
BE	754 h	765 h	851 h	790 h	795 h	782 h	762 h	754 h	791 h	785 h
BG	1 264 h	1 238 h	1 286 h	1 259 h	1 209 h	1 242 h	1 279 h	1 267 h	1 246 h	1 198 h
CH	779 h	765 h	875 h	828 h	816 h	822 h	818 h	786 h	818 h	762 h
CZ	780 h	819 h	917 h	848 h	867 h	862 h	846 h	829 h	835 h	803 h
DE	864 h	873 h	993 h	911 h	922 h	914 h	888 h	891 h	902 h	874 h
DK	736 h	755 h	780 h	754 h	758 h	755 h	736 h	767 h	769 h	748 h
ES	1 714 h	1 699 h	1 695 h	1 721 h	1 769 h	1 694 h	1 708 h	1 678 h	1 720 h	1 647 h
FI	634 h	697 h	642 h	630 h	663 h	678 h	632 h	616 h	653 h	630 h
FR	1 075 h	1 055 h	1 134 h	1 105 h	1 124 h	1 101 h	1 080 h	1 054 h	1 108 h	1 076 h
GR	1 363 h	1 321 h	1 337 h	1 346 h	1 329 h	1 322 h	1 353 h	1 339 h	1 302 h	1 297 h
HR	1 114 h	1 092 h	1 182 h	1 075 h	1 106 h	1 107 h	1 124 h	1 099 h	1 104 h	1 047 h
HU	1 049 h	1 074 h	1 160 h	1 063 h	1 084 h	1 075 h	1 106 h	1 070 h	1 089 h	1 020 h
IE	748 h	718 h	761 h	744 h	731 h	738 h	734 h	709 h	713 h	762 h
IT	1 426 h	1 355 h	1 427 h	1 384 h	1 399 h	1 407 h	1 409 h	1 386 h	1 378 h	1 339 h
LT	738 h	784 h	771 h	749 h	780 h	778 h	749 h	730 h	755 h	741 h
LU	768 h	786 h	879 h	816 h	817 h	797 h	777 h	769 h	804 h	799 h
LV	744 h	795 h	772 h	753 h	790 h	793 h	754 h	734 h	749 h	742 h
MK	1 294 h	1 261 h	1 303 h	1 276 h	1 281 h	1 284 h	1 295 h	1 288 h	1 240 h	1 204 h
NL	693 h	693 h	766 h	713 h	724 h	716 h	692 h	699 h	718 h	711 h
PL	815 h	861 h	931 h	876 h	908 h	893 h	865 h	860 h	878 h	846 h
PT	1 804 h	1 781 h	1 799 h	1 848 h	1 877 h	1 814 h	1 853 h	1 810 h	1 825 h	1 766 h
RO	1 151 h	1 150 h	1 205 h	1 154 h	1 126 h	1 150 h	1 194 h	1 170 h	1 178 h	1 108 h
RS	1 088 h	1 100 h	1 164 h	1 092 h	1 103 h	1 104 h	1 129 h	1 119 h	1 106 h	1 039 h
SI	1 068 h	1 042 h	1 156 h	1 037 h	1 070 h	1 064 h	1 088 h	1 039 h	1 054 h	1 000 h
SK	920 h	957 h	1 039 h	961 h	974 h	978 h	983 h	954 h	969 h	916 h
UK	721 h	710 h	765 h	711 h	724 h	733 h	715 h	702 h	715 h	726 h

Table 11 - PV generation yearly full load hours

7.3.3.3. Generation of offshore wind power profiles[27]

When it comes to simulate wind power offshore generation, a major difficulty is that too few (or even none) historical real generation data is generally available for modeling and fitting. Such data may be available for some plants, but even so, the distribution of those plants may be too sparse for their associated generation to be representative of what would be the national (regional) aggregated generation. In this study, real generation data from distributed capacities over each of the various considered offshore areas was not available. Then, it was decided to simulate wind power offshore profiles from wind power onshore ones. This way, one can reproduce the variable nature of the offshore generation while capturing important correlation structures that may link weather-dependent power generation and demand profiles of nearby areas.

Stronger winds make that wind power offshore generation generally has higher capacity factor than onshore generation. We computed offshore generation profiles based on scaling factors applied to onshore generation profiles, so as to reach targeted capacity factors.

Remark: Those targeted factors have been deduced from the 2030 projected installed capacities and the associated total wind power generation estimated by ENTSO-E, along with onshore capacity factors estimated through IAEW onshore generation *simulations.*

Let N denotes the yearly number of hours during which offshore generation is assumed to reach maximum generation[28], then at any given time t offshore generation p_t^{off} was estimated from onshore generation p_t^{on}, as following:

---

[27] An alternative methodology is used for the next studies

[28] Offshore maximum generation is assumed to be equal to onshore maximum generation in terms of installed capacity ratio.

$$p_t^{off} = \begin{cases} p_t^{on} \times \max_t p_t^{on} / F_{p^{on}}^{-1}(1 - N/8760), if\ p_t^{on} \leq F_{p^{on}}^{-1}(1 - N/8760) \\ \max_t p_t^{on}, otherwise \end{cases},$$

where $F_{p^{on}}^{-1}$ is the inverse cumulative distribution function of the onshore generation. For each considered area and year, we thus estimated the generation scaling factor $\max_t p_t^{on} / F_{p^{on}}^{-1}(1 - N/8760)$ (or equivalently N) used to reach the targeted capacity factor c^{off}, as following:

$$\hat{N} = argmin_N \left| c^{off} - \frac{1}{8760} \sum_t p_t^{off}(N) \right|.$$

An example of wind power offshore generation simulations based on the proposed scaling algorithm is shown in Figure 29, for France over a year. The associated onshore and offshore capacity factors are respectively 21% and 39% of installed capacity. The estimated number of hours offshore generation reaches its maximum is $\hat{N} = 1143$ h and the associated onshore generation scaling factor is 1.95.

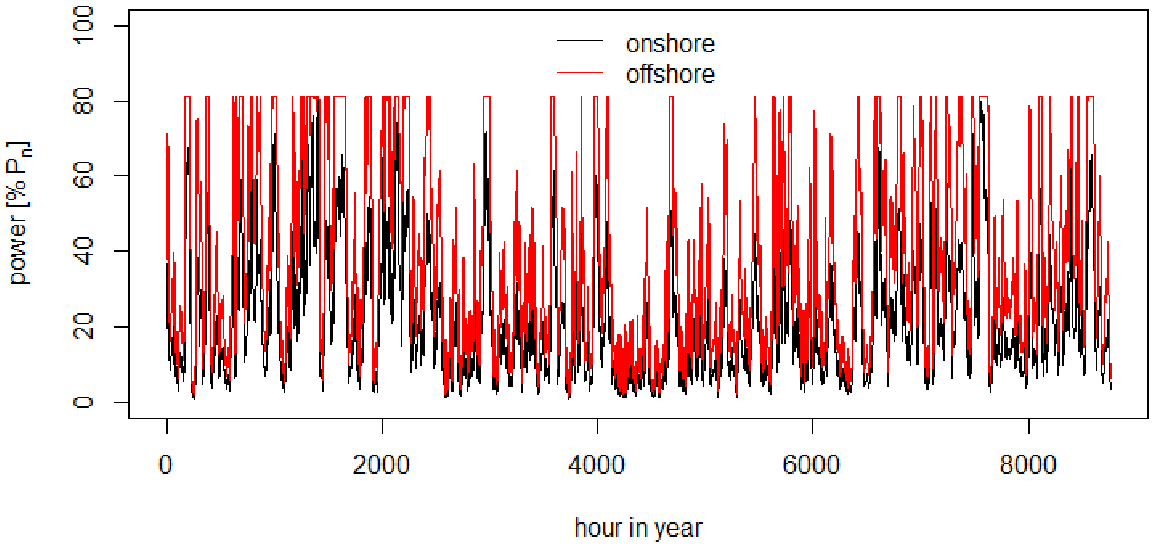

Figure 29: Example of wind power offshore generation simulations based on the proposed scaling algorithm. The time series shown here are for France over a year. P_n is the installed capacity.

7.3.3.4. Hydro power modeling

Run-of-river power plants, inter-seasonal storage dams/reservoirs and pumped hydro storage units are modelled separately.

Run-of- river power plants are represented as uncontrollable generation units, which means that their generation at all times is determined by a load factor time series. Pumped hydraulic storage is modelled as a storage module with a global efficiency rate of 80% (see next section). Inter-seasonal hydro storage is modelled as reservoirs with water inflows time series and minimum water level at the end of each week. These minimum values, called "guide curves", are based on historical values to replicate the standard management of inter-seasonal hydro storage[29].

To implement hydro power modelling, national data – for run-of-river units' generation as well as minimal allowed storage level and water inflows time series – has been derived from power generation and storage level history.

[29] The computation of guide curves requires a stochastic optimization of reservoir management to face uncertainties on water inflows and future load, which is out of the scope of this document.

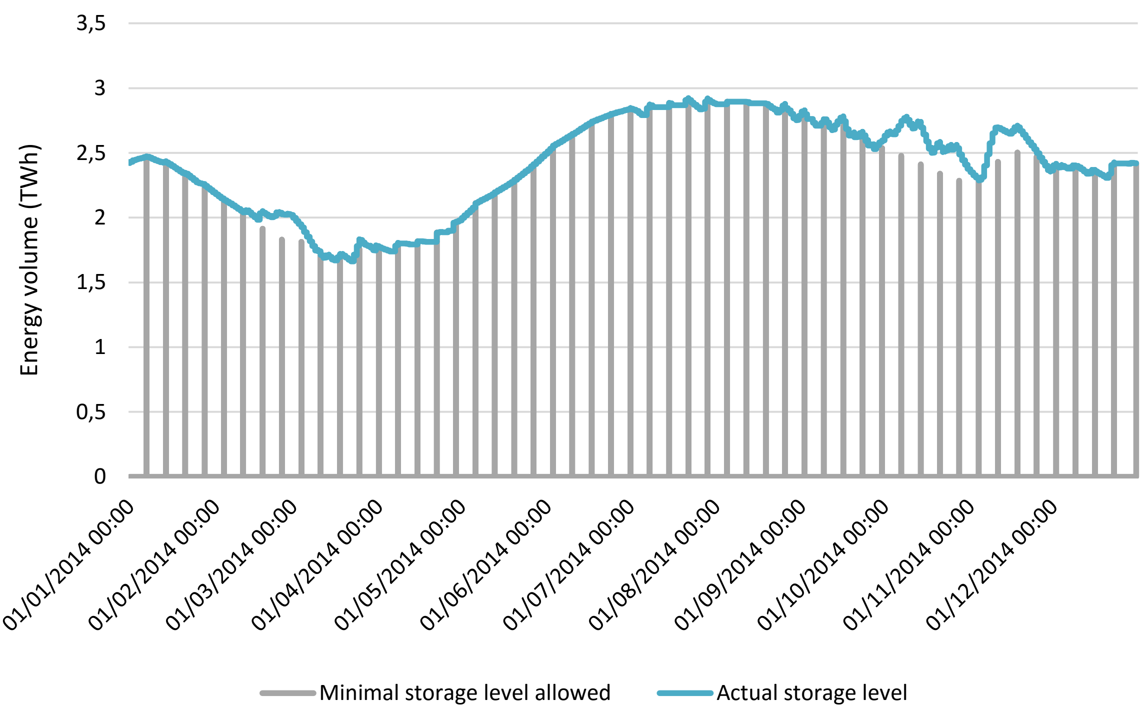

Figure 30: Yearly storage in France

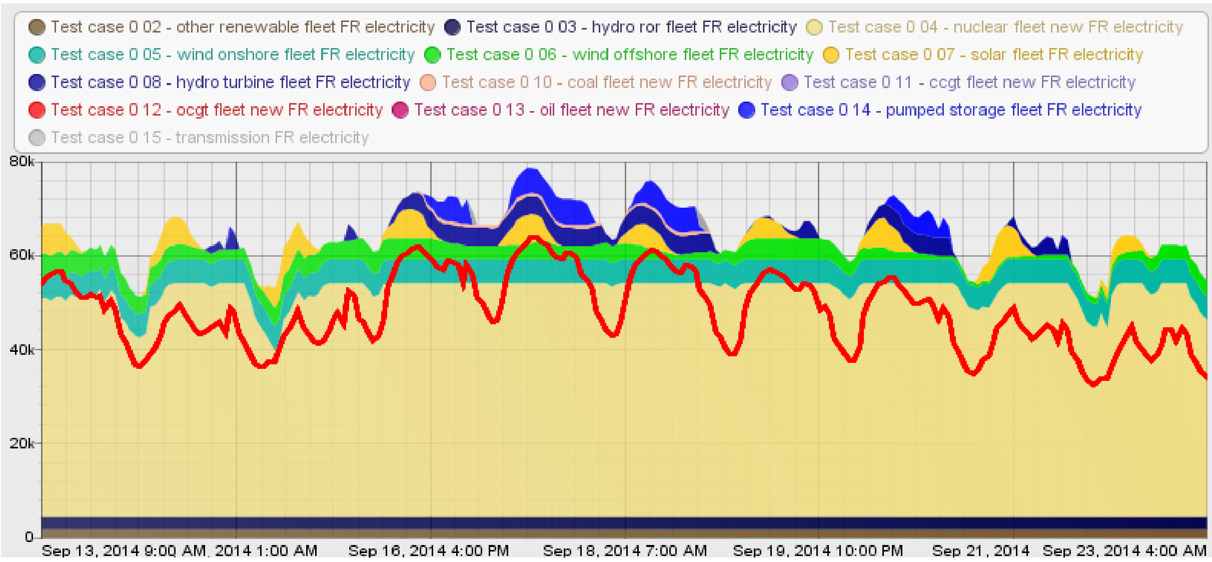

Figure 31: Example of French hydro management (in blue): PHS and reservoir are used when the French demand (red curve) and exports are high, while the minimum water level avoids to use all reservoir water before the winter period.

7.3.4. THERMAL GENERATION UNITS

Thermal generation units are subjected to a maximal generation capacity and national monthly availability ratios, which represent the proportion of units not in maintenance. They are affected efficiency rates which determine their fuel consumption volumes and, as a consequence, their CO_2 emissions volumes, depending on their generation.

To set representative monthly availabilities, historical generation time series (from every country and for several years) have been processed to provide estimations of the corresponding historical availability ratios.

The following thermal generation technologies are considered:

- Nuclear units
- Coal-fueled units
- Lignite-fueled units
- CCGT units
- OCGT units
- Oil-fueled units
- Other thermal units

7.3.5. ENERGY STORAGE

Contrarily to generation power plants, storage plants are subjected to a maximal available energy to inject in the system (the energy storage capacity), in addition of being subjected to maximal available power generation capacity.

Storage facilities are defined by a storage capacity S_{max} (which represents the maximal energy volume that can be stored), efficiency rates ρ^{IN} (accordingly ρ^{OUT}) which represent losses induced by the storage (accordingly restitution) process, and a maximal operating power P_{max}^{stock} appliable to energy input and energy out.

The storage dynamics over a time lap Δt is given by:

$$\forall\, t, \Delta t \quad storageLevel_{t+\Delta t} = storageLevel_t + \left(\rho^{IN} \cdot inPower_t - \frac{1}{\rho^{OUT}} outPower_t\right) \cdot \Delta t$$

Input and output powers being subjected to:

$$0 \leq inPower_t \leq P_{max}^{\text{storage}}$$
$$0 \leq outPower_t \leq P_{max}^{storage}$$

Moreover, the total stored volume at a given date cannot exceed the storage capacity:

$$\forall t, \qquad 0 \leq storageLevel_t \leq S_{max}$$

The storage capacity is linked to the discharge duration by the following relation:

$$dischargeDuration \cdot \frac{P_{max}^{OUT}}{\rho^{OUT}} = S_{max}$$

Should the residual load peaks be longer than the discharge duration, storage facilities will not be able to generate power at their full capacity during the whole scarcity time. Dynamical simulations are necessary to capture these limitations.

Technical characteristics of pumped hydro storage for each MS are deduced from power generation capacity (from ENTSO-E) and from discharge duration data (energy capacity/output capacity) from JRC[30]. When some data were not available, data from neighboring countries were used.

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[30] "Assessment of the European potential for pumped hydropower energy storage : A GIS-based assessment of pumped hydropower storage potential", 2013.

7.3.6. NETWORK MODEL

Imports and exports play a key role to ensure some countries' balances between demand and supply. Since the geographical distribution of RES production does not necessarily match the geographical distribution of demand, interconnections are all the more important when RES integration is high. However transfer capacities are in practice limited, which is taken into account in the model by setting a maximal power transfer capacity to each interconnection.
These maximum transfer capacities are derived from ENTSO-E scenarios (winter NTC values) for 2030.

7.3.7. INPUT DATA SUMMARY

The data needed to run the simulation, which were collected and rendered consistent for constituting the METIS data base are summarized in Table 12.

Source	Data description
ENTSO-E (SO&AF, TYNDP)	Installed power generation capacities Country level
	Historical power demand time series Country level
	Historical thermal asset availabilities Country level
	Interconnection capacities (NTC)
IAEW	Technical constraints and parameters by type of technology
	On-shore wind and solar power generation scenarios Country level
Artelys	Load profiles for different temperature scenarios Country level
Local TSOs	Hydro power management
JRC	PHS parameters
IEA (WEO)	Fuel and CO_2 prices

Table 12 - Main sources of input data for modeled scenarios

7.4. Detailed results on security of supply assessment using national, regional and European approach

7.4.1. Results by country

7.4.1.1. Austria

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**12**	12	12	12	12	12	12	12	12	12	12	**15**	15	15	14	14	15	15	15	15	14	15
	Net demand Peak (GW)	**7**	7	8	7	7	8	7	7	7	8	7	**10**	10	11	10	10	10	10	10	10	10	10
	Thermal power generation capacity (GW)	**6**	6	6	6	6	6	6	6	6	6	6	**6**	6	6	6	6	6	6	6	6	6	6
	Storage capacity (GW)	**5**	5	5	5	5	5	5	5	5	5	5	**5**	5	5	5	5	5	5	5	5	5	5
	Import capacity (GW)	**14**	14	14	14	14	14	14	14	14	14	14	**15**	15	15	15	15	15	15	15	15	15	15
LOLE (h)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**15**	-	-	-	38	-	-	116	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0**	-	-	-	-	-	-	-	-	-	1
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**11**	-	-	-	25	-	-	85	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0**	-	-	-	-	-	-	-	-	-	0
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**0.01**	-	-	-	0.03	-	-	0.09	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.00**	-	-	-	-	-	-	-	-	-	0.00
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.2. Belgium

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country / Region characte-ristics	Demand peak (GW)	**16**	16	17	15	15	15	16	15	16	16	16	**17**	18	18	17	17	17	18	17	18	17	18
	Net demand Peak (GW)	**14**	14	15	14	14	14	14	14	14	14	14	**15**	15	15	14	15	14	15	14	15	14	15
	Thermal power generation capacity (GW)	**9**	9	9	9	9	9	9	9	9	9	9	**9**	9	9	9	9	9	9	9	9	9	9
	Storage capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**2**	2	2	2	2	2	2	2	2	2	2
	Import capacity (GW)	**9**	9	9	9	9	9	9	9	9	9	9	**10**	10	10	10	10	10	10	10	10	10	10
LOLE (h)	National approach for SoS	**2,221**	2,798	2,253	2,131	1,917	2,022	2,337	2,343	2,319	1,997	2,091	**1,782**	2,219	1,820	1,690	1,620	1,557	1,928	1,943	1,877	1,569	1,592
	Regional coordination	**10**	31	41	-	4	-	3	1	13	-	8	**132**	309	118	70	132	127	124	132	95	51	158
	European coordination	**1**	5	7	-	-	-	-	-	-	-	-	**6**	34	11	-	3	-	2	3	3	-	5
Expected Energy not Served (GWh)	National approach for SoS	**3,789**	5,398	3,737	3,302	3,244	3,421	3,986	4,173	3,867	3,166	3,597	**3,648**	5,282	3,588	2,960	3,221	3,205	3,833	4,285	3,580	2,978	3,544
	Regional coordination	**7**	21	37	-	3	-	1	0	6	-	5	**194**	439	201	84	226	163	145	248	137	59	238
	European coordination	**1**	1	6	-	-	-	-	-	-	-	-	**7**	47	14	-	4	-	1	2	2	-	4
Expected Energy not Served (%)	National approach for SoS	**3.99**	5.58	3.94	3.49	3.46	3.62	4.19	4.39	4.09	3.36	3.79	**3.50**	4.97	3.45	2.85	3.13	3.09	3.67	4.10	3.45	2.88	3.40
	Regional coordination	**0.01**	0.02	0.04	-	0.00	-	0.00	0.00	0.01	-	0.01	**0.19**	0.41	0.19	0.08	0.22	0.16	0.14	0.24	0.13	0.06	0.23
	European coordination	**0.00**	0.00	0.01	-	-	-	-	-	-	-	-	**0.01**	0.04	0.01	-	0.00	-	0.00	0.00	0.00	-	0.00

7.4.1.3. Bulgaria

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**7**	8	8	7	7	7	7	7	7	7	8	**6**	7	7	6	6	6	6	6	6	6	7
	Net demand Peak (GW)	**7**	7	7	7	7	6	6	7	6	7	7	**6**	6	6	5	6	5	5	6	6	6	6
	Thermal power generation capacity (GW)	**5**	5	5	5	5	5	5	5	5	5	5	**7**	7	7	7	7	7	7	7	7	7	7
	Storage capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Import capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**3**	3	3	3	3	3	3	3	3	3	3
LOLE (h)	National approach for SoS	**31**	34	44	3	103	9	7	13	5	54	38	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**8**	11	14	-	7	2	5	5	9	18	12	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**2**	2	2	-	2	-	-	2	2	11	3	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**18**	20	24	0	62	2	1	7	2	39	26	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**5**	7	8	-	5	1	3	4	3	15	8	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**1**	0	0	-	0	-	-	1	0	4	1	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**0.05**	0.05	0.06	0.00	0.16	0.01	0.00	0.02	0.01	0.10	0.07	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**0.01**	0.02	0.02	-	0.01	0.00	0.01	0.01	0.01	0.04	0.02	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**0.00**	0.00	0.00	-	0.00	-	-	0.00	0.00	0.01	0.00	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.4. Croatia

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**4**	4	4	4	4	4	4	4	4	4	4	**5**	5	5	4	5	4	4	4	5	4	5
	Net demand Peak (GW)	**3**	4	4	3	3	3	4	3	4	3	3	**4**	4	4	4	3	4	4	4	4	4	4
	Thermal power generation capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Storage capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Import capacity (GW)	**5**	5	5	5	5	5	5	5	5	5	5	**5**	5	5	5	5	5	5	5	5	5	5
LOLE (h)	National approach for SoS	**6**	20	8	-	15	2	2	1	7	4	-	**108**	131	151	2	139	33	126	59	120	135	182
	Regional coordination	**0**	-	3	-	-	-	-	-	-	-	-	**42**	42	61	-	112	9	51	1	6	24	116
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**1**	3	1	-	4	0	0	0	1	0	-	**44**	67	61	0	69	10	43	27	28	62	77
	Regional coordination	**0**	-	0	-	-	-	-	-	-	-	-	**15**	14	28	-	29	3	24	0	1	5	46
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**0.00**	0.01	0.00	-	0.02	0.00	0.00	0.00	0.00	0.00	-	**0.18**	0.28	0.25	0.00	0.29	0.04	0.18	0.11	0.11	0.26	0.32
	Regional coordination	**0.00**	-	0.00	-	-	-	-	-	-	-	-	**0.06**	0.06	0.12	-	0.12	0.01	0.10	0.00	0.00	0.02	0.19
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.5. Czech Republic

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**12**	12	13	11	12	12	12	13	12	12	12	**14**	14	15	13	14	15	14	15	14	14	14
	Net demand Peak (GW)	**11**	11	12	10	11	11	11	12	11	11	11	**13**	13	13	12	13	13	12	14	13	13	13
	Thermal power generation capacity (GW)	**11**	11	11	11	11	11	11	11	11	11	11	**13**	13	13	13	13	13	13	13	13	13	13
	Storage capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Import capacity (GW)	**6**	6	6	6	6	6	6	6	6	6	6	**6**	6	6	6	6	6	6	6	6	6	6
LOLE (h)	National approach for SoS	**2**	-	19	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0**	-	1	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**2**	-	20	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0**	-	0	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**0.00**	-	0.03	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.00**	-	0.00	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.6. Denmark

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**7**	7	7	6	7	7	7	7	7	7	7	**8**	9	9	8	8	9	8	8	9	8	8
	Net demand Peak (GW)	**6**	6	6	6	6	6	6	6	6	6	6	**7**	8	7	7	7	7	7	7	8	7	7
	Thermal power generation capacity (GW)	**6**	6	6	6	6	6	6	6	6	6	6	**5**	5	5	5	5	5	5	5	5	5	5
	Storage capacity (GW)	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Import capacity (GW)	**8**	8	8	8	8	8	8	8	8	8	8	**10**	10	10	10	10	10	10	10	10	10	10
LOLE (h)	National approach for SoS	**283**	502	206	250	230	254	337	187	310	250	301	**631**	909	540	532	530	670	681	524	709	517	697
	Regional coordination	**0**	-	1	-	-	-	-	-	-	-	-	**74**	170	49	62	93	36	70	56	80	25	98
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**2**	20	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**91**	184	67	69	75	84	109	50	107	77	93	**422**	742	374	322	361	428	445	273	468	345	457
	Regional coordination	**0**	-	0	-	-	-	-	-	-	-	-	**81**	190	68	59	106	38	82	42	108	20	98
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**2**	22	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**0.25**	0.49	0.18	0.19	0.21	0.23	0.30	0.14	0.29	0.21	0.25	**0.94**	1.60	0.84	0.74	0.82	0.97	1.00	0.61	1.05	0.78	1.02
	Regional coordination	**0.00**	-	0.00	-	-	-	-	-	-	-	-	**0.18**	0.41	0.15	0.13	0.24	0.09	0.18	0.09	0.24	0.04	0.22
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.00**	0.05	-	-	-	-	-	-	-	-	-

7.4.1.7. Estonia

		Context entso-e 2030v1											**Context entso-e 2030v3**										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/ Region characte-ristics	Demand peak (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**3**	3	3	2	3	3	2	3	3	3	3
	Net demand Peak (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Thermal power generation capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Storage capacity (GW)	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Import capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**3**	3	3	3	3	3	3	3	3	3	3
LOLE (h)	National approach for SoS	**648**	1,065	669	166	629	644	737	632	652	611	679	**1,104**	1,585	1,227	470	953	1,062	1,174	1,165	1,188	1,080	1,131
	Regional coordination	**18**	91	27	-	2	10	-	6	14	12	17	**158**	618	132	-	157	173	37	25	131	178	129
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**40**	156	6	-	63	56	1	16	79	6	17
Expected Energy not Served (GWh)	National approach for SoS	**85**	170	72	9	104	95	79	72	86	79	83	**239**	396	244	60	253	246	239	239	250	222	238
	Regional coordination	**3**	14	6	-	0	4	-	1	5	2	1	**59**	210	49	-	78	67	11	7	60	67	42
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**16**	49	1	-	26	31	0	4	41	1	6
Expected Energy not Served (%)	National approach for SoS	**0.76**	1.49	0.64	0.08	0.95	0.86	0.70	0.64	0.76	0.71	0.74	**1.82**	2.97	1.86	0.47	1.98	1.91	1.82	1.82	1.89	1.70	1.82
	Regional coordination	**0.03**	0.12	0.05	-	0.00	0.03	-	0.01	0.05	0.02	0.01	**0.45**	1.57	0.37	-	0.61	0.52	0.08	0.05	0.45	0.51	0.32
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.12**	0.36	0.01	-	0.20	0.24	0.00	0.03	0.31	0.01	0.04

7.4.1.8. Finland

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**17**	18	16	14	18	18	17	16	18	17	18	**21**	23	20	17	23	23	21	20	23	22	23
	Net demand Peak (GW)	**14**	15	13	12	16	15	14	14	15	14	15	**18**	18	16	14	20	19	17	17	19	18	18
	Thermal power generation capacity (GW)	**12**	12	12	12	12	12	12	12	12	12	12	**13**	13	13	13	13	13	13	13	13	13	13
	Storage capacity (GW)	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Import capacity (GW)	**4**	4	4	4	4	4	4	4	4	4	4	**4**	4	4	4	4	4	4	4	4	4	4
LOLE (h)	National approach for SoS	**323**	724	138	-	402	458	204	208	354	353	384	**787**	1,629	672	109	684	971	643	729	684	929	820
	Regional coordination	**69**	275	15	-	13	118	-	14	54	30	171	**293**	1,097	199	-	219	379	64	31	248	252	438
	European coordination	**1**	-	-	-	10	-	-	-	-	-	-	**91**	274	17	-	179	103	2	22	196	20	100
Expected Energy not Served (GWh)	National approach for SoS	**340**	649	81	-	661	443	141	144	579	274	424	**1,393**	2,936	774	65	1,794	1,840	929	917	1,711	1,380	1,584
	Regional coordination	**70**	248	11	-	10	91	-	17	97	38	186	**566**	1,981	218	-	467	779	80	65	730	367	974
	European coordination	**0**	-	-	-	2	-	-	-	-	-	-	**129**	311	5	-	274	151	0	47	399	25	78
Expected Energy not Served (%)	National approach for SoS	**0.39**	0.72	0.09	-	0.78	0.52	0.17	0.17	0.67	0.31	0.49	**1.32**	2.67	0.74	0.06	1.75	1.77	0.90	0.88	1.62	1.30	1.49
	Regional coordination	**0.08**	0.28	0.01	-	0.01	0.11	-	0.02	0.11	0.04	0.21	**0.53**	1.80	0.21	-	0.46	0.75	0.08	0.06	0.69	0.35	0.92
	European coordination	**0.00**	-	-	-	0.00	-	-	-	-	-	-	**0.12**	0.28	0.00	-	0.27	0.14	0.00	0.04	0.38	0.02	0.07

7.4.1.9. France

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/ Region characte-ristics	Demand peak (GW)	**97**	102	107	92	99	93	101	92	103	86	101	**105**	109	114	99	106	100	108	99	110	93	108
	Net demand Peak (GW)	**86**	92	96	79	89	83	91	82	89	75	84	**86**	93	95	80	88	83	91	82	88	74	85
	Thermal power generation capacity (GW)	**64**	64	64	64	64	64	64	64	64	64	64	**50**	50	50	50	50	50	50	50	50	50	50
	Storage capacity (GW)	**5**	5	5	5	5	5	5	5	5	5	5	**6**	6	6	6	6	6	6	6	6	6	6
	Import capacity (GW)	**20**	20	20	20	20	20	20	20	20	20	20	**22**	22	22	22	22	22	22	22	22	22	22
LOLE (h)	National approach for SoS	**290**	634	331	155	244	250	493	224	279	13	279	**822**	1,415	693	496	763	1,000	1,147	869	784	306	746
	Regional coordination	**50**	153	107	6	34	6	56	12	73	-	52	**339**	678	354	170	275	353	490	331	289	106	345
	European coordination	**3**	10	14	-	-	-	5	-	1	-	-	**35**	117	59	8	23	22	32	25	31	3	30
Expected Energy not Served (GWh)	National approach for SoS	**1,890**	4,686	3,010	669	1,619	931	2,980	1,024	2,058	12	1,914	**8,027**	15,557	8,256	3,940	7,296	9,315	11,993	7,610	7,302	1,822	7,178
	Regional coordination	**226**	613	734	6	76	10	267	21	340	-	194	**3,232**	7,198	4,158	1,555	2,700	3,048	3,818	2,832	3,038	675	3,302
	European coordination	**8**	14	57	-	-	-	5	-	0	-	-	**203**	789	505	40	91	81	126	93	150	9	143
Expected Energy not Served (%)	National approach for SoS	**0.40**	0.96	0.64	0.14	0.35	0.20	0.63	0.22	0.44	0.00	0.41	**1.54**	2.90	1.60	0.76	1.43	1.81	2.28	1.46	1.42	0.36	1.39
	Regional coordination	**0.05**	0.13	0.16	0.00	0.02	0.00	0.06	0.00	0.07	-	0.04	**0.62**	1.34	0.81	0.30	0.53	0.59	0.73	0.54	0.59	0.14	0.64
	European coordination	**0.00**	0.00	0.01	-	-	-	0.00	-	0.00	-	-	**0.04**	0.15	0.10	0.01	0.02	0.02	0.02	0.02	0.03	0.00	0.03

7.4.1.10. Germany

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/ Region characte-ristics	Demand peak (GW)	**92**	92	92	92	92	92	92	92	93	94	92	**107**	109	108	103	107	109	106	107	110	107	106
	Net demand Peak (GW)	**79**	81	77	79	77	79	79	80	78	78	80	**90**	91	90	87	89	92	90	90	92	90	91
	Thermal power generation capacity (GW)	**62**	62	62	62	62	62	62	62	62	62	62	**56**	56	56	56	56	56	56	56	56	56	56
	Storage capacity (GW)	**10**	10	10	10	10	10	10	10	10	10	10	**10**	10	10	10	10	10	10	10	10	10	10
	Import capacity (GW)	**37**	37	37	37	37	37	37	37	37	37	37	**38**	38	38	38	38	38	38	38	38	38	38
LOLE (h)	National approach for SoS	**102**	143	77	104	68	55	71	147	98	101	156	**610**	842	609	452	503	599	463	652	653	656	672
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**121**	263	74	82	123	106	90	127	113	65	163
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**10**	43	14	-	9	4	1	7	11	2	5
Expected Energy not Served (GWh)	National approach for SoS	**642**	944	423	676	378	248	440	1,062	579	606	1,061	**6,886**	10,580	6,170	4,961	5,368	6,411	5,054	7,981	7,021	7,041	8,275
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**1,285**	2,795	881	740	1,344	1,009	970	1,467	1,182	649	1,809
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**72**	395	133	-	24	37	1	35	88	2	11
Expected Energy not Served (%)	National approach for SoS	**0.11**	0.17	0.08	0.12	0.07	0.04	0.08	0.19	0.10	0.11	0.19	**1.09**	1.65	0.98	0.79	0.85	1.02	0.80	1.26	1.11	1.12	1.31
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.20**	0.44	0.14	0.12	0.21	0.16	0.15	0.23	0.19	0.10	0.29
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.01**	0.06	0.02	-	0.00	0.01	0.00	0.01	0.01	0.00	0.00

7.4.1.11. Greece

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/ Region characte-ristics	Demand peak (GW)	**16**	15	15	16	18	16	16	15	15	15	15	**18**	18	17	19	21	18	18	17	18	17	17
	Net demand Peak (GW)	**13**	13	13	12	16	13	13	13	13	13	13	**15**	15	15	14	18	15	15	15	15	14	15
	Thermal power generation capacity (GW)	**7**	7	7	7	7	7	7	7	7	7	7	**7**	7	7	7	7	7	7	7	7	7	7
	Storage capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Import capacity (GW)	**3**	3	3	3	3	3	3	3	3	3	3	**3**	3	3	3	3	3	3	3	3	3	3
LOLE (h)	National approach for SoS	**1,251**	1,651	1,237	983	1,211	1,463	1,573	968	1,230	1,105	1,087	**2,275**	2,592	2,279	2,068	2,143	2,651	2,643	1,999	2,144	2,268	1,967
	Regional coordination	**101**	88	80	50	175	93	165	66	135	65	89	**353**	366	321	223	436	413	470	275	421	284	322
	European coordination	**95**	80	66	50	171	93	161	62	126	59	79	**339**	354	303	221	417	397	464	262	405	260	302
Expected Energy not Served (GWh)	National approach for SoS	**1,771**	2,245	1,681	1,201	2,090	2,090	2,547	1,227	1,892	1,337	1,396	**4,127**	4,926	4,036	3,265	4,262	4,965	5,166	3,269	4,161	3,737	3,480
	Regional coordination	**88**	60	59	25	268	66	106	59	124	46	66	**415**	365	323	191	752	431	597	304	556	278	357
	European coordination	**81**	51	51	25	264	63	100	52	114	34	55	**384**	335	288	188	728	405	579	276	516	222	301
Expected Energy not Served (%)	National approach for SoS	**2.30**	2.92	2.19	1.57	2.72	2.66	3.27	1.63	2.46	1.77	1.82	**4.64**	5.55	4.55	3.70	4.80	5.45	5.72	3.74	4.66	4.26	3.92
	Regional coordination	**0.11**	0.08	0.08	0.03	0.35	0.08	0.14	0.08	0.16	0.06	0.09	**0.47**	0.41	0.36	0.22	0.85	0.47	0.66	0.35	0.62	0.32	0.40
	European coordination	**0.10**	0.07	0.07	0.03	0.34	0.08	0.13	0.07	0.15	0.05	0.07	**0.43**	0.38	0.33	0.21	0.82	0.44	0.64	0.32	0.58	0.25	0.34

7.4.1.12. Hungary

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**7**	7	7	7	7	7	7	7	7	7	7	**8**	8	8	8	8	8	8	8	8	8	8
	Net demand Peak (GW)	**7**	7	7	7	7	7	7	7	7	7	7	**7**	7	7	7	7	7	7	7	7	7	7
	Thermal power generation capacity (GW)	**8**	8	8	8	8	8	8	8	8	8	8	**9**	9	9	9	9	9	9	9	9	9	9
	Storage capacity (GW)	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Import capacity (GW)	**9**	9	9	9	9	9	9	9	9	9	9	**9**	9	9	9	9	9	9	9	9	9	9
LOLE (h)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.13. Ireland

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**6**	7	6	6	6	6	6	6	6	6	6	**6**	7	6	6	6	6	6	6	6	6	6
	Net demand Peak (GW)	**5**	6	5	5	5	5	5	5	5	5	5	**5**	6	5	5	5	5	5	5	5	5	5
	Thermal power generation capacity (GW)	**5**	5	5	5	5	5	5	5	5	5	5	**4**	4	4	4	4	4	4	4	4	4	4
	Storage capacity (GW)	**0**	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0
	Import capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**3**	3	3	3	3	3	3	3	3	3	3
LOLE (h)	National approach for SoS	**13**	115	-	3	-	5	-	2	-	-	2	**35**	160	13	26	7	35	28	19	17	11	29
	Regional coordination	**13**	116	-	5	-	5	-	2	-	-	3	**8**	60	1	5	-	4	2	-	2	-	5
	European coordination	**3**	31	-	-	-	-	-	-	-	-	-	**5**	43	-	3	-	2	-	-	-	-	1
Expected Energy not Served (GWh)	National approach for SoS	**6**	60	-	0	-	0	-	0	-	-	0	**13**	88	1	9	1	13	7	4	2	3	7
	Regional coordination	**7**	67	-	0	-	0	-	0	-	-	0	**5**	48	0	2	-	1	0	-	0	-	1
	European coordination	**1**	9	-	-	-	-	-	-	-	-	-	**4**	35	-	1	-	0	-	-	-	-	0
Expected Energy not Served (%)	National approach for SoS	**0.02**	0.19	-	0.00	-	0.00	-	0.00	-	-	0.00	**0.04**	0.26	0.00	0.03	0.00	0.04	0.02	0.01	0.00	0.01	0.02
	Regional coordination	**0.02**	0.21	-	0.00	-	0.00	-	0.00	-	-	0.00	**0.02**	0.14	0.00	0.00	-	0.00	0.00	-	0.00	-	0.00
	European coordination	**0.00**	0.03	-	-	-	-	-	-	-	-	-	**0.01**	0.10	-	0.00	-	0.00	-	-	-	-	0.00

7.4.1.14. Italy

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**63**	63	62	63	62	64	62	63	64	64	63	**79**	79	78	79	77	80	78	78	80	80	79
	Net demand Peak (GW)	**51**	52	51	50	51	52	51	51	51	51	52	**63**	65	63	62	63	63	62	62	63	63	64
	Thermal power generation capacity (GW)	**52**	52	52	52	52	52	52	52	52	52	52	**55**	55	55	55	55	55	55	55	55	55	55
	Storage capacity (GW)	**8**	8	8	8	8	8	8	8	8	8	8	**9**	9	9	9	9	9	9	9	9	9	9
	Import capacity (GW)	**16**	16	16	16	16	16	16	16	16	16	16	**16**	16	16	16	16	16	16	16	16	16	16
LOLE (h)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.15. Latvia

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Net demand Peak (GW)	**1**	2	1	1	1	2	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Thermal power generation capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Storage capacity (GW)	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Import capacity (GW)	**3**	3	3	3	3	3	3	3	3	3	3	**4**	4	4	4	4	4	4	4	4	4	4
LOLE (h)	National approach for SoS	**82**	183	91	17	43	81	38	132	83	87	64	**4**	21	-	-	-	8	-	5	2	-	4
	Regional coordination	**2**	7	3	-	-	5	-	3	6	-	-	**3**	21	-	-	-	4	-	2	2	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**1**	8	-	-	-	4	-	-	2	-	-
Expected Energy not Served (GWh)	National approach for SoS	**7**	19	4	0	2	10	1	13	8	4	6	**0**	1	-	-	-	0	-	0	0	-	0
	Regional coordination	**0**	0	0	-	-	1	-	0	1	-	-	**0**	1	-	-	-	0	-	0	0	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0**	1	-	-	-	0	-	-	0	-	-
Expected Energy not Served (%)	National approach for SoS	**0.07**	0.20	0.04	0.00	0.02	0.10	0.02	0.14	0.08	0.05	0.06	**0.00**	0.02	-	-	-	0.00	-	0.00	0.00	-	0.00
	Regional coordination	**0.00**	0.00	0.00	-	-	0.01	-	0.00	0.01	-	-	**0.00**	0.02	-	-	-	0.00	-	0.00	0.00	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.00**	0.01	-	-	-	0.00	-	-	0.00	-	-

7.4.1.16. Lithuania

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**4**	4	4	3	4	4	3	4	4	4	4
	Net demand Peak (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**3**	4	3	3	3	4	3	3	4	4	3
	Thermal power generation capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Storage capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Import capacity (GW)	**3**	3	3	3	3	3	3	3	3	3	3	**4**	4	4	4	4	4	4	4	4	4	4
LOLE (h)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**729**	1,357	716	162	586	873	677	674	832	702	711
	Regional coordination	**0**	-	-	-	-	1	-	-	-	-	-	**127**	508	108	-	118	113	24	13	107	208	74
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**28**	121	6	-	22	47	-	14	59	-	10
Expected Energy not Served (GWh)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**447**	866	427	65	362	566	404	432	542	424	381
	Regional coordination	**0**	-	-	-	-	0	-	-	-	-	-	**63**	264	52	-	46	67	10	12	73	90	20
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**14**	56	1	-	4	25	-	8	41	-	2
Expected Energy not Served (%)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**2.48**	4.69	2.39	0.38	2.05	3.15	2.24	2.41	3.01	2.38	2.12
	Regional coordination	**0.00**	-	-	-	-	0.00	-	-	-	-	-	**0.35**	1.43	0.29	-	0.26	0.37	0.06	0.06	0.40	0.51	0.11
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.08**	0.30	0.01	-	0.02	0.14	-	0.04	0.23	-	0.01

7.4.1.17. Luxembourg

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/ Region characte-ristics	Demand peak (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Net demand Peak (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Thermal power generation capacity (GW)	**0**	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0
	Storage capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Import capacity (GW)	**4**	4	4	4	4	4	4	4	4	4	4	**4**	4	4	4	4	4	4	4	4	4	4
LOLE (h)	National approach for SoS	**8,746**	8,757	8,754	8,757	8,733	8,750	8,757	8,739	8,735	8,736	8,740	**8,737**	8,751	8,749	8,756	8,724	8,743	8,752	8,730	8,720	8,722	8,722
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**72**	168	51	49	89	49	53	64	59	35	106
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**3**	23	1	-	-	-	-	2	4	-	-
Expected Energy not Served (GWh)	National approach for SoS	**2,944**	3,026	2,942	2,947	2,892	2,916	2,965	2,968	2,919	2,918	2,947	**3,143**	3,241	3,144	3,143	3,078	3,111	3,174	3,169	3,124	3,108	3,139
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**30**	70	20	22	35	19	24	30	24	16	44
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**1**	10	0	-	-	-	-	1	2	-	-
Expected Energy not Served (%)	National approach for SoS	**43.80**	44.61	43.83	43.82	43.26	43.55	44.08	43.99	43.63	43.50	43.76	**43.18**	44.12	43.25	43.16	42.52	42.90	43.58	43.36	43.13	42.77	43.05
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.41**	0.95	0.27	0.30	0.48	0.26	0.33	0.41	0.33	0.22	0.60
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.02**	0.13	0.01	-	-	-	-	0.01	0.02	-	-

7.4.1.18. Netherlands

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**19**	19	19	18	19	18	18	19	18	19	19	**25**	25	25	25	25	25	25	25	25	25	25
	Net demand Peak (GW)	**18**	17	18	17	18	18	17	18	17	18	17	**23**	23	24	23	24	24	23	24	24	24	23
	Thermal power generation capacity (GW)	**25**	25	25	25	25	25	25	25	25	25	25	**25**	25	25	25	25	25	25	25	25	25	25
	Storage capacity (GW)	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Import capacity (GW)	**10**	10	10	10	10	10	10	10	10	10	10	**10**	10	10	10	10	10	10	10	10	10	10
LOLE (h)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.19. Poland

		Context entso-e 2030v1											Context entso-e 2030v3											
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/ Region character-ristics	Demand peak (GW)	**29**	29	29	29	29	29	29	29	29	29	29	**34**	34	34	34	34	34	34	34	34	34	34
	Net demand Peak (GW)	**28**	28	28	27	28	27	27	28	27	28	28	**33**	34	33	33	33	33	33	33	33	33	33
	Thermal power generation capacity (GW)	**22**	22	22	22	22	22	22	22	22	22	22	**20**	20	20	20	20	20	20	20	20	20	20
	Storage capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Import capacity (GW)	**5**	5	5	5	5	5	5	5	5	5	5	**5**	5	5	5	5	5	5	5	5	5	5
LOLE (h)	National approach for SoS	**610**	673	723	498	542	535	572	600	726	593	634	**4,779**	4,898	4,806	4,566	4,499	4,939	4,924	4,824	4,884	4,567	4,886
	Regional coordination	**8**	10	11	3	13	3	8	12	5	10	5	**1,536**	1,641	1,631	1,388	1,309	1,538	1,582	1,576	1,710	1,419	1,562
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**761**	863	890	614	682	722	710	730	938	695	769
Expected Energy not Served (GWh)	National approach for SoS	**1,272**	1,379	1,641	1,006	1,177	956	1,214	1,204	1,526	1,274	1,340	**20,176**	20,932	21,154	18,467	18,374	20,511	20,878	20,496	21,272	18,750	20,930
	Regional coordination	**5**	6	11	1	11	1	2	6	5	4	2	**4,827**	5,689	5,412	3,933	4,252	4,458	4,707	4,898	5,508	4,394	5,018
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**1,984**	2,553	2,438	1,458	1,812	1,639	1,751	1,900	2,438	1,818	2,032
Expected Energy not Served (%)	National approach for SoS	**0.72**	0.77	0.92	0.57	0.66	0.54	0.68	0.67	0.86	0.72	0.75	**9.50**	9.83	9.97	8.71	8.69	9.70	9.80	9.61	10.02	8.86	9.82
	Regional coordination	**0.00**	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**2.27**	2.67	2.55	1.86	2.01	2.11	2.21	2.30	2.59	2.08	2.35
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.93**	1.20	1.15	0.69	0.86	0.78	0.82	0.89	1.15	0.86	0.95

7.4.1.20. Portugal

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**11**	11	11	10	11	10	11	10	11	10	11	**12**	13	13	12	13	12	13	11	12	11	12
	Net demand Peak (GW)	**8**	9	9	8	9	8	8	8	8	8	8	**10**	11	11	9	10	9	9	9	10	9	9
	Thermal power generation capacity (GW)	**4**	4	4	4	4	4	4	4	4	4	4	**5**	5	5	5	5	5	5	5	5	5	5
	Storage capacity (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Import capacity (GW)	**3**	3	3	3	3	3	3	3	3	3	3	**3**	3	3	3	3	3	3	3	3	3	3
LOLE (h)	National approach for SoS	**47**	41	124	12	48	65	110	9	30	19	8	**236**	93	316	114	418	510	415	119	172	100	106
	Regional coordination	**0**	1	-	-	3	-	-	-	-	-	-	**12**	20	18	8	26	17	5	9	8	-	8
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**7**	14	16	3	11	9	4	4	3	-	2
Expected Energy not Served (GWh)	National approach for SoS	**44**	22	180	2	31	60	110	1	11	16	1	**308**	65	496	104	600	682	553	108	181	152	137
	Regional coordination	**0**	0	-	-	3	-	-	-	-	-	-	**9**	14	25	7	19	11	2	2	11	-	3
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**6**	10	22	3	11	5	1	1	4	-	1
Expected Energy not Served (%)	National approach for SoS	**0.08**	0.04	0.33	0.00	0.06	0.11	0.20	0.00	0.02	0.03	0.00	**0.48**	0.10	0.78	0.16	0.94	1.07	0.85	0.17	0.28	0.24	0.21
	Regional coordination	**0.00**	0.00	-	-	0.01	-	-	-	-	-	-	**0.01**	0.02	0.04	0.01	0.03	0.02	0.00	0.00	0.02	-	0.00
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.01**	0.02	0.03	0.00	0.02	0.01	0.00	0.00	0.01	-	0.00

7.4.1.21. Romania

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/ Region characteristics	Demand peak (GW)	**12**	12	12	11	11	12	12	12	12	12	12	**15**	16	15	15	14	16	15	15	15	15	15
	Net demand Peak (GW)	**9**	10	10	9	9	9	10	9	9	10	10	**12**	13	12	12	12	13	12	13	12	13	12
	Thermal power generation capacity (GW)	**6**	6	6	6	6	6	6	6	6	6	6	**6**	6	6	6	6	6	6	6	6	6	6
	Storage capacity (GW)	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Import capacity (GW)	**3**	3	3	3	3	3	3	3	3	3	3	**4**	4	4	4	4	4	4	4	4	4	4
LOLE (h)	National approach for SoS	**342**	294	383	293	236	480	383	291	423	338	297	**3,319**	3,243	3,512	3,200	2,955	3,581	3,479	3,155	3,956	2,853	3,251
	Regional coordination	**28**	38	31	-	13	21	42	18	15	63	36	**312**	321	316	222	218	383	357	265	361	323	356
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**45**	68	46	9	11	68	47	52	14	89	44
Expected Energy not Served (GWh)	National approach for SoS	**192**	200	207	120	96	263	226	172	201	260	177	**3,884**	3,746	4,154	3,356	3,250	4,538	4,208	3,598	4,686	3,538	3,770
	Regional coordination	**15**	15	21	-	4	9	24	13	8	39	18	**303**	360	328	110	181	381	357	277	265	394	374
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**28**	53	29	2	5	38	30	34	5	62	22
Expected Energy not Served (%)	National approach for SoS	**0.29**	0.30	0.31	0.18	0.14	0.39	0.34	0.26	0.30	0.39	0.27	**4.64**	4.49	4.99	4.04	3.91	5.39	5.00	4.31	5.52	4.25	4.51
	Regional coordination	**0.02**	0.02	0.03	-	0.01	0.01	0.04	0.02	0.01	0.06	0.03	**0.36**	0.43	0.39	0.13	0.22	0.45	0.42	0.33	0.31	0.47	0.45
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.03**	0.06	0.03	0.00	0.01	0.05	0.04	0.04	0.01	0.07	0.03

7.4.1.22. Slovakia

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**5**	4	5	4	5	4	5	5	5	5	5	**5**	5	5	5	5	5	5	5	5	5	5
	Net demand Peak (GW)	**4**	4	4	4	4	4	4	4	4	4	4	**4**	4	4	4	4	4	4	4	4	4	4
	Thermal power generation capacity (GW)	**4**	4	4	4	4	4	4	4	4	4	4	**4**	4	4	4	4	4	4	4	4	4	4
	Storage capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**1**	1	1	1	1	1	1	1	1	1	1
	Import capacity (GW)	**5**	5	5	5	5	5	5	5	5	5	5	**5**	5	5	5	5	5	5	5	5	5	5
LOLE (h)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.23. Slovenia

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**3**	3	3	3	3	3	3	3	3	3	3
	Net demand Peak (GW)	**2**	2	2	2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2
	Thermal power generation capacity (GW)	**1**	1	1	1	1	1	1	1	1	1	1	**3**	3	3	3	3	3	3	3	3	3	3
	Storage capacity (GW)	**0**	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0
	Import capacity (GW)	**6**	6	6	6	6	6	6	6	6	6	6	**6**	6	6	6	6	6	6	6	6	6	6
LOLE (h)	National approach for SoS	**38**	38	49	21	22	61	46	42	45	28	32	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (GWh)	National approach for SoS	**2**	1	2	1	1	2	2	2	2	1	1	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
Expected Energy not Served (%)	National approach for SoS	**0.01**	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	**-**	-	-	-	-	-	-	-	-	-	-
	Regional coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-

7.4.1.24. Spain

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**60**	61	60	59	62	60	62	56	57	56	62	**73**	75	72	73	76	73	74	69	70	67	76
	Net demand Peak (GW)	**50**	52	50	50	53	50	50	48	50	43	49	**58**	62	58	58	63	60	58	56	59	50	57
	Thermal power generation capacity (GW)	**45**	45	45	45	45	45	45	45	45	45	45	**45**	45	45	45	45	45	45	45	45	45	45
	Storage capacity (GW)	**5**	5	5	5	5	5	5	5	5	5	5	**5**	5	5	5	5	5	5	5	5	5	5
	Import capacity (GW)	**7**	7	7	7	7	7	7	7	7	7	7	**8**	8	8	8	8	8	8	8	8	8	8
LOLE (h)	National approach for SoS	**0**	1	-	-	3	-	-	-	-	-	-	**18**	29	20	14	42	25	9	21	7	-	16
	Regional coordination	**0**	1	-	-	3	-	-	-	-	-	-	**16**	21	16	14	39	22	9	15	6	-	15
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**7**	17	13	3	9	9	6	5	1	-	3
Expected Energy not Served (GWh)	National approach for SoS	**0**	1	-	-	2	-	-	-	-	-	-	**46**	73	38	43	133	62	24	29	19	-	41
	Regional coordination	**0**	1	-	-	2	-	-	-	-	-	-	**43**	67	35	40	126	57	23	20	19	-	39
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**18**	62	32	3	36	16	17	4	1	-	11
Expected Energy not Served (%)	National approach for SoS	**0.00**	0.00	-	-	0.00	-	-	-	-	-	-	**0.01**	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.00	-	0.01
	Regional coordination	**0.00**	0.00	-	-	0.00	-	-	-	-	-	-	**0.01**	0.02	0.01	0.01	0.03	0.01	0.01	0.01	0.00	-	0.01
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.00**	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.00	-	0.00

7.4.1.25. Sweden

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**29**	30	28	26	28	29	28	30	30	29	30	**31**	32	31	28	31	32	30	33	33	32	33
	Net demand Peak (GW)	**24**	25	24	21	23	25	23	26	26	23	25	**27**	28	26	24	26	28	25	29	29	25	27
	Thermal power generation capacity (GW)	**11**	11	11	11	11	11	11	11	11	11	11	**11**	11	11	11	11	11	11	11	11	11	11
	Storage capacity (GW)	**-**	-	-	-	-	-	-	-	-	-	-	**-**	-	-	-	-	-	-	-	-	-	-
	Import capacity (GW)	**12**	12	12	12	12	12	12	12	12	12	12	**12**	12	12	12	12	12	12	12	12	12	12
LOLE (h)	National approach for SoS	**175**	569	191	7	79	139	85	147	205	125	207	**369**	999	464	66	176	313	236	362	359	284	427
	Regional coordination	**46**	234	35	-	-	42	-	11	7	32	98	**134**	617	169	-	5	116	3	15	87	115	209
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**8**	61	-	-	-	6	-	4	13	-	-
Expected Energy not Served (GWh)	National approach for SoS	**300**	1,240	350	1	85	168	68	149	356	299	288	**762**	2,598	857	64	262	536	304	532	892	751	821
	Regional coordination	**94**	714	24	-	-	29	-	8	5	47	110	**351**	1,870	370	-	3	231	1	47	137	329	521
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**19**	155	-	-	-	12	-	1	18	-	-
Expected Energy not Served (%)	National approach for SoS	**0.20**	0.81	0.24	0.00	0.06	0.12	0.05	0.10	0.24	0.21	0.20	**0.47**	1.56	0.54	0.04	0.17	0.35	0.19	0.34	0.57	0.48	0.52
	Regional coordination	**0.06**	0.46	0.02	-	-	0.02	-	0.01	0.00	0.03	0.07	**0.22**	1.12	0.23	-	0.00	0.15	0.00	0.03	0.09	0.21	0.33
	European coordination	**-**	-	-	-	-	-	-	-	-	-	-	**0.01**	0.09	-	-	-	0.01	-	0.00	0.01	-	-

7.4.1.26. United Kingdom

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/Region characteristics	Demand peak (GW)	**68**	76	71	67	69	63	68	66	67	68	67	**76**	86	79	75	76	71	75	74	75	76	74
	Net demand Peak (GW)	**57**	66	56	58	56	55	56	56	54	55	57	**59**	69	56	61	59	59	56	58	57	57	59
	Thermal power generation capacity (GW)	**47**	47	47	47	47	47	47	47	47	47	47	**52**	52	52	52	52	52	52	52	52	52	52
	Storage capacity (GW)	**3**	3	3	3	3	3	3	3	3	3	3	**3**	3	3	3	3	3	3	3	3	3	3
	Import capacity (GW)	**8**	8	8	8	8	8	8	8	8	8	8	**13**	13	13	13	13	13	13	13	13	13	13
LOLE (h)	National approach for SoS	**72**	310	61	40	52	47	39	25	29	35	80	**15**	79	3	11	8	12	8	4	3	7	12
	Regional coordination	**57**	280	37	34	30	31	29	15	23	23	66	**14**	76	3	10	6	11	7	3	3	6	10
	European coordination	**9**	72	3	4	1	-	2	-	1	-	4	**6**	49	-	5	3	2	-	1	-	-	3
Expected Energy not Served (GWh)	National approach for SoS	**281**	1,761	120	145	128	126	103	54	54	88	233	**69**	537	4	42	24	23	12	11	5	10	23
	Regional coordination	**237**	1,605	72	126	79	96	78	39	38	57	185	**65**	525	4	37	13	20	10	7	5	9	20
	European coordination	**42**	396	3	7	0	-	2	-	2	-	5	**31**	296	-	9	4	2	-	0	-	-	4
Expected Energy not Served (%)	National approach for SoS	**0.08**	0.50	0.04	0.04	0.04	0.04	0.03	0.02	0.02	0.03	0.07	**0.02**	0.14	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01
	Regional coordination	**0.07**	0.46	0.02	0.04	0.02	0.03	0.02	0.01	0.01	0.02	0.05	**0.02**	0.14	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01
	European coordination	**0.01**	0.11	0.00	0.00	0.00	-	0.00	-	0.00	-	0.00	**0.01**	0.08	-	0.00	0.00	0.00	-	0.00	-	-	0.00

7.4.2. Results at European level

7.4.2.1. Europe

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country / Region characteristics	Demand peak (GW)	**557**	575	585	543	560	551	552	539	561	537	562	**648**	670	685	628	649	647	642	628	658	628	651
	Net demand Peak (GW)	**451**	472	469	437	448	451	445	447	449	439	454	**496**	519	515	476	488	503	487	494	494	489	497
	Thermal power generation capacity (GW)	**419**	419	419	419	419	419	419	419	419	419	419	**412**	412	412	412	412	412	412	412	412	412	412
	Storage capacity (GW)	**51**	51	51	51	51	51	51	51	51	51	51	**55**	55	55	55	55	55	55	55	55	55	55
	Import capacity (GW)	**-**											**-**										
Expected Energy not Served (GWh)	National approach for SoS	**13,677**	22,009	14,559	10,149	12,653	11,815	14,973	12,321	14,248	10,450	13,588	**53,645**	72,634	53,779	40,867	48,733	56,462	57,266	53,065	55,243	44,321	54,083
	Regional coordination	**759**	3,371	984	158	463	308	479	169	632	247	777	**11,544**	22,100	12,172	6,780	10,377	10,782	10,861	10,259	11,853	7,352	12,903
	European coordination	**132**	471	117	32	266	63	107	53	116	38	62	**2,918**	5,177	3,469	1,703	3,020	2,442	2,506	2,404	3,705	2,139	2,614
Expected Energy not Served (%)	National approach for SoS	**0.42**	0.66	0.44	0.31	0.39	0.36	0.45	0.37	0.43	0.32	0.41	**1.40**	1.87	1.41	1.08	1.29	1.48	1.49	1.39	1.45	1.17	1.41
	Regional coordination	**0.02**	0.10	0.03	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.02	**0.30**	0.57	0.32	0.18	0.27	0.28	0.28	0.27	0.31	0.19	0.34
	European coordination	**0.00**	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.08**	0.13	0.09	0.04	0.08	0.06	0.07	0.06	0.10	0.06	0.07

7.4.2.2. ENTSO-E

		Context entso-e 2030v1											Context entso-e 2030v3										
		Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10	Avg	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
Country/ Region characte-ristics	Demand peak (GW)	**605**	627	637	590	606	595	600	590	613	585	610	**701**	726	742	678	699	696	693	684	714	679	703
	Net demand Peak (GW)	**494**	517	515	477	490	494	488	483	495	479	497	**540**	566	561	518	533	546	532	534	544	529	542
	Thermal power generation capacity (GW)	**430**	430	430	430	430	430	430	430	430	430	430	**421**	421	421	421	421	421	421	421	421	421	421
	Storage capacity (GW)	**54**	54	54	54	54	54	54	54	54	54	54	**59**	59	59	59	59	59	59	59	59	59	59
	Import capacity (GW)	**-**											**-**										
Expected Energy not Served (GWh)	National approach for SoS	**28,099**	40,176	27,618	22,520	25,253	26,165	30,247	26,569	29,360	22,286	30,800	**80,669**	104,802	79,123	65,027	72,752	83,862	85,874	80,055	83,337	67,980	83,876
	Regional coordination	**1,481**	6,956	2,146	158	465	634	490	170	633	1,134	2,027	**12,744**	27,747	13,657	6,786	10,597	11,636	11,040	10,360	11,930	8,499	15,183
	European coordination	**132**	471	117	32	266	63	107	53	116	38	62	**2,936**	5,312	3,475	1,703	3,026	2,444	2,511	2,409	3,706	2,143	2,627
Expected Energy not Served (%)	National approach for SoS	**0.79**	1.10	0.77	0.63	0.71	0.74	0.84	0.74	0.82	0.63	0.86	**1.95**	2.49	1.92	1.58	1.78	2.04	2.07	1.94	2.02	1.66	2.02
	Regional coordination	**0.04**	0.19	0.06	0.00	0.01	0.02	0.01	0.00	0.02	0.03	0.06	**0.31**	0.66	0.33	0.17	0.26	0.28	0.27	0.25	0.29	0.21	0.37
	European coordination	**0.00**	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.07**	0.13	0.08	0.04	0.07	0.06	0.06	0.06	0.09	0.05	0.06

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