2015

SCENARIO OUTLOOK & ADEQUACY FORECAST

30th June 2015

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Reliable Sustainable Connected

Contents

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1 Executive summary

The Scenario Outlook and Adequacy Forecast (SO&AF) report aims at providing stakeholders in the European electricity market with a Pan-European overview of generation adequacy with a five to ten year time frame. Within this time frame, relevant stakeholders, e.g. Member State authorities, policy makers, regulatory agencies and energy producers, are able to establish countermeasures in order to ensure the desired adequacy levels.

The Regulation (EC) N°714/2009 requires the issuing of an SO&AF every two years along with the Ten Year Network Development Plan package. However, because of the importance and increased relevance of the forecasts provided by the SO&AF report, ENTSO-E has decided as an internal standard to publish it every year.

Enhancement of SO&AF 2015 compared with previous editions

As in SO&AF 2014, the generation adequacy is still assessed using a power balance-based approach, but in the present edition the analysis has been extended to a monthly resolution over the time frame 2016–2020–2025. This should be recognised as a significant step forward in the methodology for adequacy analysis and has been made in response to our stakeholder's increasing expectations. However, we appreciate that further developments are still required to realise the target methodology of full probabilistic, market-based modelling for adequacy, on a Pan-European basis, and development work is currently in progress to enhance the methodology for SO&AF 2016.

Other than the monthly generation adequacy for each country separately, the SO&AF 2015 also introduces simultaneous ENTSO-E regional assessment to assess the feasibility of improving the (national) level of adequacy by means of imports from a Pan-EU point of view.

Moreover, as another step forward towards probabilistic assessment of generation capacity, a *residual load* assessment has been carried out in order to report on the flexibility and ramping needs of the power system. The residual load is the remaining part of the load minus variable renewable production (wind and solar) plus *must-run* generation in an hourly time interval.

Scenario outlook

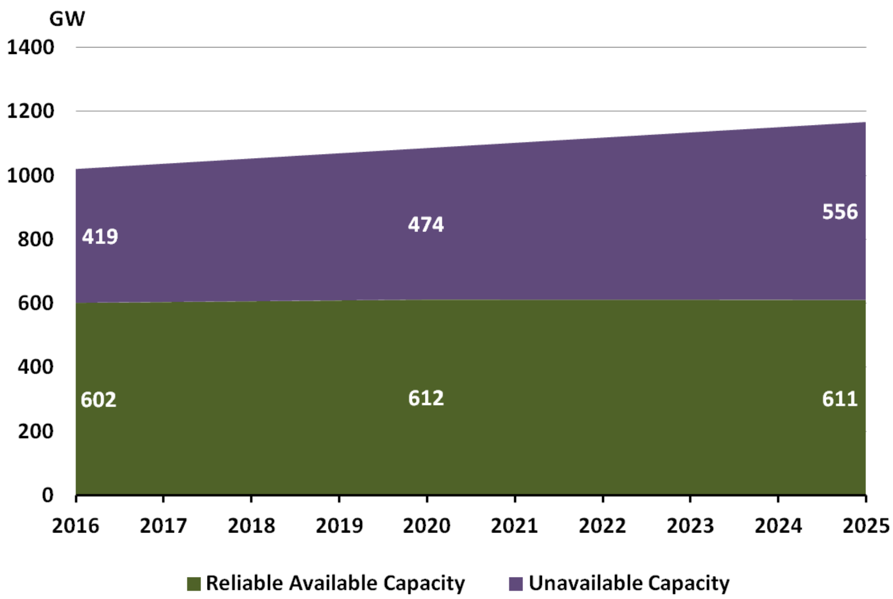
The figures for load in the report refer to highest expected load growth forecast by TSOs. These figures do not necessarily mean most probable load growth forecast by ENTSO-E, but indicate the most challenging forecast, which is most relevant regarding generation adequacy assessments. Highest expected load growth forecast seems to be impacted by electrification processes and economic recovery. Annual monthly peak loads increase over the period 2016–2025 by 0.9%, and show a somewhat higher trend than energy consumption growth (0.8% annual).

In 2016, the expected net generating capacity (NGC) is lower than previously reported in both *Scenarios A* and *B*. On the other hand, in the mid (2020) and long term (2025), the confirmed development of generation capacity, indicated in Scenario A, points to higher values than in SO&AF 2014. In the case of Scenario B a general postponement of new units is observed. Fossil fuel-based capacity is expected to fall after 2016 with lower values than in previous reports. Along with this general decrease of fossil fuel capacity, gas-fired power stations are also forecast to replace coal power stations. In the case of Scenario B, the total gas capacity increases by approximately 22 GW (annual growth of 1.13%) by 2025.

In the case of nuclear power, capacity at ENTSO-E level will be maintained at around 120 GW until 2020. From 2020 until 2025, a decrease of 12% is foreseen in Scenario B. This results in a similar level of nuclear generation to that reported in Scenario A in SO&AF 2014. This means that the nuclear capacity in this year's Scenario B is nearly 9% (–11 GW) lower in 2025 compared with last year's forecast.

Renewable energy sources (RES) will have a dominant role in new capacity additions over the upcoming years. While RES-HPP (Hydro Power Plants) NGC is expected to remain stable until 2025, the installed wind and solar NGC are forecast to increase by 80% and 60%, respectively. Biomass and other RES technologies will have a more marginal role. The progressively growing gap between Scenarios A and B reflects the uncertainty related to the revision of incentive policies and changes in the general economic framework conditions.

Although the NGC is increased from 1021 GW in 2016 to 1167 GW in 2025 (in Scenario B), the increase in the so-called *Reliable Available Capacity* shows very little increase, from 602 GW to 611 GW. These results should be understood within the applied assumptions regarding so-called *Unavailable Capacity*, which for RES is proportional to (1 – RES Load Factor).



Unavailable Capacity (UC) is closely linked to variable RES penetration because of the limited availability of their primary energy sources. Between 2016 and 2025, 94% of the NGC increase is considered as UC (corresponding to 137 GW); meaning that only a minor part (9 GW) can be taken into account as Reliable Available Capacity.

Upward generation adequacy assessment

While the Pan-European level requires a common reference point in time for all countries (see Chapter 6), national power balance evaluations can be assessed against their monthly peak loads (results in Chapter 4).

The regional analysis shows that from a Pan-European system point of view, the level of imports necessary to maintain adequacy is **feasible** and **within** the level of forecast cross-border interconnectivity for the period 2016–2025. These results rely on the assumption that the forecast cross-border interconnectivity is in place in 2020 and 2025.

The number of countries relying on imports to maintain adequacy (in blue below) increases between 2016 and 2025, showing the increasing role of cross-border exchanges in maintaining adequacy in the Pan-European system.

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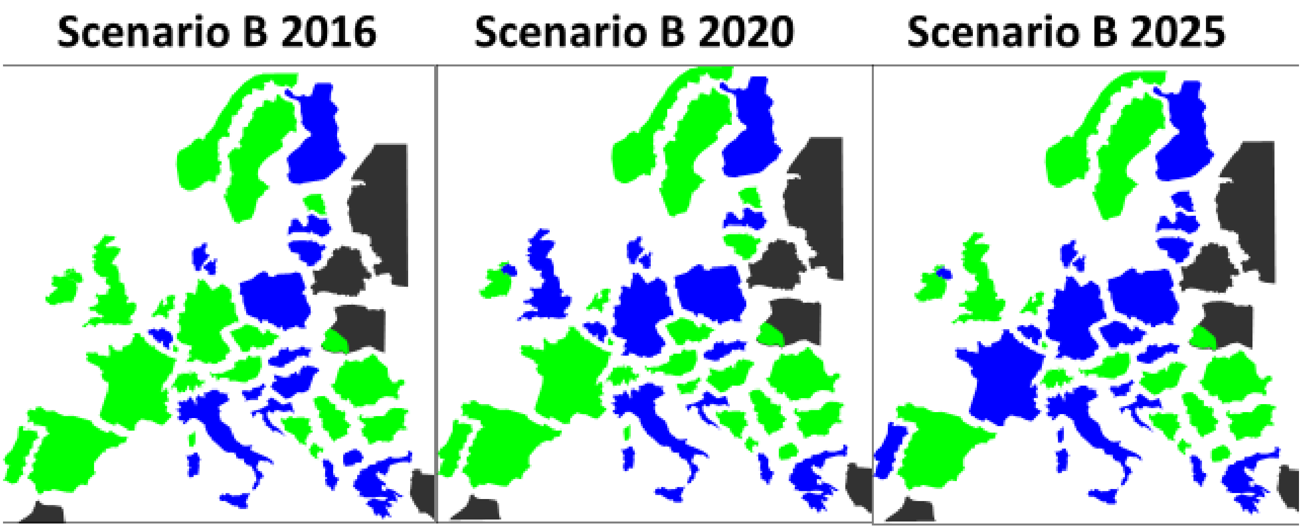


- Some countries, e.g. BE, DK, FI and SK, are structurally dependent on imports through the period analysed 2016–2020–2025.
- The need for imports appearing at the beginning and at the end of the year indicates the effect of low temperatures and a corresponding increase in demand.
- In 2020, DE will need imports during January, February and December under extreme conditions. This is a different trend from that in 2016, correlated with the expected close-down of conventional power plants in 2020. Further, in 2025, imports are needed under less extreme conditions more correlated with increased RES penetration.

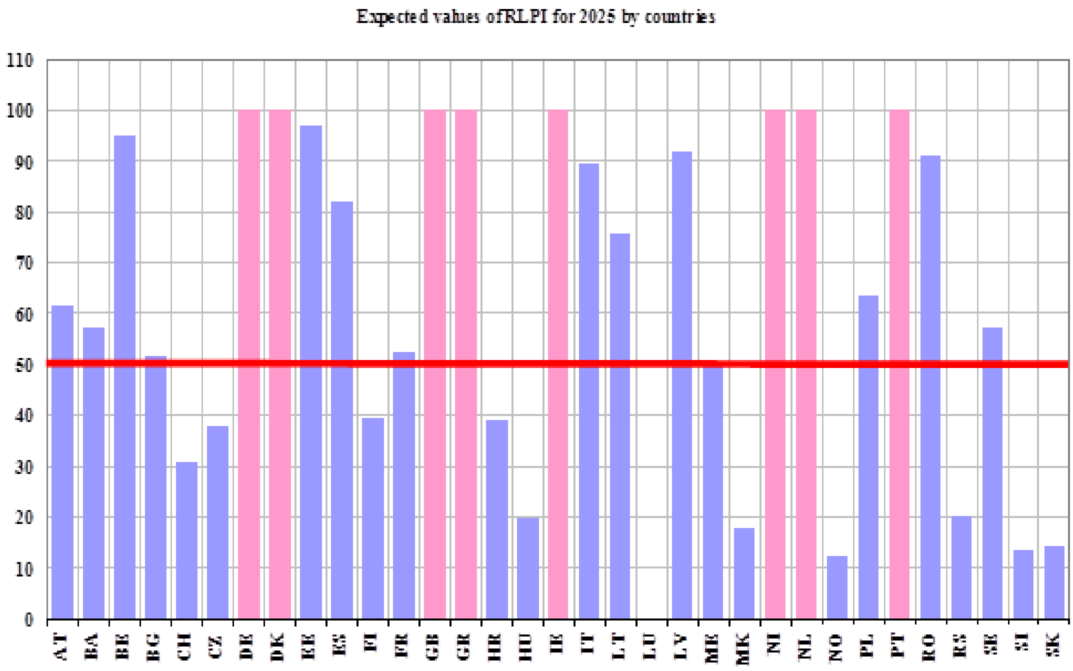
It should be noted that the current methodology does not highlight all of the potential adequacy problems in all countries (e.g. those with high levels of hydro power). The ongoing evolution of the adequacy methodology towards the market-modelling probabilistic approach, described earlier, will improve the assessments in subsequent reports to address some of these issues with a higher level of accuracy.

High RES penetration puts pressure on challenge of system flexibility

To assess the operational risk to cover sudden changes, driven by the inherent variability in the power system portfolio, several indicators have been defined and quantified using a one-hour resolution. The Pan-European Climate Database (PECD) has been used as the basis input for solar and wind generation and to account for the load-temperature sensitivities. A statistically relevant set of climatic time series has been generated for the analysis, requiring the use of advanced modelling techniques.

The penetration of variable RES, mainly wind and solar, in the power system requires constant monitoring of different climate conditions. Therefore, relevant indices such as the RES Load Penetration Index have been defined, as the maximum hourly variable RES coverage of load.

By 2025, 22 countries are reported to have a RES capacity penetration level higher than 50%. Eight countries (DE, DK, GB, GR, IE, NI, NL and PT) will reach full hourly load penetration level (100%). However, it should be noted that this result does not mean that 100% penetration occurs simultaneously for these eight countries on the same hour.

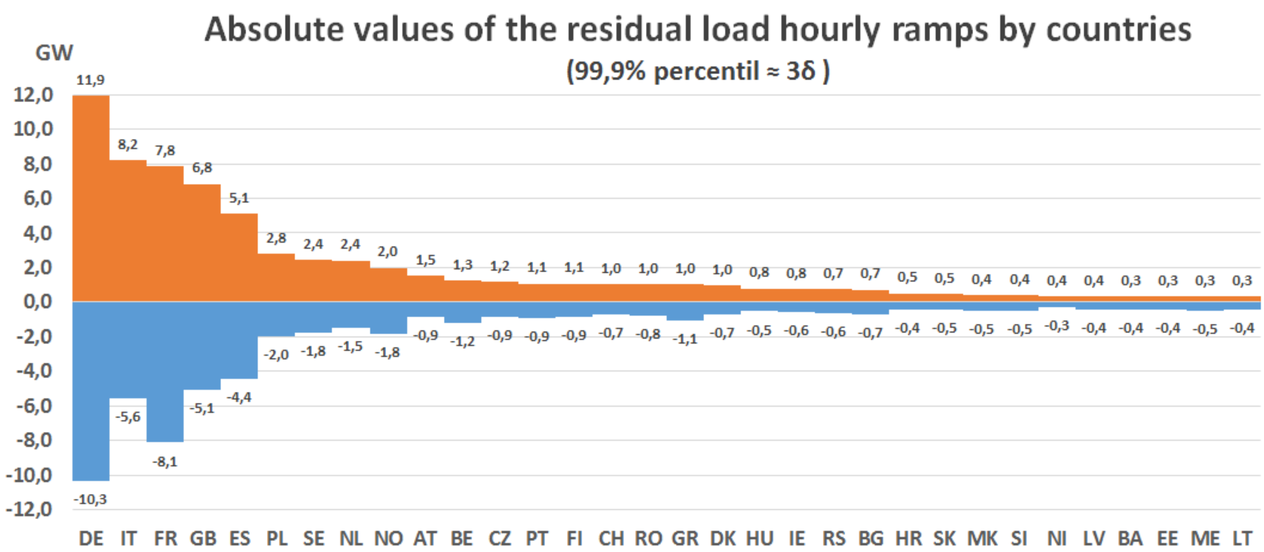


Expected values of RES capacity penetration level by countries for 2025

Applying relative values for the assessment of the residual load ramps is important in order to compare power systems with different dimensions and sizes. On the other hand, this could cause some loss of relevant information about the real size of the extreme power ramps in the system.

The absolute values of the residual load ramps have been assessed. For each country, the calculated 99.9% +/– percentile of the absolute ramps is simulated for Scenario 2020-B. This equals the nine worst hourly ramps (8760 × 0.1% ~ 9 hours) within the 14 climatic years analysed. In the case of a normal distribution, it can be represented by the 3σ value. Countries in the graph are sorted in descending order.

These numbers indicate the higher bound for hourly residual load ramps during the worst nine hours within the 14 climatic years analysed.



2 Introduction

2.1 Regulatory framework

ENTSO-E is mandated by Regulation (EC) N°714/2009 to deliver a *Community-wide ten-year network development plan* every two years, *including a European generation adequacy outlook*. Within that mandate, Regulation (EC) N°714/2009 further specifies that '*The European generation adequacy outlook will build on national generation adequacy outlooks prepared by each individual transmission system operator*'.

2.2 Purpose of this report

The Scenario Outlook and Adequacy Forecast (SO&AF) report aims at providing stakeholders in the European electricity market with a Pan-European overview of **generation adequacy** by using **bottom-up** scenarios and focusing on the power balance, adequacy reference margins, adequacy indicators, the role of interconnection and cross-border exchanges to achieve adequacy.

The focus of the Adequacy Forecast assessment is to assess overall generation adequacy in the **mid-term 5 years – 10 years (maximum)**. Therefore, the risks of adequacy are identified in due time (beyond five years ahead) and by recognising that in this time frame the increase in cross-border capacity is only from projects with a high level of confidence to be commissioned before the considered time horizon.

Within this time frame, relevant stakeholders (e.g. Member State authorities, policy makers, regulatory agencies, energy producers) are able to establish countermeasures in order to ensure the desired adequacy levels. Furthermore, the fast evolution of the energy mix (i.e. growing development of RES and increased reduction of conventional power plants), requires a regular assessment of the adequacy situation.

Because of the importance and increased relevance of the forecasts provided by the SO&AF report, ENTSO-E has adopted as an internal standard to publish it every year.

2.3 SO&AF scenario definition

Regulation (EC) 714/2009 specifies *'The European generation adequacy outlook will build on national generation adequacy outlooks prepared by each individual transmission system operator*'. Two **bottom-up** generation scenarios have been defined to help assess the range of uncertainty and evaluate the risk for the security of supply over the coming years. These scenarios, known as **Scenario A 'Conservative'** and **Scenario B 'Best Estimate'**, are based on national generation adequacy outlooks prepared by each individual transmission system operator (TSO).

In parallel, ENTSO-E has developed, and publicly consulted[1], **four '2030 Visions'** in the framework of the Ten-Year Network Development Plan (TYNDP) 2016. Ambitious targets as set by the European Council in October 2014 on renewables, energy efficiency, decarbonisation and interconnection targets, give a stronger direction to the studies and resulting recommendations for grid development up to 2030. Visions are used as background assumptions regarding generation, demand and their adequacy, for carrying out the market and network studies within the TYNDP framework. Within this **fundamentally long term**[2] approach, there is uncertainty on the evolution of the energy mix, which motivates the 'Visions' approach. Irrespective of this

[1] https://www.entsoe.eu/news-events/announcements/announcements-archive/Pages/News/TYNDP-2016--ENTSO-E-calls-for-views-on-the-scenarios-report.aspx

[2] Deployment of grid infrastructure requires longer planning and decision horizon (~15 years). Average time needed to complete a high-priority electricity infrastructure project across Europe is 5–10 years (source ENTSO-E TYNDP 2010). Proper assessment of grid infrastructure development therefore requires a long-term vision and planning starting at least ~15 years ahead.

uncertainty, the ENTSO-E mandate is to develop an adequate grid infrastructure in the future. Such infrastructure is central[3] to the completion of the European Internal Electricity Market, to enable European targets to be met and, at the same time, ensure Pan-European adequacy.

The differences between TYNDP and SO&AF reports and scope motivate the use of different scenarios. Figure 2.3.1 below provides an overview of the main differences in order to understand this point. It should be noted that the TYNDP package (TYNDP report, 6 RgIP and SO&AF report), is the main ENTSO-E product fulfilling the obligations in accordance with the regulatory framework mentioned above.

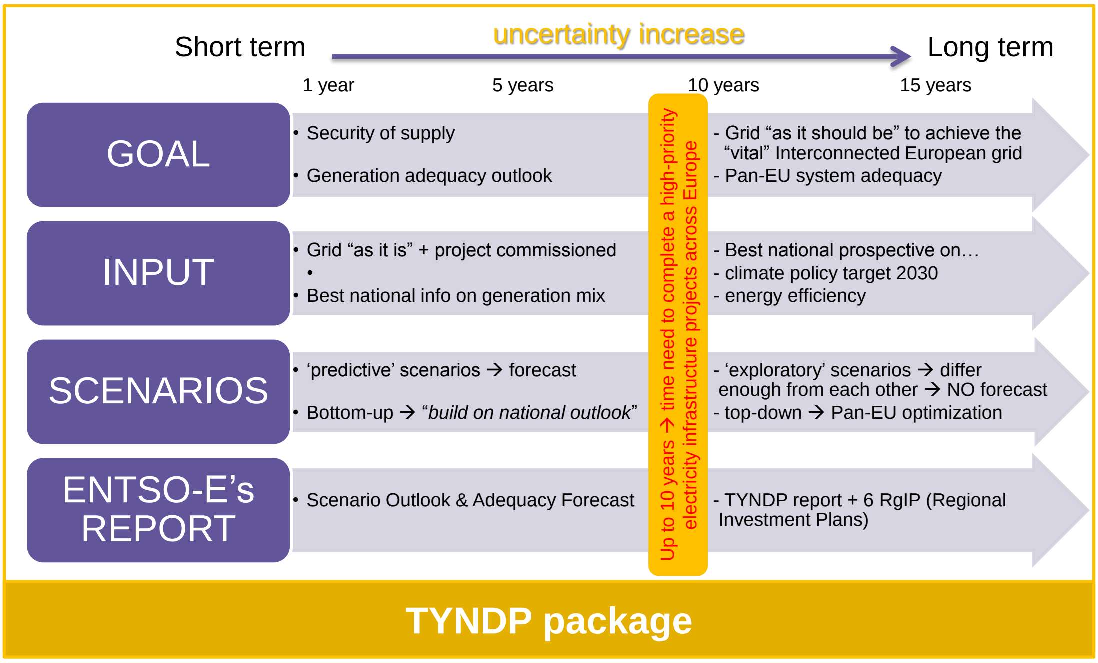


Figure 2.3.1.–TYNDP package composition: link and differences between TYNDP and SO&AF in the same framework

The TYNDP 2016 Scenario Development Report[4] presents contrasting scenarios that reflect similar boundary conditions and storylines for every country, and which differ enough from each other to capture a realistic range of possible future pathways. All storylines result in different future challenges for the grids, which the TYNDP grid endeavours to accommodate. A predefined level of adequacy is a basic assumption of each Vision. This assumption can be justified because of the longer time horizon of the Visions (2030), because until 2030 there are substantial possibilities to improve adequacy by means of infrastructure investments.

The SO&AF analysis and Scenarios A and B cover a shorter time period. The analysis of this shorter time horizon indicates whether there are risks related to adequacy that need to be identified in due time (beyond five years ahead) relevant because of the shorter investment cycle for investments in new generation and by recognising that in this time frame the increase in cross-border capacity is only from projects with a high level of confidence (by TSOs) to be commissioned before the considered time horizon.

Despite these differences, it should be noted that the 2020 Expected Progress scenario represents another common link between the SO&AF and the TYNDP. The addition of the 2020 Expected Progress scenario compared with previous TYNDP editions is a concrete response to comments received from stakeholders during prior consultations.

[3] http://ec.europa.eu/priorities/energy-union/docs/energyunion_en.pdf
[4] https://www.entsoe.eu/news-events/announcements/announcements-archive/Pages/News/TYNDP-2016--ENTSO-E-calls-for-views-on-the-scenarios-report.aspx

According to Reg. 714/2009 '*the European generation adequacy outlook referred in point 8.3 (b) will cover the overall adequacy of the electricity system to supply current and projected demands for electricity for the next five-year period as well as for the period between 5 and 15 years from the date of that outlook*'. **This requirement, as explained above, is met with the entire TYNDP package**, resulting in the conjunction of different approaches taking into account the different levels of uncertainty in the different time-horizons.

Hereinafter, this report will focus only on **Scenarios A and B** covering the following years: **2016**, **2020** and **2025.**

- <u>Conservative Scenario or Scenario A</u>

The conservative scenario considers additional investments in generation or decommissioning with high certainty of happening and best estimate of load forecast.

This scenario takes into account the **commissioning of new power plants considered as certain** (power plants under construction) and whose commissioning decision can no longer be cancelled (whose investment decision has been notified as firm to the corresponding company).

As far as decommissioning is concerned, the most likely shutdown of power plants expected during the study period should be considered. **Official notifications cannot be the only source for this estimation**. Therefore, an assessment of decommissioning based on additional criteria such as technical lifetimes is recommended.

Load forecast in this scenario is the best national estimate available to the TSOs, <u>taking into account the highest expected growth of the consumption according to national grid development plans</u>. It is estimated according to technical, economic and political assumptions, especially on demography, economic growth and energy efficiency policy.

- <u>Best Estimate Scenario or Scenario B</u>

This scenario takes into account the generation capacity evolution described in Scenario A as well as future power plants **whose commissioning can be considered as reasonably credible** by TSOs according to the available national information. Therefore, an assessment of the likeliness of the projects, based on reasonable regional economic considerations of generation projects for instance, is expected in this scenario.

Furthermore, whenever there is no official communication of decommissioning, it is considered that the units will be available for security of supply reasons, including strategic reserves considerations, also taking into account potential extension of the technical lifetime of units.

However, load forecast should <u>take into account the highest expected growth of the consumption according to national grid development plans, as in Scenario A, and in case the 'Expected Progress' scenario did not consider such a situation already.</u>

As is well known, the EU has set targets for the share of renewable energy sources in 2020. As a consequence, many countries have implemented support mechanisms that lead to increasing capacities of renewables. The forecast of renewable energy sources in Scenario B has to take into account the current supporting mechanisms for renewable energy sources in each country and the expected development of support mechanisms, if changes are under discussion. Including the cost digression, **a realistic forecast for the year 2020, as well as for 2025, has to be derived by TSOs**, even if this means that the targets set by the National Renewable Energy Action Plans (NREAPs) will not be met.

The interpretation of the generation adequacy–power balance analysis may differ depending on the Scenario that is under consideration.

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For the "Conservative" Scenario A, the effect on adequacy of a lack of additional investments in power generation is assessed. These results provide a view of the relative importance for confirmation of projects that are not yet firmly engaged or the need for new investment in generation.

The "Best-Estimate" Scenario B, considers whether the expected level of investment is adequate from an ENTSO-E point of view. The results on the assessment of generation adequacy–power balance should therefore be understood within this assumption.

2.4 Geographical perimeter of this report

The geographical perimeter covered by this study is depicted in Figure 2.4.1. Beyond the ENTSO-E members, Energy Community Countries synchronously connected to the Continental Europe Synchronous Area, such as Albania and Ukraine West–Burshtyn Island, are also included.

Figure 2.4.1.–ENTSO-E countries and contributing areas (* = This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence.)*

2.5 Structure of the report and presentation of the analyses performed

The present SO&AF report provides in Chapter 3 a Pan-European general overview of load and energy consumption forecast over the time frame 2016–2020–2025 resulting from the data submitted by the TSOs under the same guidelines and assumptions based on the scenarios described above. Chapter 3 presents a general overview on the evolution of generation mix for the two different scenarios described above

(Scenarios A and B). For both generation and demand, a comparison with the figures from the previous edition[5] of the SO&AF is provided.

In the current SO&AF 2015, the generation adequacy is still assessed through the parameters Reliable Available Capacity (RAC), Remaining Capacity (RC) and Adequacy Reference Margin (ARM) depicted in Figure 2.5.1. The approach is a power balance-based assessment, extended to a monthly resolution over the time frame 2016–2020–2025.

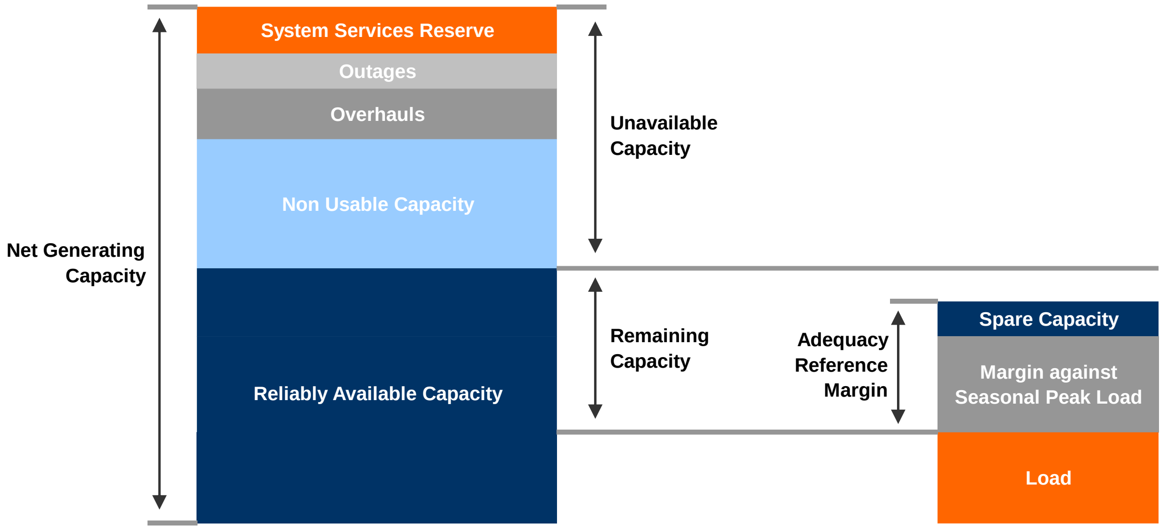

Figure 2.5.1–Schematic depiction of adequacy methodology

Power balance will be assessed in Chapter 4 for each country separately. While Pan-European level requires a common reference point in time for all countries (see Chapter 6), national power balance evaluation can be done at different times referred to the national peak load time. The 3rd Wednesday of each month on the 19th hour[6] (from 18:00 to 19:00) is therefore chosen as a common reference point, taking into account that the ENTSO-E peak load has been achieved, in all of the last three years, on the 19th hour.

In the national analysis, the worst power balance during every month is chosen between the balance at the reference point in time and the balance at the national peak load time. Remaining Capacity at peak time has been recalculated using solar and wind load factor from PECD[7] at the daily hour of the expected peak, as requested in the SO&AF data collection template to TSOs. To complete the information provided by the national power balance, National Comments are also included in Chapter 4. Those comments refer to i) Load and annual demand forecast; ii) Net Generating Capacity forecast; iii) Generation and System Adequacy forecast, over the time frame 2016–2020–2025.

Chapter 5 aims to provide information about the potential lack of flexible generation in the expected power system operation. Residual load assessment is a first step towards the targeted stakeholder expectations regarding probabilistic assessments for the generation adequacy studies[8]. SO&AF 2015 will report on expected needs for flexibility in its adequacy assessments using a one-hour resolution as a first step.

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5 https://www.entsoe.eu/publications/system-development-reports/adequacy-forecasts/Pages/default.aspx
6 Times in the SO&AF report are expressed in Central European Time (CET = UTC + 1) in winter, and in Central European Summer Time (CEST = UTC + 2) in summer. All of the data and analyses provided are in accordance with this approach.
7 The Pan-European Climate Data have been provided to ENTSO-E by the Technical University of Denmark.
8 ENTSO-E Target Adequacy Methodology: https://www.entsoe.eu/about-entso-e/system-development/system-adequacy-and-market-modeling/adequacy-methodology/Pages/default.aspx

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In Chapter 6, a regional assessment of generation adequacy is performed. The target is to complement the national analysis of Chapter 4 to detect if problems can arise on a Pan-European scale because of a lack of available capacity and lack of available cross-border capacity to import the required power. The basis of the regional analysis is a constrained linear optimization problem to minimise the deficit in power balance at the Pan-European level. The goal is to provide an indication whether countries requiring imports will be able to obtain these across neighbouring regions under the conditions considered.

2.6 Methodological improvements for generation adequacy assessments

The integration of **large amounts of renewable energy sources (RES)**, the **completion of the internal electricity market**, the emergence of **capacity remuneration schemes**, as well as **new** (storage, transmission, generation) **technologies, demand-side response** and **evolving policies** require ***revised adequacy assessment methodologies.***

At present, the point with the highest load (peak load) is chosen to assess generation adequacy, and the same approach is applied to evaluate the associated impacts on security of supply at a Pan-European level. However, with the development of the energy generation mix, which means more fluctuating renewables in the system and less conventional fossil fuel generation, critical situations may occur in the future at different times than at peak demand.

This was well formulated in an ENTSO-E policy paper on the Viability of Energy Mix. Therefore, SO&AF methodology is being improved by ENTSO-E towards a market-based stochastic modelling approach to assess adequacy, so

- SO&AF assessment is moving towards an hour-by-hour simulation, analysing the “residual load”;
- Consistently taking into account fluctuations of external factors such as wind, sun, temperatures;
- Assessment provides an even more detailed view of cross-border contributions to the country’s generation adequacy, **<u>especially in moments of scarcity</u>**;
- Complete the information about the “need for flexibility” in the power systems through ramping analyses of the dynamic changes.

The target is that the **Pan-EU target methodology is <u>implemented, proof-of-concept tested and proven to provide reliable indicators for adequacy assessment</u>** based on stochastic sequential market modelling tool(s), implementing efficient sequential hourly resolution algorithms[8]. Available tool(s) for market modelling within TSO are currently being benchmarked to provide robust results regarding main adequacy indicators, e.g. Loss Of Load Expectation (LOLE), Expected Energy Not Served (EENS) and Loss of Load Probability” (LOLP). Such methodology will be deployed in a stepwise fashion during the publication of future editions of ENTSO-E adequacy reports: SO&AF report and the Seasonal Outlooks (summer and winter) reports.

2.7 Disclaimer

ENTSO-E emphasises that it cannot be held liable for any inaccurate or incomplete use of the data contained in this report or for any resulting misled assessment based on such data.

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3 Scenario Outlook

3.1 Load and energy consumption forecast–general overview

For all analysed years, the highest ENTSO-E load (at the reference point) among the 12 monthly reference points assessed occurs during January. In the present SO&AF edition, in Scenario B[9], the forecast of load for January 2016 is higher than in the previous edition by 4 GW, while for 2020 and 2025 there is an opposite situation–the load is lower than in the previous report by 8 GW and 6 GW, respectively. The growth of load between 2016 and 2020 in the present edition of the report is in line with trend 2015 to 2016 in SO&AF 2014, what is visible on Figure 3.1.1. Finally, it is worth noticing that an overall decrease in load has been observed in the last two years. For instance, the load in SO&AF 2013 (not shown in Figure 3.1.1) was forecast for January 2020 at a value 35 GW higher than in the present edition SO&AF 2015.

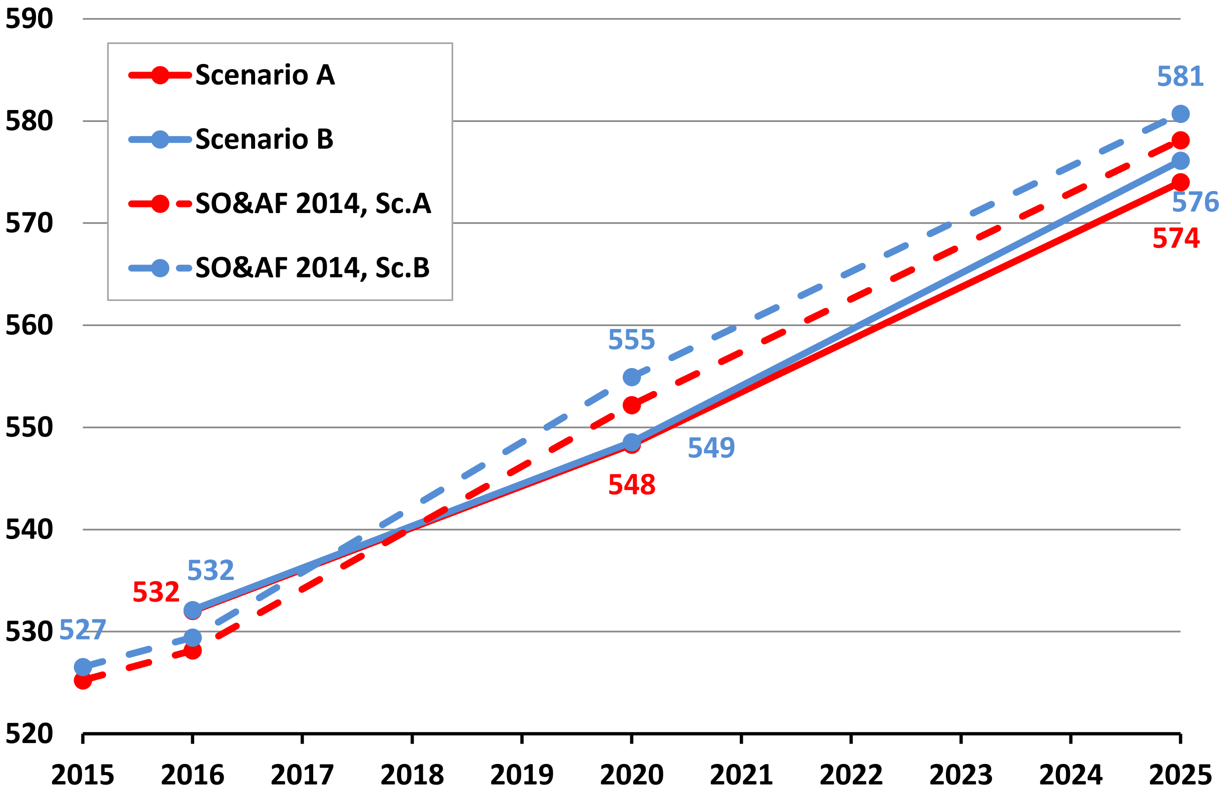

Figure 3.1.1–ENTSO-E load forecast in SO&AF 2014 and in SO&AF 2015; all scenarios; January 7 p.m. [GW]

A much more interesting situation is depicted by comparison of the monthly peak load and consumption relative growth (starting point 2016 = 100%). Trends of monthly peak load increases for the period 2016–2020 (counted as average value among all monthly peak loads) are more or less similar to energy consumption growth, while for years 2020–2025 nine of twelve monthly peak loads are increasing faster than

[9] According to guidelines for SO&AF, the load in Scenario A should be the same as Scenario B; however, some countries provided different values to scenarios. Based on comparisons done for load in January reference point in the present SO&AF edition, it is confirmed that in year 2016 differences are negligible, while for 2025 the load in Scenario A is lower than in Scenario B by about 2.1 GW. Main contributors are: GB (1.6 GW) and BG (0.5 GW). ENTSO-E load in year 2020 looks to be the same in both scenarios, but there are national differences that compensate the ENTSO-E result, in particular: NO load in Scenario A is lower than in Scenario B by 1 GW, while the GB load in Scenario A is higher than in Scenario B, also by 1 GW.

the energy consumption. Of those, the August peak load is increasing the fastest. The average growth among all monthly peak loads is higher by 1.0% than energy consumption growth, whereas for August it is 1.9%. Figure 3.1.2 shows the mentioned trends and Table 3.1.1 presents the trends with an annual resolution.

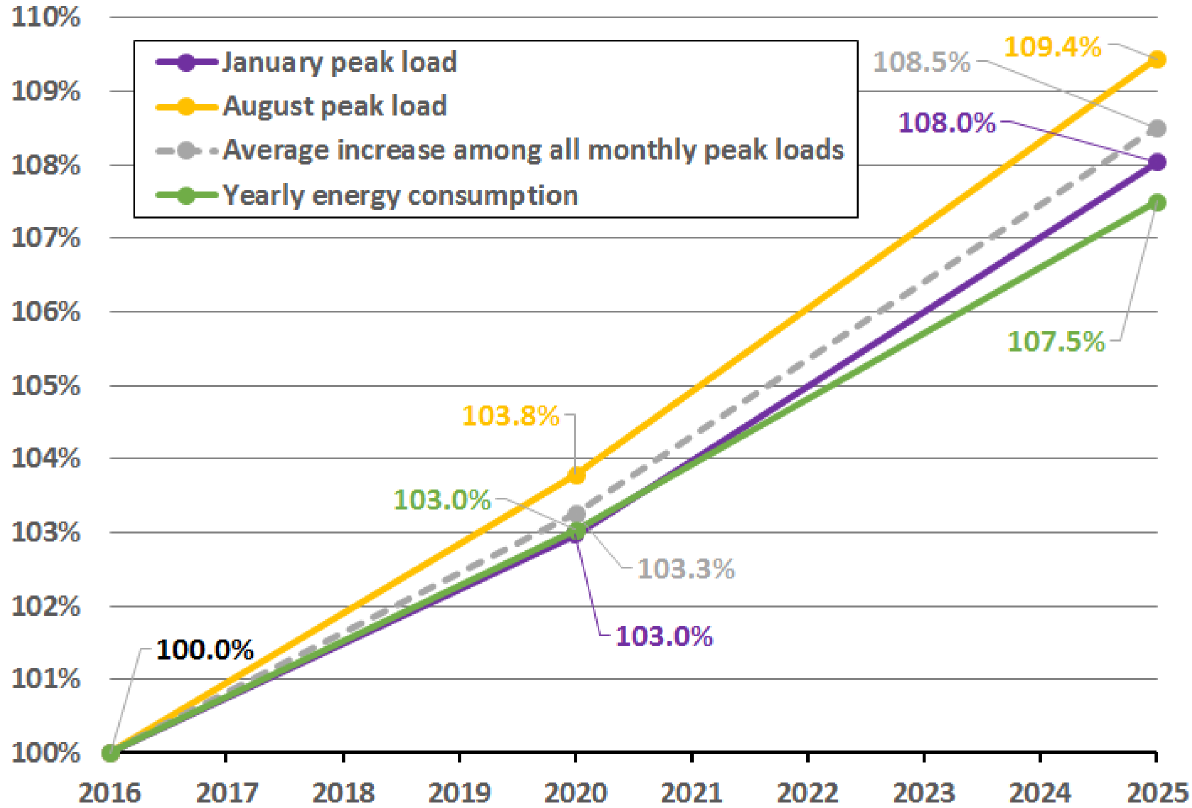

Figure 3.1.2–ENTSO-E forecast of relative growth of monthly peak load energy consumption in Scenario B (2016 = 100%)

	2016-2020		2020-2025		2016-2025	
	[annual]		[annual]		[annual]	
January peak load	0,7 %	16,3 GW	1,0 %	27,8 GW	0,9 %	44,0 GW
August peak load	0,9 %	16,2 GW	1,1 %	24,2 GW	1,0 %	40,4 GW
Energy consumption	0,8 %	100 TWh	0,9 %	148 TWh	0,8 %	248 TWh

Table 3.1.1–ENTSO-E forecast of annual peak load and energy growth in Scenario B.

Figure 3.1.3 below presents the annual load growth for the January reference point between 2016 and 2025. Two countries–Germany and Great Britain–report a decrease of load in Scenario B[10]. In fact, Germany forecasts a decrease for the period 2016–2020 and stagnation of load from 2020 until 2025. Great Britain reported a gradual decrease for the whole analysed period. Similar trends refer to energy consumption.

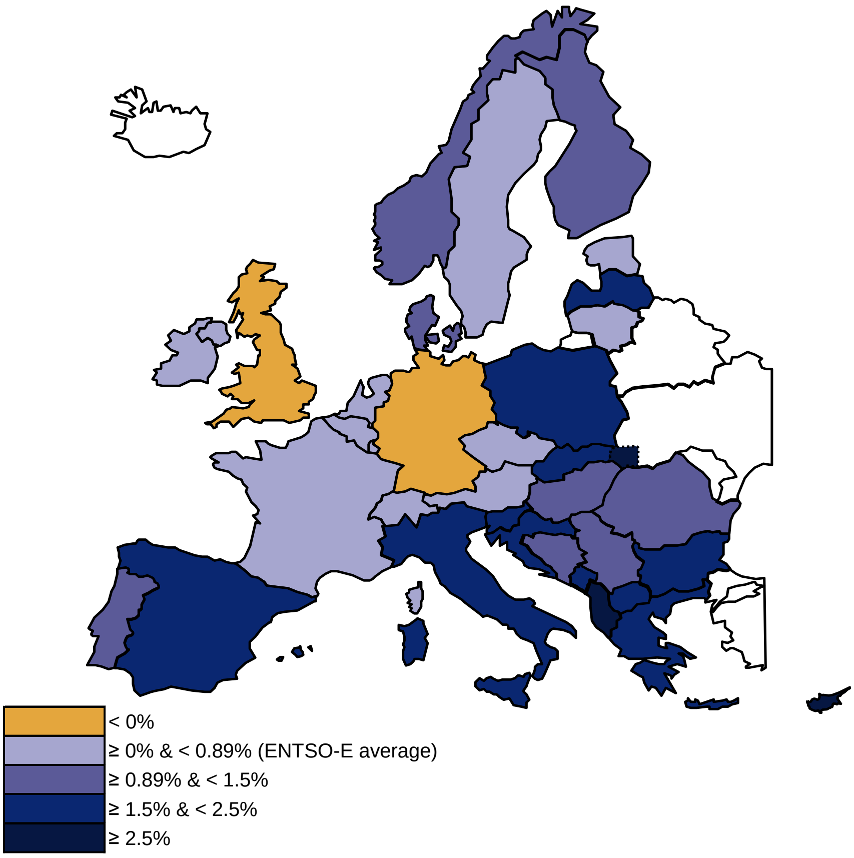

Figure 3.1.3–ENTSO-E average annual load growth per country between 2016 and 2025, Scenario B, January

[10] For the October reference point, DE reports a small load increase in 2020.

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3.2 Net Generating Capacity (NGC)–general overview

In 2016 in Scenario A[11], the NGC is lower than reported in the previous SO&AF report, which could be understood as a delay in commissioning and/or the growth of decommissioning units in relation to the IED EU directive[12] and/or units life span. On the other hand, for years 2020 and 2025 NGC development is higher than in SO&AF 2014, which means that more investment could be confirmed by TSOs as certain in the present report.

NGC development in Scenario B shows a trend in which investments in generation have been reviewed and/or postponed. Therefore, for all analysed years, the NGC level is below the level of SO&AF 2014 in Scenario B. In 2016, the NGC is even lower than forecast for 2015 in the previous SO&AF and corresponds to the level of NGC in Scenario A from SO&AF 2014.

Details can be found on Figure 3.2.1 and in Table 3.2.1.

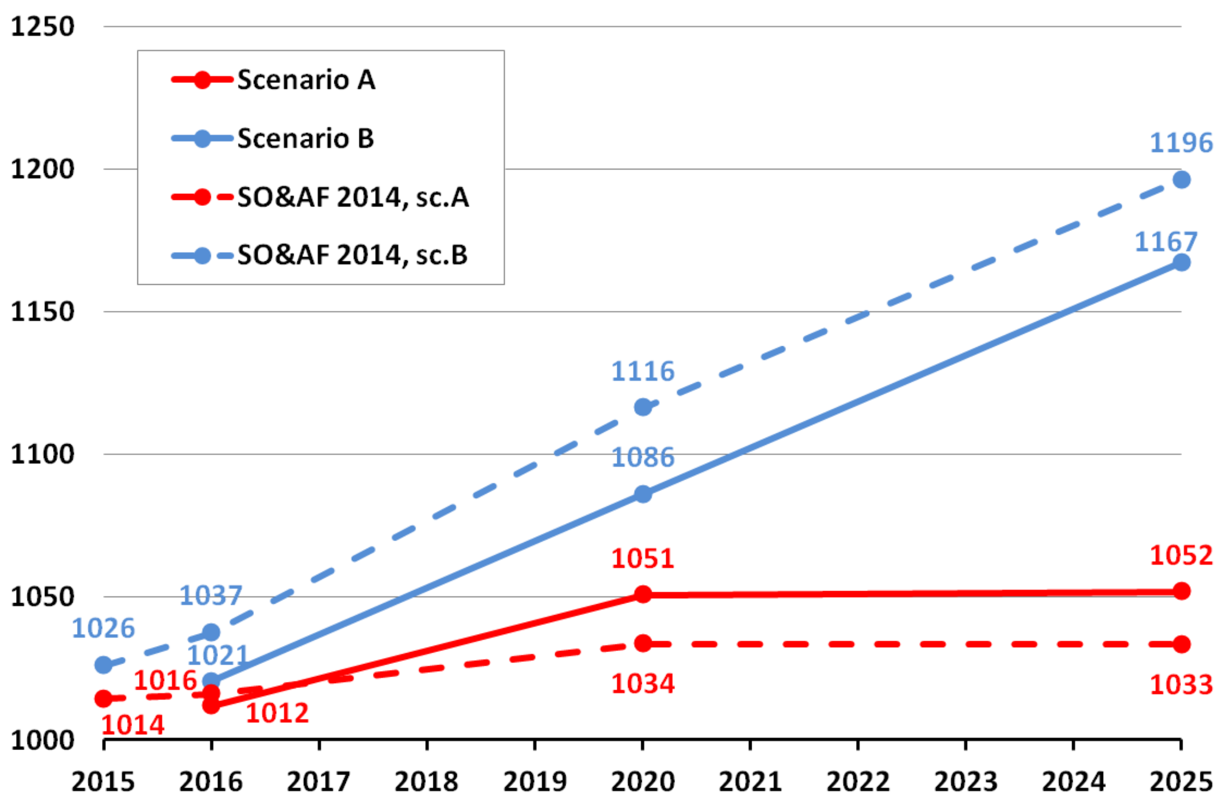

Figure 3.2.1–ENTSO-E total NGC forecast in SO&AF 2014 and in SO&AF 2015; all scenarios; January 7 p.m. [GW]

[11] According to SO&AF guidelines, Scenario A assumes that decisions about generation investments have been already taken and can no longer be cancelled.

[12] IED–Industrial Emissions Directive 2010/75/EU comes into effect on 1st January 2016 and refers to SO_2, NO_x and dust emission.

		Scenario A			Scenario B		
		2016–2020	**2020–2025**	**2016–2025**	**2016–2020**	**2020–2025**	**2016–2025**
January 7 p.m.	**[GW, total]**	39	1	40	65	81	147
	[%, yearly]	0.94%	0.02%	0.43%	1.57%	1.46%	1.50%

Table 3.2.1–ENTSO-E evolution of total NGC for Scenarios A and B

Looking at the changes in the structure of NGC presented on Figure 3.2.2, a high development of Renewable Energy Sources (RES) is observed in both scenarios. Both absolute values and relative shares increase. In 2020 in Scenario B, the NGC of RES makes up 48% of total NGC (46% in Scenario A). It is important to underline that availability of RES power, which can be used for covering load, is lower than e.g. nuclear or fossil fuel generation (more information can be found in Section 3.6). NGC of fossil fuel, nuclear and not-clearly-identifiable categories are decreasing both in absolute and relative values, while non-renewable hydro increases in absolute values, but remains stable in relative terms.

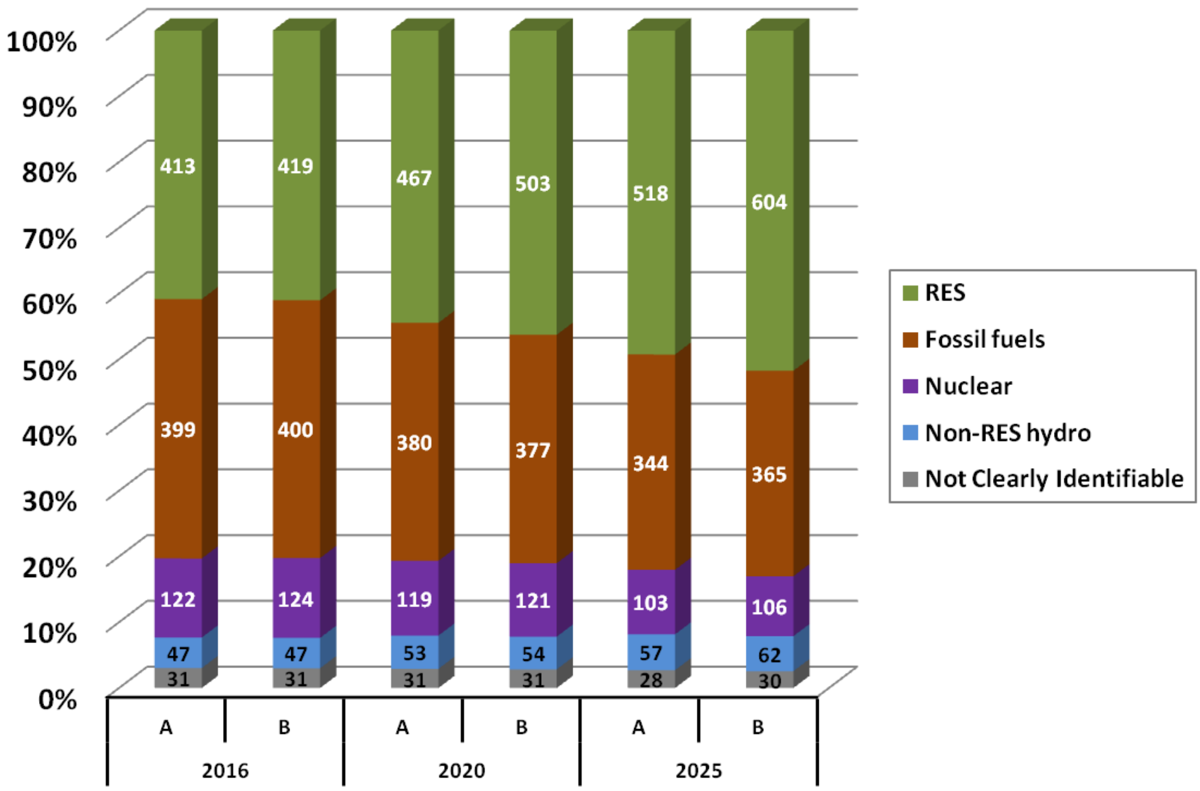

Figure 3.2.2–ENTSO-E total NGC breakdown in 2016, 2020 and 2025; all scenarios; January 7 p.m. [absolute partial values in GW]

Table 3.2.2 presents the trend of NGC per source in absolute value as well as in percentage changes for the whole period analysed, 2016–2025.

	Scenario	2016–2025	Fossil fuels	RES	Non-RES hydro	Nuclear
January 7 p.m.	A	[GW, total]	−55	105	10	−18
		[%, yearly]	−1.62%	2.55%	2.25%	−1.81%
	B	[GW, total]	−35	185	15	−17
		[%, yearly]	−1.02%	4.16%	3.12%	−1.67%

Table 3.2.2–ENTSO-E NGC subcategories evolution for Scenarios A and B

The NGC breakdown per country is presented below. Systems with the highest NGC in both 2020 and 2025 are the same as in the past: DE, FR, IT, ES, GB. Details for all countries can be found in Figures 3.2.3 and 3.2.5.

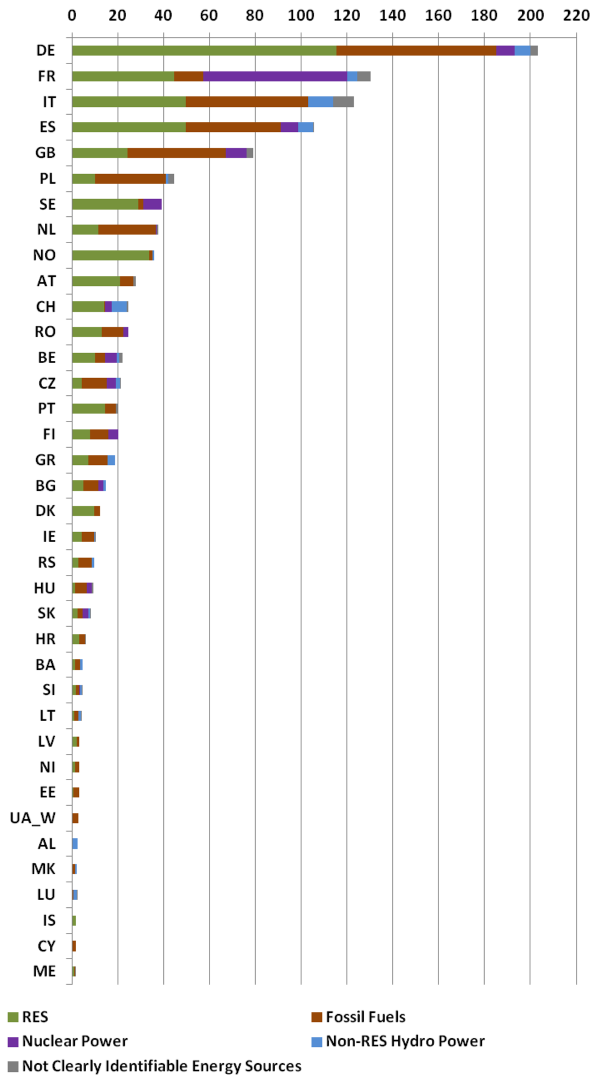

Figure 3.2.3–Total NGC breakdown per country in 2020; Scenario B; January 7 p.m. [GW]

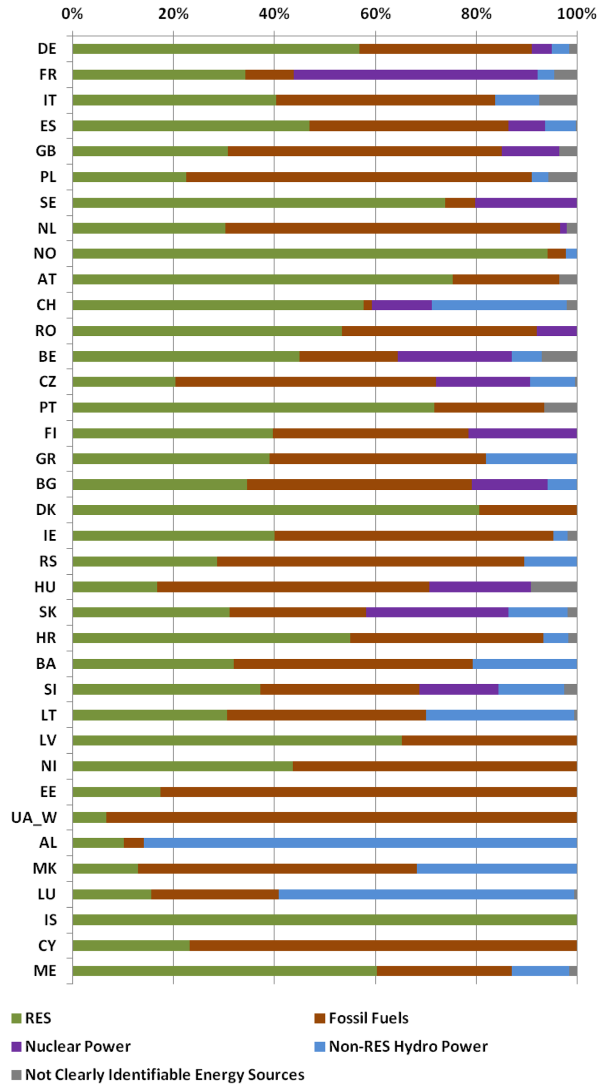

Figure 3.2.4–Total generation capacity mix per country in 2020; Scenario B; January 7 p.m. [%]

Figures 3.2.4 and 3.2.6 present the structure of NGC per country in 2020 and 2025. The most "green" countries (more than 80% RES in 2025, Scenario B) are: Iceland (almost 100%, mainly because of renewable hydro), Norway (94%, also because of renewable hydro) and Denmark (88%, mainly because of wind and biomass). On the opposite end of the spectrum (RES share less than 20% in 2025, Scenario B) are: Ukraine West (7%), Albania (14%), FYRO Macedonia (15%), Hungary (16%), Luxembourg and Montenegro (both 17%). It should be mentioned that Albania, Luxembourg and Montenegro reported a significant part of hydro as non-renewable.

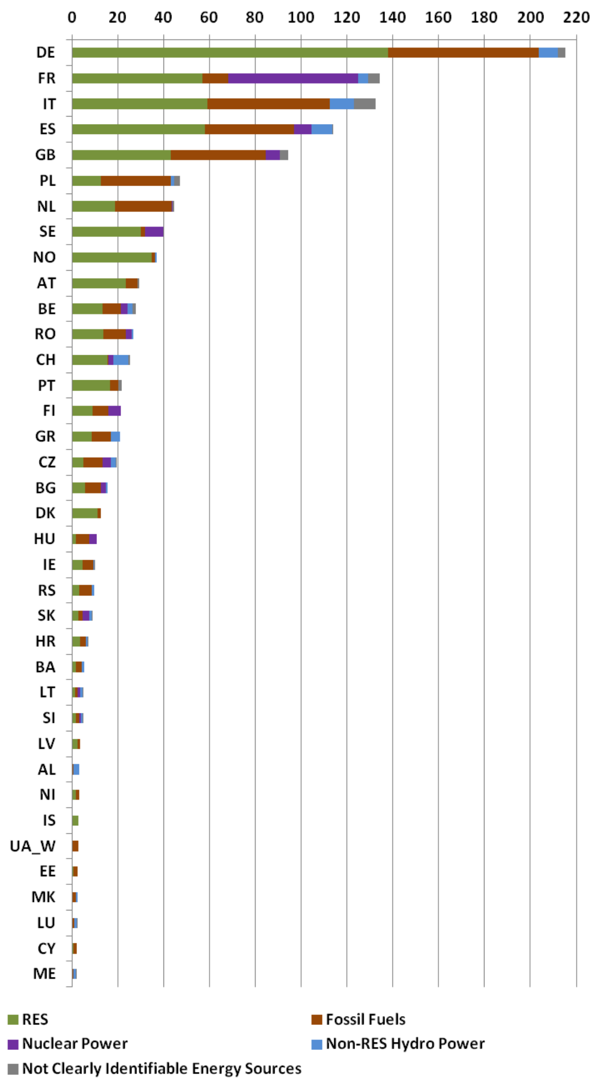

Figure 3.2.5–Total NGC breakdown per country in 2025; Scenario B; January 7 p.m. [GW]

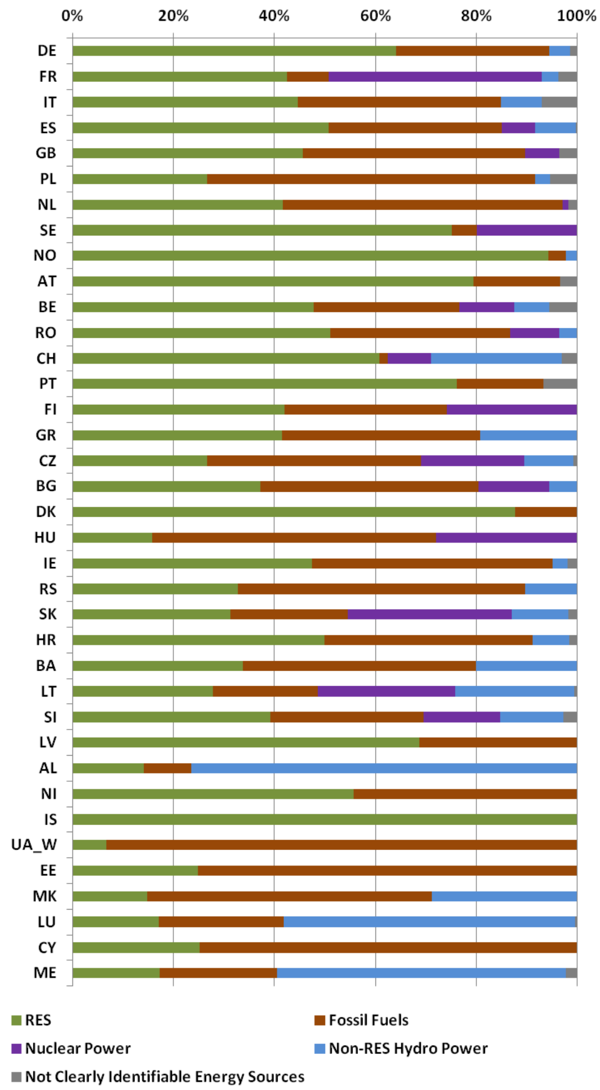

Figure 3.2.6–Total generation capacity mix per country in 2025; Scenario B; January 7 p.m. [%]

3.3 Fossil fuel generation capacity

Until 2025, as seen in Figure 3.3.1, the NGC of the fossil fuel category is expected to fall after 2016 (to 344 GW in Scenario A and 365 GW in Scenario B).

When compared with the previous SO&AF report, fossil fuel capacity is lower, ranging between –9% (in 2025) and –10% (in 2020) in Scenario B and between –6% (in 2020) and –7% (in 2025) in Scenario A.

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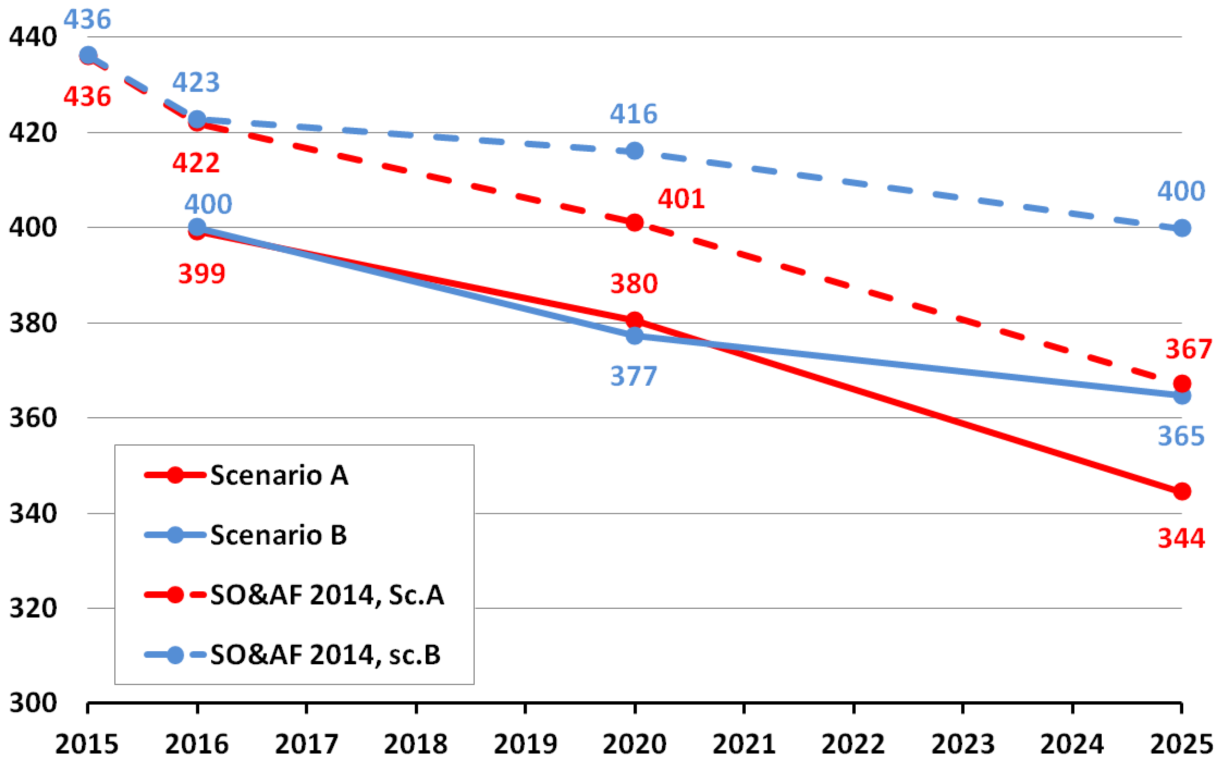


Figure 3.3.1–ENTSO-E Fossil fuels generation capacity forecast in SO&AF 2014 and in SO&AF 2015; all scenarios; January 7 p.m. [GW]

Along with the general decreasing trend of fossil fuel-based capacity, a clear replacement trend of coal (as well as lignite, oil and other fuels) by natural gas is forecast, as seen in Figure 3.3.2 (Scenario B).

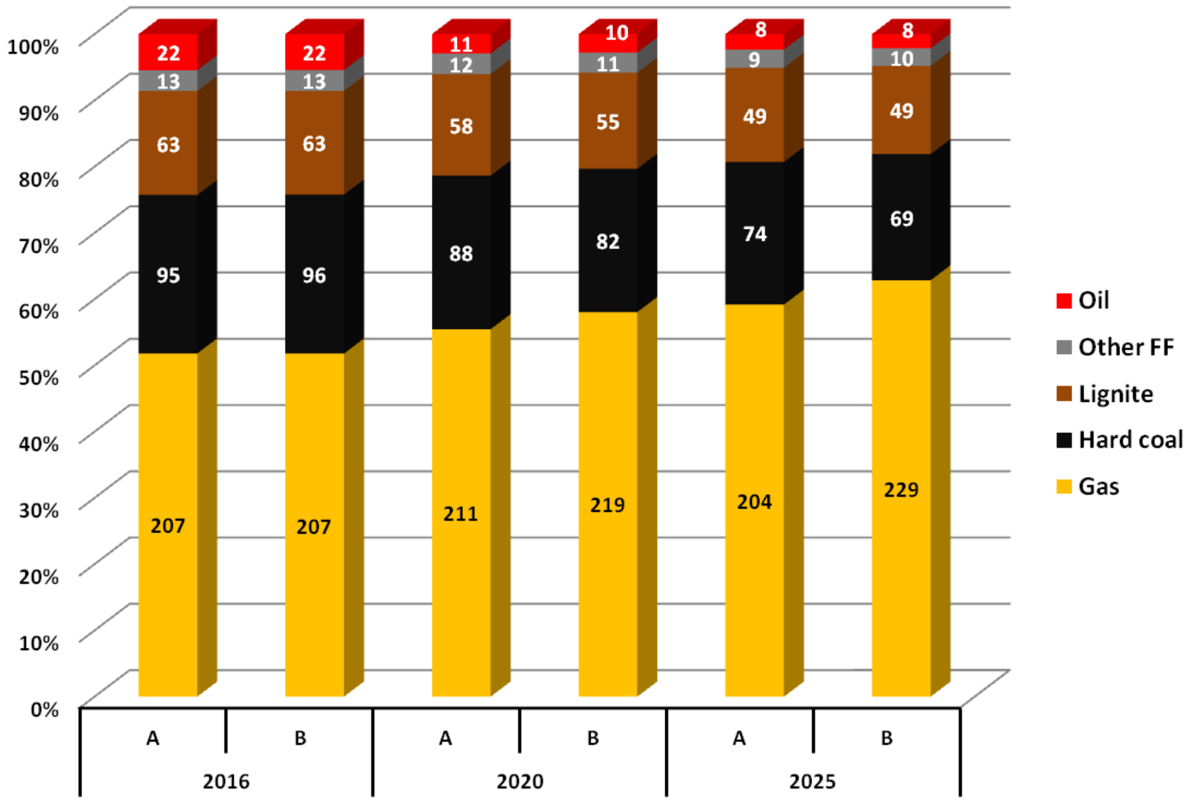


Figure 3.3.2–ENTSO-E fossil fuels generation capacity breakdown in 2016, 2020 and 2025; all scenarios; January 7 p.m. [absolute partial values in GW]

According to Table 3.3.1, independently of scenario (A or B) and for the 2016–2025 period, a forecast annual growth rate of hard coal-based capacity is always negative, ranging between –2.77% and –3.54%. The same applies to lignite (between –2.69% and –2.78%) as well as oil and others (–7.21%). In the case of natural gas fuelled power plants, this only happens in Scenario A (–0.16%). In the case of Scenario B, total gas capacity increases by approximately 22 GW (annual growth of 1.13%).

	Scenario	2016–2025	Hard coal	Lignite	Gas	Oil and other
January 7 p.m.	A	[GW, total]	–21	–14	–3	–17
		[%, yearly]	–2.77%	–2.69%	–0.16%	–7.21%
	B	[GW, total]	–27	–14	22	–17
		[%, yearly]	–3.54%	–2.78%	1.13%	–7.21%

Table 3.3.1–ENTSO-E fossil fuels subcategories evolution for Scenarios A and B

Individual changes of fossil fuel shares in 2016 NGC in Scenario B (in January) are depicted, by country, in Figure 3.3.3. Until 2025, the highest growth (more than 20% of 2016 NGC) is observed in Belgium and Montenegro. On the other hand, a highly reduced share (more than 10% of 2016 NGC) is foreseen in Estonia, Finland, Lithuania, Denmark, Ireland, Northern Ireland and the Czech Republic. As a result of this evolution, the countries with the highest levels of fossil fuels in 2025 are expected to be West Ukraine (93% of total NGC), Cyprus (75%), Estonia (75%) and Poland (69%).

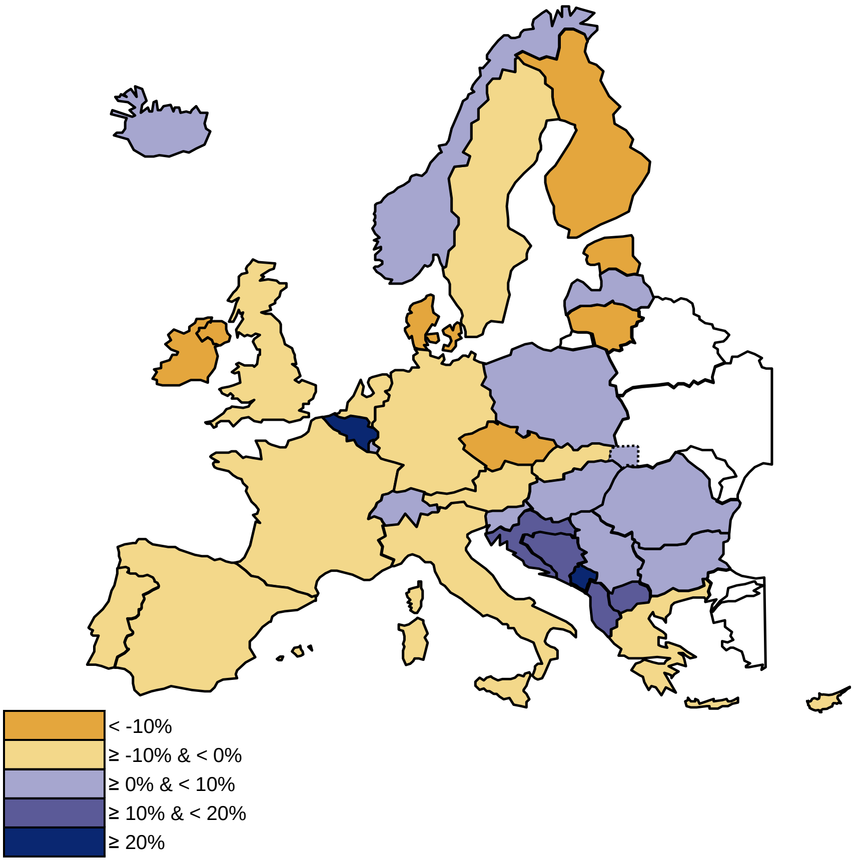


Figure 3.3.3–Fossil fuels installed capacity changes 2016/2025 as a part of total NGC in 2016 per country; Scenario B; January 7 p.m.

3.4 Nuclear generation capacity

Nuclear capacity at ENTSO-E level will be maintained around 120 GW from 2016 until 2020, as shown in Figure 3.4.1. A difference of 2 GW separates Scenario A from Scenario B (reported by Belgium and Sweden).

From 2020 until 2025 a decrease of 12% is foreseen in Scenario B. Main contributors for this trend include Germany (–8.1 GW), France (–6.3 GW), UK (–2.6 GW) and Belgium (–2 GW). Nevertheless, some countries increase their nuclear installed capacity during this period, as is the case of Lithuania (+1.3 GW), Finland (+1.2 GW), Hungary (+1.1 GW), Romania (+0.7 GW) and Slovakia (+0.5 GW).

In the long run, compared with the SO&AF 2014 report, the new Scenario B is the former Scenario A regarding nuclear. This means that the 2025 updated Scenario B has been reduced by nearly 9% (–11 GW) compared with last year's forecast.

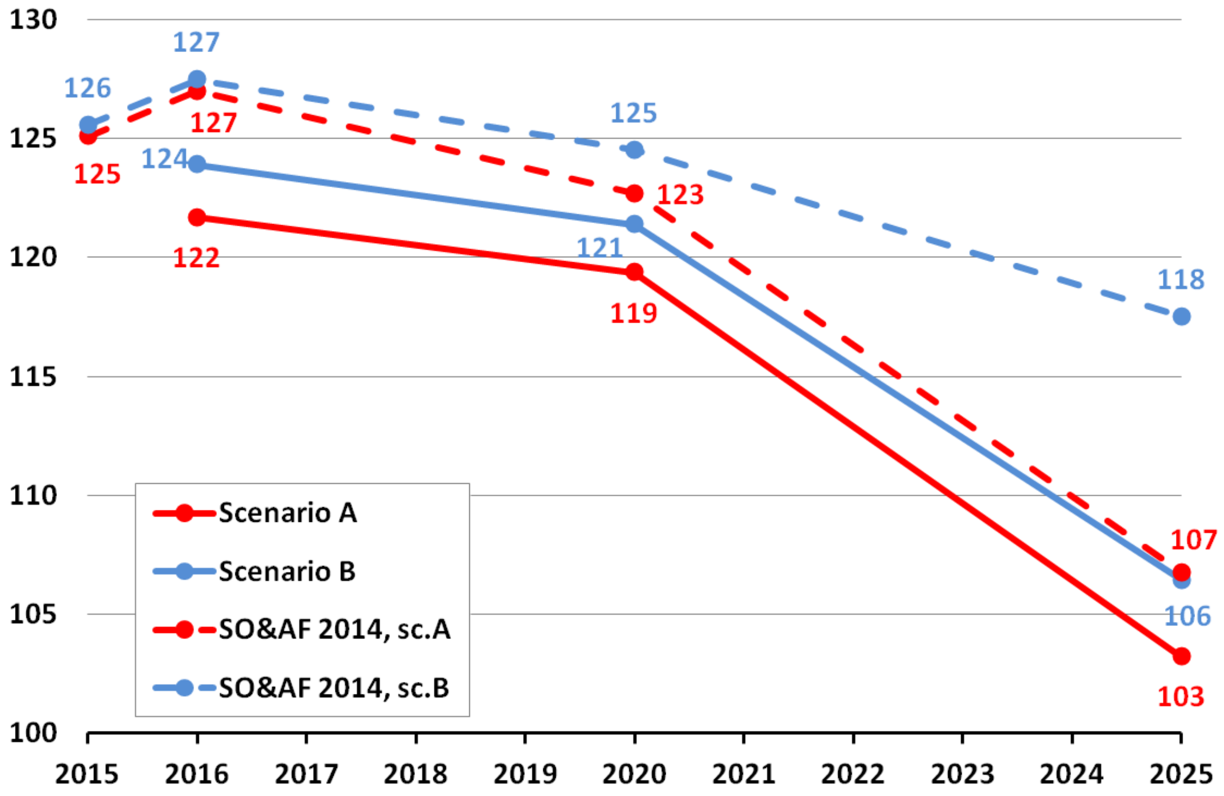


Figure 3.4.1–ENTSO-E Nuclear generation capacity forecast in SO&AF 2014 and in SO&AF 2015; all scenarios; January 7 p.m. [GW]

A map showing Scenario B evolution of nuclear capacity by country as part of (2016) NGC is depicted in Figure 3.4.2. Until 2025, the highest growth is observed in Lithuania (+37.9%) with the first nuclear power plants foreseen in 2025. Other countries with growing nuclear energy include Finland (+15.8%), Hungary (+13.8%), Slovakia (+13.3%) and Romania (+6.3%). In contrast, Belgium (–9.9%), Switzerland (–5.7%), Germany (–5.5%), France (–5.2%), Sweden (–5%) and Great Britain (–3.6%) decrease.

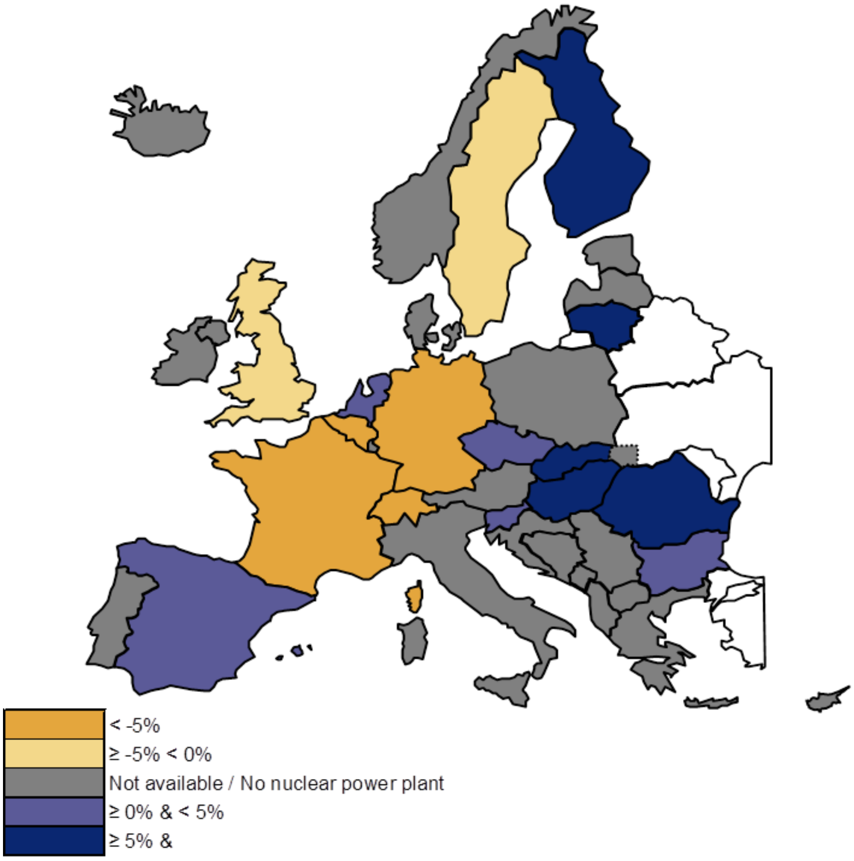


Figure 3.4.2–Nuclear installed capacity changes 2016/2025 as a part of the total NGC in 2016 per country; Scenario B; January 7 p.m.

3.5 Renewable energy sources

As shown in the general overview of the NGC development, renewable energy sources (RES) will have a dominant part in new capacity additions in the future. In this chapter, a more detailed assessment of all RES categories is presented, including renewable hydro power plants (RES HPPs).

For a proper understanding of the data analysed here, some clarifications are necessary on the distinction between the RES and non-RES HPP categories. Run-of-river and natural inflow storage HPPs are considered as RES HPPs and that definition can be applied for most of the ENTSO-E countries. Pure pump storage HPPs and the pumping part of pump storage HPPs with natural inflow are classified as non-RES HPPs. However, in individual cases of pump storage HPPs with natural inflow, it can be difficult to apply these general rules and make a proper distinction in order to identify the RES and non-RES HPP parts of the NGC. This difficulty of classification can therefore have an impact, although minor, on the results of the analysis.

Figure 3.5.1 presents the RES generation capacity forecast according to both scenarios and compares them with the scenarios published in the previous edition of the report. While only slight adjustments have been made since the last edition of the report, the progressively growing gap between the two scenarios reflects the uncertainty related to the potential development subject to the revision of incentive policies and changes in general economic framework conditions.

Figure 3.5.2 shows the RES generating capacity breakdown. While RES-HPP NGC is expected to remain stable until 2025, the installed wind and solar NGC can increase by 80% and 60%, respectively. Biomass and other RES technologies will have a marginal role. The evolution and annual capacity growth rate per category is summarized in Table 3.5.1.

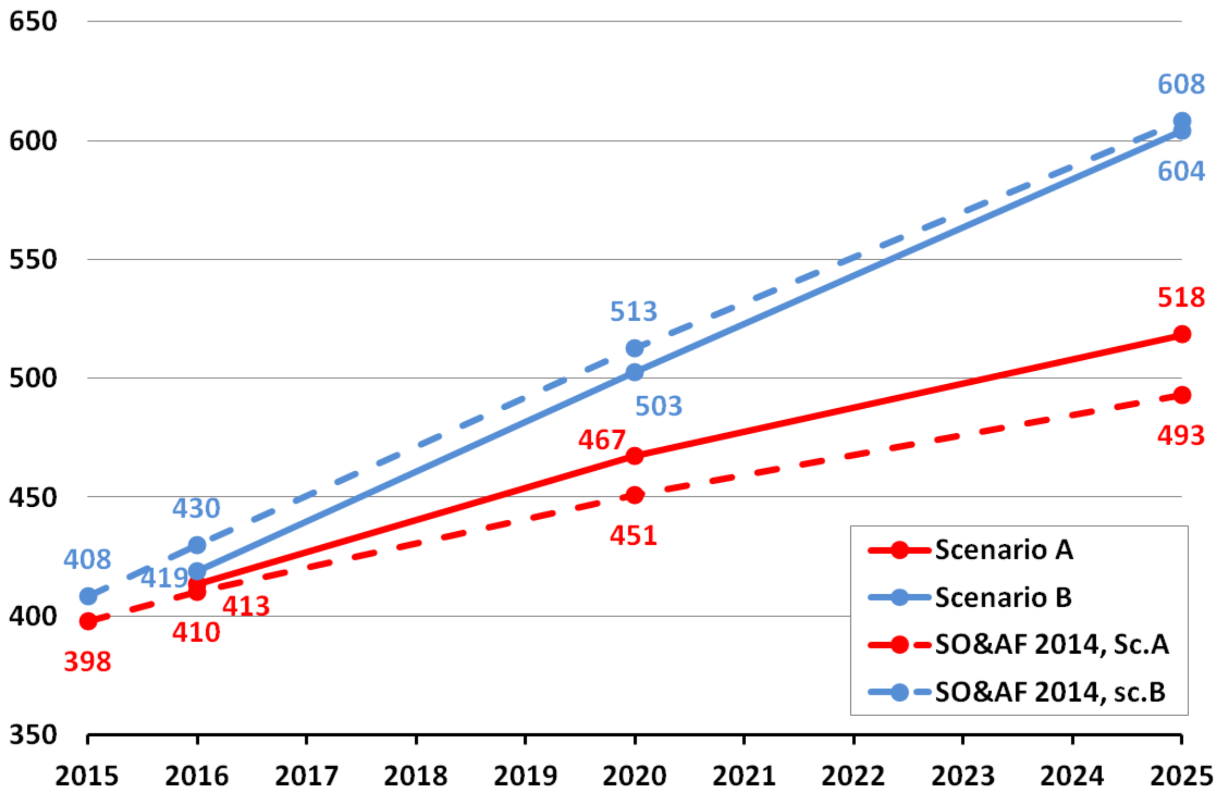


Figure 3.5.1–ENTSO-E RES generation capacity forecast in SO&AF 2014 and in SO&AF 2015; all scenarios; January 7 p.m. [GW]

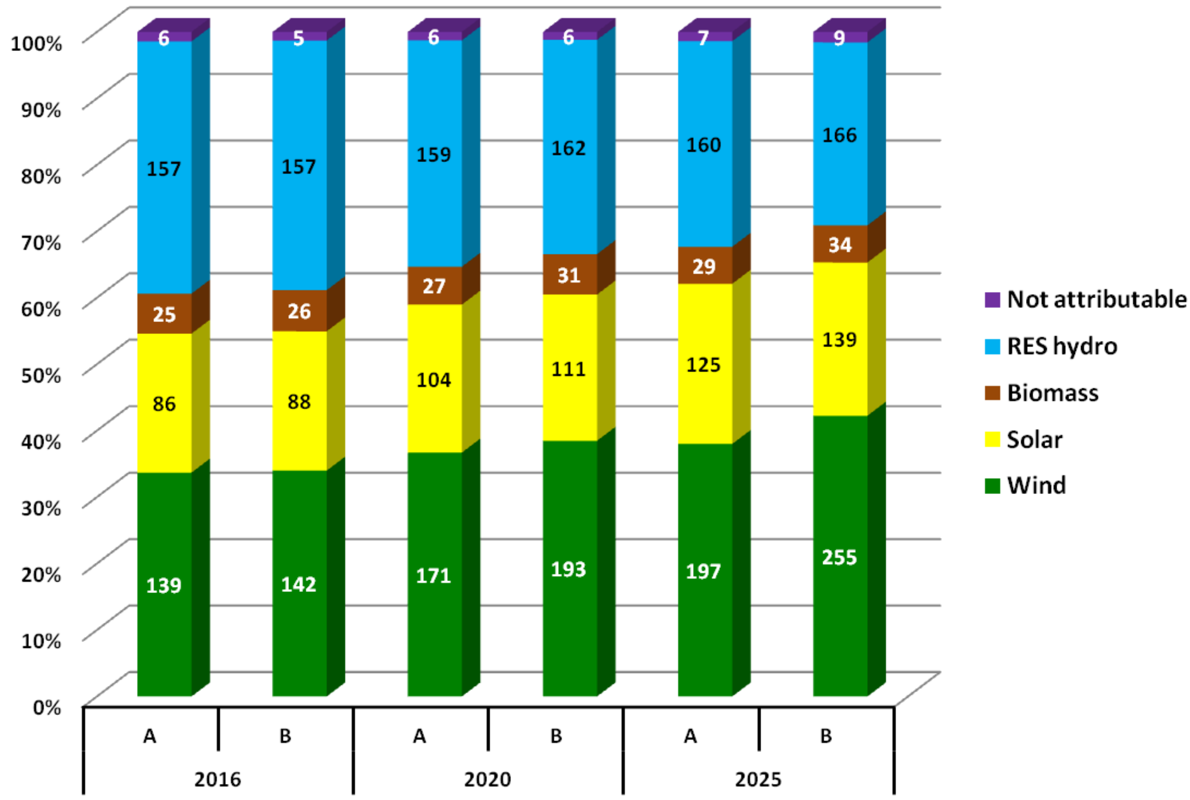


Figure 3.5.2–ENTSO-E RES generation capacity breakdown; all scenarios; January 7 p.m. [absolute partial values in GW]

	Scenario	2016–2025	Wind	Solar	Biomass	RES hydro
January 7 p.m.	A	[GW, total]	58	39	4	3
		[%, yearly]	3.93%	4.18%	1.66%	0.24%
	B	[GW, total]	113	52	8	9
		[%, yearly]	6.71%	5.27%	2.96%	0.63%

Table 3.5.1–ENTSO-E RES subcategories evolution; Scenarios A and B

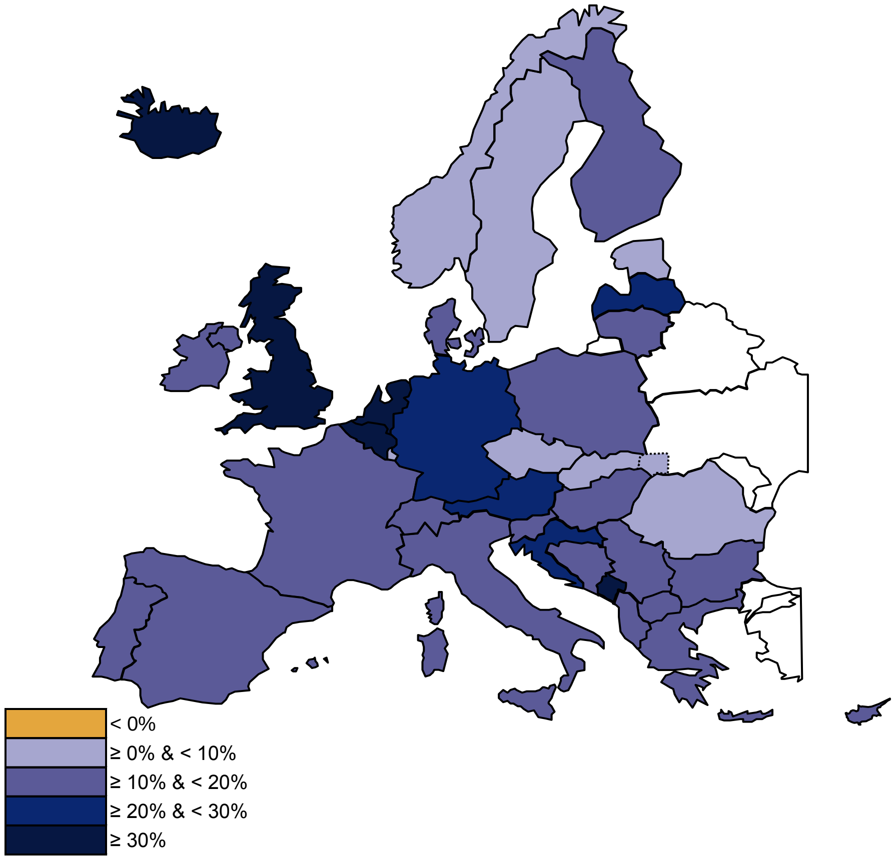


Figure 3.5.3–RES installed capacity changes 2016/2025 as a part of the total NGC in 2016 per country; Scenario B; January 7 p.m.

Figure 3.5.3 shows a per country overview for Scenario B. While the share of RES in the generation mix will increase in all countries, the largest shift towards RES is projected for the UK and Belgium, followed by the Netherlands and Montenegro.

3.6 Unavailable Capacity and Reliable Available Capacity

Unavailable Capacity (UC) is made up of four subcategories: aggregating Non-Usable Capacity, Maintenance and Overhauls, Outages and System Services Reserve. In addition to seasonal effects, such as maintenance schedules and availability of hydro power, UC is closely linked to variable RES penetration because of the limited availability of certain primary energy sources.

Aggregated UC and RAC data for the forecast period and Scenario B appear in Figure 3.6.1. 94% of the NGC increase between 2016 and 2025 is considered as UC (corresponding to 137 GW); and only a minor part of 6% (equal to 9 GW) can be taken into account as RAC.

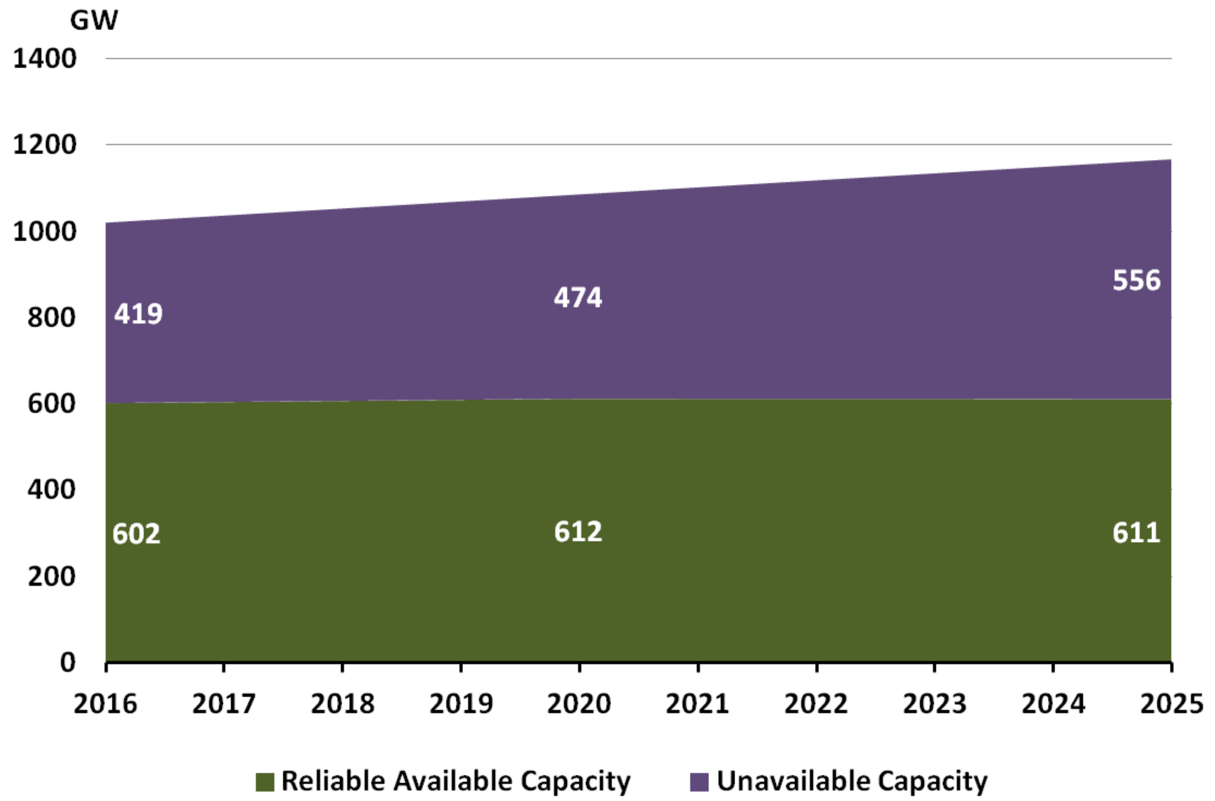


Figure 3.6.1–ENTSO-E RAC and UC forecast (RAC + UC = NGC); Scenario B; January 7 p.m. [GW]

Figure 3.6.2 assesses the monthly evolution of UC as a part of NGC for the forecast period. For 2025, a slightly more ambitious RES penetration level is foreseen, resulting in an increased percentage of UC.

Comparing trends of monthly data, higher UC ratios can be observed in the period between the end of summer and the beginning of autumn. To discover the reason, the precise share of each element in the total UC is presented in Figure 3.6.3 below. There is no single reason for the UC peak in this period. It is a combination of the following trends:

- maintenance and overhauls, which have their peak in May and June, but showing high levels also in July, August, September (summer, because of lower level of load, is a typical period for maintenance),
- non-usability of solar, which registers in this period the change between high usage in the summer period and the lowest usage during the winter season (7 p.m.),
- non-usability of wind, which has higher levels in the period from April to October,
- non-usable capacity except for wind and solar with the peak in September (it could be understood as a transitional month for CHPs, where maintenance has ended, but operation has not started yet).

The level of system services reserves and outages is more or less flat within the calendar year.

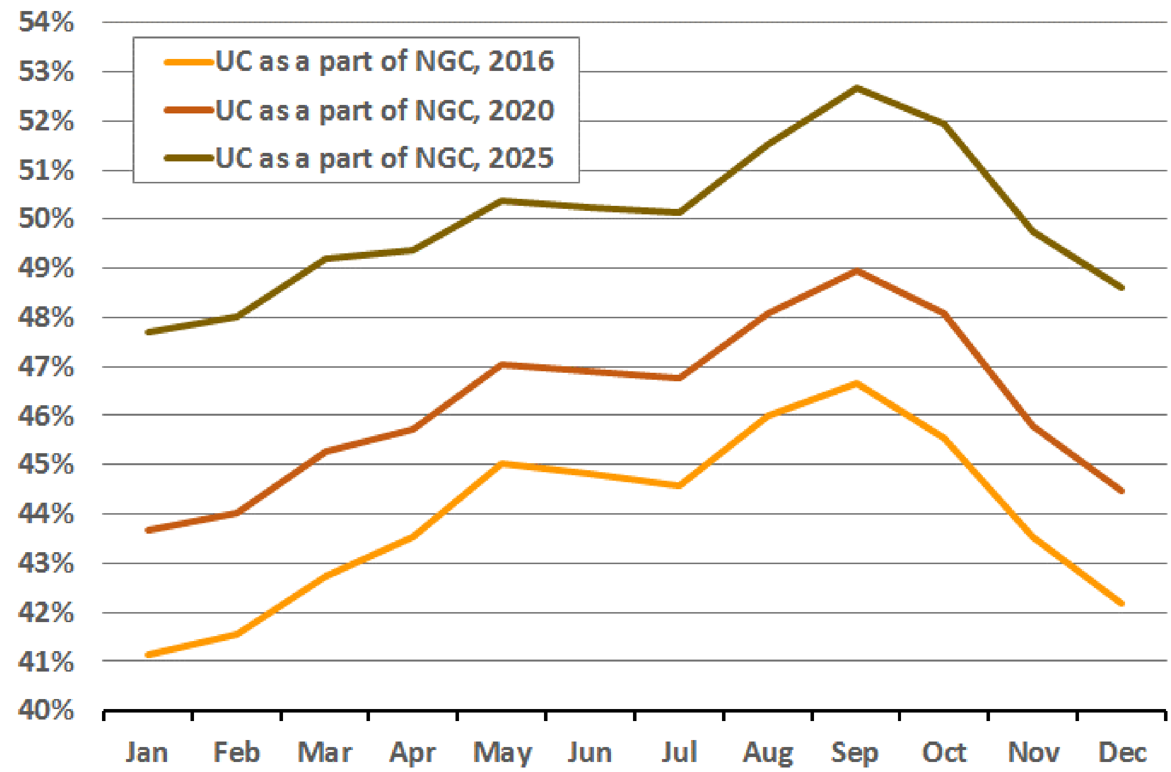


Figure 3.6.2–ENTSO-E forecast of Unavailable Capacity as a part of NGC, Scenario B

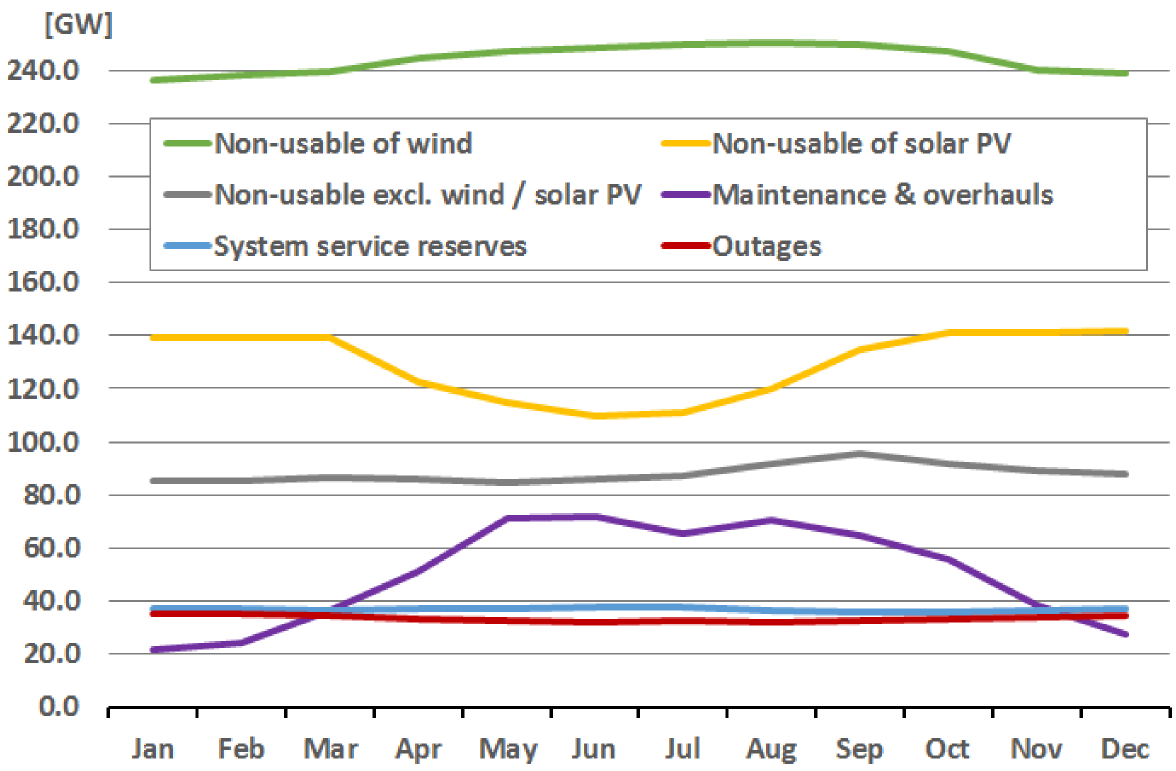


Figure 3.6.3–ENTSO-E forecast of UC elements, Scenario B, year 2025

Figure 3.6.4 gives an overview of the components of UC among the different scenarios. The main driver of the growth of UC is clearly non-usable capacity. This category encompasses reductions of NGC for various reasons, such as unavailability of primary energy sources (most characteristic of RES generation), transmission constraints or decisions on mothballing taken by power plant operators. Maintenance and overhauls are expected to increase marginally, similarly to the component System Service Reserve. As a consequence of the gradual modernisation of the fleet, nearly constant levels of outages appear in all scenarios.

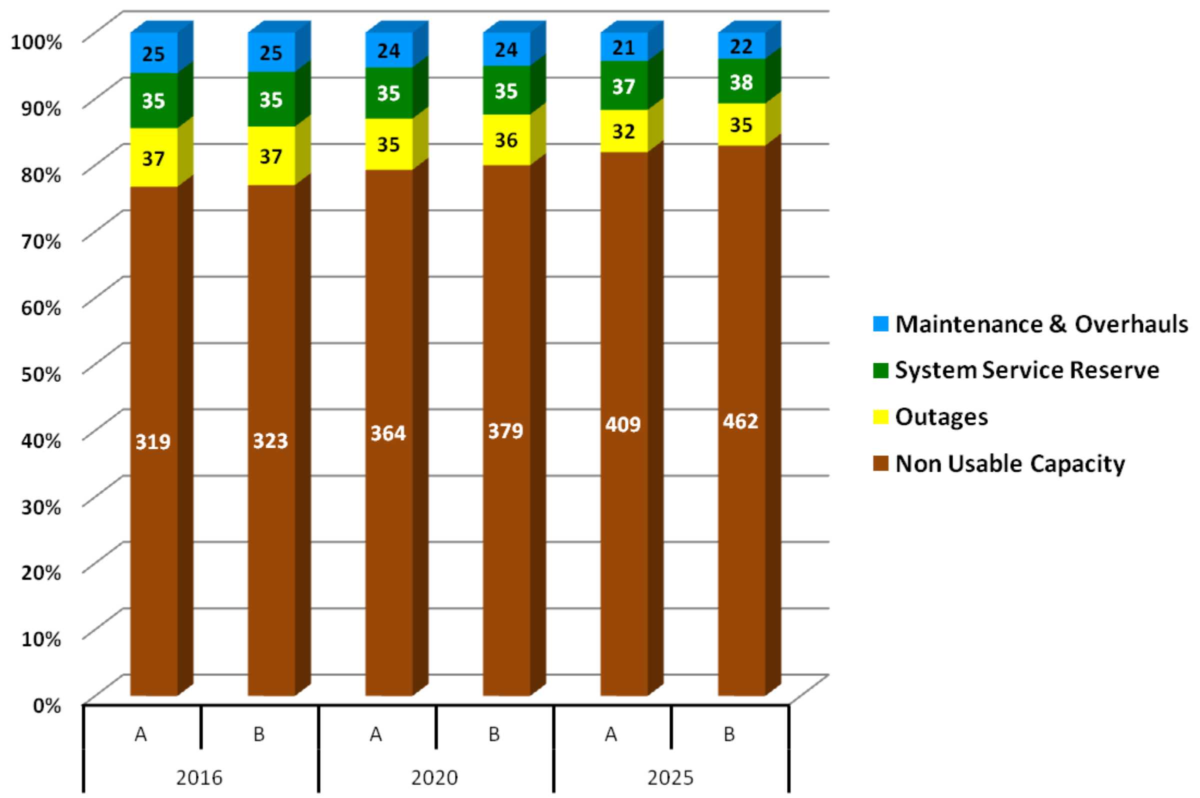


Figure 3.6.4–ENTSO-E UC forecast breakdown; all scenarios; January 7 p.m. [absolute partial values in GW]

When assessing the geographical variation in UC percentages, the following trends can be observed:

– At ENTSO-E level, only a negligible difference can be found in the UC ratios of Scenarios A and B in 2016 (41.08% vs. 41.05%), because most countries provided similar forecasts for both scenarios in terms of generation mix.

– At the same time, there are large geographical differences in accordance to the generation mix and assumed RES penetration. Rapidly growing renewable generation capacity (especially wind and solar) has a much lower availability factor than other generation types.

Figure 3.6.5 compares UC as a part of NGC per country in 2020 for Scenario B. The ENTSO-E average of UC can reach 44% and country values range from 0% (Iceland) to 70% (Denmark). In addition to Denmark, there are other countries with a UC percentage equal to or exceeding 50%: Germany (58%), Romania (55%), Northern Ireland (55%), Italy (52%), Slovakia (51%) and Greece (50%).

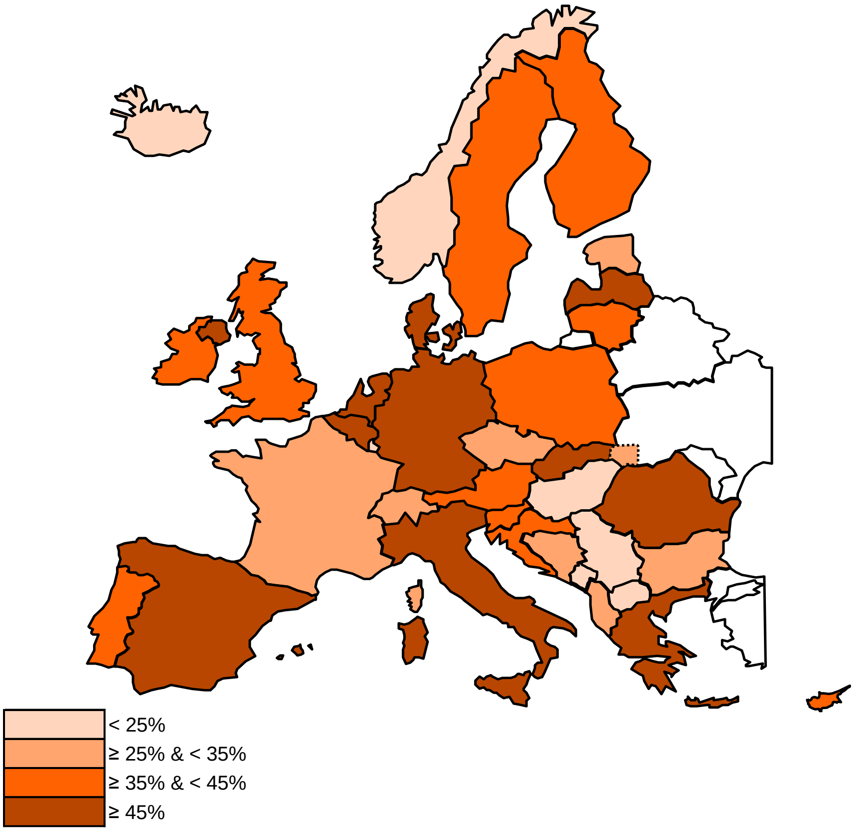


Figure 3.6.5–UC as a part of NGC per country in 2020, Scenario B, January

4 National upward generation adequacy assessment

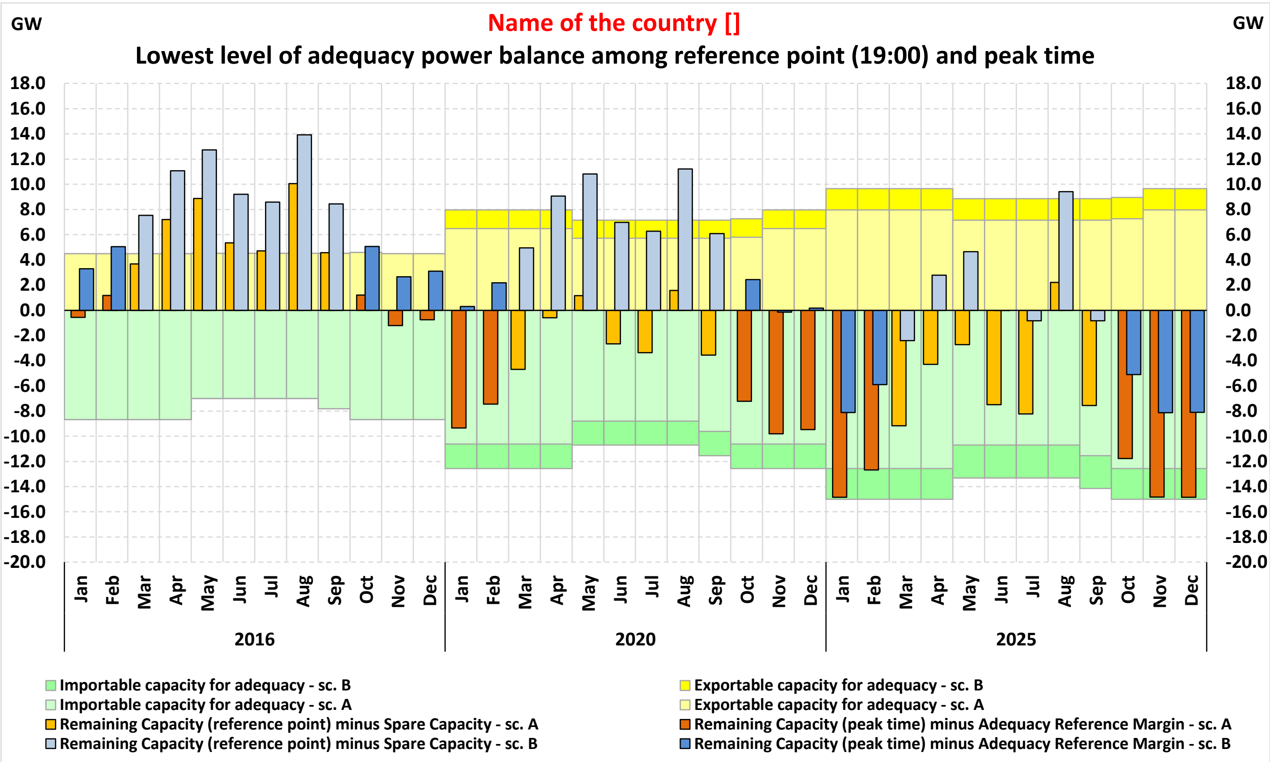
In this chapter, the power balance for each country will be assessed separately. While the Pan-European level requires a common reference point in time for all countries (see Chapter 6), national power balance evaluation can be done also at different moments referred to the national peak load time. In the national analysis, the worst power balance during every month is chosen between the reference point time and the national peak load time.

The power balance for reference points was calculated as Remaining Capacity at reference point (3rd Wednesday every month at 7 p.m.) minus Spare Capacity (SC):

RC_{7pm} – SC, where RC_{7pm} is Remaining Capacity with PECD[13] solar and wind monthly load factor for 7 p.m. (per country).

The power balance for peak load time was calculated as Remaining Capacity at national peak time minus Adequacy Reference Margin:

RC_{peak} – ARM, where RC_{peak} is Remaining Capacity with PECD solar and wind monthly load factor at the daily hour of expected peak load in each country (requested in SO&AF data collection template) and ARM is Spare Capacity + Margin Against Monthly Peak Load.



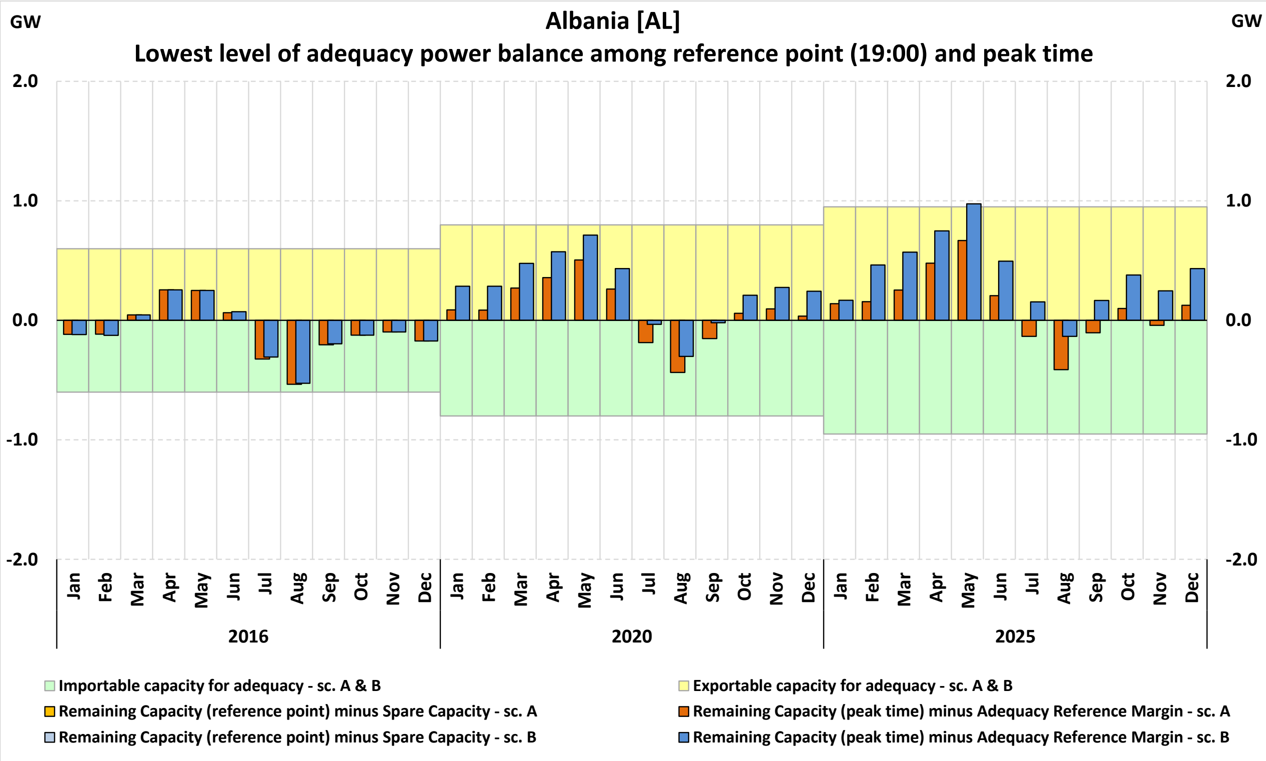
The above figure depicts the lowest level of power balance in every single month (for both Scenarios A and B) among the reference point and peak load point. Taking into account this assumption, only a single result is allowed in each month to be presented in the figure. For most countries, the worst power balance situation will take place at peak time, so in this case only series representing power balance at peak time will be visible on the figure.

[13] The Pan-European Climate Data have been provided to ENTSO-E by the Technical University of Denmark.

For countries that reported higher simultaneous importable/exportable capacity in Scenario B than in Scenario A, these additional capacities are shown on the figure using a darker area than the area referring to capacities for Scenario A.

Moreover, the simultaneous importable/exportable capacity used in this report for adequacy assessment **should not be confused** with the *interconnection capacity*[14]. The simultaneous importable/exportable capacity taken into account in this framework could be lower than the sum of NTCs on each profile of a Control Area or country. It is calculated taking into account the mutual dependence of flows on different profiles because of internal or external network constraints as well as the specific characteristics of the power system related to adequacy. **For the interconnection level of countries, and checking the compliance with the *10% target requirement*, please refer to the TYNDP 2016[15] and the new Regional Development Plans**.

Albania



Load and annual demand forecast

The National Load and the demand forecast are based on the "Albania Network Development Plan 2015–2025" and the restricted measures undertaken in the distribution system and in the entire power sector. Till now, no infrastructure is foreseen for Load Management.

Net Generating Capacity forecast

The generation in Albania is 100% by Hydro Power Plants. The National Power System is facing a large number of applications for the construction of small hydro power plants by exploiting a considerable part of the rivers that cross the national territory.

[14] http://ec.europa.eu/priorities/energy-union/docs/interconnectors_en.pdf
[15] https://www.entsoe.eu/major-projects/ten-year-network-development-plan/ten%20year%20network%20development%20plan%202016/Pages/default.aspx

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Albania has set up appropriate structures for facilitating the integration of renewable energy, but even though there were several applications from foreign investment, until 2025 for the generation forecast, according to Scenario A a conservative development is taken into consideration and no RES integration is expected.

For this conservative scenario after 2020, only one Combined Cycle Gas Turbine of 100 MW is foreseen to be in operation and the net generating capacity till the year 2025 will be increased by 36%.

In order to be consistent with the “Best Estimate Scenario” (Scenario B) and the “National Strategy for Energy”, till 2025 a small integration of RES is expected.

Depending on the construction of the Trans-Adriatic Pipeline, which will transport natural gas from the Caspian Sea, starting from Greece via Albania and the Adriatic Sea to Italy and further to Western Europe, concerning the thermal generation after 2020, three Cycle Gas Turbines with installed power of 300 MW are expected to be in operation. With this project, an extension of the 400 kV internal network is expected.

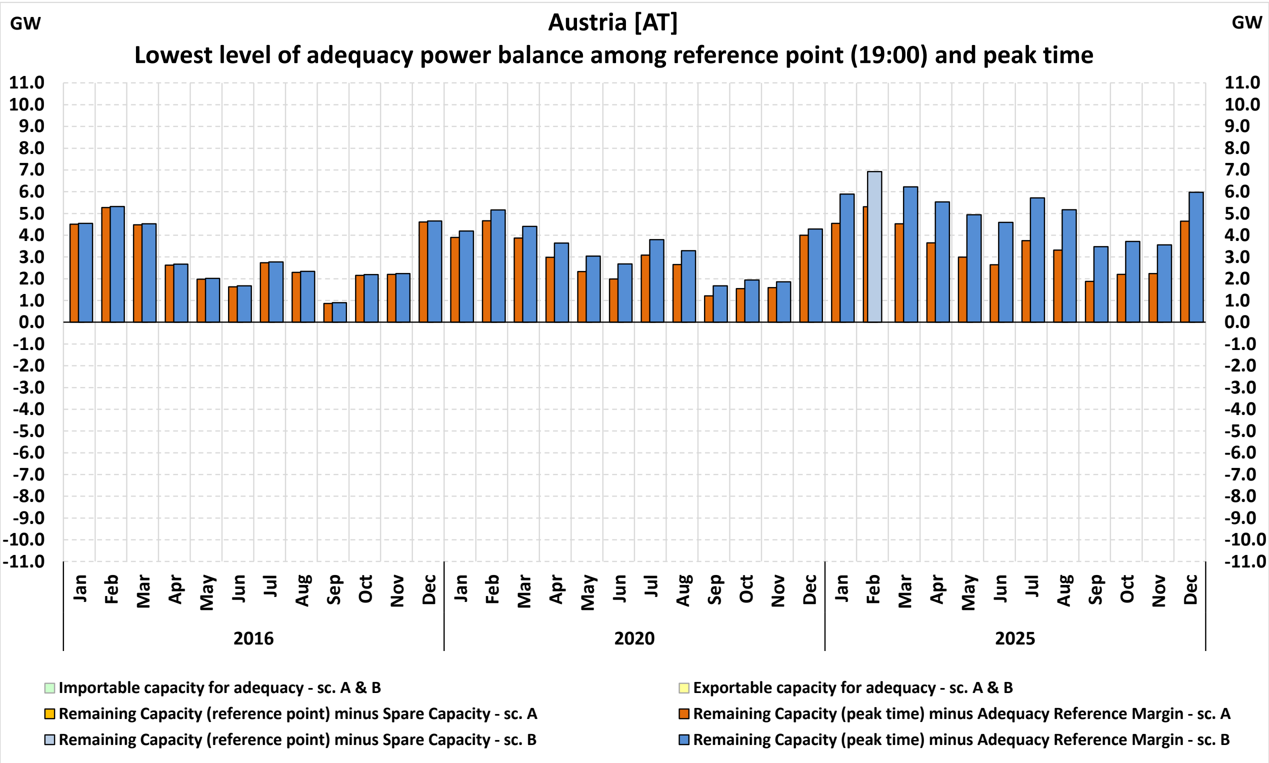
In the year 2025, in the south of Albania by implementation of two hydro-cascade projects, the hydro generation will grow by 47% and the total net generating capacity is expected to increase by 63%.

Generation and System Adequacy forecast

For the Albanian power system, in the 10-year period 2016–2025, for both conservative and best estimate scenarios, no issue is envisaged regarding the system adequacy.

The system reserve is foreseen to cover any issues according to generation uncertainties and the two new connections to the 400 kV network through Albania–Kosovo (expected to be in operation in April 2016) and Albania–Macedonia (expected in 2021) will improve the net transfer capacity values.

Austria



Load and annual demand forecast

For the load forecasts of Scenarios A and B, an increase of 0.5% per year is assumed until 2020. Beyond 2020, because of energy efficiency, an increase of 0.25% per year is taken into account. These increased rates are also used for TYNDP 2016. The forecasts are based on a normalised load curve assuming average temperatures in the coming years.

Net Generating Capacity forecast

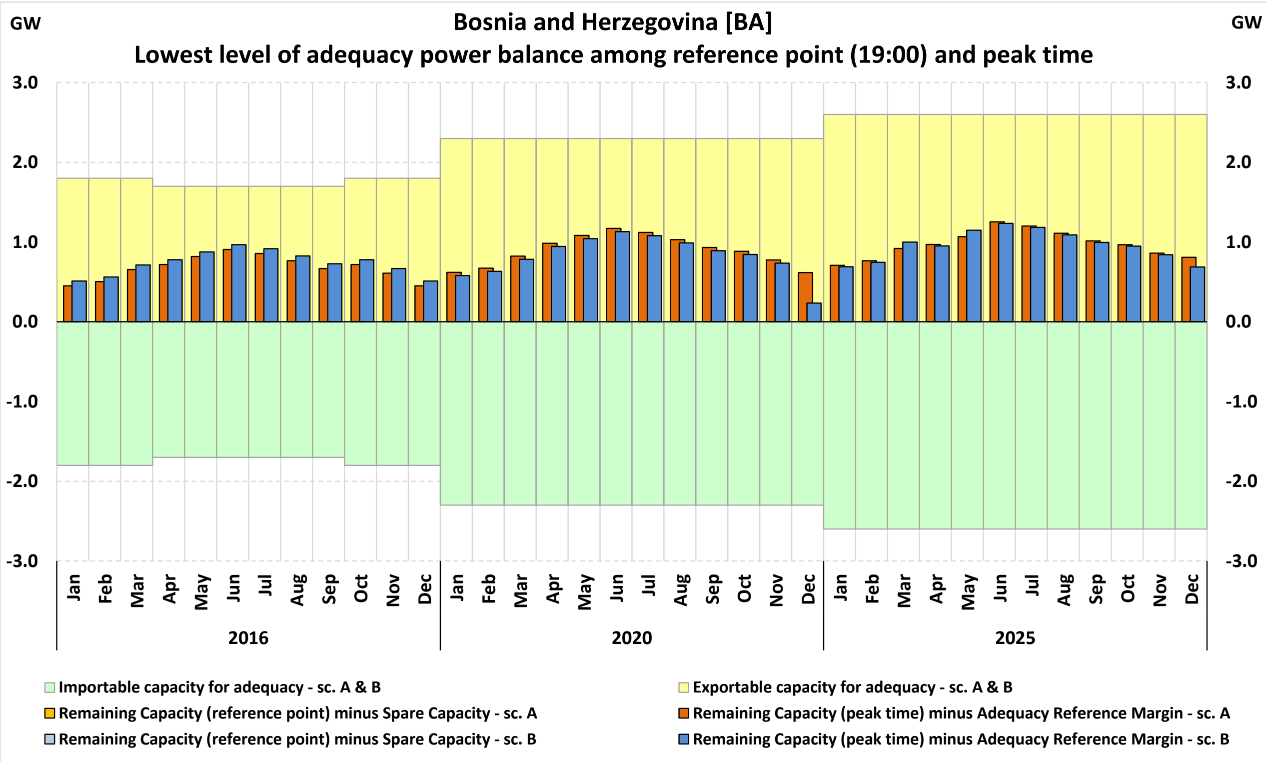
The calculations are based on the data collected from market participants for the preparation of the TYNDP 2016. A further increase of renewables (wind and solar power plants) is expected.

Planned shut-down of thermal units such as Riedersbach (2016: 168 MW), Neudorf–Werndorf 2 FHKW (2015: 164 MW) and Dürnrohr Verbund (2015: 405 MW) means they were taken as not available.

Generation and System Adequacy forecast

For all scenarios, sufficient remaining capacity is expected for the Austrian electricity system. Because of new tie-line projects, BTCs are supposed to rise until 2025. As there is a common market area with Germany, no BTC limitations are taken into account at this border.

Bosnia and Herzegovina



Load and annual demand forecast

Load and demand for Scenarios A (Conservative) and B (Best Estimate) in the SO&AF 2015 report for Bosnia and Herzegovina are predicted according to the Indicative Production Development Plan 2014–2023, made by an Independent System Operator in Bosnia and Herzegovina (ISO BIH).

Scenario A has a higher load and consumption prediction than Scenario B.

Net Generating Capacity forecast

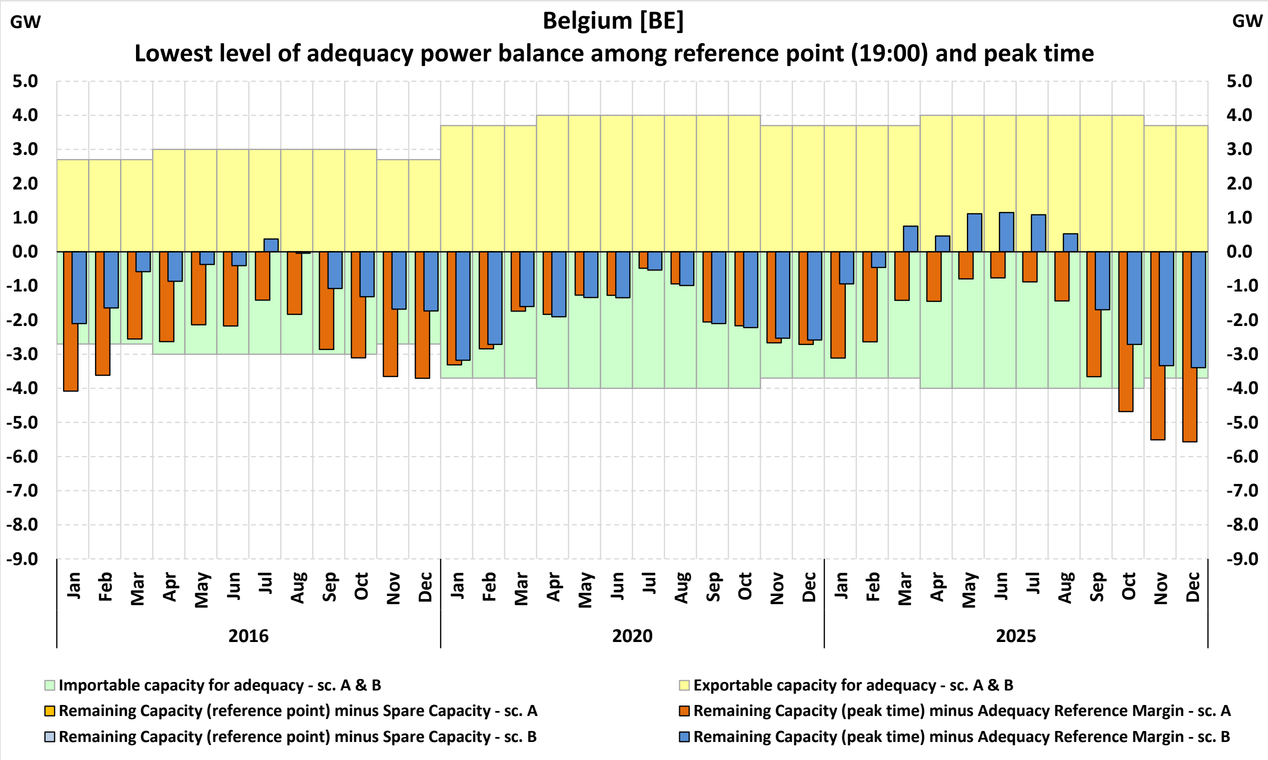
As there is still no National Renewable Energy Action Plan (NREAP) or Energy Strategy on a national level in Bosnia and Herzegovina, the data announced in the Indicative Production Development Plans (IPDPs) in the last three years were used. These plans are made every year for the next 10 years' period.

Scenarios A and B in SOAF 2015 are based on generation capacities that were balanced in IPDPs, and Scenario B contains more hydro capacities than Scenario A.

Generation and System Adequacy forecast

In general, no problems are expected regarding power system adequacy in Bosnia and Herzegovina for the period 2016–2025 for both Scenarios A and B. An increase of BTCs to Croatia and Serbia is expected after 2020 because of construction of new 400 kV interconnection lines.

Belgium



Load and annual demand forecast

The proposed ENTSO-E load methodology is applied. The Belgian figures refer to Belgian territory including all voltage levels. The national load and annual demand forecast for Scenarios A and B are taken from the high GDP scenario published in a study by the Federal Planning Bureau in October 2014. The annual growth rate is about 0.3%.

Elia has numerous load-shedding contracts with industrial customers. These contracts are part of the system services reserve and amount to about 300 MW. No estimations of the system services needs in 2020 and 2025 are available, therefore the level is assumed to remain the same.

In the framework of the strategic reserve mechanism, demand plays an important role. For the exercise, an estimation is made of the total amount of strategic reserves, without making a distinction between strategic demand and strategic generation reserve.

Net Generating Capacity forecast

The renewable generation capacity in Scenarios A and B is taken from the Belgian federal development plan 2015–2025. The estimated figures are in line with the renewable energy level in TWh announced in the Belgian NREAP; however, they deviate in installed capacities. The deviation results from taking into account regional objectives regarding the installed generation capacity of wind, renewable hydro, solar and biomass, as well as the current installed generation capacities.

There is a lot of uncertainty about the Belgian nuclear capacity and the nuclear phase-out. The following assumptions are made. As stated by the Belgian law, the nuclear phase-out starts with two nuclear units with a joint capacity of 1 GW by 2016. Because of anomalies in the reactor vessels of two other nuclear units, 2 GW of nuclear capacity is temporarily unavailable and there is uncertainty if they will ever be back in operation. Therefore, in Scenario A, it is assumed that these units will no longer be operational in the Belgian electricity system. In Scenario B on the other hand, it is assumed that their capacity will be available by 2016.

For both scenarios the capacity assumed in 2016 is the same as in 2020. According to the Belgian phase-out law, all of the nuclear capacity will be decommissioned by the end of 2025.

For the year 2016, it is assumed that no new thermal units will be commissioned and that no existing large thermal units will be decommissioned or mothballed as a consequence of the strategic reserve mechanism set up in Belgium. On top of this, two additional gas power plants are assumed for the horizon 2020. For the horizon 2025 (year of the nuclear phase-out), new gas units are commissioned based on the assumption that generation adequacy should be maintained for Scenario B. For Scenario A, no new gas units are commissioned for 2025 because this is too far in the future to be certain of such projects.

The assumed volume of strategic reserves is determined by a probabilistic generation adequacy study performed by Elia. For Scenario B, the strategic reserve capacity is assumed for 2016 to ensure security of supply. For 2020 and 2025, the strategic reserves are no longer assumed because of additional interconnection capacity and additional production units. For Scenario A (unavailability of nuclear units + no new gas units after 2020), the strategic reserve capacity is assumed constant and needed for all time horizons to improve the adequacy situation.

The simultaneous import capacity used in simulations for Belgium is normally 3500 MW in winter. However, Elia recommends reducing the import capacity from 3500 MW to 2700 MW for a very limited number of hours that are critical for ensuring security of supply in view of structural changes established in energy flows during the winter peaks in the CWE network. Furthermore, the market risk associated with the possibility of purchasing energy is expected to increase because of power plants being shut down in neighbouring countries. This simultaneous import capacity is supposed to increase by 1000 MW for the years 2020 and 2025 because of new interconnection projects. The possible positive impact of the day-ahead flow-based market coupling is not yet taken into account.

Generation and System Adequacy forecast

Given the assumptions explained above, in 2016, despite the strategic reserves mechanism, adequacy problems are not excluded for Scenario A (unavailability of nuclear units) during winter. Elia is looking for possible solutions and is preparing to handle situations of scarcity.

Because of the strategic reserves mechanism and an increase in import and net generation capacity, no adequacy problems are expected in 2020. In 2025, according to Scenario A, adequacy problems can occur because of the nuclear phase-out. As Scenario B demonstrates, new generation capacity is necessary to cover the nuclear phase-out.

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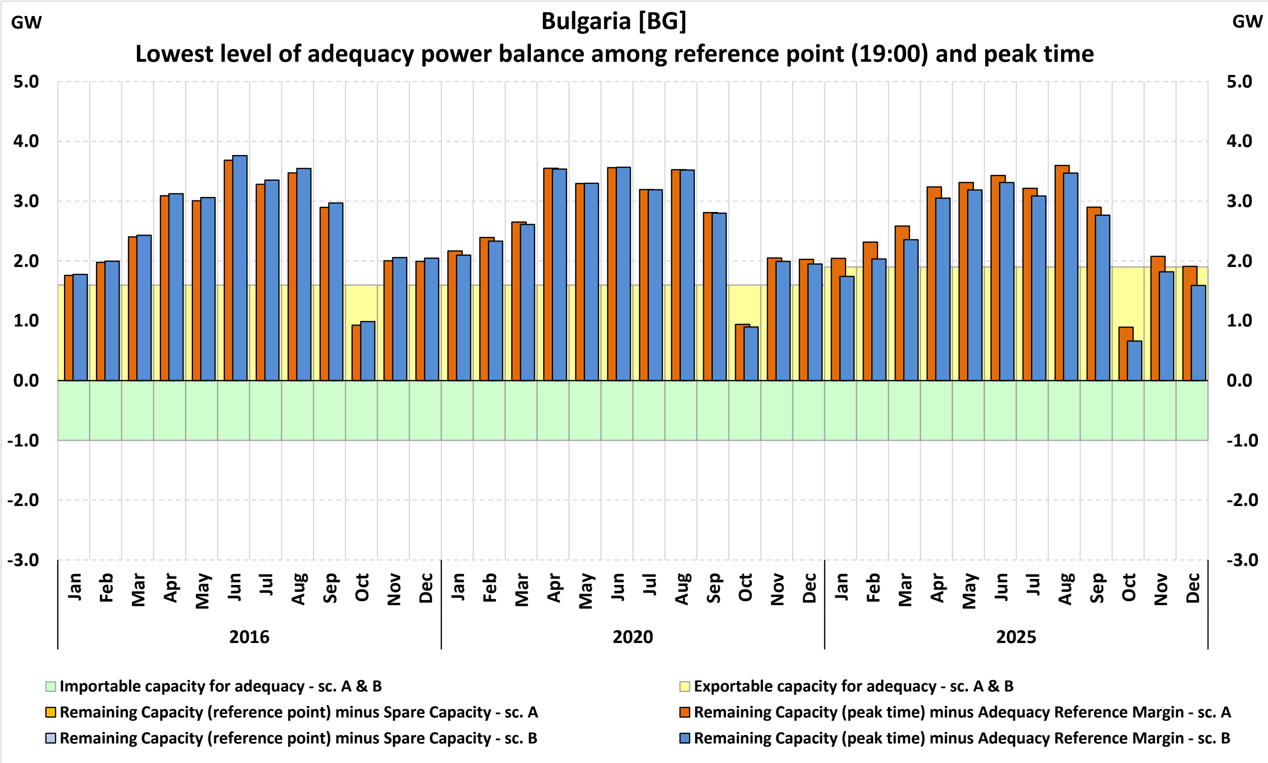
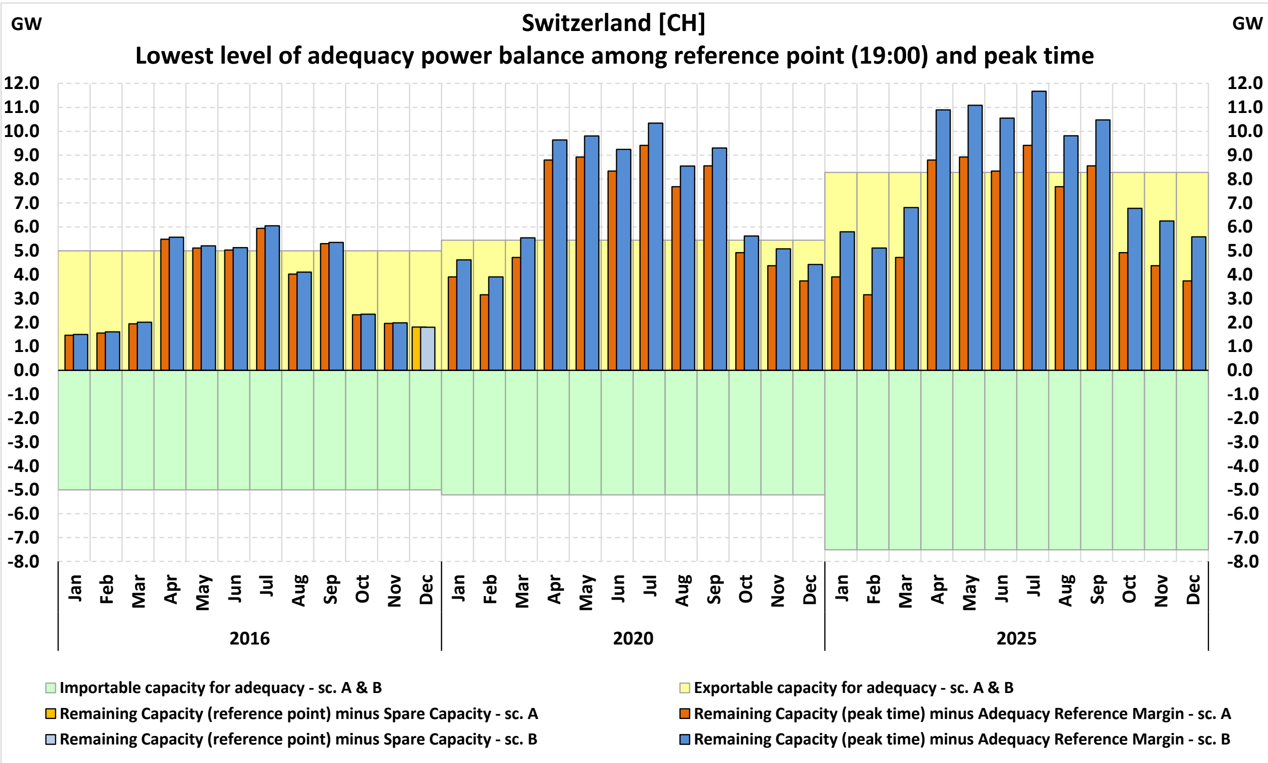
Bulgaria



Switzerland



Load and annual demand forecast

The load in both Scenarios A and B follow the TYNDP 2016, “Best Estimate 2020”.

Net Generating Capacity forecast

In general, only capacity already under construction is included in Scenario A, and only capacity whose decommissioning is already announced is removed.

For Scenario B, feedbacks from generators for the current national grid planning study were included.

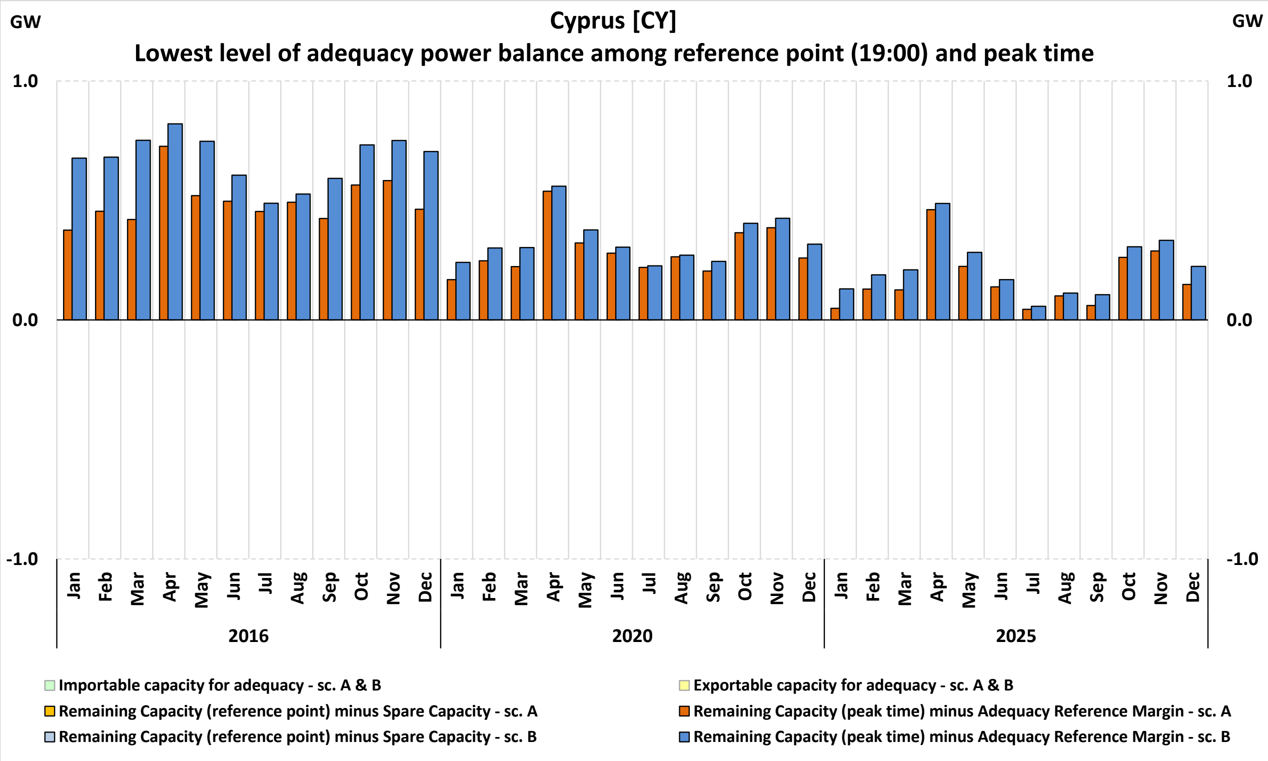
Wind and PV capacity is, according to the guidelines, only growing in Scenario B. The growth rates are in line with the corresponding scenario for national grid planning.

Generation and System Adequacy forecast

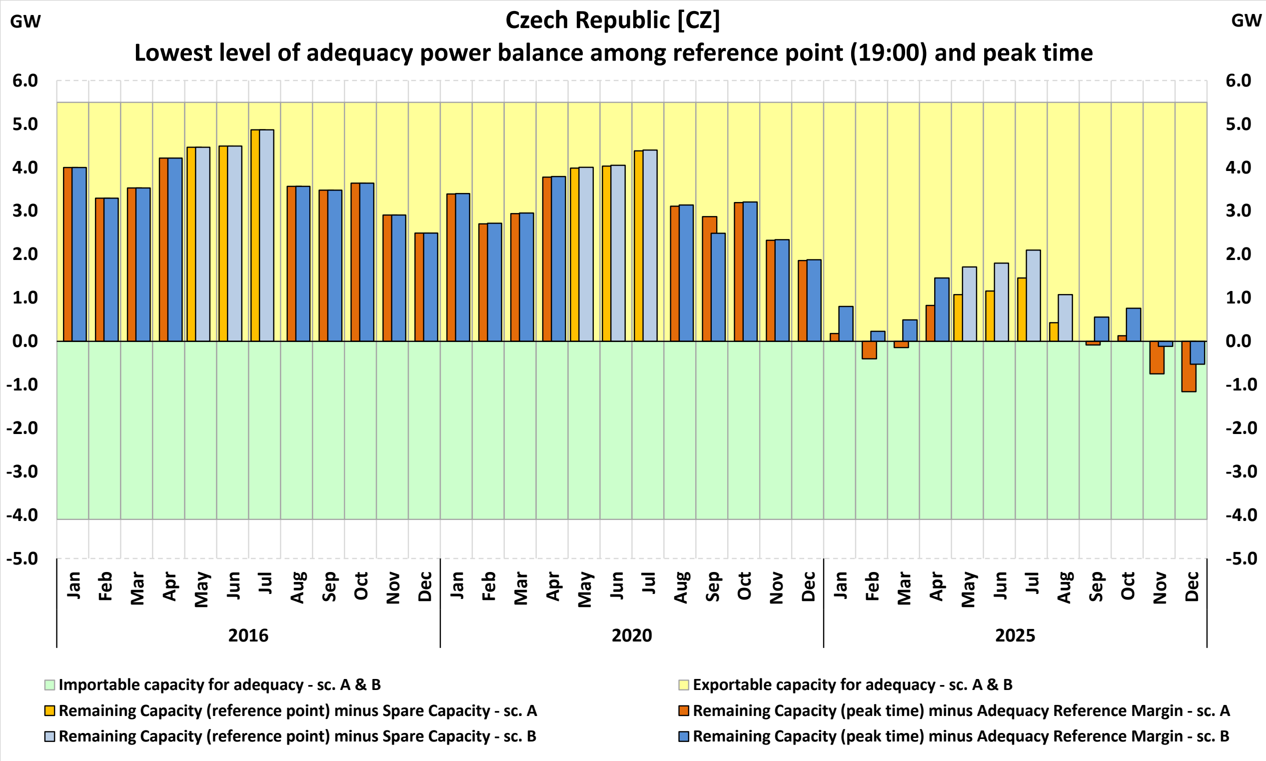
No problems can be identified for Switzerland.

The current methodology from ENTSO-E is focused on capacity [MW] only; it cannot reveal potential problems faced by hydro-dominant countries like Switzerland. In particular, for Switzerland it is very important to also take into account energy constraints [MWh].

Cyprus



Czech Republic



Load and annual demand forecast

Load forecasts in Scenarios A and B are the best national estimates available to the TSO, under normal climatic conditions, taking into account the highest expected growth of the consumption according to national grid development plans.

We expect an increase in consumption because of mild economic growth between 2015 and 2025.

Net Generating Capacity forecast

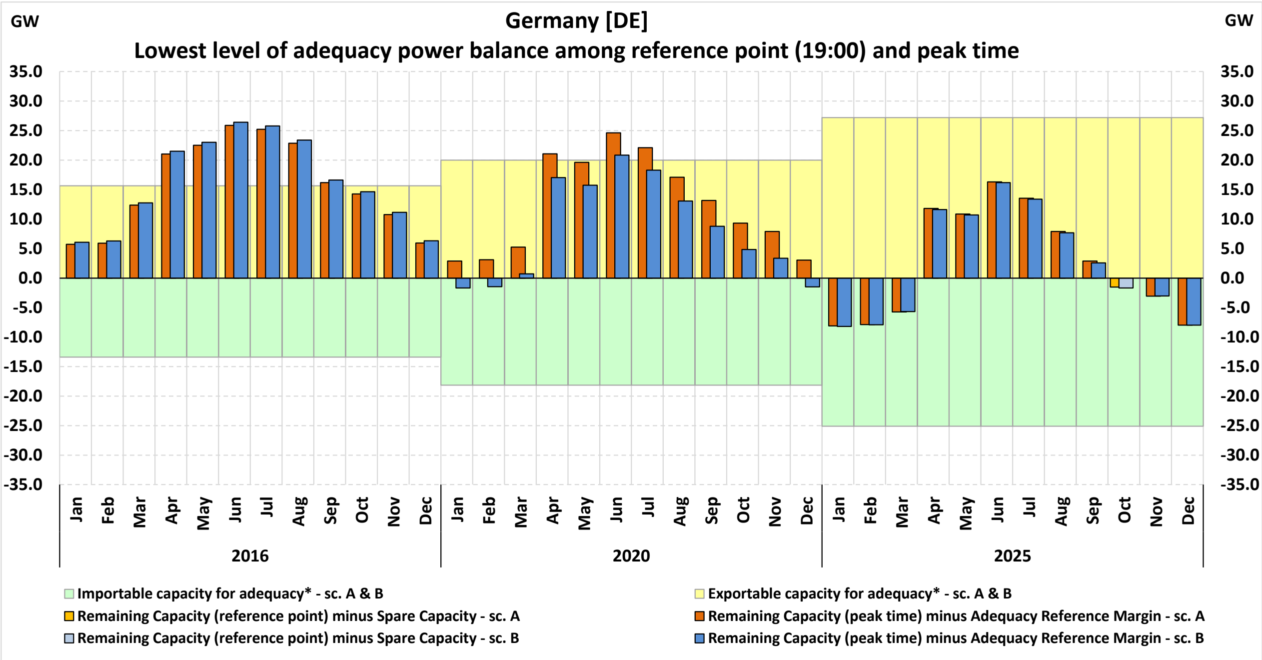
The power system of the Czech Republic has at present 21.9 GW of generation capacity installed, and that capacity will be sufficient to cover peak loads according to both Scenarios A and B. Currently, electricity production is mainly based on Nuclear Power and Fossil fuels of Lignite and Hard Coal and the remaining share is covered by Fossil fuels of Gas, Hydro power, Solar power and Wind power in the Czech Republic.

- The only new capacity included in Scenario A is that which is already under construction or where the project is too far advanced to be cancelled.
- The whole nuclear fleet will remain open until 2025.
- Between 4.4 GW and 5.1 GW Fossil fuels of Lignite and Hard Coal will close between 2015 and 2025.
- The Wind Power and Solar Power are the same for Scenarios A and B between 2015 and 2025.
- Change is not expected in the case of Hydro power in the future.
- Increase of 4.1 GW is expected in the case of Solar and Wind Power in 2025.

Generation and System Adequacy forecast

The Czech Republic has a positive Remaining Capacity in Scenario A until October 2025 and in Scenario B until the end of 2025. This negative Remaining Capacity will be brought from abroad.

Germany



* = The value of Importable/Exportable capacity does not include the border with Austria as there is a common market between Germany and Austria for which no NTC exists

Load and annual demand forecast

In recent years, no clear upward or downward trend for the annual consumption in Germany could be observed. It is to be expected that the future demand will stay on a similar level compared with today. It is understood that factors such as an efficiency increase and an increase of mobility and heat generation will counterbalance each other. For 2016, the assigned value for peak load and annual demand is slightly higher than in 2020 and 2025. These assumptions are in accordance with current projects in Germany and the National Grid Development Plan. There are no differences between Scenarios A and B.

Net Generating Capacity forecast

The German nuclear phase-out will be completed in 2022. In view of the political developments, there is a further reduction of conventional power plants to be expected in all scenarios. This particularly relates to lignite and coal power plants. In alignment with the National Grid Development Plan, the technical and economic lifetime of conventional power plants is shortened by five years in Scenario B compared with Scenario A. This leads to lower conventional capacities in Scenario B from the year 2020 on, although on the other side, only in Scenario B is the construction of additional flexible gas power plants assumed.

The growth of renewable energies is embodied in German law. The renewable capacities are assumed to be at the upper edge of the policy objectives in Scenario B and at the lower edge in Scenario A.

Generation and System Adequacy forecast

In the near future, power generation in Germany will continue covering German peak load at all time points of the year. This will probably begin to change in 2020 because of the expected close-downs of conventional power plants. In 2025, this trend will continue and Germany is expected to have a non-positive power balance in the winter half of the year.

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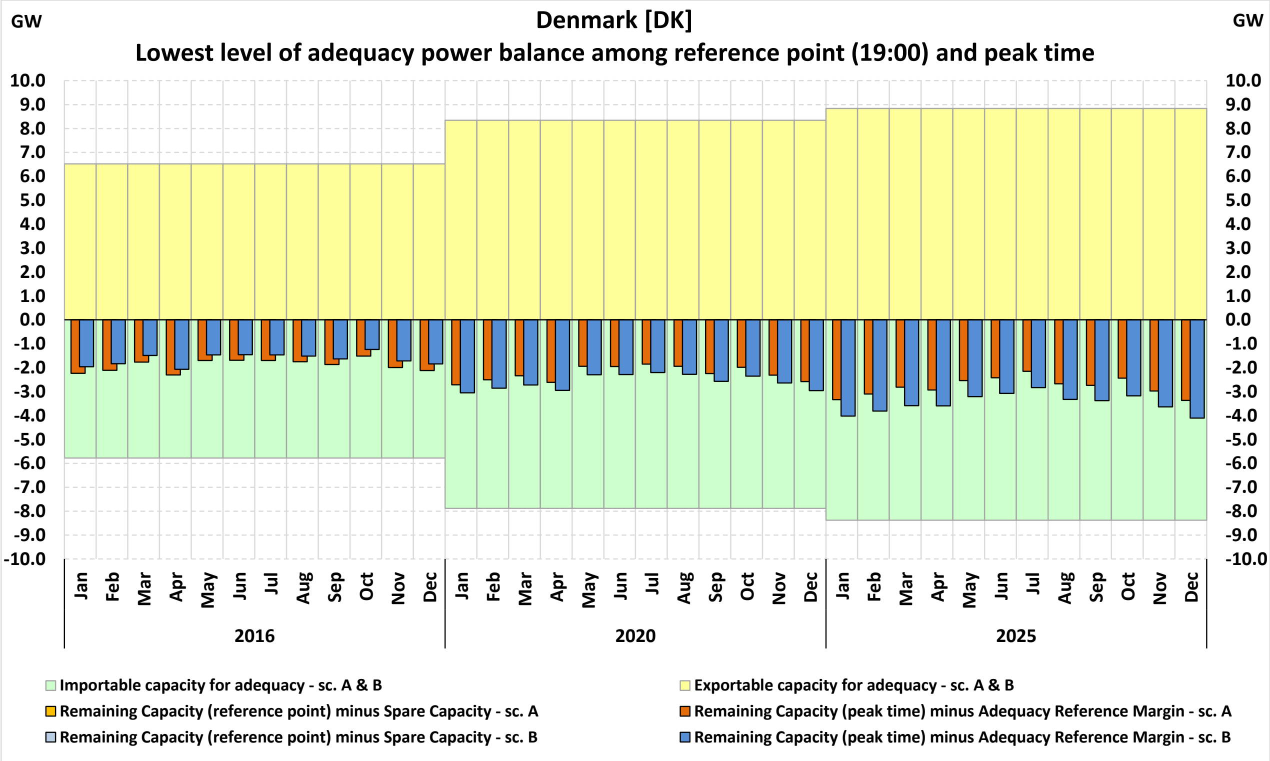
Denmark



Load and annual demand forecast

The annual load increases by 9% from 2016 to 2025 in the conservative Scenario A and the best estimate Scenario B.

Net Generating Capacity forecast

For the conservative Scenario A, the net generating capacity will decrease overall by approximately 2% from 2016 to 2025, with a minor increase in net generating capacity from 2020 to 2025.

The fossil fuelled net generating capacity will decline by 17% from 2016 to 2025, while the generating capacity of the renewable energy sources will rise by 4% from 2016 to 2025.

For the best estimate Scenario B, the total net generating capacity will decrease by 0.33% from 2016 to 2025. The fossil fuelled capacity will decline by 60% from 2016 to 2025, while the renewable generating capacity will increase by 29% from 2016 to 2025.

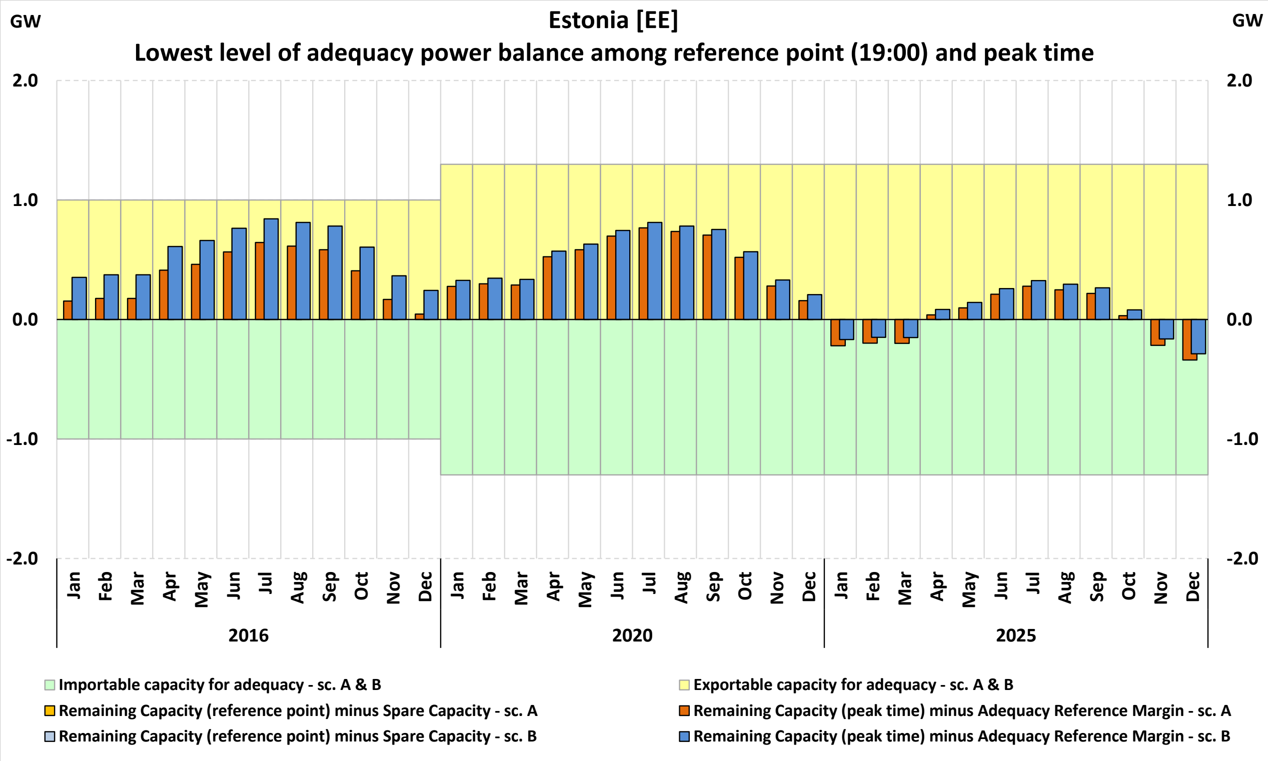
Generation and System Adequacy forecast

For Scenario A, the remaining capacity in 2016 is within the range of –0.26 GW to –1.45 GW depending on the season, while the range in 2025 is –0.98 GW to –2.62 GW.

For Scenario B, the remaining capacity ranges from –0.03 GW to –1.17 GW in 2016 and from –1.69 GW to –3.45 GW in 2025.

There are no problems regarding the balances because Denmark is so well connected to its neighbouring countries.

Estonia



Load and annual demand forecast

The worked-out electricity demand forecast is based on the respective forecast in the main branches of economy as well as on the projections of GDP growth, under normal climatic conditions. All provided load data agree with the SO&AF guidelines.

Net Generating Capacity forecast

For Scenario A, generating capacity for the most part (fossil, mixed fuels, hydro and biomass) is based on the data provided by the power producers for the annual estimation of the national generation adequacy. Scenario B is based on the Scenario A data with some adjustment taking into account the SO&AF guidelines.

Generation and System Adequacy forecast

Generation adequacy of the Estonian system should not be at risk up to 2020. The power system of Estonia has at present 2.7 GW of generation capacity installed and that capacity will be sufficient to cover peak loads according to both Scenarios A and B. After 2020, the possible shortage of capacity can be covered by imports from neighbouring countries.

The most important investments from the security of supply point of view were implementation of a second interconnection between Finland and Estonia with a capacity of 0.65 GW and construction of the new power plant with 0.25 GW as an emergency reserve.

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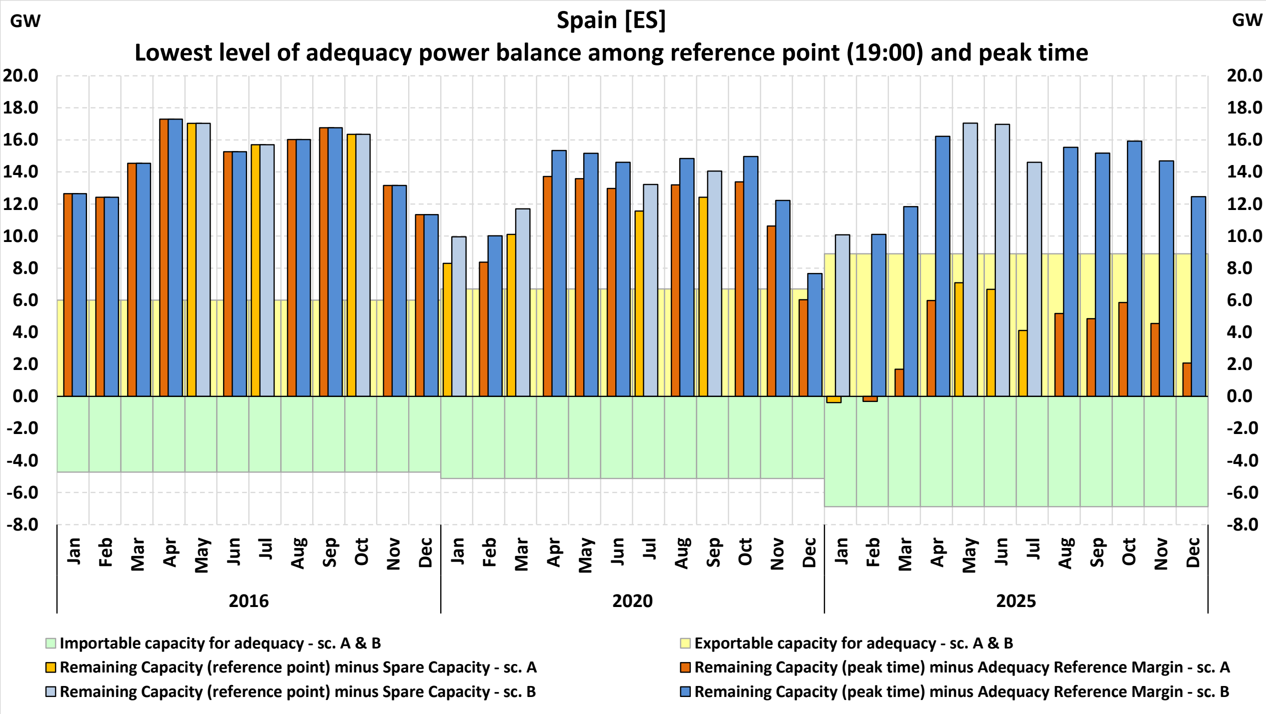
Spain



Load and annual demand forecast

The load forecast for both Scenarios A and B is the best estimate of the TSO, corresponding to a high economic growth scenario as in ENTSOE's Vision 3 and considering average temperature conditions. The average growth rate of demand for the forecast period is expected to be 2.5%.

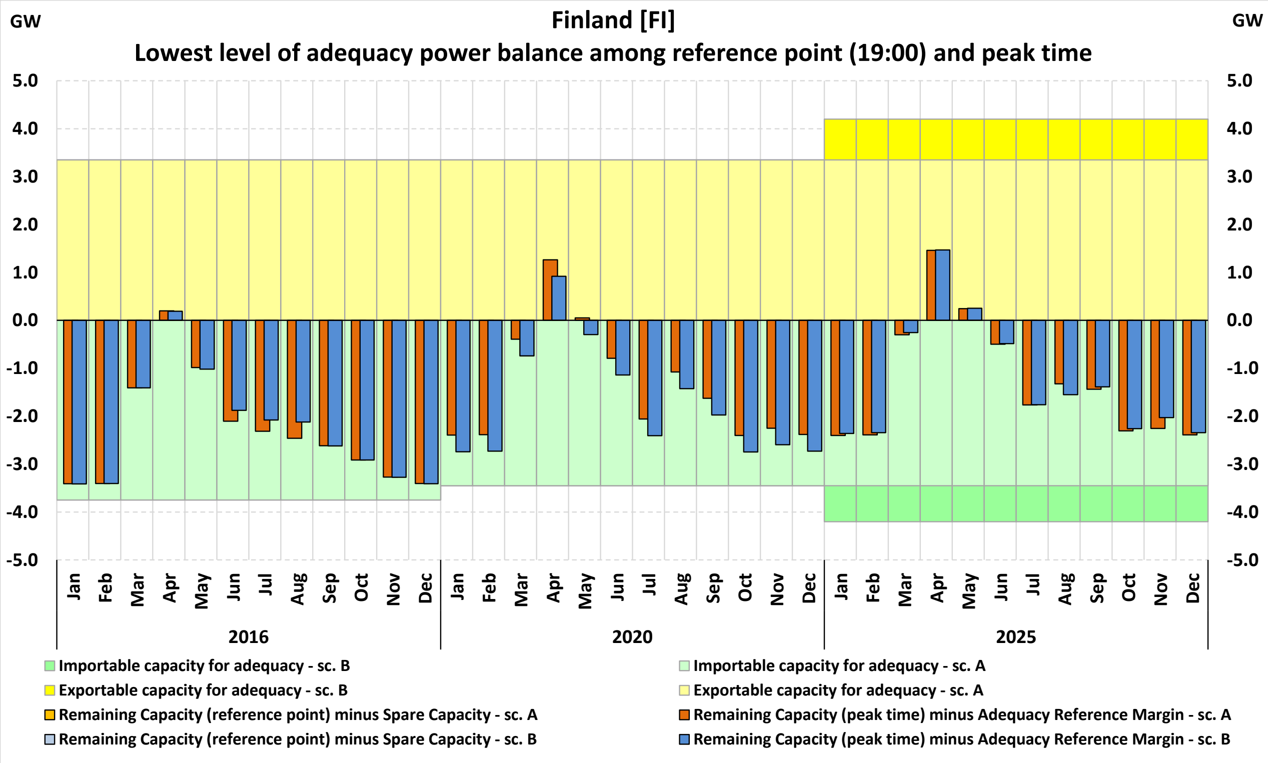
Net Generating Capacity forecast

No new investments in conventional thermal generation are expected in the forecast period and decommissioning of carbon power plants could occur after the 2020 horizon as a result of the application of the Industrial Emissions Directive 2010/75/EU. The evolution of the net installed capacity in the mainland Spanish electricity system includes the moderate growth of RES technologies. In the year 2025, the expected installed power in wind and solar technologies will be 30 GW and 12 GW, respectively (up from the actual installed power of 23 GW and 7 GW, respectively).

Generation and System Adequacy forecast

Under the assumptions in Scenario B, it is expected that the system will keep the actual level of adequacy throughout the analysed period. Adequacy will be maintained in the short term even under the hypothesis of some 6 GW mothballed units in the year 2016, as long as these units come progressively back into service so that by the year 2025 no units are mothballed. Under these assumptions, national adequacy criteria will be fulfilled in 2025 under severe 1 in 10 temperature conditions. The adequacy power balance in Scenario A could, however, become negative in certain winter months of the year 2025, hence making the system occasionally dependent on energy imports.

Finland



Load and annual demand forecast

Increase in electricity demand during the period is assumed to be moderate. Increased use of electricity for heating (heat pumps) affects demand peak during the heating season and on hot summer days.

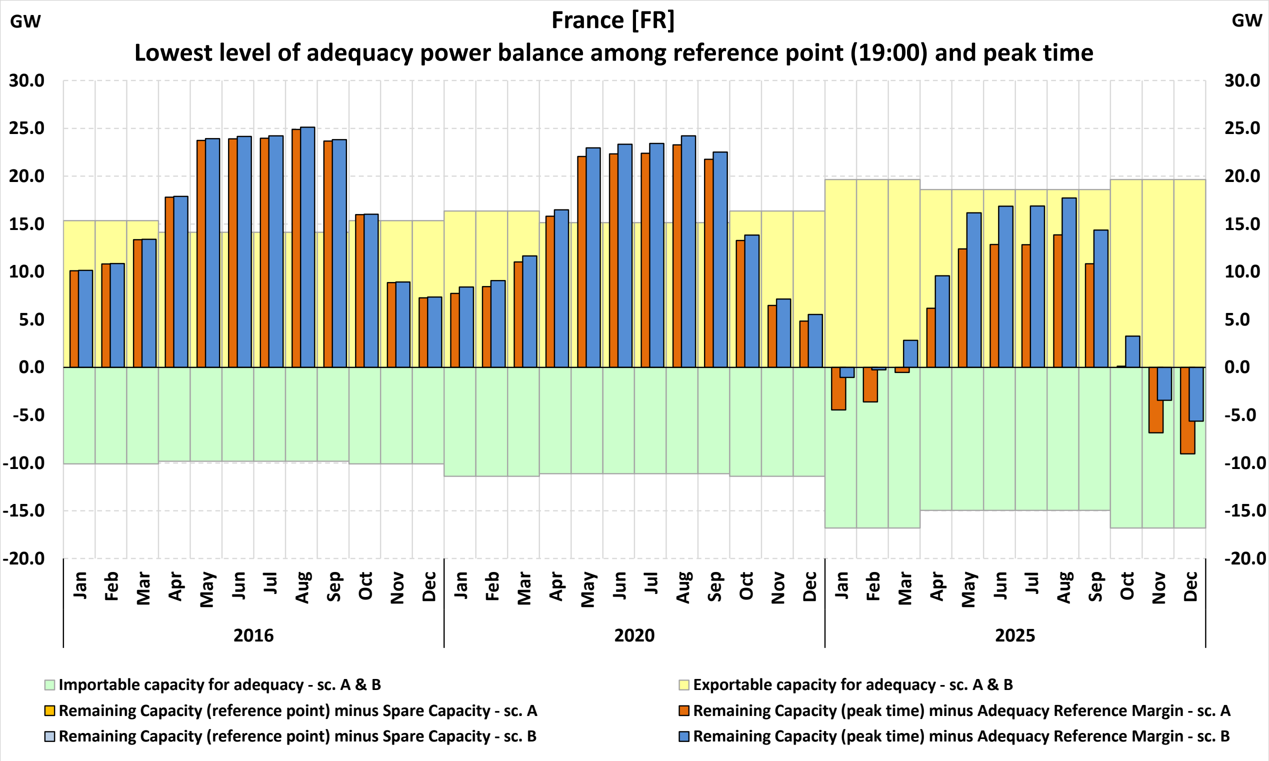
Net Generating Capacity forecast

It is assumed that domestic generation capacity available during peak load will decrease until the Olkiluoto 3 power plant is commissioned.

Generation and System Adequacy forecast

Finland is expected to remain heavily dependent on electricity imports during peak load as well as during most other parts of the year, especially before the Olkiluoto 3 power plant becomes operational. The role of interconnectors to enhance adequacy is therefore vital.

France



Load and annual demand forecast

The load forecasts in both scenarios are based on the highest expected growth in consumption. They consider a favourable evolution of the economic context, and a high evolution of demography. Some energy efficiency measures are taken, but not at the maximum level. Some uses of electricity are developed at a large scale, such as electrical vehicles.

Net Generating Capacity forecast

For generation forecasts, some uncertainties still remain about mothballing of CCGT. Indeed, in a difficult context for this type of generation, some producers have not completely decided their strategy yet for the next five years. Between one and three units could be mothballed in this time frame. Hypotheses in Scenarios A and B consider three mothballed units, which was the actual situation in 2014. On the other hand, a CCGT is currently under construction. The hypothesis is a commissioning at the end of 2016.

Some oil units could be shut down in the next five years, so both scenarios take these closures into account. However, this hypothesis can be considered quite conservative.

Between 2016 and 2020, a nuclear unit should be decommissioned, according to political announcements. On the other hand, a new EPR unit is under construction and will be commissioned in the next few years.

Between 2020 and 2025, some old thermal units will be decommissioned because of their ages.

In Scenarios A and B, hypotheses about nuclear generation in 2025 are consistent with the 2030 projection of Scenario C (“Diversification”) of RTE’s generation adequacy report (edition 2014). Nuclear capacity decreases from 63 GW in 2020 to 56.7 GW in 2025.

A more significant development of renewable energies in Scenario B brings a larger contribution to adequacy than in Scenario A.

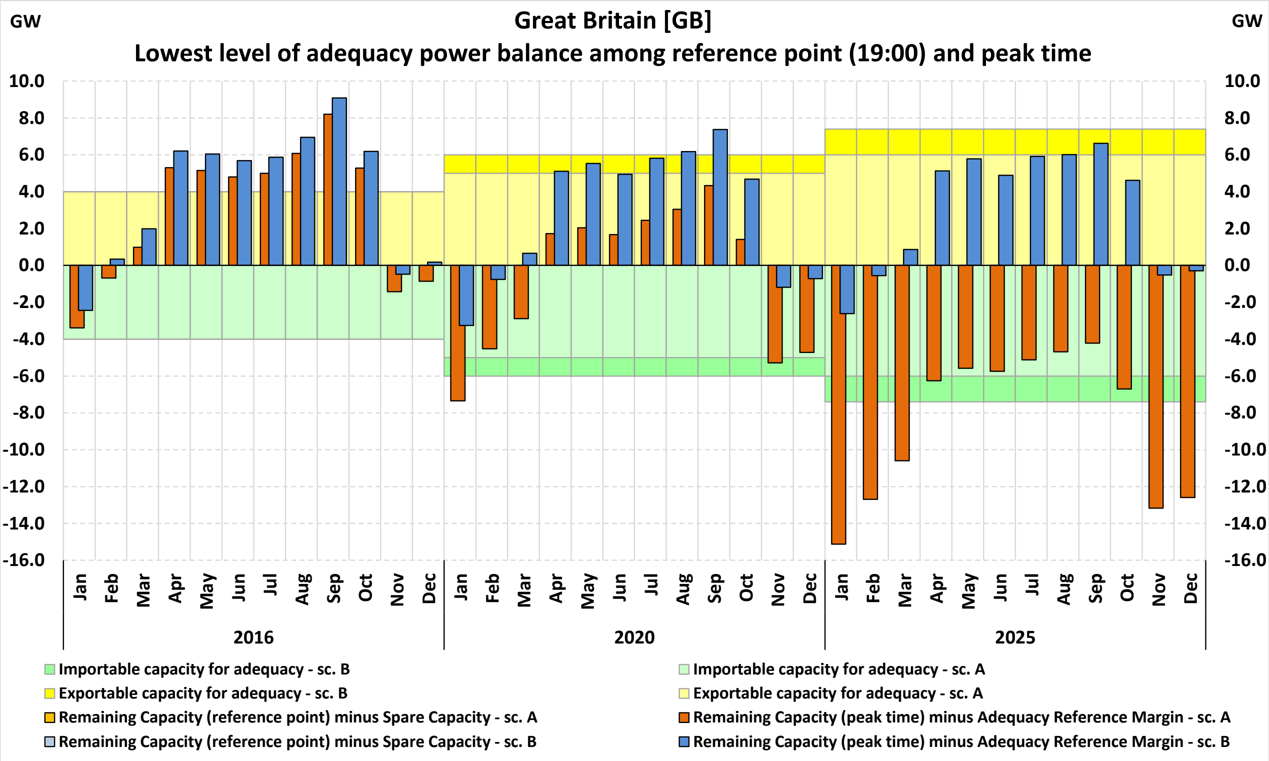
Generation and System Adequacy forecast

Considering the results of both scenarios, security of supply should be guaranteed in years 2016 and 2020, although it could be more fragile between these two dates because of fluctuations in thermal and nuclear capacities. It should also be noted that the capacity margins would be quite lowered by taking into account the sensitivity to temperature.

By 2025, it appears that more imports from other countries could be necessary to keep security of supply in winter. Further analyses, taking into account the risk of low temperatures, could lead to a need for some new capacity in France.

Such complete analyses are carried out by RTE every year, in the annual generation adequacy report[16]. They are performed using a probabilistic and chronological approach with an hourly resolution, at a regional perimeter. France's sensitivity to temperature is taken into account in these studies.

Great Britain



Additional National information

The "Best-Estimate" Scenario B is based on the 2014 Gone Green Scenario developed for GB by National Grid as part of its Future Energy Scenarios, and involves extensive stakeholder engagement. Gone Green has been designed to meet all renewable generation and environmental targets including 15% of all energy from renewable sources by 2020 and an 80% reduction in greenhouse gas emissions by 2050.

The "Conservative" Scenario A is based on the 2014 No Progression Scenario, also developed by National Grid, but only includes new capacity that is already under construction or the project is too far advanced to be cancelled, and should be considered as being a less realistic scenario for GB.

Generation capacity and load data are all for the National Grid transmission system and do not include generation connected to lower voltage distribution networks. The data represent around 85% of the total GB electricity market.

[16] http://www.rte-france.com/en/article/forecast-assessment-electricity-supply-demand-balance

Load and annual demand forecast

There are many different factors driving changes in electricity demand over the next 10 years, but the net effect is a downward trend over this period in both scenarios.

In Scenario B, this is mainly driven by energy efficiency gains in domestic appliances and the move towards low-energy lighting. Further reductions are brought about by an ambitious roll-out of domestic heat pumps to replace inefficient electric resistive heating.

Net Generating Capacity forecast

There is currently around 70 GW of installed generation capacity connected to the National Grid transmission system, which is expected to increase to over 90 GW by 2025 in Scenario B.

- Coal and oil generation declines as power stations close in response to environmental legislation of the large plant combustion directive (LPCD) and the industrial emissions directive (IED)
- Net increase of around 6 GW of gas plant between 2016 and 2025, with around 3 GW expected to be built by 2020
- No CCS plant on gas or coal generating capacity is built before 2020
- In Scenario B, the total onshore and offshore wind capacity is expected to approach 20 GW by 2020 and exceed 35 GW by 2025
- There is no significant development of tidal or wave capacity, nor is there a significant increase in existing hydro or pumped storage capacity.

Unavailable Capacity: For the purposes of this analysis, the system services held by the TSO have been included in the Unavailable Capacity calculation in line with the ENTSO-E method. This is different from the GB capacity adequacy method, which includes these services as being available. The net effect is that the generation adequacy for Scenario B shifts upwards by around 5 GW.

Generation and System Adequacy forecast

In the GB market, the national capacity adequacy standard has been set by the Government at 3 hours/year based on the probabilistic loss of load expectation (LOLE) metric as part of Electricity Market Reform (EMR). In 2013, the UK Government introduced a Capacity Market as part of EMR. Capacity auctions will be held annually from late 2014 for the delivery of capacity from winter 2018/19 onwards. The aim of the Capacity Market is to ensure sufficient investment in the overall level of reliable capacity needed to provide secure electricity supplies in line with the standard of 3 hours/year LOLE.

In winter 2014/15, two contingency balancing services of supplemental balancing reserve (SBR) and demand side balancing reserve (DSBR) were introduced to help ensure that the national adequacy standard is met in the short term. This capacity is held outside of the market by the TSO. These contingency balancing services will also be available in winter 2015/16.

Interconnection Capacity: Scenario B includes an additional 3.4 GW of new interconnection built to/from GB during the analysis period.

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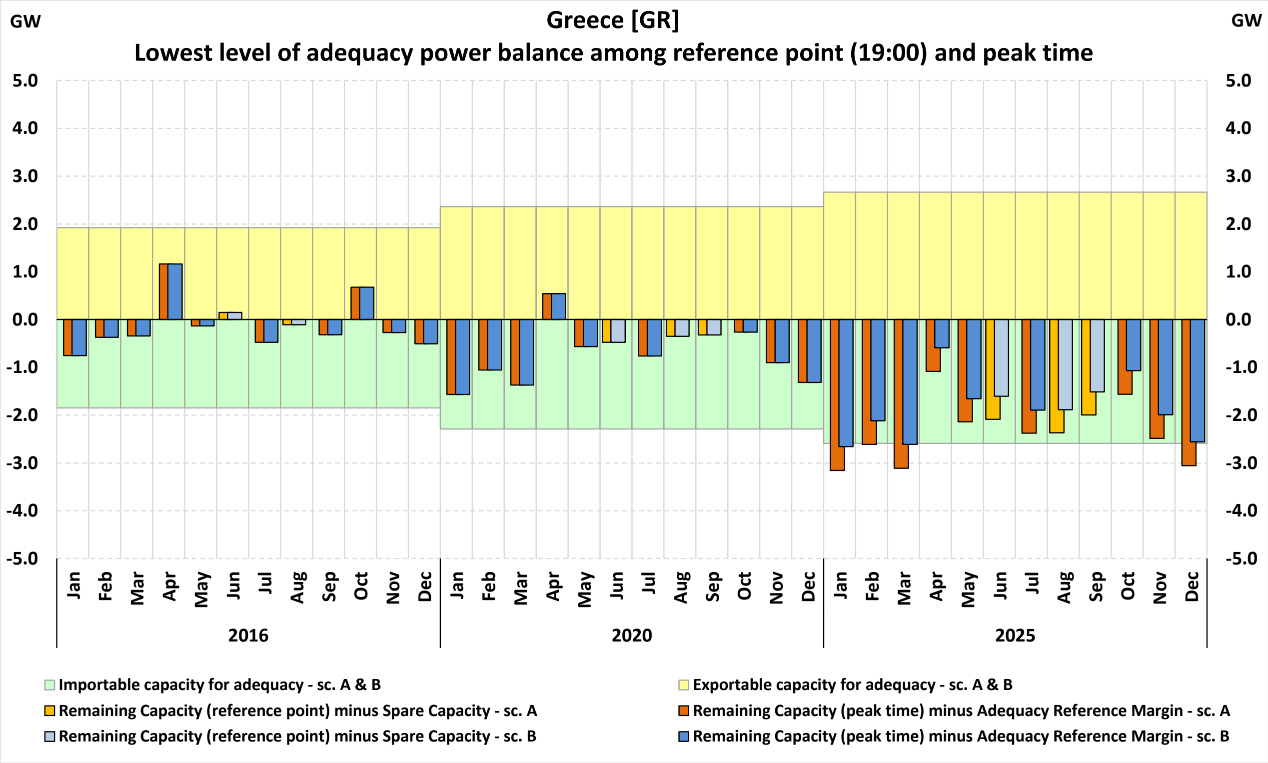
Greece



Additional National information

Long-term adequacy assessment has always been challenging, given the wide range of uncertainties involved, and decentralized planning of projects has made this task even more difficult for TSOs. This is particularly true for the case of Greece, where the prolonged economic crisis and the extensive uncertainties regarding the future of the country have led to behavioural changes of the consumers and private business decisions postponed. IPTO (Independent Power Transmission Operator of Greece) believes strongly that any forecasts beyond the year 2020 are highly unreliable and therefore focus is given to the period up to the year 2020. Values (loads and NGC) for the year 2025 are solely indicative.

All data provided by IPTO refer solely to the system of the mainland and the islands that are interconnected to it. For the construction of all scenarios, it is considered that in the year 2017 the Cyclades Islands will be interconnected to the system of the mainland, while the island of Crete will be interconnected in the year 2021.

Load and annual demand forecast

Because of the prolonged economic crisis, the growth rate of the electricity demand in Greece has decreased considerably compared with previous years. The total electricity demand in 2014 amounted to the levels that were observed in 2003. It is expected that electricity demand will slowly start to increase again, reaching pre-crisis maximum demand (observed in 2008) after the year 2020.

Load forecasts provided for Scenarios A and B are obtained from the ‘High’ development scenario of the latest national TYNDP, complying with the guidelines for SO&AF. It should be noted that these loads refer to the total demand (loads at the transmission level, as well as dispersed generation from RES at the distribution level) for the mainland and the interconnected islands.

Net Generating Capacity forecast

Because of the prolonged economic crisis and the limited funding of projects through banks, the main factor in Net Generating Capacity evolution for the period 2016–2025 appears to be the decommissioning of old lignite-fired units and the increase of RES capacity.

As already mentioned, data provided in SO&AF 2015–2025 focus on the period up to the year 2020, because any predictions beyond that seem to be highly risky. With this in mind, only the projects that are under construction, or have already been contracted are assumed in the construction of Scenarios A and B, even though several new plants have obtained generation licenses. Confirmed projects include an 810 MW CCGT plant in Megalopoli (which is expected to be operational in 2016) and a new lignite-fired plant of 620 MW in Ptolemaida (expected in 2019), as well as a couple of new hydro storage plants. Despite the uncertainties regarding the economic situation of the country, it is believed that the signals given by IPTO adequacy studies and ENTSO-E SO&AF will lead to the realization of viable business decisions for new projects after the year 2020.

In compliance with national legislation and IED 2010/75/EE, PPC (Public Power Corporation) has announced a large-scale decommissioning schedule. Old inefficient units (mainly oil and lignite units) are to be decommissioned by 2016, while 1656 MW of lignite units have been included in the limited operation regime. It has not been made public how PPC intends to operate these units during the transitional period of 2016–2023, however, for the purposes of SO&AF 2015–2025 it is assumed that they will be retired in 2019 (worst case scenario).

Considering renewable energy sources, and in view of achieving nationally set targets for 2020, new legislation has given strong motivation for the installation of RES, as well as simplifying licensing procedures. Many RES projects have been announced by investors. Scenario A assumes that a small portion of these will be realized, while in Scenario B it is assumed that a large portion of these will be realized (including RES projects on islands that will be interconnected in the time frame examined).

Generation and System Adequacy forecast

Increased RES penetration, namely photovoltaics, in the Greek generation system, as well as shift of consumers to electricity for heating has altered significantly the load patterns observed in the past. Adequacy concerns in the past were always concentrated on the peak loads during midday in the summer months. The last couple of years have shown that, while the total peak loads still occur in those hours because of the operation of the photovoltaics (over 2.5 GW), peak loads faced by the transmission system now appear during evening hours and annual peaks are shifted to the winter months.

From the analysis, it appears that Greece may need to rely on some imports when facing peak loads or extreme cases during evening hours, even from the year 2016. These needs increase significantly from 2020, raising concerns about system adequacy, if no other thermal plants (beyond the ones considered) are introduced to the system. It is crucial to take into consideration that no new thermal plants are considered in Scenarios A and B after the year 2020. This is apparently the worst case scenario; however, it is highly unlikely because, despite the uncertainties regarding the economic situation of the country, the signals of adequacy concerns after the year 2020 should lead to viable projects in the future.

It should be noted that the results are based on the ‘High load evolution’ scenario, according to the SO&AF guidelines. IPTO adequacy studies have shown that when considering lower load forecasts (Baseline scenario), adequacy results are not so alarming. IPTO analysis has also shown that maintaining the lignite units included in the limited operation regime in operation for three months per year until the end of 2023 (instead of retiring them in 2019) has a very positive effect on adequacy indicators. In addition, available historical data suggest a lower non-usable capacity for photovoltaics during midday summer peak hours (compared with the PECD), which shows that some energy should be exportable during those hours, even in extreme cases, until the year 2020.

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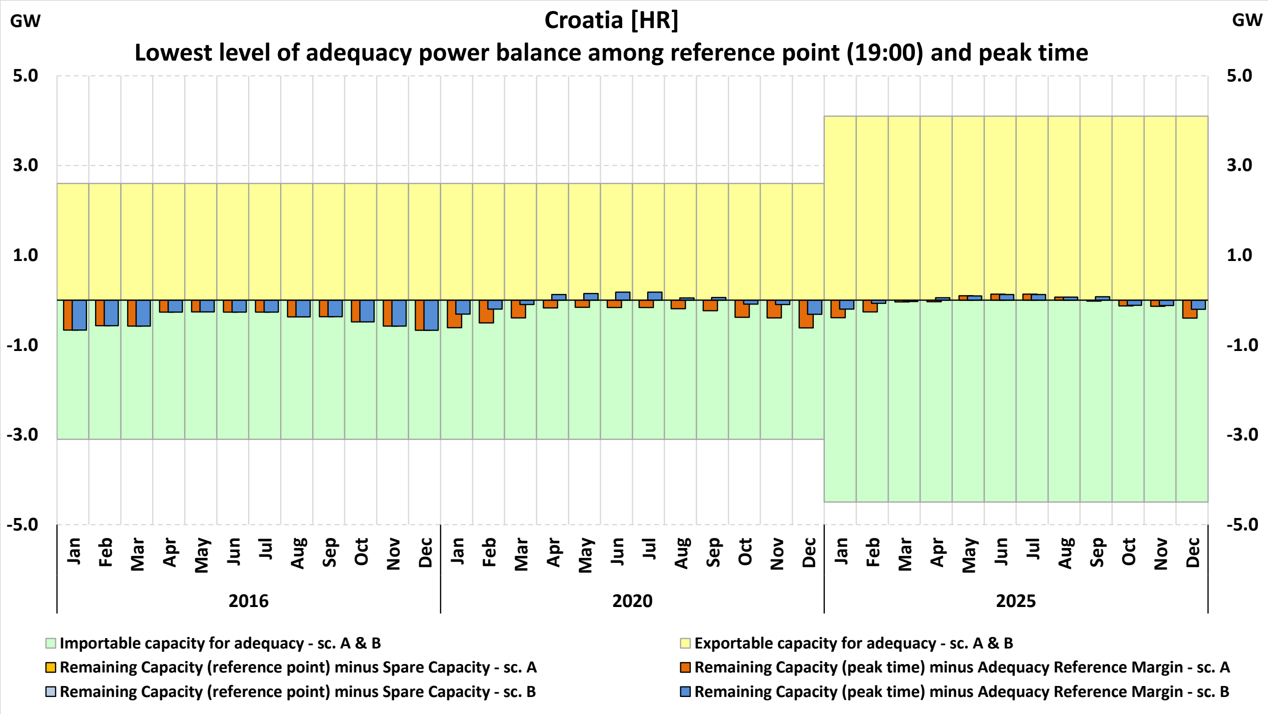
Croatia



Load and annual demand forecast

Because of the economic crisis in the last five years, electricity consumption in Croatia was about 18 TWh per year. In the next five to ten year period we expect a recovery of the economy and a moderate growth of electricity consumption in Croatia.

The load forecast has been obtained taking into account medium and long term projections of the economic growth rate. Growth of the load depends directly on the industry development and growth of household consumption. Investments in energy efficiency are expected and that will slightly slow the growth of electricity consumption.

Net Generating Capacity forecast

In accordance with the currently installed RES generating capacities, the full realization of the objectives of the National Renewable Energy Action Plan is expected in terms of installed capacity and generated electricity by 2020.

There is great interest from investors in building thermal power plants in Croatia, but most of the projects are currently in the initial phase. Decommissioning is planned for a certain number of thermal units, which depends largely on the requirements relating to environmental (air) protection. The total installed capacity of TPP till 2020 and 2025 is predicted optimistically.

Generation and System Adequacy forecast

At the moment, Croatia is dependent on imports of electricity during the whole year, which is especially noticeable during the winter months. The capacity of interconnections to neighbouring countries is high, so Croatia can always import sufficient electricity to cover domestic needs.

In the future, an increased construction of power plants is expected, which will reduce dependence on imported electricity. However, in the coming decade, Croatia will depend on the import of electricity, especially during the winter months.

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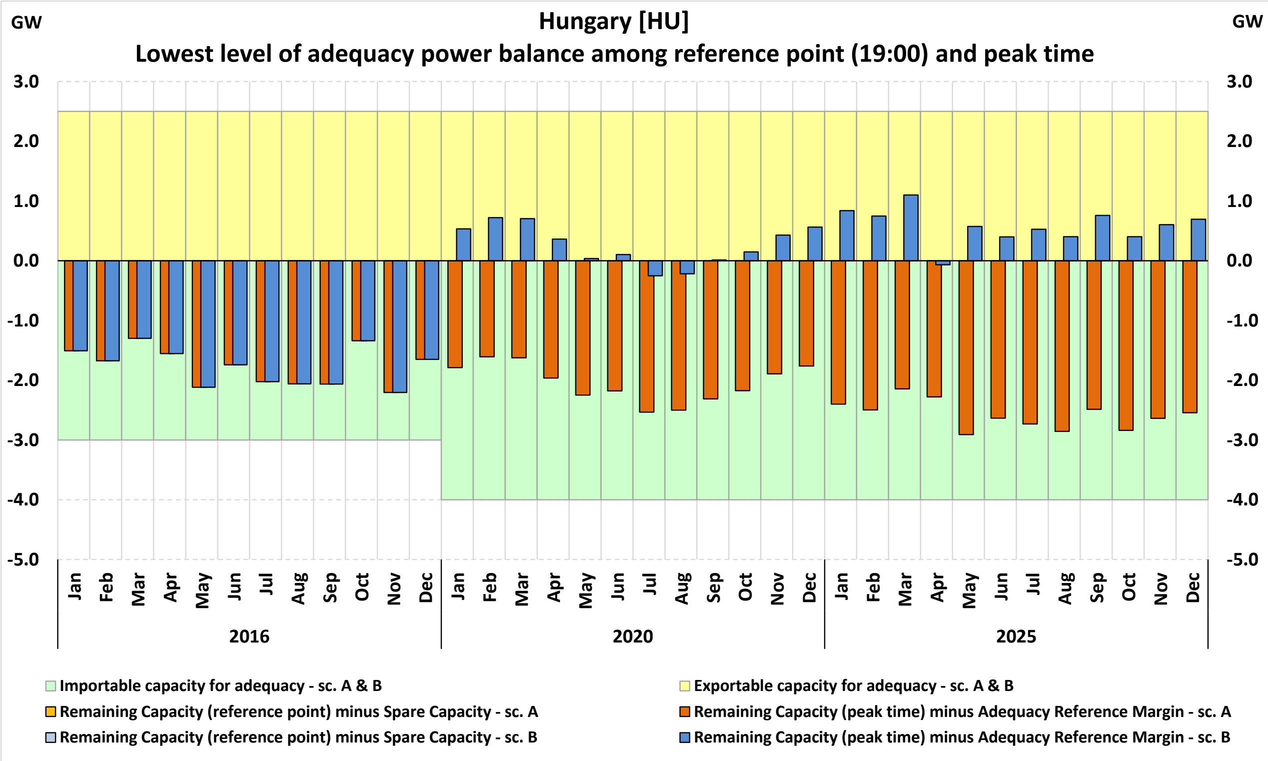
Hungary



Load and annual demand forecast

Load forecasts are based on the short-term capacity plan (2016) and on the mid- and long-term generation adequacy forecast report, where a moderate increase in demand was assumed based on projections of economic growth.

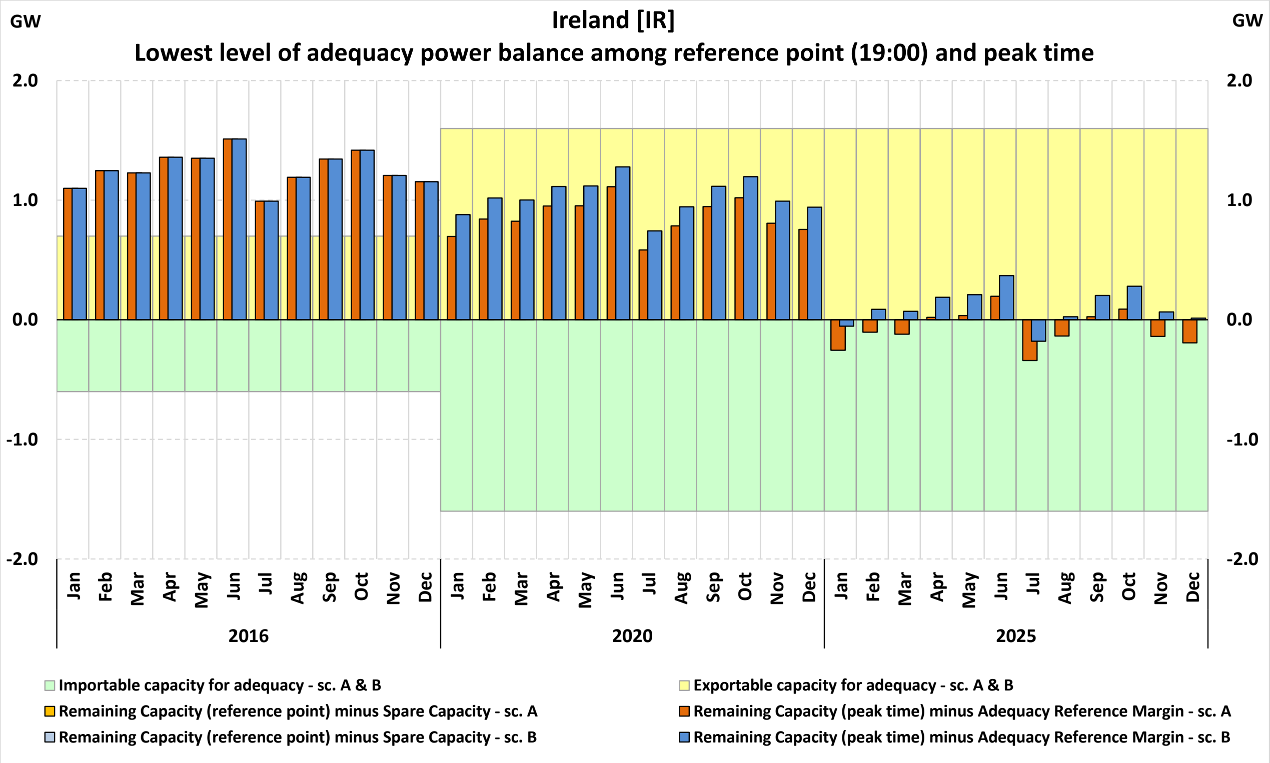
Net Generating Capacity forecast

In cases of large power plants, information on capacity additions and withdrawals were obtained from the annual forecasts provided by power generation companies according to Grid Code provisions. In addition, grid connection requests were considered. While new units are planned at Paks Nuclear Power Plant to be commissioned in the mid-2020s, all large CCGT projects are delayed or cancelled because of the present unfavourable market framework conditions. The National Renewable Energy Action Plan (NREAP, under revision) was taken into account for assumptions on RES generating capacity. Parallel to the revision of NREAP, a national action plan for power plant development is under elaboration on the basis of the National Energy Strategy adopted in 2011.

Generation and System Adequacy forecast

At present, the remaining capacity without imports is negative for Hungary at most reference points, as highlighted by the last edition of the YS&AR report. When considering firm capacity additions only (in Scenario A), this trend is expected to continue. In Scenario B, some of the announced but delayed CCGT projects were considered in order to reduce import dependency.

The Republic of Ireland



Load and annual demand forecast

After some years of economic recession and the corresponding drop in electricity demand, there are indications of demand increasing again, particularly with the growing data centre sector. Demand is forecast with regard to the most likely projections of economic growth. The same forecast is used for Scenarios A and B.

The sensitivity of load to temperature variations is not an appreciable factor in summer. However, the extreme winter of 2010 showed the load peaking significantly. Load forecasts are made for Average Cold Spell conditions.

Net Generating Capacity forecast

The demand and plant assumptions used in Scenario B are the same as in the Base Case Scenario in EirGrid's Generation Capacity Statement (GCS) 2015–2024, published February 2015[17]. For Scenario A, there is slightly less new conventional plant, and less RES.

As in the GCS, we assume for the SO&AF that some older plant will reach the end of its life over the course of the years studied. The amount of demand side management is increasing, with over 160 MW now available, and increasing. This helps to improve our adequacy position.

Generation and System Adequacy forecast

As can be seen in the figure above, the Power Balance at Peak demand ('RC-ARM') is positive for most of the years studied.

Currently, there is a Capacity Payment Mechanism in the Single Electricity Market in Ireland and Northern Ireland that has successfully ensured that there is sufficient capacity in the market. The outlook presented in

[17] http://www.eirgrid.com/media/Eirgrid_Generation_Capacity_Statement_2015.-2024.pdf

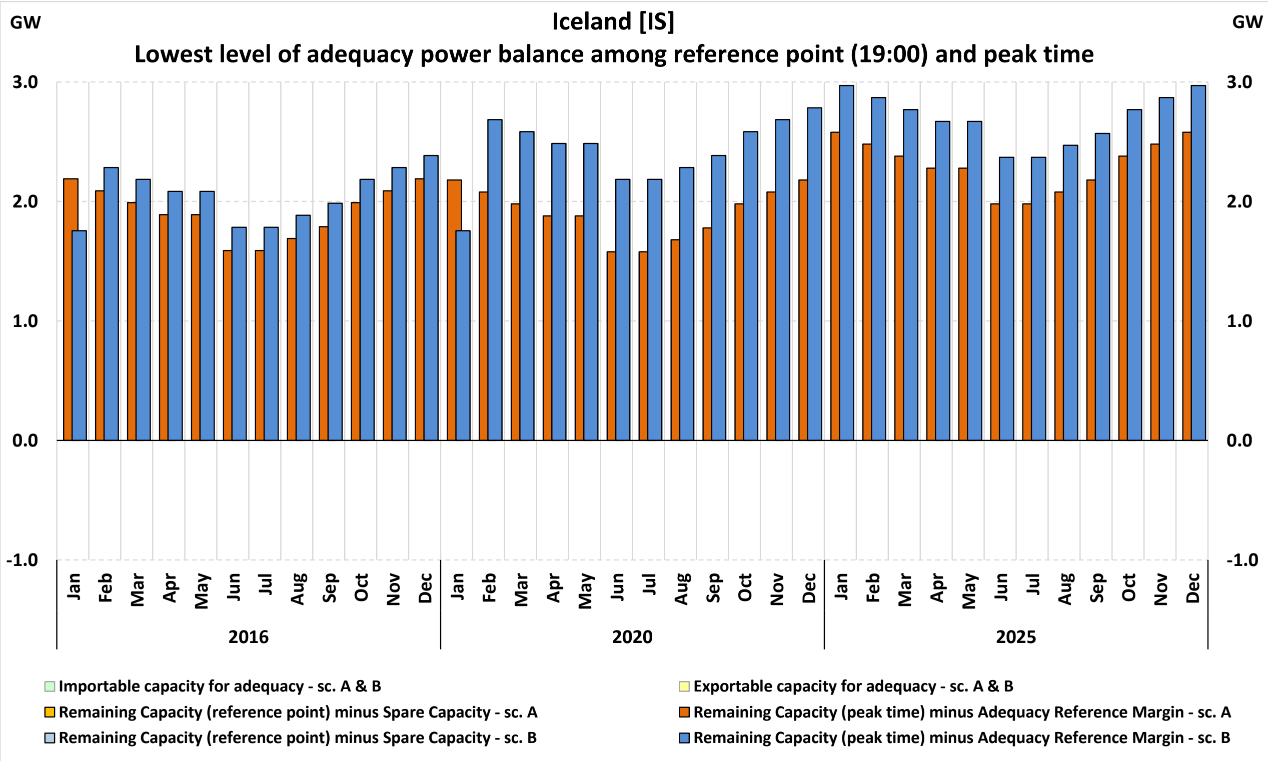
this SO&AF report is predicated on the assumption that there will be an effective capacity remuneration mechanism in place in the future.

This is especially so with the increasing amount of RES, whose intermittency highlights the need for flexibility in the rest of the generation portfolio.

This need for flexibility is being addressed by EirGrid with their DS3 program (Delivering a Secure Sustainable Electricity System), which aims to reward generators for the provision of system services, such as voltage support and RoCoF (Rate of Change of Frequency) services.

Interconnection is an important factor in maintaining adequacy, and we need to keep in constant review the availability of plant in Great Britain. The recent capacity auctions and demand side measures in Great Britain serve to strengthen their ability to provide assistance if needed over the two undersea interconnectors to Ireland and Northern Ireland.

Iceland



Load and annual demand forecast

The electricity consumption in Iceland at present is about 18 TWh per year, with a maximum load of approximately 2200 MW. Power intensive industry accounts for 80% of the load, which is expected to grow slowly in the coming years. Traditionally, connection of a large customer has been followed by connection of a new power plant. This may be changing. The domestic load growth is approximately 1.7% per year.

Net Generating Capacity forecast

At present, the installed generating capacity is around 2500 MW. The generating capacity is entirely RES: 75% hydro power and 25% geothermal power. There is an increasing interest in wind power and most likely some wind power plants will be erected in the next 10 years, capable of generating some 10s of MW.

The most likely increase will be in geothermal power. At present, the first phase of a new geothermal plant is under construction, which will provide 45 MW.

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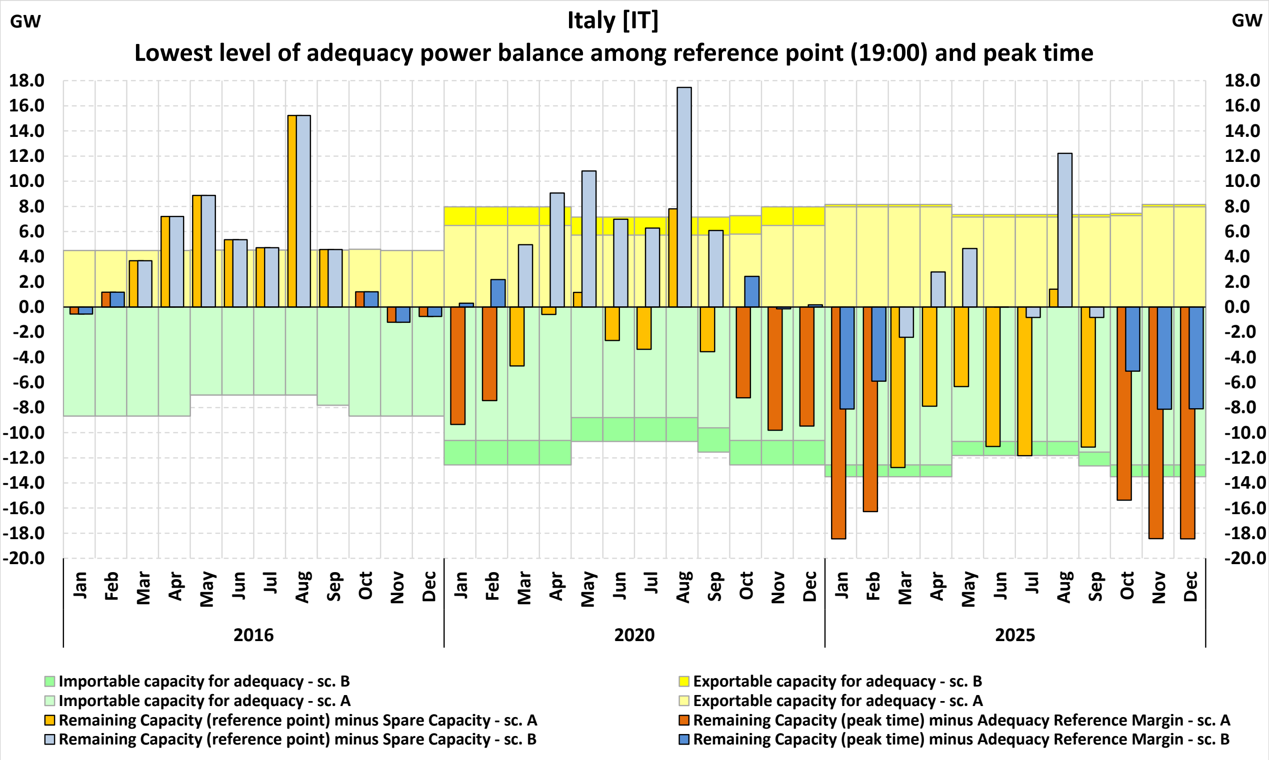
Generation and System Adequacy forecast

The Icelandic system is a stand-alone system, i.e. not connected to any other power system. Some work has been done on studying the feasibility of a sub-sea link to the UK. However, no concrete plans have been made. Nevertheless, the link is in the TYNDP 2016 of ENTSO-E.

It is the Icelandic TSO's responsibility to ensure the adequacy of the system. It is expected that increased consumption will be complemented by corresponding generation.

Italy



Load and annual demand forecast

In the next decade, the electricity demand will be affected by a moderate recovery, according to the latest issue of forecasts. In line with Terna's developing scenario, demand in Italy is expected to increase by about 1% CAGR, after the reduction experienced in the last three years.

Since 2010, the maximum annual peak load in Italy firmly occurs in summer, decreasing in size in the last three years. Moderate growth of the peak load, also because of recovery in electricity demand, has been forecast in the next decade, following our developing scenario. Differences between daily hour of the expected monthly peak load and the reference point (19:00) have emerged, particularly in summer, when Italian peak load is expected to take place in the late mornings.

Net Generating Capacity forecast

In Italy, during the last two/three years, the available conventional generation capacity decreased because of the mothballing of a large number of power plants, mostly old oil-fired power plants, but also some recent combined cycle.

In fact, several power plant operators decided to reduce their generation capacity in order to reduce cost, because of:

- increasing penetration of RES-E;
- uncertainty about demand evolution;

– lack of efficient long-term signals for investment.

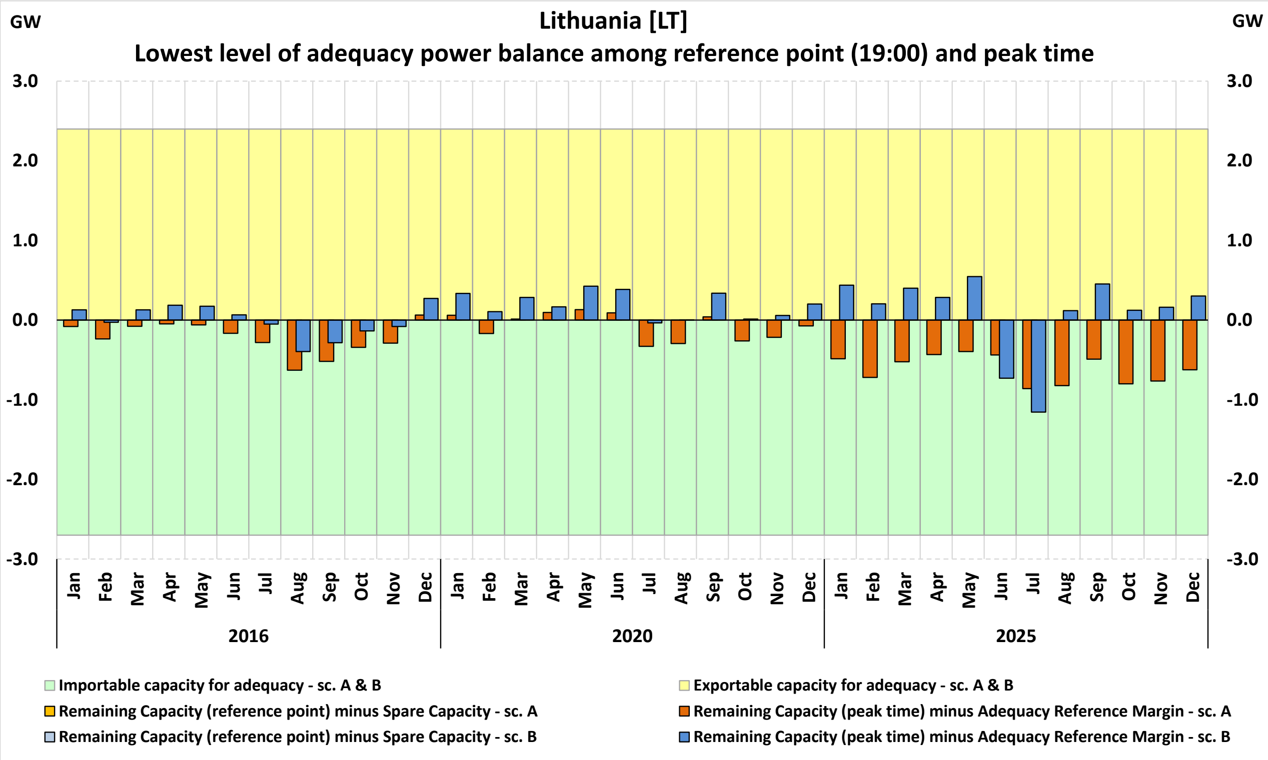
For the next horizon, from 2016 until 2020 and 2025, this reduction of the available capacity in Italy is expected to continue while, on the other side, commissioning of conventional new power plants is not expected.

The new capacity remuneration mechanism under development in Italy could reverse this trend.

Generation and System Adequacy forecast

Because of the decrease in the net available generating capacity, there might be risks of reduction of adequacy margins for the coming years, at the peak time, even showing negative margins in particular conditions as from 2025 on the best estimate scenario (Scenario B), or from 2020 on the conservative scenario (Scenario A).

Lithuania



Load and annual demand forecast

Since 2008, Lithuanian electricity consumption has been low because of the financial crisis, as electricity consumption is closely linked to economic activity. However, now there are indications of demand increase.

Annual demand is forecast with regard to the most likely projections of economic growth. The load forecasts in both scenarios are based on the same growth level of consumption. The growth is expected to be faster until 2020 and slower in later years. Some energy efficiency measures are taken into account.

Net Generating Capacity forecast

The generating capacity forecast was prepared in accordance with producers' information, received during the annual inquiry and the targets, set in National Energy Independence Strategy of the Republic of Lithuania. RES development is obtained by using information from National Renewable Energy Action Plan (NREAP) and the Law on Renewable Energy and other laws governing the development of RES.

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Following the definition of Scenario A, no additional fossil fuel generating capacities were taken into consideration. RES development is in accordance of Renewable Energy Law.

For Scenario B, a few new power units are assumed: the new Visaginas nuclear power plant (construction is set in National Energy Independence Strategy), a new fifth unit in the pump storage power plant and a few new biofuel units, replacing old mixed fuel units.

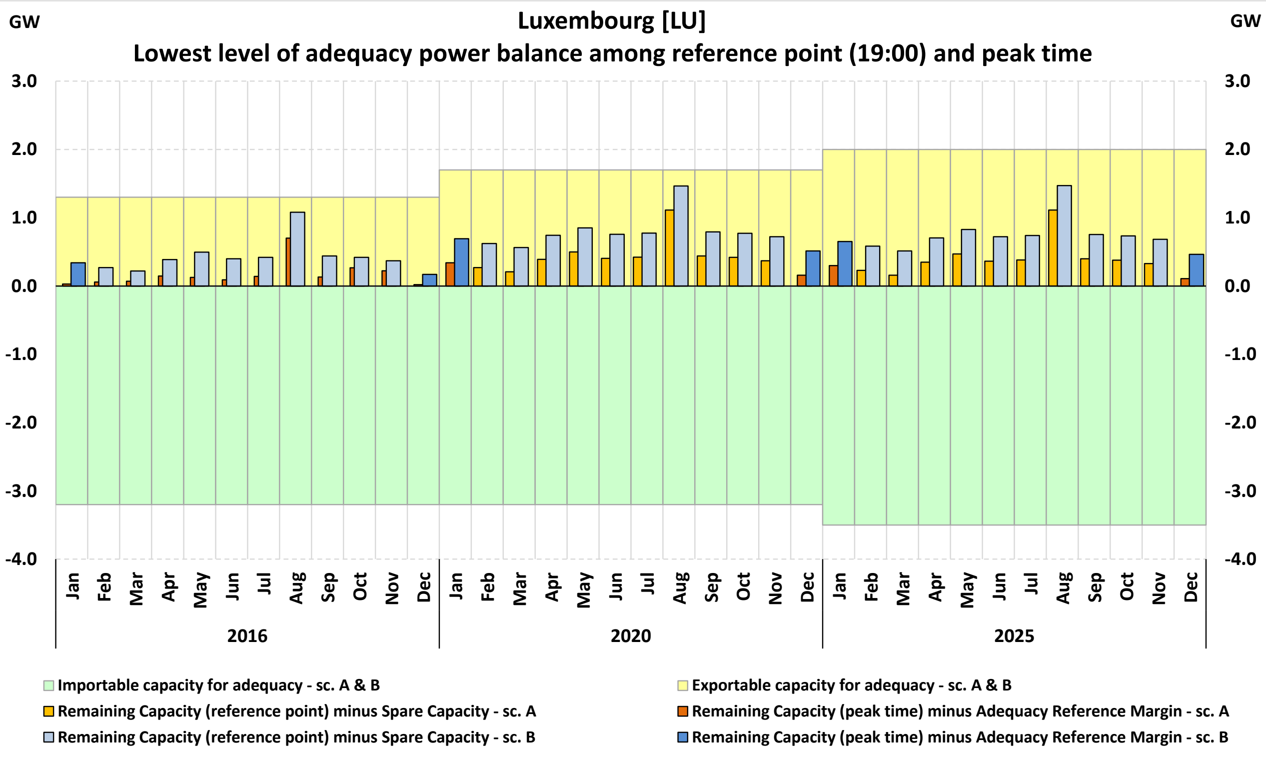
Decommissioning of old units evaluated in Scenarios A and B is based on information provided by generating companies (annual survey performed).

Generation and System Adequacy forecast

Most of the time, Lithuania does not fulfil adequacy criteria for Scenario A. In 2016 and 2025, for almost the whole year remaining capacity is negative and Lithuania will rely on energy import. For Scenario B, because of development of generating sources (replacement of old units by new, more efficient units), the situation in the system will be slightly better.

Despite the lack of generating capacity, from 2016 Lithuania will have new interconnections with Sweden and Poland (700 MW and 500 MW, respectively). These connections will ensure the technical possibility of importing the shortfall in capacity.

Luxembourg



Load and annual demand forecast

After some years of economic stagnation and the corresponding flattening in electricity demand, there are indications of demand increase. Demand is forecast with regard to the most likely projections of economic growth on an annual growth of 1.1% according to a GDP scenario STATEC called the "base scenario". The same forecast is used for Scenarios A and B.

The sensitivity of load to temperature variations is not an appreciable factor in Luxembourg. Load forecasts are made for Average Cold Spell conditions.

Net Generating Capacity forecast

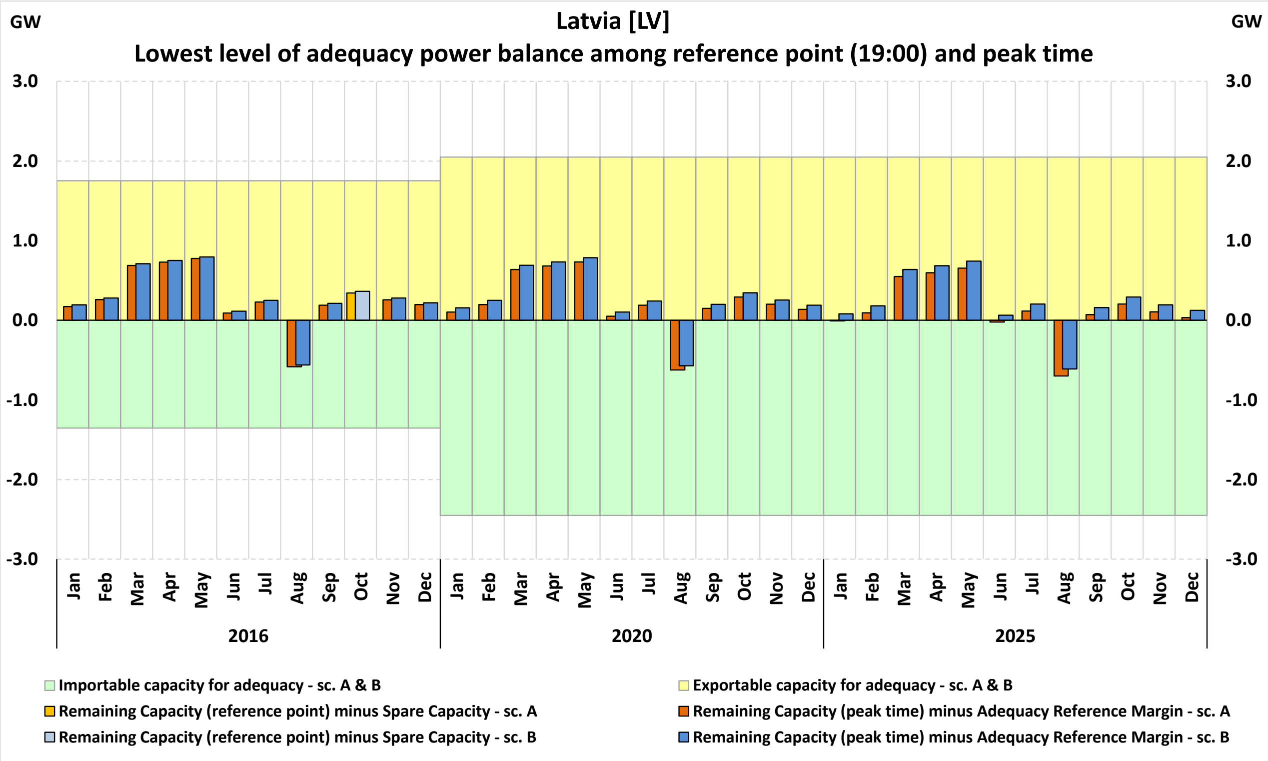
The plant assumptions used in Scenario A consider the announced mothballing of a CCGT by October 2015, still available for strategic reserve until 2025. In Scenario B, the CCGT is available for strategic reserve in 2016, but considered being decommissioned in 2020 and 2025. A new interconnection between Belgium and Luxembourg will be in operation in 2016.

Generation and System Adequacy forecast

Although the Net Generating Capacity installed on the Luxembourg territory exceeds the load expectation, the capacities of the two major power plants do not directly contribute to the adequacy of Luxembourg but of the whole region.

Because of the specific situation of the generation and demand of Luxembourg, the Power Balance at Peak demand ('RC-ARM') is positive. Luxembourg's generation capacity is specific because of the fact that the main production units located in Luxembourg are injecting into the grid of the neighbouring countries Germany and Belgium, and thus make an important contribution to the security of supply in the region.

Latvia



Load and annual demand forecast

It is expected that the National load is going to increase by around 1.5–2% annually in both scenarios and the peak load is equal in both scenarios. The maximum peak load is forecast in January at around 1.42 MW in 2016 and 1.71 MW in 2025. The expected consumption/demand can vary among scenarios from 7.8 TWh in 2016 in the Conservative Scenario to 8 TWh in 2016 in the Best Estimate Scenario. In 2025 the consumption gap could be higher; it is foreseen as 8.2 TWh in the Conservative Scenario and 9.2 TWh in the Best Estimate Scenario.

Net Generating Capacity forecast

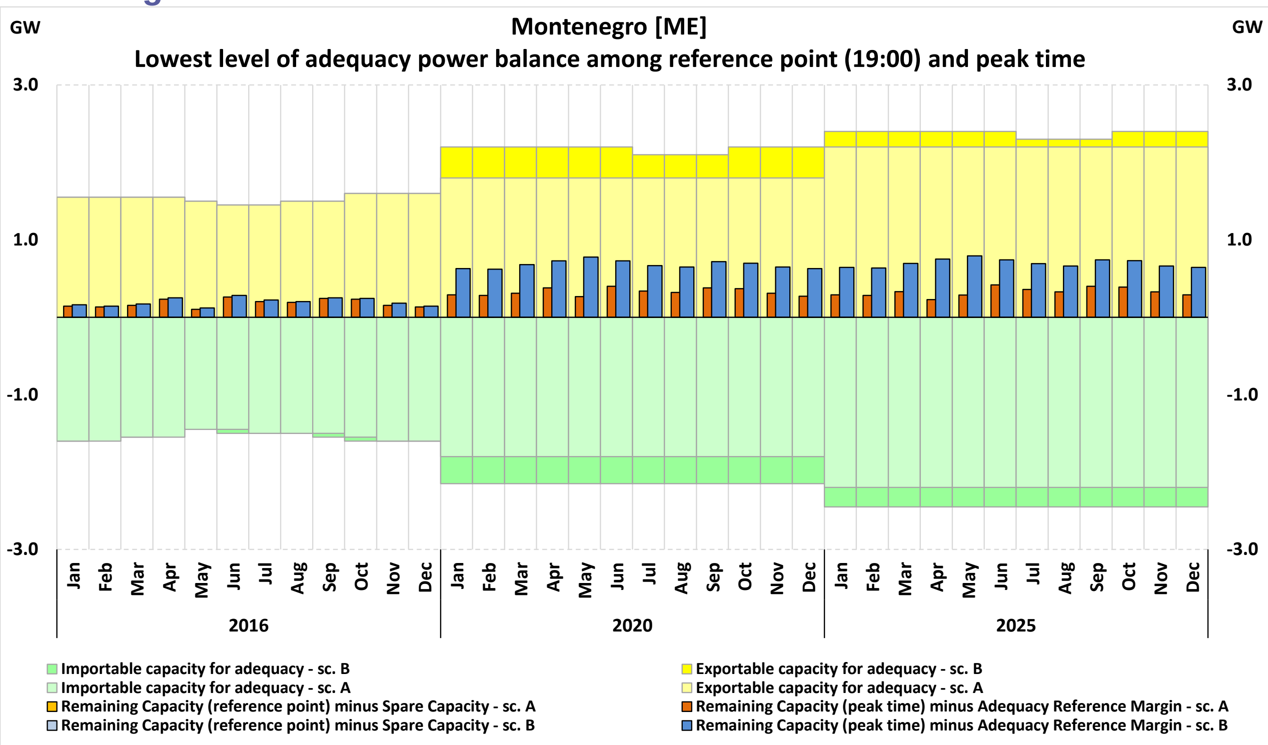
The base load is covered by two main CHPs in Riga (Rigas CHP1 and Rigas CHP2) with installed capacity of 1.025 GW. There are no plans for an increase in capacity of these power plants. The hydro power plants

(Rigas HPP, Kegums 1 & 2 HPP and Plavinas HPP) on the Daugava River are used to cover peak demand during peak hours, and water inflow is the main limiting factor for operation of the Daugava cascade. Hydro units will have a slight increase in capacity because of refurbishment of hydro turbine and generator and resulting increase in efficiency. The increase in capacity because of efficiency reasons is from 1.575 GW in 2016 to 1.591 GW in 2025. The increase of small gas CHPs distributed within the territory of Latvia is expected from 130 MW to 150 MW, depending upon the scenario. The highest increase in generation capacities is expected in Wind and Biomass/Biogas fields. Currently, Latvia has around 80 MW of wind installed, which is going to increase to around 500 MW in 2025 in the Conservative Scenario and 640 MW in the Best Estimate in 2025. In wind generation is included on-shore and off-shore wind plants, whose developments depend on the scenario. The Biomass/Biogas generation type dominates for the coming years and Latvian TSO is expecting that Biomass/Biogas generation will reach 130–190 MW, depending on the scenario. The generation of solar is very insignificant and does not influence the generation pattern at all.

Generation and System Adequacy forecast

The Latvian TSO expects that we can cover a peak load till 2025 almost all of the time in case of adequacy issues. Today, the liberal electricity market shows that it is beneficial to import energy from neighbouring countries as well as run our own generation units, but in the case of a need to cover the balance by ourselves the Latvian TSO can rely on national generation, for instance gas CHPs (Riga CHP1 and Riga CHP2, distributed gas CHPs within the area of Latvia), hydro (cascade on the Daugava River) and distributed Biogas/Biomass within the area of Latvia.

Montenegro



Load and annual demand forecast

According to the “Energy Development Strategy”, electricity consumption forecast in Montenegro will highly depend on aluminium and steel industry power demand forecast, which is significantly decreased in the period of the financial crisis.

The electricity consumption forecast is based on the national highest estimations of energy consumption growth until 2025, along with efficiency measures according to the Energy Development Strategy. The hourly projected load pattern at the reference time is based on historical data.

Net Generating Capacity forecast

Generation expansion planning is based on the National Energy Strategy Development of Montenegro until 2030.

NGC is expected to increase. There are plans for several new hydro and thermal power plants. An increase of capacity from renewable sources is also expected from 2020, primarily from wind and hydro. The trend of construction of renewable energy sources will continue in 2025. Remaining Capacity is positive in all years.

Scenarios for the development and construction of new power plants are under the assumptions in the National Energy Strategy Development and the new long-term development plans have not yet been produced during preparation of this report.

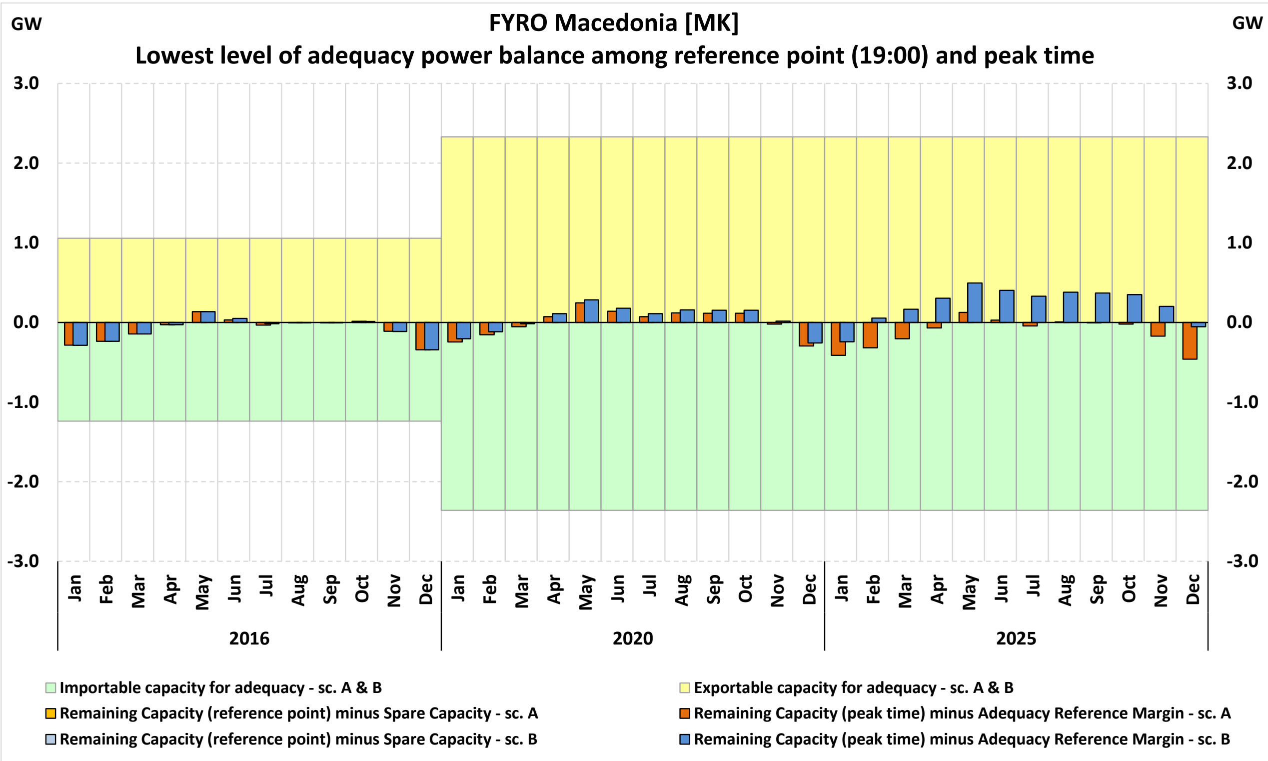
Generation and System Adequacy forecast

For the considered period, transmission in Montenegro fulfils the criteria of adequacy. The Simultaneous Import and Export Capacities are assumed to be the maximum Net Transfer Capacity (NTC). This could not be possible without the new interconnection lines. Montenegro will be interconnected with Italy by HVDC undersea cable and also with foreseen projects of 400 kV interconnections to neighbouring countries.

The new interconnections would increase security of supply and also capacities for transit and across border market.

If the future development of the transmission network follows the defined plans in a reliable and secure way, the Montenegrin Transmission Network will meet the needs of producers and consumers of electricity.

FYRO Macedonia



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Load and annual demand forecast

Projected load that is taken into account in this report is according to the latest updated MEPSOs forecast plans. New annual demand forecasts are according to the projection of the expected GDP growth for the coming years and the assumption that after 2014 the economy will start to recover from the impact of the crisis.

Net Generating Capacity forecast

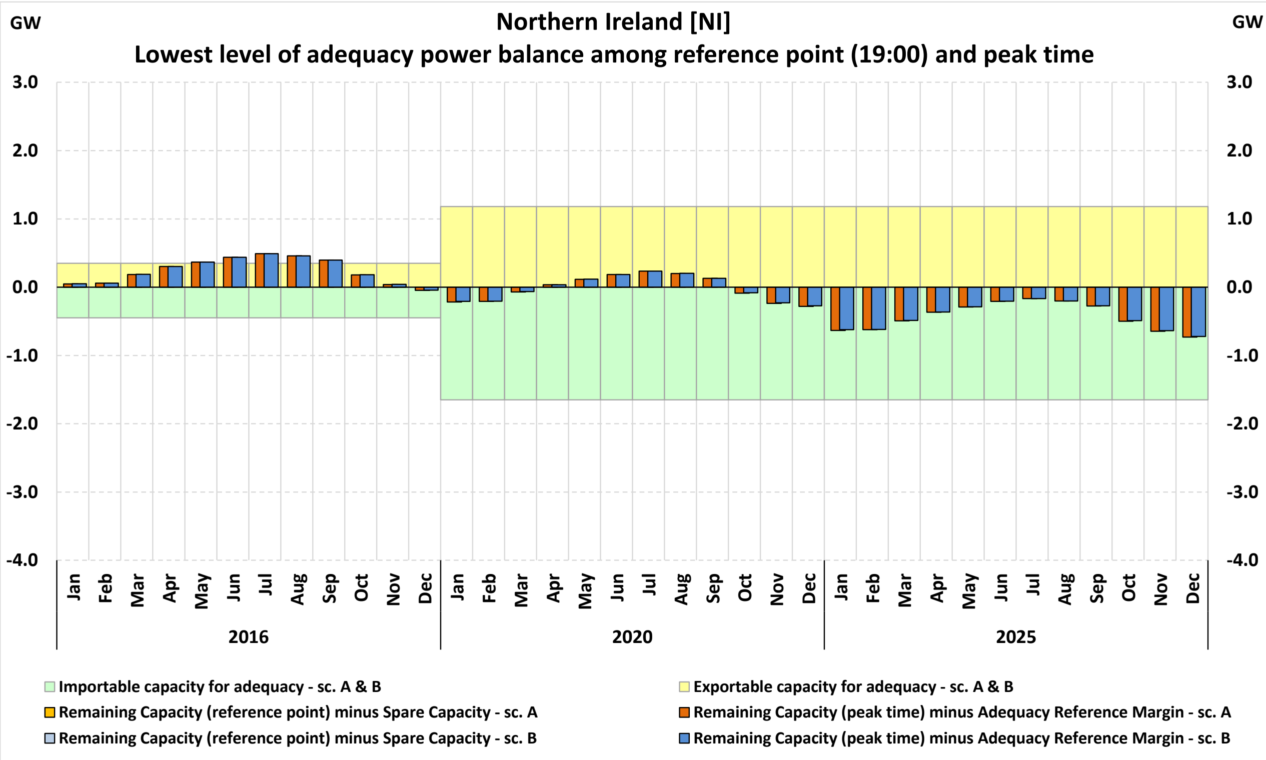
During the preparation of this report, Macedonia has not yet officially released the Strategy for Energy Development of the Republic of Macedonia (2015–2035). Scenarios for the development and construction of new power plants are under the assumptions in the Strategy for use of RES in the Republic of Macedonia until 2020 and the last development plans according to our production company.

Generation and System Adequacy forecast

For the considered period, production only partially fulfils the adequacy criteria. In 2016, almost the whole year remaining capacity is negative and Macedonia will import energy. However, in 2020 and 2025, because of the increased number of installed production units, production adequacy is satisfied throughout the year, except during the winter months when the load is higher.

For the considered period, the transmission network fulfils the criteria of adequacy. If the development of transmission networks follows the defined plans in a reliable and secure way, the Macedonian Transmission Network can meet the needs of producers and consumers of electricity. The cross-border transmission capabilities of the Republic of Macedonia are such that they can support all import or export electricity transactions into/out of the Republic of Macedonia, while allowing unimpeded transit of electricity across the region.

Northern Ireland



Load and annual demand forecast

After some years of economic recession and the corresponding drop in electricity demand, there are indications of demand increase. Demand is forecast with regard to the most likely projections of economic growth. The same forecast is used for Scenarios A and B.

The sensitivity of load to temperature variations is not an appreciable factor in summer. However, the extreme winter of 2010 showed the load peaking significantly. Load forecasts are made for Average Cold Spell conditions.

Net Generating Capacity forecast

The demand and plant assumptions used in Scenario B are the same as in the Base Case Scenario in the All-Island Generation Capacity Statement (GCS) 2015–2024, published February 2015[18]. For Scenario A, there are slightly less RES.

As in the GCS, we assume for the SO&AF that some older plant will reach the end of its life over the course of the years studied.

Generation and System Adequacy forecast

As can be seen in the figure above, the Power Balance at Peak demand ('RC-ARM') is positive for 2016. However, the adequacy position turns into a deficit in 2020 and 2025 without increased interconnection or generation capacity.
Currently, there is a Capacity Payment Mechanism in the Single Electricity Market in Ireland and Northern Ireland. The outlook presented in this SO&AF report is predicated on the assumption that there will be an effective capacity remuneration mechanism in place in the future.

This is especially so with the increasing amount of RES, whose intermittency highlights the need for flexibility in the rest of the generation portfolio.

This need for flexibility is being addressed by SONI and EirGrid with their DS3 program (Delivering a Secure Sustainable Electricity System), which aims to reward generators for the provision of system services, such as voltage support and RoCoF (Rate of Change of Frequency) services.

Interconnection is an important factor in maintaining adequacy, and we need to keep in constant review the availability of plant in Great Britain. The recent capacity auctions and demand side measures in Great Britain serve to strengthen their ability to provide assistance if needed over the two undersea interconnectors to Northern Ireland and Ireland.

[18] http://www.soni.ltd.uk/media/documents/Operations/CapacityStatements/All%20Island%20Generation%20Capacity%20Statement%202015%20-%202024.pdf

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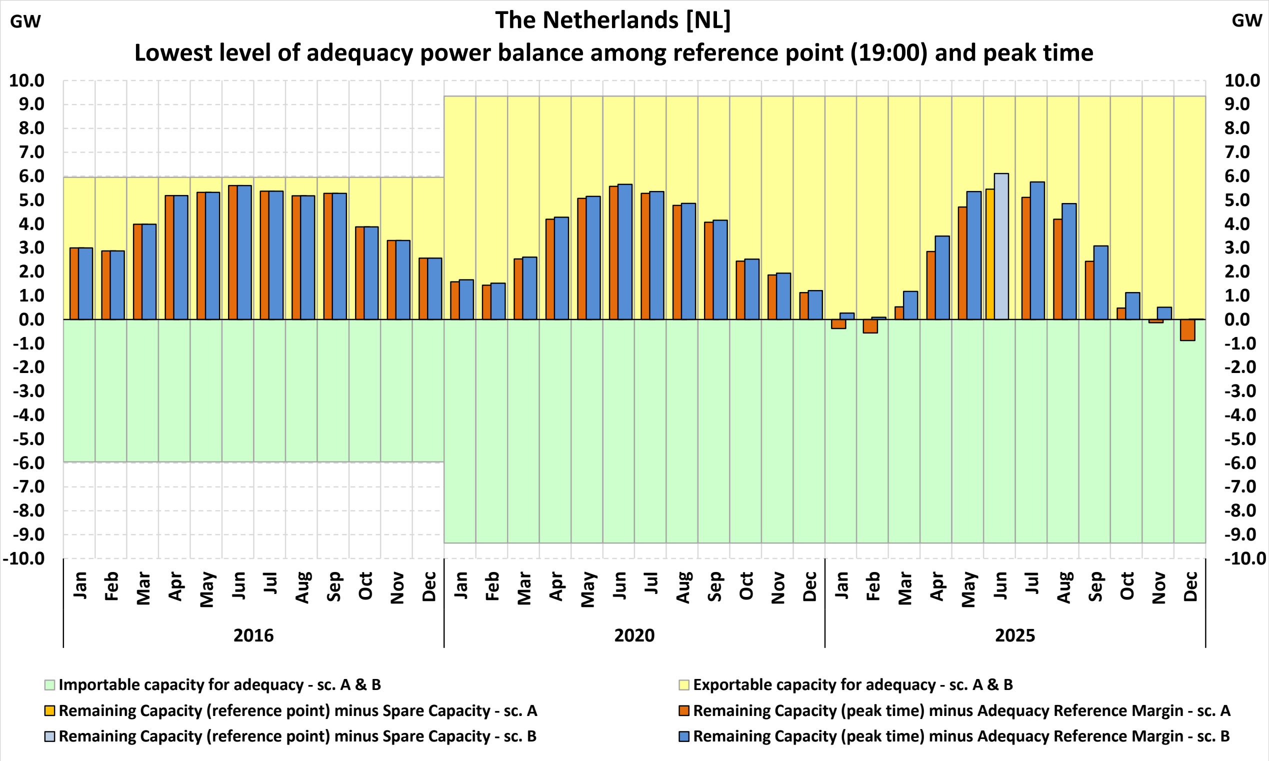
The Netherlands



Load and annual demand forecast

Historically, the actual electricity consumption rates have shown a strong correlation with economic growth rates, including the lasting economic crisis in the Netherlands. However, recently the electricity consumption is developing differently from the development of economic growth. The development of demand in the future will also be more determined by energy saving programs and development of heat pumps as well as electric vehicle developments. The assessment of demand development will be based on the 'Reference' scenario in accordance with the updated load assessments for the new Dutch Quality and Capacity Plan. In this scenario, demand increases 0.1% till 2021 and 0.4% beyond.

Net Generating Capacity forecast

The Dutch Energy Agreement (so called '*Energie Akkoord*') settled in the summer of 2013 has been taken into account with regard to thermal generation capacity. The early closing of the oldest coal units will be effected in 2016 (1.61 GW) and 2017 (1.05 GW). For all scenarios, newly built coal fired capacity (3.37 GW) as well as gas fired capacity (1.85 GW) have been taken into account if commissioned before 2015. From 2016 till 2025, about 0.4 GW of small gas fired CHP units will be replaced. Foreseen decommissioning of 0.9 GW blast furnace gas units in 2024 has recently been postponed till 2026.

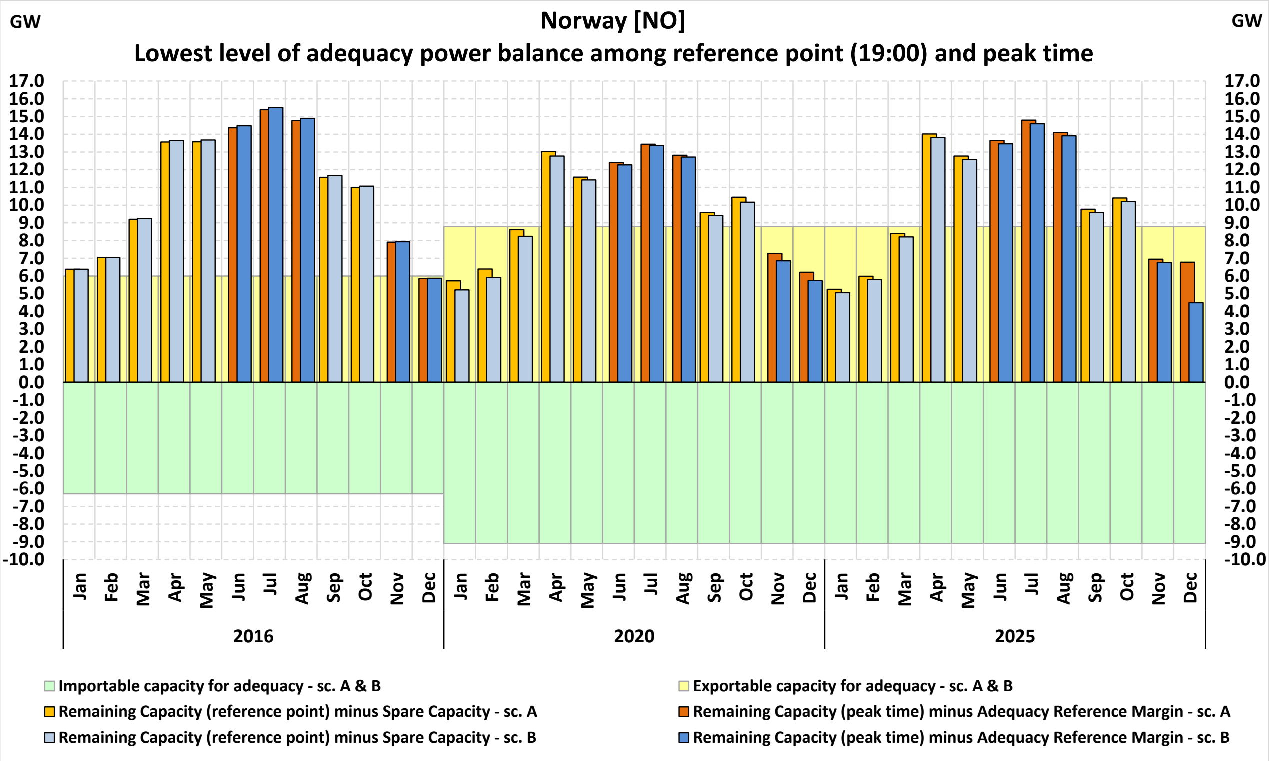
The growth of renewable power in these scenarios is based on the government document Netherlands National Energy Outlook 2014 (in Dutch: Nationale Energieverkenning 2014; http://www.pbl.nl/en/publications/netherlands-national-energy-outlook-2014). As from 2016, onshore wind power will develop from 3.1 GW to 6.4 GW in 2025 and offshore wind will increase from 0.3 GW to 2.5 GW in 2025. The capacity of solar power (PV) in 2016 (2.0 GW) is assumed to expand to 9.2 GW in 2025.

The NGC in 2020 shows in both scenarios around 37.7 GW and the amount of mothballed gas fired capacity is expected to be 4.2 GW in 2020 and 6.5 GW in 2025.

Generation and System Adequacy forecast

The supply–demand balance will be realised on the basis of the price-driven demand principle and a TSO should not intervene in a well-functioning market. The specific TSO's task is balancing the system and supplying emergency power when necessary. TenneT TSO B.V. provides on behalf of the Ministry of Economic Affairs a report on national adequacy, the so-called Monitoring Security of Supply, 15 years ahead (in Dutch: Rapport Monitoring Leveringszekerheid; www.tennet.eu).

Norway



Load, Generation and System Adequacy forecast

The generation and system adequacy forecast for Norway in 2015 and 2016 is good. A surplus of 5–16 GW is available for export, after balancing services are subtracted. Only a slow growth in load and demand is forecast over the next 5–10 years. In addition, a small growth in generating capacity is expected in the same period. Hence, the surplus in 2020 and 2025 is expected to be the same as today.

Because the demand is much higher in winter than in summer, the surplus available for export is lower in winter than in summer. It is also necessary to take into consideration that the balance is calculated for a normal precipitation and temperature year. In dry and cold years, the surplus in winter and spring may be much lower, and there will be a need to import electricity.

The new interconnections with Germany and Great Britain will enable more export, and import in some situations, from (to) Norway after 2020. This means both exchange within the day-ahead market and export of balancing services.

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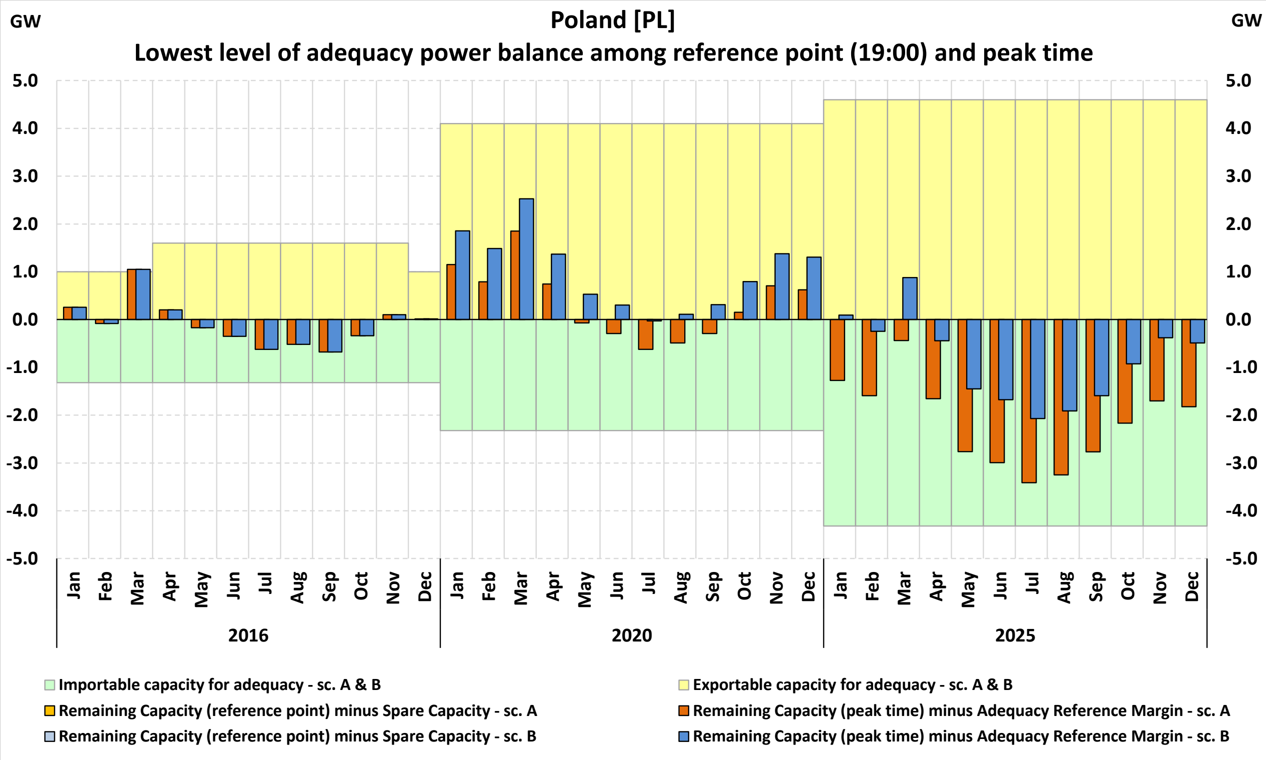
Poland



Load and annual demand forecast

Load and energy consumption data in Scenarios A and B are the same and come from PSE's own analysis prepared in September 2014. PSE assesses that the registered trend of faster increasing peak load during the summer period than during the winter period will remain until 2030, therefore the annual increase of peak load during summer will be at about 0.6% higher than during the winter peak load:

- annual increase for winter months–1.6%
- annual increase for summer months–2.3%

Energy consumption yearly increase amounts to 1.5% and 1.6% for periods 2016–2020 and 2021–2025, respectively.

Net Generating Capacity forecast

1. Information on the subject of derogation clause from LCP and IE directives in Poland

During negotiations on its accession to the European Union (joined May 1, 2004), Poland achieved the derogation clause from LCP Directive (2001/80/EC), which came into effect in 2008 (for SO_2) and 2016 (for NO_x). The derogation clause from the Directive means that the emission limit values will not apply until January 1, 2016 for SO_2 and January 1, 2018 for NO_x for selected power stations and combined heat and power plants (CHPs). No derogation for power plants is in force for dust.

The IE Directive (2010/75/EU), implemented in Polish law in July 2014, amends the LPCD and the IPPCD and introduces new, more restrictive limits concerning SO_2, NO_x and dust emissions for power plants as well as for CHPs. It will come into effect from 2016, although when taking into account the derogation described above, the new limits for NO_x emission for the groups of producers listed in the accession treaty will be in force in Poland not earlier than at the beginning of 2018.

2. The level of decommissioning of fossil fuel power plants

The Polish TSO, based on present producers' declaration, assesses that in Poland the following amount of fossil fuel Net Generating Capacity will be decommissioned in both Scenarios A and B:

- 0.8 GW in 2015,
- 2.4 GW between 2016 and 2020, mainly until the end of 2017,
- 2.0 GW is to be decommissioned between 2020 and 2030. The decommissioning after the year 2020 is mainly caused by exceeding the life span of units.

The total decommissioned conventional thermal net capacity in Poland till 2020 amounts to 3.2 GW (5.2 GW till 2030).

3. Detailed information concerning NGC in SO&AF scenarios

Generation data for Scenarios A and B are based on information from producers collected until the end of 2014 with the most recent review in February 2015 (SO&AF 2015 data collection process ended in February 2015). Development of NGC in 2016 is identical in both scenarios.

3.1 The Conservative Scenario A

Following the ENTSO-E definition, this scenario indicates potential unbalance owing to a lack of new investments in the future. For thermal and nuclear power plants, PSE adopted the following criterion of confirmation regarding the execution of the investment: concluding an agreement (with subcontractors) by an investor for the construction of a unit. For other generating sources, mainly wind farms, the Polish TSO has utilized the level of the net generation capacity that is to be reached by the end of 2020.

Taking into account the criteria mentioned above, there are eight new commissionings of big fossil fuel units taken into account in this scenario (projected gross installed capacity):

- hard coal: 1075 MW, 910 MW and 2 × 900 MW,
- lignite: 496 MW,
- gas: 596 MW, 473 MW and 467 MW.

All of these units are expected to be decommissioned before 2020. A development of wind generation up to the level of 8.9 GW is envisaged as well as a small development of CHPs (different fuel types).

3.2 The Best Estimate Scenario B

An additional three gas projects are taken into account in this scenario with the power amounting to 1337 MW (projected gross installed capacity). No additional hard coal or lignite big power plants are forecast in Scenario B. Further development of RES is assumed until 2025 up to 11.8 GW.

Generation and System Adequacy forecast

1. Unavailable capacity

Elements of unavailable capacity and short description:

1.1. Non-usable capacity:

- Load factor of wind and solar, based on PECD, as proposed by ENTSO-E with the usage between 1.1% and 6.3% (depending on month and hour). This means that 93.7–98.9% of wind is treated as non-usable capacity. This factor looks to be quite conservative (factor to be reached in 90% of hours) compared with PSE's own analysis, which amounted to 10%.
- technological limitation of production in combined heat and power plants (summer season),
- restrictions owing to cooling water temperature in certain thermal power plants (summer season),
- limitations owing to transmission network capacity constraints caused by high temperature (summer season),
- increase in the heat production in combined heat and power plants (winter season),
- part (ca. 40%) of pump storage total availability is treated as non-usable.

1.2. Maintenance and overhauls:
Long- and mid-term level of maintenance and overhauls were taken into account.

1.3. Outages:

- forced outages,
- outages owing to unexpected faults during the start of the unit within on-going maintenance processes.

1.4. System Services Reserve:
PSE sets the level of primary reserve according to ENTSO-E requirements and secondary reserve at the level of the potential outage of the largest element in the system (bus bar, unit). Reserves are kept in conventional thermal system power plants and in pump-storage hydro plants.

2. Spare Capacity

Spare capacity refers to severe conditions that may take place in the case of long lasting heat spells leading to significant deterioration of the Polish power balance (increase of load with simultaneous decrease of generating capacities because of higher forced outage rate of generators, worse cooling conditions and increase in network constraints).

3. Margin against Monthly Peak Load and hour of month peak load

Typical working day load curves of each month were analysed to calculate margin and hour of peak load. February reference point strictly refers to peak load hour and for this month the margin amounts to zero.

4. Adequacy power balance

In all reference points, the worst adequacy power balance situation (among reference point at 19:00 and peak time) takes place during peak load time, means in early afternoon for summer months (May, June, July, August) and in the evening (or late afternoon) during the other months.

In 2016, during severe conditions, an import may be required to balance the system.

In 2020, when all forecasts in Scenario B projects will be realised, PSE will be able to balance the system by itself; periodically, some surplus can exported even during severe conditions.

The adequacy power balance in 2025 is negative for most reference points because of the fact that PSE assumes reasonably big fossil fuel projects in Scenario B, the last unit will be commissioned in 2021. In its own analysis, PSE takes into account nuclear development based on the Nuclear Polish Plan, but the first unit is forecast to be commissioned beyond the SO&AF 2015 horizon. Because of the low-usage RES factor proposed by ENTSO-E, the influence of RES development on adequacy power balance analysis is negligible.

5. Development of interconnections and simultaneous NTC

For years, PSE S.A. has been affected by high unscheduled transit flows through the system from the western to the southern part of Poland. A part of these flows is the result of normal unscheduled flows occurring in interconnected networks, but a significant part comes from market transactions in the region. Year by year, these flows increase (the frequency, as well as the volume of energy) and also limit capacity on the whole synchronous DE/CZ/SK profile, which could be offered to the market (lack of import capacity and significant reduction of export capacity in yearly planning time horizon) and on top of that, cause congestions on the western border (violation of the ‘*n – 1*’rule).

PSE follows a single coherent scenario of cross-border interconnection development as well as development of internal grids caused by the increase of NTC; therefore, the values presented in Scenario A are the same as in Scenario B.

NTC [1] [MW]	2016		2020	2025
	Winter	Summer		
PL->DE/CZ/SK [2]	400	1000	2500	2500
DE/CZ/SK[2] ->PL	0	0	500	2000
PL->SE	100	100	600	600
SE->PL	600	600	600	600
PL->UA [3]	0	0	500	500
UA->PL	220	220	720	720
PL->LT [4]	500	500	500	1000
LT->PL [4]	500	500	500	1000
PL export	1000	1600	4100	4600
PL import	1320	1320	2320	4320

1) Values presented in the table **are not interconnection capacities**–these are NTC values forecast in the yearly horizon at the peak time of the working day for adequacy analysis (state as of February 2015). Capacity offered to the market, especially for monthly/daily/intraday auctions may differ from values shown above, especially in 2016 as DE/CZ/SK profile values can be higher, depending on the forecast level of unscheduled flows from the west to the south. PL exports to Sweden can be higher and depend on the load–generation situation in the northern part of Poland.
2) PSE gives aggregated data for the whole synchronous PL-DE/CZ/SK profile.
3) Radial connection using 220 kV Zamosc–Dobrotvir line at the moment.
4) Back-to-back connection.

The following projects will influence simultaneous NTC:

- New 400 kV double circuit line Alytus–Ełk with back-to-back in Alytus SS (PL–LT)–the end of 2015.
- Physical phase shifter installation in substations connected to Polish and German systems as well as change in the voltage level for the Krajnik–Vierraden line from 220 kV to 400 kV (synchronous profile)–until 2020.
- Improvements of internal grid in the northern part of the Polish system (PL–SE)–the end of 2020.
- Reconstruction of existing connections between PL and UA–the end of 2020.
- Improvements in the internal grid in the western part of the Polish system (synchronous profile)–beginning of 2021.
- Realisation of second stage of PL–LT connection (PL–LT)–beginning of 2021.

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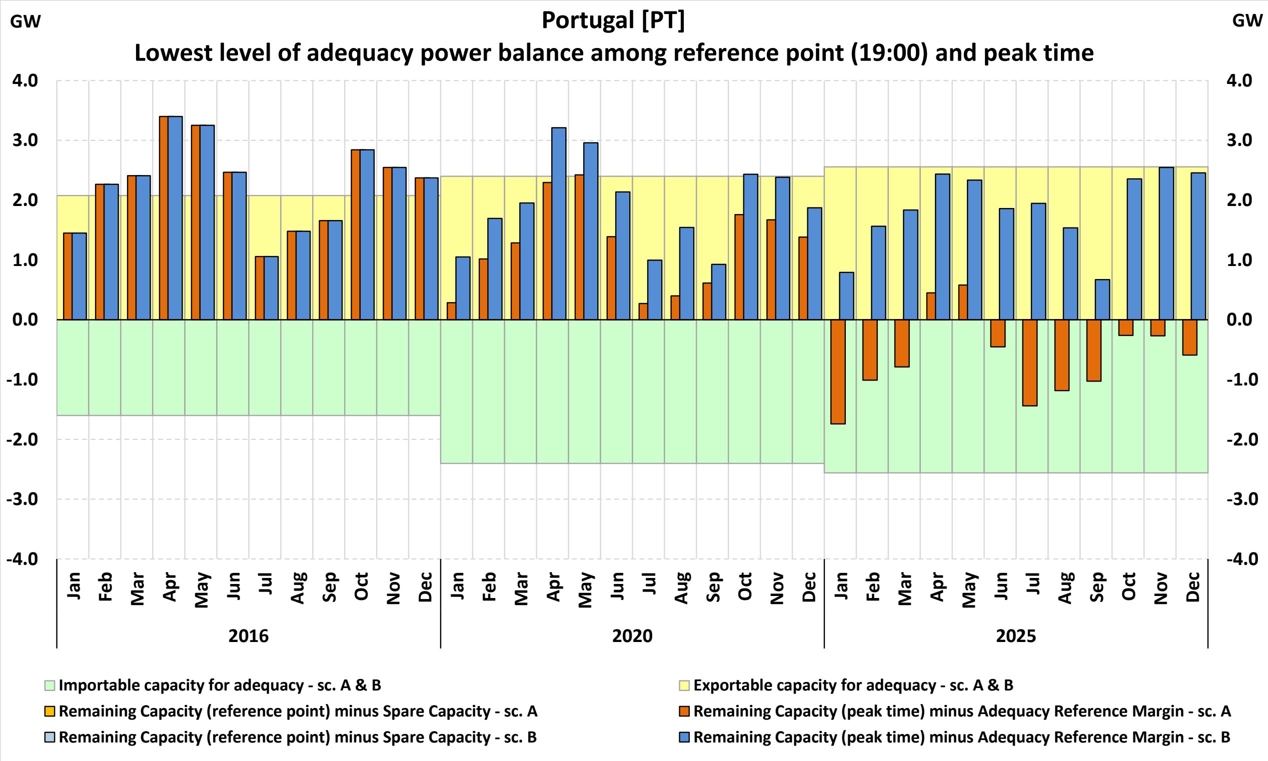
Portugal



Load and annual demand forecast

The electricity consumption forecast is based on the national highest estimations of growth along with efficiency measures as defined in the revised “National Energy Efficiency Action Plan” and electric vehicles according to the “National Renewable Energy Action Plan”. No Load Management is assumed.

Net Generating Capacity forecast

The Portuguese electricity system is currently characterised by high penetration levels of renewable energy, having supplied 62% of total electricity consumption in 2014. Nevertheless, the national strategies for energy development keep supporting the important growth of RES, with further goals having been set for 2020, considering new pumped-storage hydro, wind and solar generation development.

Scenario B is based on national energy policy drivers defined by the Portuguese government. Main developments include the development of renewable energy sources until 2020, particularly wind power, reaching 5300 MW, as well as large hydro power plants up to 7400 MW (of which 3292 MW is pumped storage). An additional large hydro input (+1155 MW) is foreseen between 2020 and 2025, most of it increasing pumping capacity (+880 MW), which is of absolute importance to compensate successfully the volatility of intermittent generation from wind and solar. Decommissioning of old coal and gas power plants (2745 MW) is expected until 2025, partly compensated by new CCGT units (880 MW).

In Scenario A, a conservative approach is used, meaning that no further generation capacity is assumed beyond the current system, except for those added by firm known investments. Given this, there are no new thermal units considered. However, new (already licensed) large hydro power plants are assumed along with some development of renewable energy sources, wind power included, and other non-renewable sources.

Unavailable Capacity

Expected Non-Usable Capacity (beyond wind and solar) is obtained from probabilistic adequacy studies, accounting for the variability of hydro and other non-dispatchable energy sources, such as thermal RES, CHP and Wastes.

Concerning Outages, input for conventional thermal power plants is obtained from statistical historical data.

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System Services Reserve is defined in order to face load forecast uncertainties and interconnection capacity forecast uncertainties.

Generation and System Adequacy forecast

In the calculation of the Adequacy Reference Margin (ARM), Spare Capacity results from probabilistic adequacy studies that account for load supply in 99% of the situations.

According to performed calculations, RC-ARM remains positive except for 2025 in Scenario A.

Interconnection Capacity

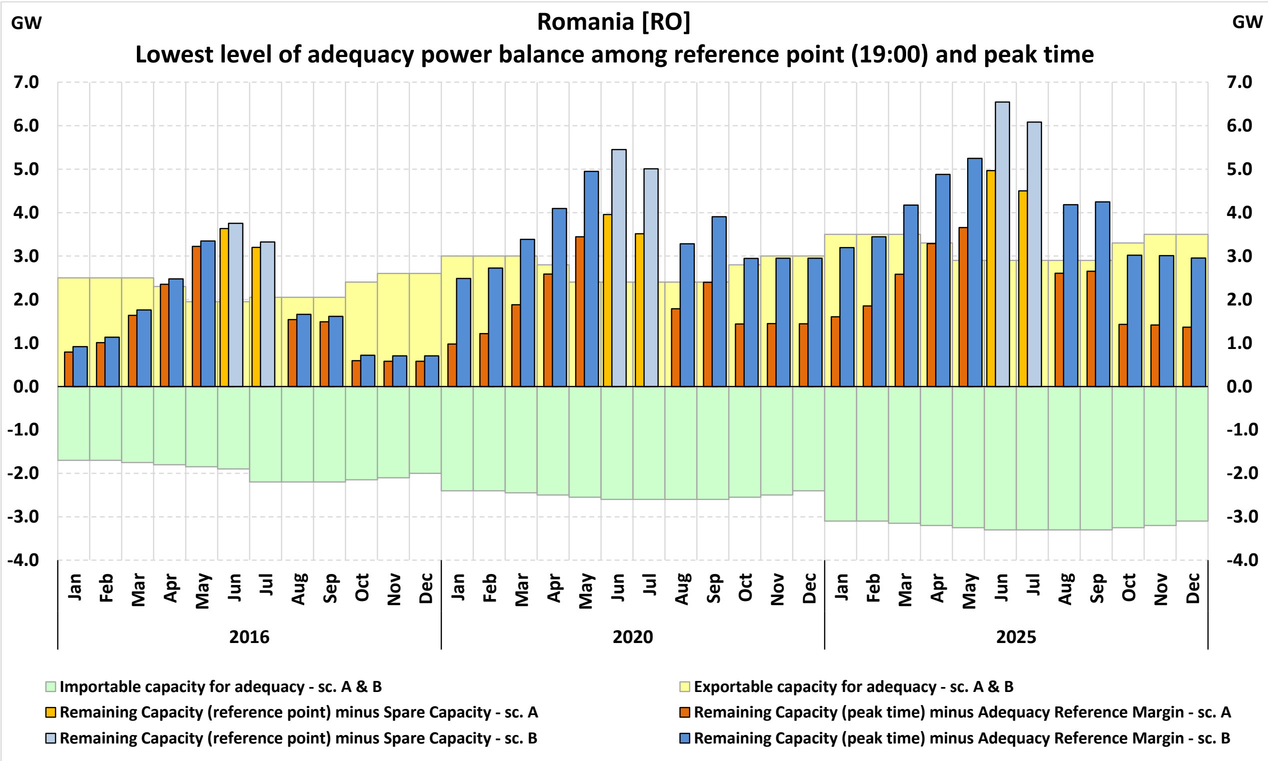
The Iberian Electricity Market (MIBEL) requires interconnection capacity in order to enable the required market energy exchanges, in both directions and with limited grid congestion.

REN and REE have been developing several projects (internal reinforcements and interconnections), which have allowed for the improvement of the interconnection capacity between Portugal and Spain from 550–850 MW in 2003 to 2000–2100 MW in 2014.

Despite this great increase, significant congestion still exists. To overcome this congestion, several investment projects, including two new 400 kV interconnections, are in progress. REN and REE have a common goal, namely to increase the NTC value to a value of around 3000 MW[19].

Also note that currently the Iberian Peninsula has a very low interconnection exchange capacity with the rest of ENTSO-E. The reinforcement of the Spain–France interconnection will allow for an improvement of the quality and safety of supply, the growth of energy trade between the Iberian Peninsula and the rest of ENTSO-E. It will also allow for a greater and more efficient integration of renewable energy into the Iberian Peninsula system.

Romania



[19] For system adequacy purposes, Simultaneous Interconnection Transmission Capacity is based on 80% of expected NTC between Portugal and Spain.

Load and annual demand forecast

Load forecast has been built in line with the national Ten Year Network Development, taking into account the available projections of the economic growth rate in Romania, that lead to an overall annual growth rate of 1.2% in the electricity demand for the 2016–2025 period. The hourly pattern of the load is based on the historical data.

Net Generating Capacity forecast

The installed fossil fuel generation capacity increases by about 1.9% in the 2016–2025 period, mainly as the result of commissioning of new fired gas units.

After a higher increase in the previous years in the wind and solar capacity because of a favourable legal framework, a limited increase is expected in the period 2016–2025 with about 1200 MW in wind and 200 MW in solar PV.

An increase in the hydro capacity of 277 MW is expected in the 2016–2020 period, and also a pump storage hydro power plant of 970 MW to be commissioned by 2025.

The overall capacity of RES will increase with an annual growth rate of 1.7% in the 2016–2025 period.

Two more nuclear units, totalling 1330 MW, are expected to be installed by the end of the year 2020.

Generation and System Adequacy forecast

Unavailable capacity in 2025 reaches 14.7 GW, mainly because of the hydro, wind and solar non-usable capacity.

Remaining Capacity shows positive figures for the whole 2016–2025 period, increasing as the NCG increases.

Remaining Capacity minus Adequacy Reference Margin also increases from 2016 to 2025.

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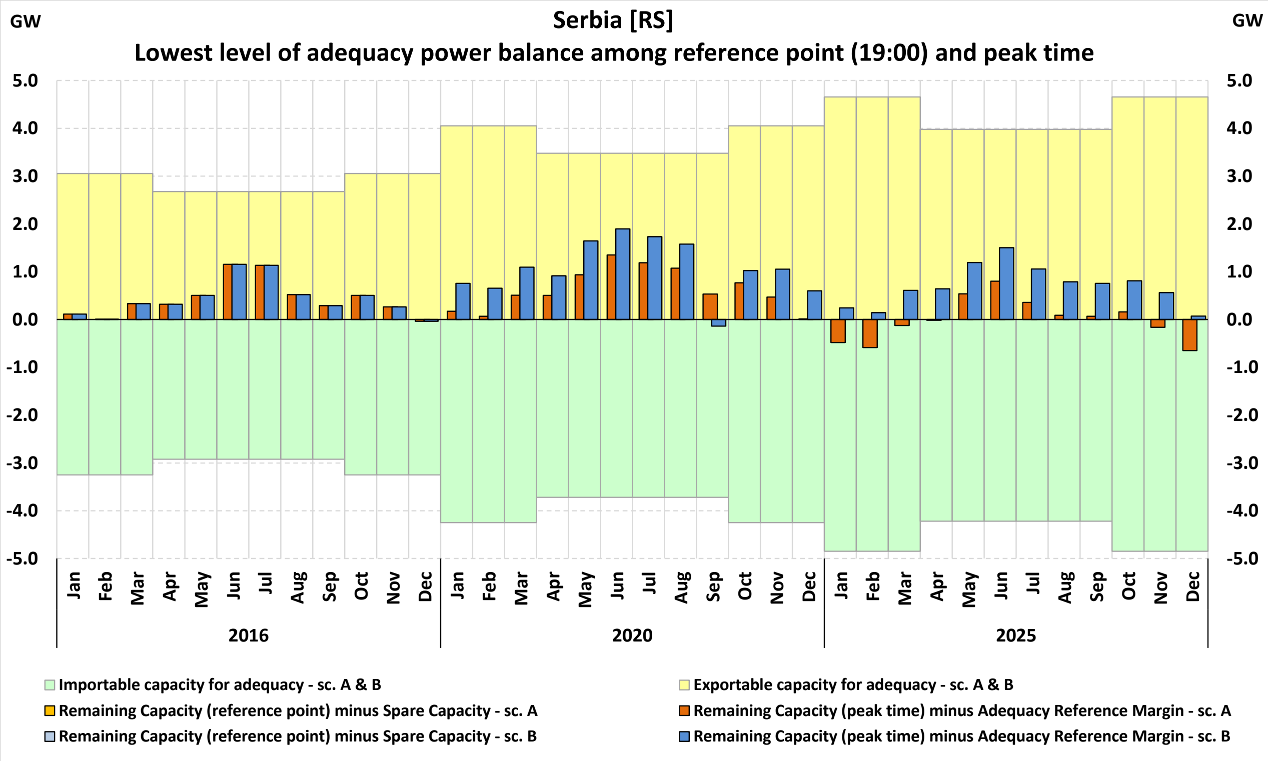
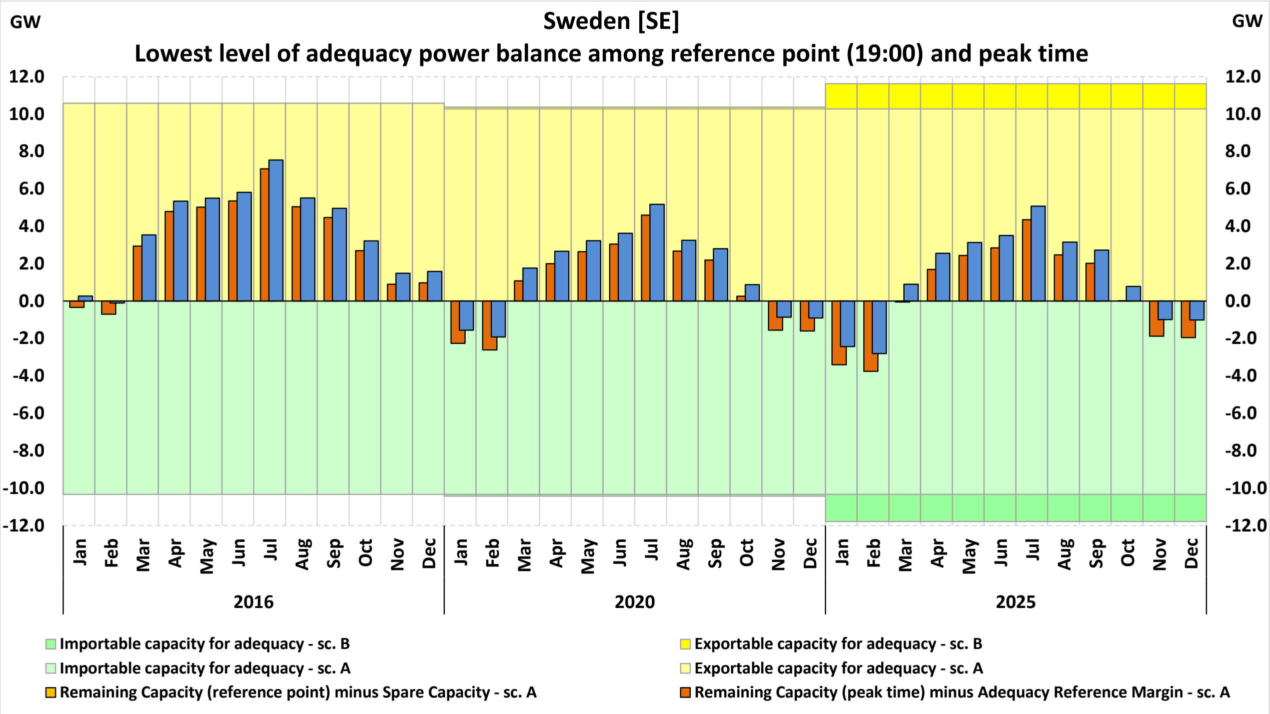
Serbia



Sweden



Load and annual demand forecast

Forecasts of the yearly electricity consumption are used as a reference value when the loads of the reference times have been approximated. Since 2008, the Swedish electricity consumption has been low because of the financial crisis, as electricity consumption is closely linked to economic activity. However, it should be mentioned that the Swedish electricity consumption has hovered around 135–150 TWh during the last decade, whilst there has also been a trend of a stable consumption in Sweden even before the financial crisis. It is assumed that the electricity consumption in 2016 will be 142.7 TWh. The economic situation is assumed to be better in the future and therefore the demand is assumed to increase to 146.8 TWh in 2020 and 148.2 TWh in 2025.

Load management consists of load that can be disconnected. Historically, Svenska Kraftnät has been procuring reserve capacity for each winter season. The reserve capacity consists of both production capacity and load that can be disconnected. The volume of procured reserve capacity will gradually decrease until 2019/2020. In the winter of 2019/2020, the reserve capacity is expected to be handled by the market. At the same time, the share of load that can be disconnected will gradually increase until 2019/2020.

Net Generating Capacity forecast

The NGC of nuclear power is expected to decrease because of decommissioning of nuclear power. It is also expected that a large increase in capacity from renewable sources is driven by the Swedish green certificates (the electricity certificate system). The increase in the capacity from renewable sources is expected to come primarily from wind power generation and biomass. The trend of refitting existing fossil fuel plants to biomass is expected to continue. The NGC of fossil fuels is expected to decrease.

Unavailable Capacity

9% of the NGC of nuclear power is assumed to be unavailable as a result of maintenance during winter. During summer, approximately 30% of the NGC of nuclear power is assumed to be unavailable due to maintenance and refuelling.

10% of the NGC of fossil fuels and biomass is assumed to be Non-Usable Capacity. Some “mothballed” fossil fuel plants are also included in the Non-Usable Capacity.

5% of the NGC of fossil fuels and biomass is assumed to be unavailable as a result of maintenance during winter. During summer, approximately 15% of the NGC for fossil fuels and biomass is assumed to be unavailable because of maintenance.

94% of the NGC of wind power is assumed to be Non-Usable Capacity. This assumption is made due to the intermittent characteristics of wind power.

2.8 GW of the NGC of hydropower is assumed to be Non-Usable Capacity because of hydrological limitations and permits.

Generation and System Adequacy forecast

Scenario A:

Remaining Capacity (RC) is slightly negative in January and February 2025.

Adequacy Reference Margin (ARM):

ARM is higher than RC in January and February 2016, January, February, November and December 2020, January, February March, October, November and December 2025.

Scenario B:

Remaining Capacity (RC) is positive in all of the years.

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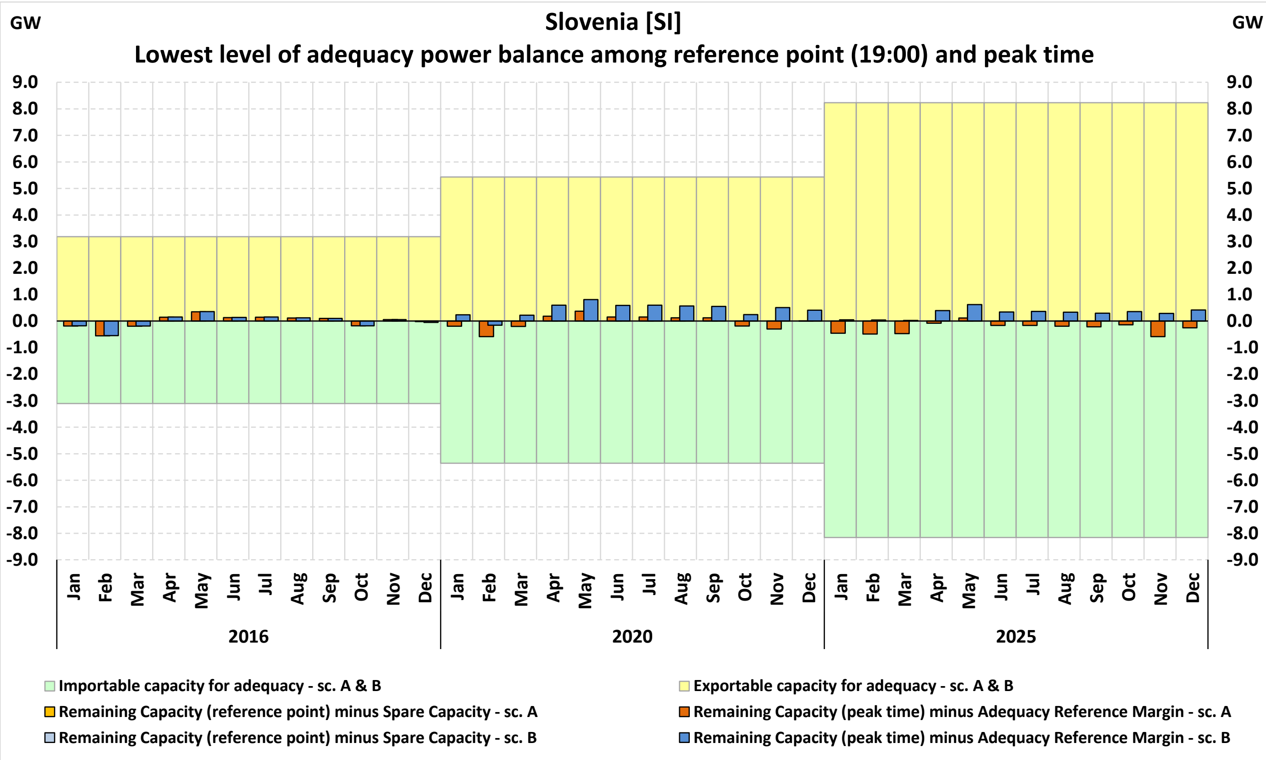
Adequacy Reference Margin (ARM):

ARM is higher than RC in February 2016, January, February, November and December 2020, January, February, November and December 2025.

Interconnection Capacity:
The Simultaneous Import and Export Capacities are assumed to be the maximum NTC. These capacities might be somewhat higher than the real Simultaneous Import and Export Capacities. In the beginning of 2016, the NordBalt link between Sweden and Lithuania is expected to be in operation. In 2023, the Hansa Power Bridge might be in operation if Svenska Kraftnät and 50 Hz decide to build this link between Sweden and Germany.

Slovenia



Load and annual demand forecast

The demand forecast is mainly based on GDP growth and demography development. Slovenia is one of the countries that were heavily affected by the economic crisis, thus reducing the GDP of Slovenia as well as the national electricity consumption and load. Because of the economic crisis in the last five years, electricity consumption in Slovenia was about 12.8 TWh per year. According to the methodology, the same load and annual demand forecast for time horizons 2016, 2020 and 2025 in Scenarios A and B are considered. In the next five to ten year period, a slow recovery of the national economy is expected, with a moderate growth of electricity consumption in Slovenia following it.

Net Generating Capacity forecast

The generating capacity increases in all scenarios. The NGC increases because of new hydro power plant units on the middle and lower Sava River, a new pump-storage unit on the Drava River, a new lignite thermal unit in Šoštanj and gas units in Brestanica. The highest increases for RES because of construction of solar

PV and hydro units and a new pump-storage unit on the Drava River are expected in Scenario B. Decommissions in both scenarios are expected at the end of the thermal units' lifetime.

The tables include 100% of the existing nuclear power plant at Krško, although its ownership is equally divided between Slovenia and Croatia, thus half of its production is delivered to Croatia according to the international agreement between Slovenia and Croatia.

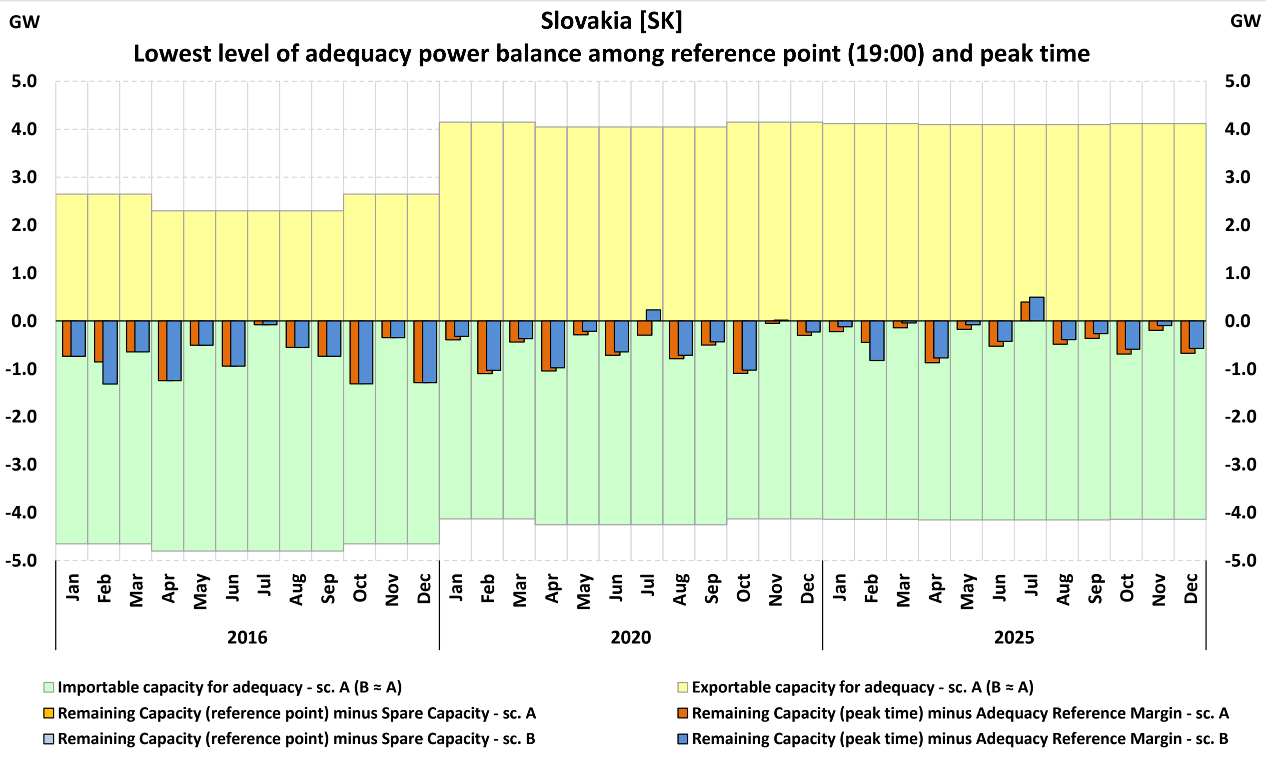
Generation and System Adequacy forecast

Unavailable capacity is mostly present as non-usable capacity, which is mainly the lack of primary sources for RES. The unavailable capacity is higher in winter than in the summer reference point because of the unavailability of solar PV generation at that time.

The Non-Usable Capacity comes mainly from the lower availability of the primary energy source in hydro power stations and wind farms. The reserves increase significantly because of commissioning of the new lignite unit in Šoštanj in 2015.

In contrast, interconnectors have an important role in terms of electricity export, as well. Till 2025, the interconnection capacities will increase because of the new interconnection lines with Hungary and Italy (new interconnectors to Italy are still under consideration) and also because of reinforcement of the internal grid.

Slovakia



Load and annual demand forecast

According to the methodology, the same load and annual demand forecast for time horizons 2016, 2020 and 2025 in Scenarios A and B are considered. The load and annual demand forecasts are in line with the national development plan of SEPS. It stems from the electricity consumption forecast study of the Slovak Republic by 2050.

The load in 2013 is the base for the derivation of the load forecast for concrete time horizons 2016, 2020 and 2025. The high-load forecast scenario is used and it takes into consideration more significant economic and demographic growth. At the same time, there is expected to be a decrease in the energy intensity of technologies because of technology innovation that is joined by exchange of obsolete technology for energy-efficient technology.

During the financial crisis, which peaked in 2009, the net demand was around 25.4 TWh. Between 2009 and 2013, demand growth was about 1.18 TWh. We assume 1.43% average demand growth from 2013 to 2025, and during this period it is assumed that electricity consumption will be 27.55 TWh in 2016, 29.32 TWh in 2020 and 31.51 TWh in 2025.

The electricity consumption should rise by 4.93 TWh to 2025, which means that in comparison with 2013, an increase in electricity consumption by almost 18.5% is assumed, and in comparison with 2016 an increase in electricity consumption by almost 14.4% is assumed.

However, regarding the above-mentioned facts, which take into account the highest expected growth of the electricity consumption, it is necessary to state that in fact we do not assume so rapid a growth of electricity consumption for time horizons 2016, 2020 and 2025.

Net Generating Capacity forecast

For the time horizons 2016, 2020 and 2025 in Scenarios A and B, there is a significant change of proportion of the different power plants' technologies in the total NGC. The mentioned changes relate primarily to nuclear power plants. The most significant increase in NGC is expected due to commissioning of two new nuclear units in Mochovce (approximately 995 MW till the end of 2017). The NGC increase in nuclear power plants is affected by increasing the NGC of existing nuclear power units, as well.

Another factor that has a significant impact on NGC is fossil fuels technology. It is expected that approximately 640 MW in gas units will be included in the Non-Usable Capacity (NuC) in Scenarios A and B. The exclusion of mentioned gas-fired technology from NuC depends on market gas price in the future.

With regard to hard-coal-fired technology, we expect approximately 220 MW in hard coal to be included in the NuC for the time horizons 2016 and 2020, and definitive decommissioning of this capacity is expected in 2025.

In 2016, we expect decommissioning capacity of approximately 46 MW also in lignite fired technology.

Increasing capacity in the above mentioned three technologies for the time horizons 2016, 2020 and 2025 in Scenarios A and B is currently not expected.

Concerning renewable energy sources (RES), the prognoses in evolution of RES capacity in particular to 2020 are negligible from realistic TSO prognoses.

With regard to hydro technology, there is no expected construction of hydro power plants with a high installed capacity, only construction of small hydro power plants is considered to 2025.

Generation and System Adequacy forecast

When considering commissioning of all planned generation capacities, we do not assume problems with the generation adequacy on Slovak territory.

However, in case that it will not be met in view of a proposed high-load scenario in SO&AF, there is a probability that problems with the generation adequacy on Slovak territory may occur.

In this case, the current and forecast interconnectors between SK and neighbouring countries play a vital role in maintaining Slovak generation adequacy. The interconnectors have an important role in terms of the electricity market, as well. For example, if there is a high price of electricity from domestic generators, cheaper electricity can be imported from generation sources that are out of the Slovak territory and in such a way the Slovak consumption can be covered.

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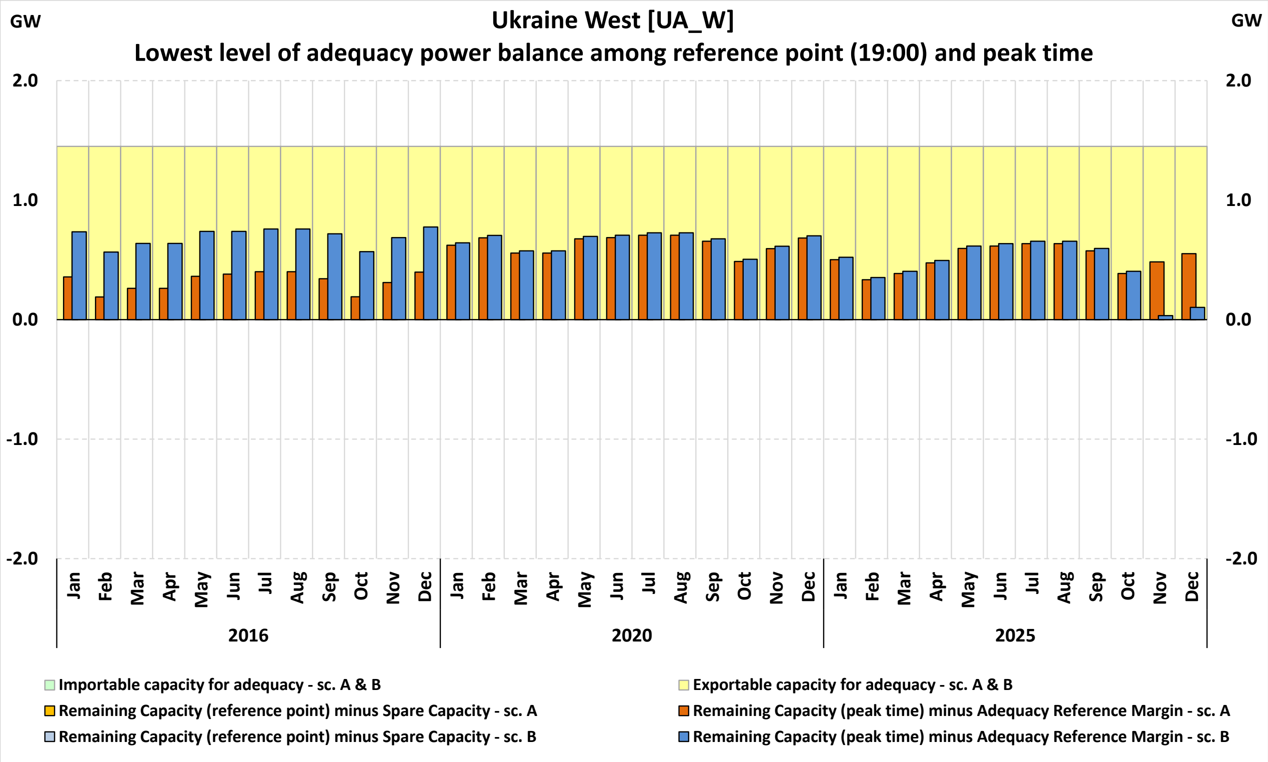
In contrast, interconnectors have an important role in terms of electricity export, as well. Through the interconnectors, reliable electricity export from the Slovak territory can be ensured, which may become important if the expected NGC evolution is to be met.

Ukraine West



5 National Residual Load Analyses/Ramping–Need for flexibility

5.1 Introduction

This chapter aims to provide information about the potential lack of flexible generation in expected power system operation. This study partly answers the improved adequacy methodology, which uses probabilistic assessment methods to identify how often the system is not balanced or when availability of ancillary services might be affected. These changes correspond with the actual hour-on-hour evolution of the climate situation.

Residual load assessment is a first step towards target stakeholder expectation to implement probabilistic assessment for the generation adequacy study. ENTSO-E will report on expected needs for flexibility in its adequacy assessments using a one-hour resolution as a first step. The existing Pan-European Climate Database (PECD) is fully applicable for the assessment of weather-dependent effects related to load variation and generation patterns of wind and solar power plants.

5.2 Definition of the residual load

We can consider the residual load as an indicator to show the flexibility and ramping needs for adequate power system operation. With the ENTSO-E definition, the residual load ($\boldsymbol{RL}$) is the actual load ($\boldsymbol{L}$) minus production of wind ($\boldsymbol{W}$), solar ($\boldsymbol{S}$) and ***must-run*** generation within the hourly time interval. To be able to quantify the requirements on the availability of sufficient flexible capacities or assess the operational risk to cover sudden balancing changes, it is necessary to evaluate statistically the distribution of the:

- RES (wind and solar) penetration of the load, including must-run generation
- hourly RES and residual load ramps (calculated as the difference between consecutive hours)

The presentation of results will be preferably in relative values, which allows comparison of different systems exposed by various penetrations of RES. Absolute values will indicate the demand on flexibility (in GW) for the remaining conventional portfolio in extreme conditions, such as 3σ values, assuring the high reliability of the power system operation.

Definition of absolute values: $\boldsymbol{RL(h) = L(h) - W(h) - S(h)}$ **– must_run** **GW**

In relative values: $\boldsymbol{rl(h) = RL(h)/L(h)}$ **%**

In this chapter, more details will be discussed of the various usage of relative and absolute values evaluating stochastic processes of the residual load and RES ramps. To assure this, TSO data correspondents were asked to submit through data collection the following time series with hourly resolution:

- $\boldsymbol{L(h)}$ $\boldsymbol{L(h) = Lnorm(h)}$ **+/–** $\boldsymbol{\Delta L(t^{\circ}C, h)}$ *... hourly load (GW)*
  $\boldsymbol{t^{\circ}C}$ *... temperature or* Δ $^{\circ}\mathbf{C}$ *temperature fluctuation (℃)*
  $\boldsymbol{Lnorm}$ *... normalized load*
  $\boldsymbol{W(h), S(h)}$ *... hourly wind and solar generation (GW)*

Example of residual load simulation–Figure 5.2.1

An example of a residual load simulation is presented in the following graph. We have selected a typical week from the summer season, which corresponds to the situation when RES generation is significantly challenged in the power system operation. In this case, the climate conditions are causing relatively extreme power ramps, especially in combination with a flat daily load shape. Such conditions of power system operation with high RES penetration of wind and solar installations require an extended need for flexible power or cross-border exchanges.

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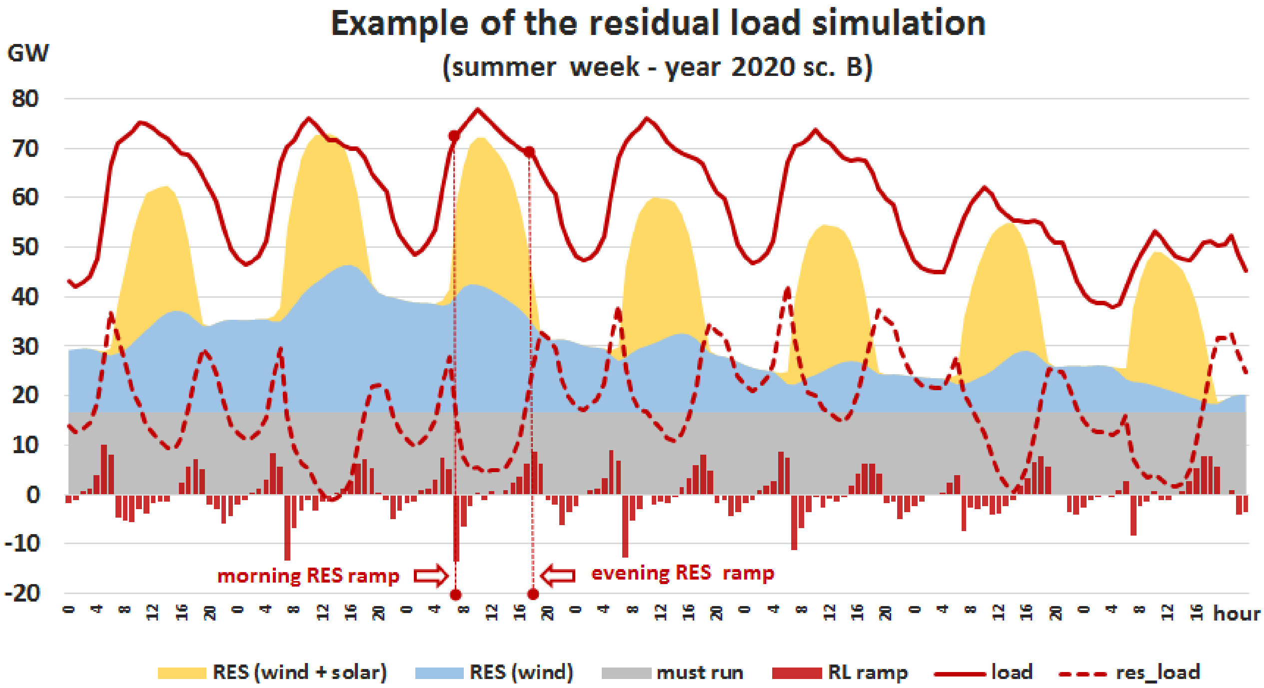

Figure 5.2.1–Example of a residual load simulation year 2020 Scenario B

5.3 Variation of demand–simulation of the temperature sensitivity

Available historical and climate data from the PECD, such as temperature, wind speed and irradiation, provide a sufficient basis for the mathematical treatment of input time series from Load and RES, and its direct correlation with weather conditions. Load temperature sensitivity represents a first important step in the deployment of a probabilistic adequacy assessment because it allows consideration of the load changes based on historical temperatures and generation of a statistically representative set of time series for the analysis.

Therefore, we decided to explore at first, the **sensitivity of the daily energy to daily temperature–d*E*day** (in MWh/°C).

The simulation algorithm we can describe by formulae as follows:

Ln = ***f(Tn)***,	... *where Ln is the load in normal temperature – Tn*
Ls = ***f(Ts)***,	... *where Ls is simulated load for temperature – Ts*
Δ*L* = ***Ls*** – ***Ln*** = ***f*(Δ*T*)**	... *where temperature change ΔT = Ts – Tn*

Assuming that **Δ*E*day** = ***f*(Δ*T*)**, we will use for the temperature change simulation the following formula:

Δ*Li* = **(Δ*E*day/*E*day)** × ***Ln_i*** ... *where ΔLi is the load change in i-hour of the day*
Ln_i *is "normal" load Ln in the i-hour of the day*

5.4 Indices measuring the RES penetration[20]

The increased penetration of variable RES into the power system production portfolio, mainly wind and solar, requires proper monitoring by use of adequate quantification. For this purpose, we will use the following annual indices:

RLPI – **R**ES **L**oad **P**enetration **I**ndex = Maximum hourly coverage of Load by RES

- **RLPI =** $\mathbf{max(W_i + S_i)}/L_i$ **for i=1,2,3,….8760**

REPI – **R**ES **E**nergy **P**enetration **I**ndex = Share of annual energy demand covered by RES production

- **REPI =** $\mathbf{(W_{annual} + S_{annual})}/E_{annual}$

RCR – **R**ES **C**urtailment **R**isk = Probability for RES curtailment in the power system

- **RCR = (number of hours in the year with** $P_{resid\ i} < 0$**)/(total number of hours in the year)**

The resulting values of all three indices are shown (in %) in Table 5.4.1 for all member countries with 2016, 2020 and 2025 data (Scenario B). The expected values of RLPI for 2025 are shown in Figure 5.4.1. Twenty two countries have a value higher than 50% and eight of them reach full load penetration level (100%) – DE, DK, GB, GR, IE, NI, NL and PT. This result does not mean, however, that 100% penetration occurs simultaneously for these eight countries at the same hour. The overall average RES penetration level in energy production of ENTSO-E countries has a linear increasing trend–Figure 5.4.2–with maximum values for all three years referring to Denmark. Values of the indices for years 2016, 2020 and 2025 are connected with a line to increase visibility and highlight the growing trend. The same situation is observed also for the overall average RES penetration level in hourly **power** generation–Figure 5.4.3.

[20] The figures in this section are calculated on the basis of the Pan-European Climate Database (PECD). It should be noted that for some countries historical full load hours might exceed the values estimated by PECD.

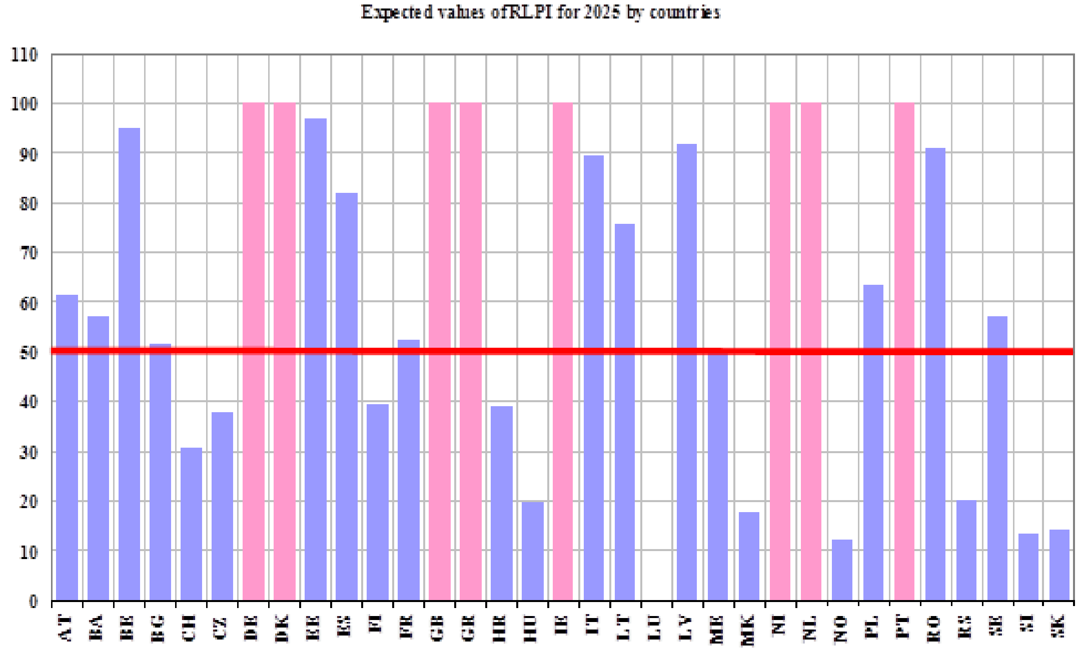

Figure 5.4.1–Expected values for RLPI by countries for 2025

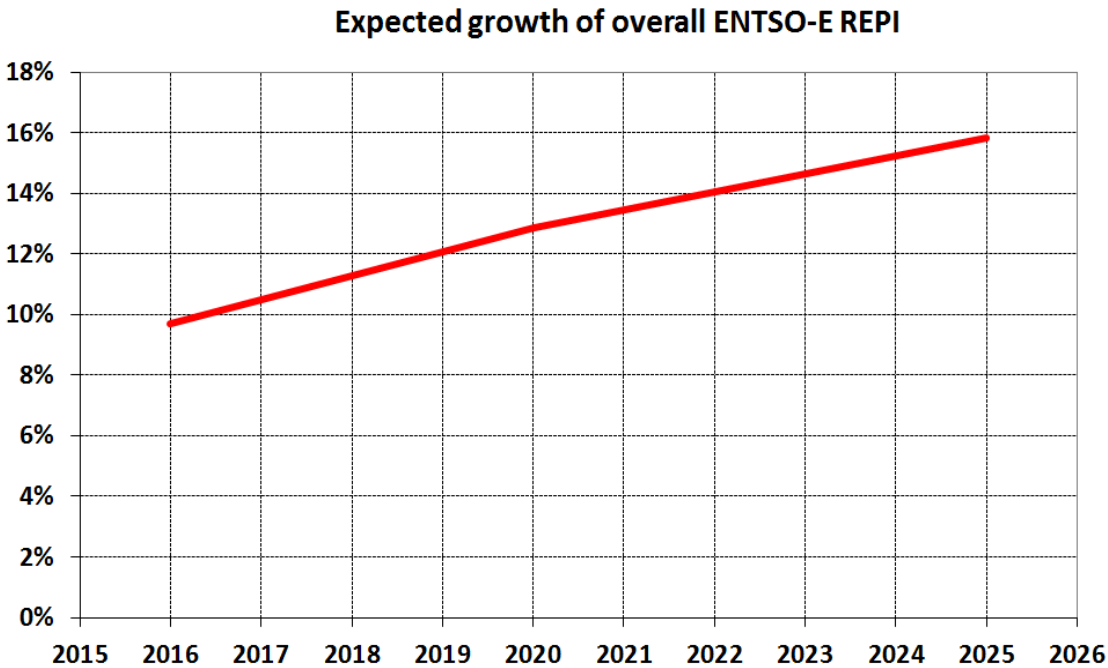

Figure 5.4.2–Expected growth of the RES energy penetration index–REPI

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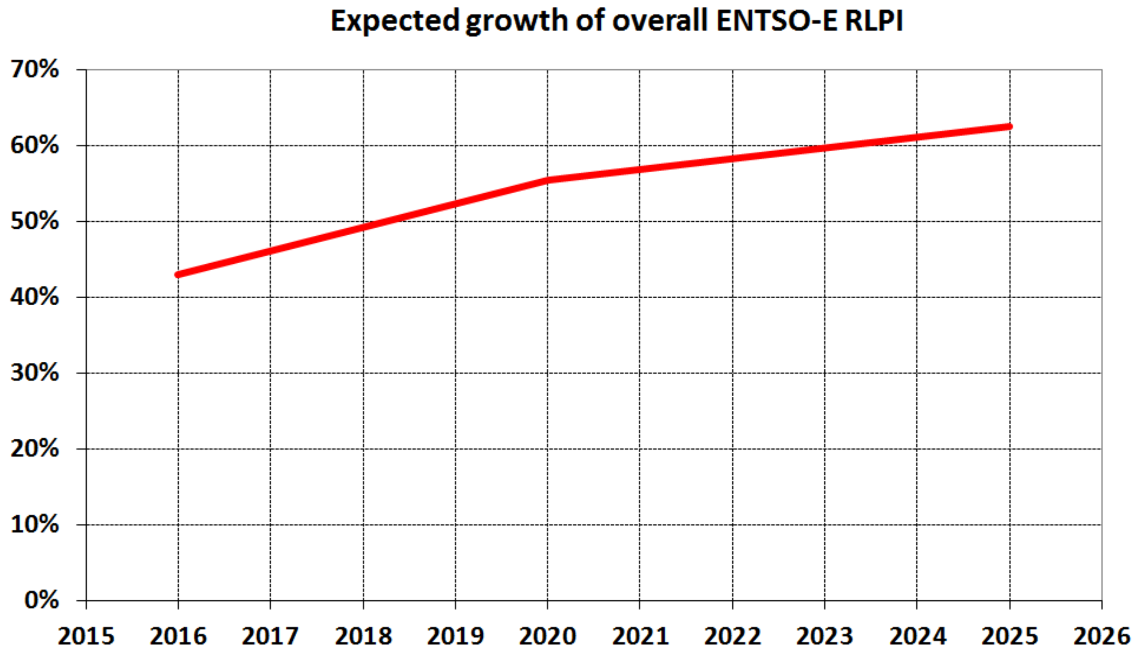

Figure 5.4.3–Expected growth of the RES load penetration index–RLPI

Starting from 2020, the average risk level of RES curtailment is greater than 0.5, which can be classified as a "significant" penetration of RES in the power balance. Denmark, Germany, Ireland, Northern Ireland and Portugal will reach full load penetration of RES in 2016, Greece in 2020 and The Netherlands in 2025. Slovenia has, on the other hand, the lowest RES penetration. All countries with full RES load penetration (100%) will experience some risk for RES curtailment, with the highest risk referring to Northern Ireland for 2025.

As a whole, the increasing penetration of RES is expected to impose higher ramping capabilities on the conventional generation portfolios. The expected growth of overall ENTSO-E RES curtailment risk is shown on Figure 5.4.4. The growth rate doubles after 2020, and this seems to be an additional indicator for possible challenging situations with downward regulation. The calculated values of RCR do not take into account the effect of must-run generation. Must-run constraints will generally increase the risk of curtailment here reported.

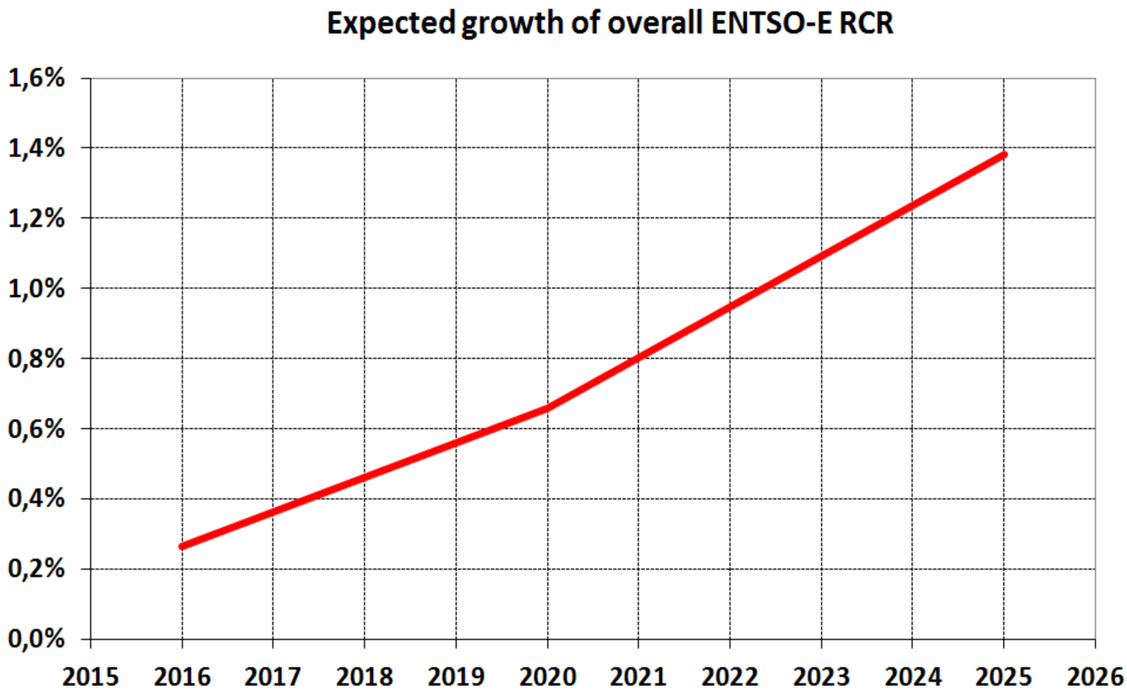

Figure 5.4.4–Expected growth of the RES curtailment risk–RCR

Table 5.4.1–Values of the indices of RES load and energy penetration as a RES curtailment risk for all ENTSO-E countries referring to years 2016, 2020 and 2025 Scenario B

Country	RLPI RES load penetration index			REPI RES energy penetration index			RCR RES curtailment risk		
	2016	2020	2025	2016	2020	2025	2016	2020	2025
AT	40,9%	60,3%	61,5%	7,2%	11,6%	12,5%	0,0%	0,0%	0,0%
BA	19,8%	33,7%	57,3%	2,5%	4,2%	7,2%	0,0%	0,0%	0,0%
BE	43,8%	71,8%	94,9%	9,3%	16,7%	21,1%	0,0%	0,0%	0,0%
BG	36,5%	45,8%	51,7%	7,8%	9,8%	10,8%	0,0%	0,0%	0,0%
CH	13,9%	20,8%	30,7%	2,5%	3,8%	5,6%	0,0%	0,0%	0,0%
CZ	28,8%	31,5%	37,9%	5,4%	5,9%	7,2%	0,0%	0,0%	0,0%
DE	> 100%	> 100%	> 100%	22,0%	28,5%	35,6%	0,1%	5,3%	9,4%
DK	> 100%	> 100%	> 100%	35,7%	44,7%	51,3%	3,9%	9,2%	14,2%
EE	71,3%	85,4%	97,1%	11,3%	13,5%	15,3%	0,0%	0,0%	0,0%
ES	85,9%	85,4%	82,1%	24,0%	23,8%	25,3%	0,0%	0,0%	0,0%
FI	12,4%	30,1%	39,5%	2,3%	5,7%	7,4%	0,0%	0,0%	0,0%
FR	23,9%	35,2%	52,5%	5,0%	7,4%	11,3%	0,0%	0,0%	0,0%
GB	38,7%	90,4%	> 100%	9,0%	21,3%	43,5%	0,0%	0,0%	7,3%
GR	79,4%	> 100%	> 100%	19,3%	24,7%	26,0%	0,0%	0,0%	0,0%
HR	24,2%	37,9%	39,2%	3,5%	6,2%	6,3%	0,0%	0,0%	0,0%
HU	8,9%	19,3%	19,6%	1,3%	2,9%	3,0%	0,0%	0,0%	0,0%
IE	> 100%	> 100%	> 100%	26,6%	33,4%	37,4%	1,8%	4,9%	7,8%
IT	69,7%	77,8%	89,5%	14,6%	16,7%	19,2%	0,0%	0,0%	0,0%
LT	52,0%	64,0%	75,5%	10,4%	12,7%	14,9%	0,0%	0,0%	0,0%
LU	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
LV	22,1%	54,2%	91,9%	2,8%	7,8%	13,8%	0,0%	0,0%	0,0%
ME	0,0%	43,4%	50,3%	0,0%	5,8%	6,7%	0,0%	0,0%	0,0%
MK	9,4%	13,6%	18,0%	1,5%	2,2%	2,8%	0,0%	0,0%	0,0%
NI	> 100%	> 100%	> 100%	27,8%	34,4%	41,2%	3,1%	6,2%	11,3%
NL	40,3%	76,4%	> 100%	7,9%	15,3%	25,9%	0,0%	0,0%	0,0%
NO	8,9%	10,5%	12,4%	2,0%	2,3%	2,7%	0,0%	0,0%	0,0%
PL	33,2%	56,0%	63,3%	6,4%	10,8%	12,6%	0,0%	0,0%	0,0%
PT	> 100%	> 100%	> 100%	22,4%	23,6%	24,2%	0,1%	0,2%	0,3%
RO	79,8%	92,3%	91,2%	15,7%	18,1%	18,1%	0,0%	0,0%	0,0%
RS	0,0%	13,9%	20,0%	0,0%	2,1%	3,0%	0,0%	0,0%	0,0%
SE	48,7%	53,0%	57,2%	9,5%	10,3%	11,2%	0,0%	0,0%	0,0%
SI	14,3%	13,7%	13,3%	2,6%	2,5%	2,4%	0,0%	0,0%	0,0%
SK	12,1%	13,0%	14,3%	2,4%	2,6%	2,8%	0,0%	0,0%	0,0%
average	**32,8%**	**45,5%**	**50,4%**	**9,7%**	**13,1%**	**16,0%**	**0,3%**	**0,8%**	**1,5%**

Comment:

Highlighted countries with REPI and RCR indices correspond to the conditions of power system operating with high RES energy penetration (REPI > 25%) and curtailment risk (RCR > 2.5%).

5.5 Probabilistic assessment of the residual load and RES ramping

Probabilistic modelling requires application of analytical tools, which evaluate large sets of time series ensuring proper statistical relevance. At the present time, the PECD database contains hourly data of 14 years for the simulation of various climate conditions. Therefore, the graphic form of chromatic graphs is one of the most efficient ways to introduce the results of a probabilistic assessment in a concise way. Based on this assumption, we will now describe the graphs used to present the results of the probabilistic assessment for each individual country below.

Presentation of normal and real daily temperatures in 2000–2013, Figure 5.5.1

The evolution of daily temperature deviation during the simulated period (simulation runs) is very important in understanding the patterns of load temperature sensitivity. The graph at the top of the country set demonstrates the spread of daily temperature around the average temperature during PECD climatic years. The red line is the average temperature (30 years) and the yellow dots correspond to observed daily country temperatures. Values of daily temperatures refer to **the population-weighted average**, so highly populated areas have a relatively higher weight regarding temperature dependence.

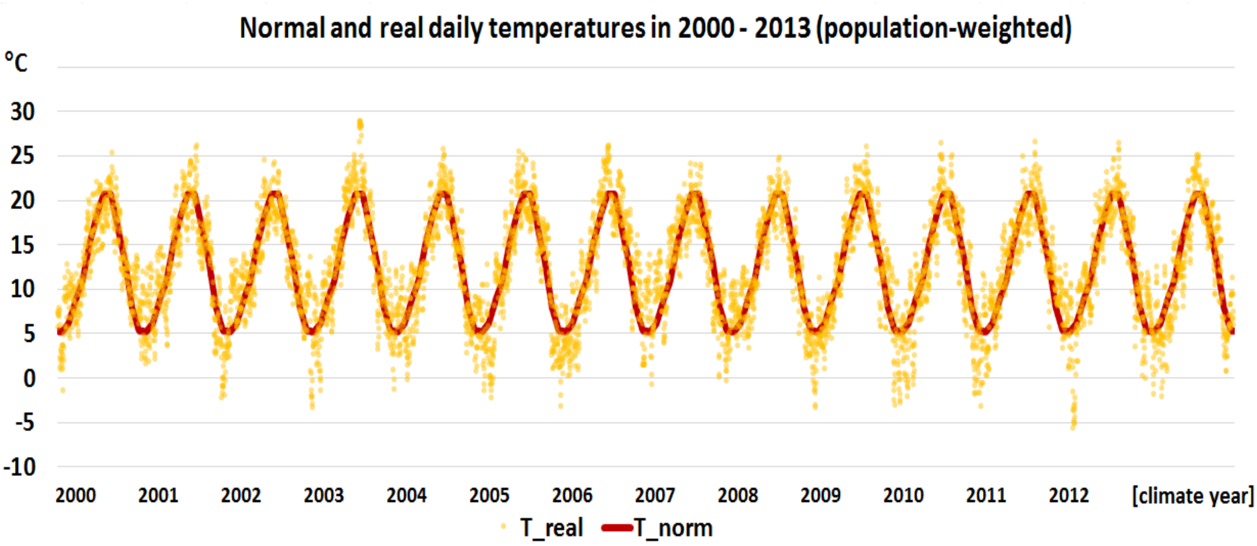

Figure 5.5.1–Example for average and actual temperature distribution in years 2000–2013

Presentation of the statistical distribution of the RES penetration and hourly RES ramps:

The purpose of statistical graphs is to present the distribution of residual load penetration and hourly RES generation ramps. These graphs complete the analytical information of the RES indices, aggregated in Table 5.3.1, to allow comparison in one place of different values between individual ENTSO-E countries. The statistical distribution graphs with overlapping areas provide a visual indication of the individual country statistical distribution and simultaneously present the evolution in time for the concerned indicator for the analysed years 2016, 2020 and 2025 and for SO&AF Scenario B.

Relative values in percentage (%) of the load are used in the statistical graphs. The advantage of this approach is to assess objectively the impact of the RES penetration and RES power ramps independently on the range of the country load.

Distribution of the absolute residual load ramps–Figure 5.5.2

By applying relative values for the assessment of the residual load ramps, information can be lost about the real size of the extreme power ramps in the system, challenging the reliable system operation and requiring additional need for flexible capacities. We have to take into account that the ramps of the residual load are combining two stochastic events, which are not correlated: load fluctuations and volatility of RES generation. At the same time, there are significant differences in RES penetrations and RES generation mix (wind and solar) in each ENTSO-E country.

Based on this assumption, we also need to demonstrate the distribution of the absolute values of the residual load ramps to give information about the local impact on the power system operation. For each country, we calculated 99.9% +/– percentile of the absolute residual load ramps simulating 14 PECD climate years for Scenario 2020-B. This is equal to the nine worst hourly residual load ramps (8760 × 0.1% ~ 9 hours) during the year. In the case of a normal distribution, it is equal to the 3σ value.

In the following Figure 5.5.2, we present the results of the absolute ramps evaluation. Countries on the graph are in descending order of ramp size.

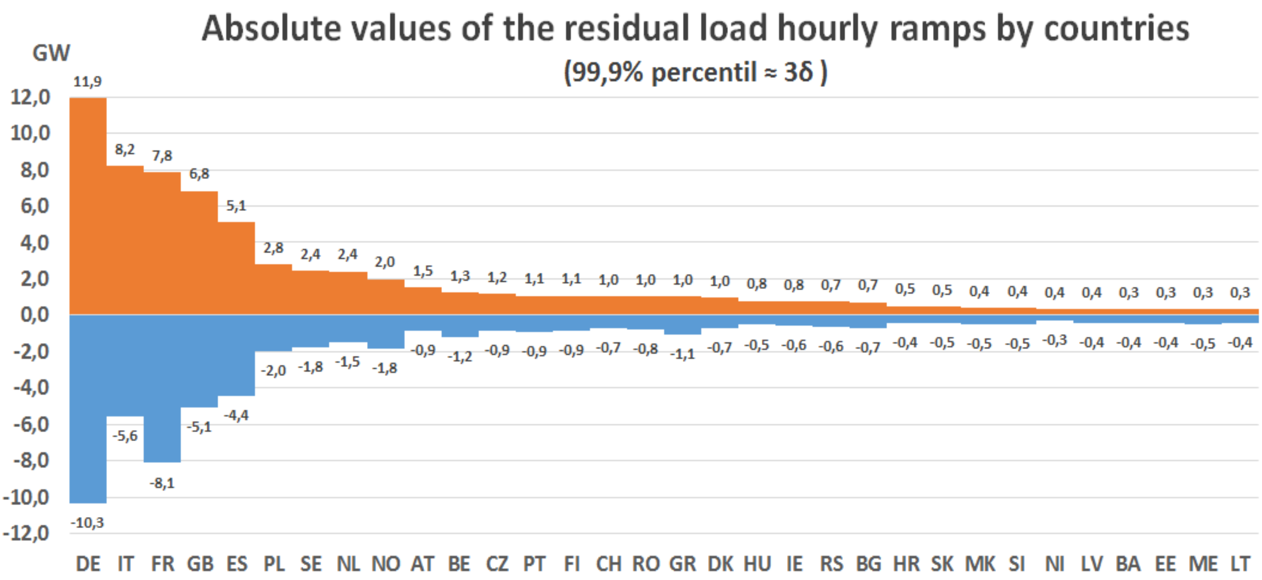

Figure 5.5.2–3σ distribution of the absolute residual load ramp by ENTSO-E countries calculated for year 2020 Scenario B.

Comment:

We note that the relative values are more suitable for analysis of one non-correlated statistical event. The reason is the changing relation to the load during the week, especially on non-working days when we are convolving together the relative values of the stochastic load ramps and RES generation ramps.

These are two separate statistical evaluations referring to different stochastic processes in the power system operation. Based on this finding, we recommend evaluation of the relative ramps separately for load and RES generation, on the country level. In this SO&AF report we provide information on the statistical distribution of the RES ramps and its impact on the flexibility needs of the power system operation.

Enhanced probabilistic assessment of the residual load ramps and capability of the conventional generation portfolio to absorb these sudden changes will be assessed in the next reports within the ongoing development of the market-modelling target methodology and implementation road map.

Distribution of RES penetration (including the must run)–Figure 5.5.3

Values of the RES generation on the graph are relative (percentage) for the country load. We present the residual load in (1 – RL) form. This corresponds to the conditions when RES penetration exceeds the critical levels of the natural absorption by country consumption. Values above 100% mean that RES generation including must runs exceeds the country consumption. The highlighted area on the graph shows this penetration zone. Flexible generation of the conventional portfolio in that case is very limited. Simultaneous unexpected changes in RES generation or national load could significantly expose cross-border interconnection capacities affecting the system adequacy. Values on the vertical axes present, in percentage, the appearance of residual load (as a percentage of the load). The statistical assessment covers all simulated periods of climate conditions for the years 2000–2013 for different time horizons 2016, 2020 and 2025 of selected Scenario B.

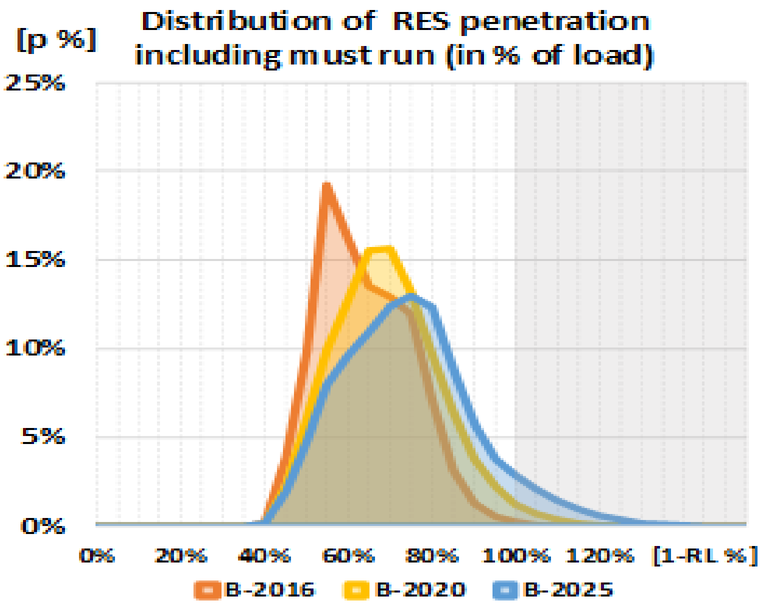

Figure 5.5.3–Example of graphic presentation of statistical distribution of the RES penetration in relative values of the load for years 2016, 2020 and 2025, Scenario B.

Distribution of hourly RES ramps–Figure 5.5.4

The goal is to assess the RES in-feed intraday changes. The proposed method is based on evaluation of the hourly changes (hourly ramps) at a 1-hour granularity. Individual values of the hourly ramps ΔP_{1h}, are obtained from: $\Delta P_{1h\,i} = P_{i+1} - P_i$. These ramps will need to be handled considering their correlation with other power fluctuations, such as system load or flows on interconnectors.

RES ramp values are expressed relative to the load to analyse the impact of RES of power ramps independently of the generation size. This is relevant because values given in percentage of the load reflect the requirements for flexibility needs to the power system. Furthermore, countries with higher RES installations potentially generate unexpected power ramps more frequently. In such situations, TSOs are applying internal and external balancing measures as a direct reaction to sudden system imbalances because of RES in-feed.

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Highlighted areas on Figure 5.5.4 are symmetrically setting the potential thresholds for the higher needs on the flexibility. Therefore, power systems with values of RES ramps exceeding 10% of the load are in potential risk because they might be affected by insufficient flexible capacities. **This threshold was set as a preliminary value, and its representativeness needs further detailed assessment and historical back testing.** Values on the vertical axes present the % appearance of RES generation range for given statistical classes (in % of the load). In accordance with the previous example, the statistical assessment will cover all simulated periods of climate conditions for the years 2000–2013 for the different time horizons 2016, 2020 and 2025 of Scenario B.

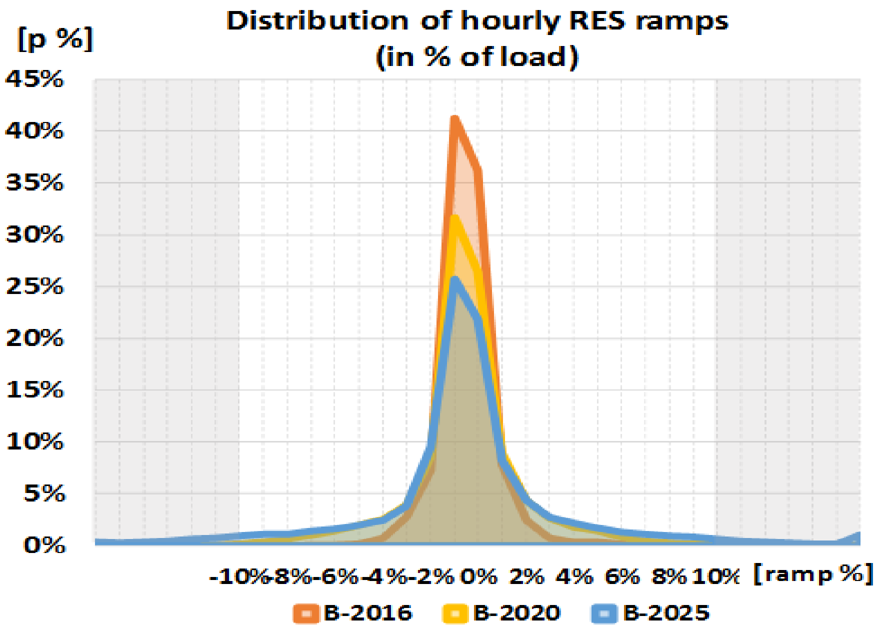

Figure 5.5.4–Example of graphical presentation of the statistical distribution of the RES generation ramps in values relative to the load for years 2016, 2020 and 2025 Scenario B.

Chromatic graph–Figure 5.5.5

The purpose of a chromatic graph is to demonstrate the hourly behaviour of the residual load at maximum possible resolution–hourly. Simultaneously, by using the relevant colour scheme, we are able to highlight the periods of the year linked with challenging conditions of the power system balance and the need for and availability of flexible generation.

Although having a large number of statistical hourly samples of 14 simulated climate years (equal to 122640 = 14 × 365 × 24), we present only a one-year climate condition run. The simulated year is 2020 Scenario B, and we have chosen the climate conditions of year 2012 because of its higher spread of temperature fluctuations, especially in the winter period.

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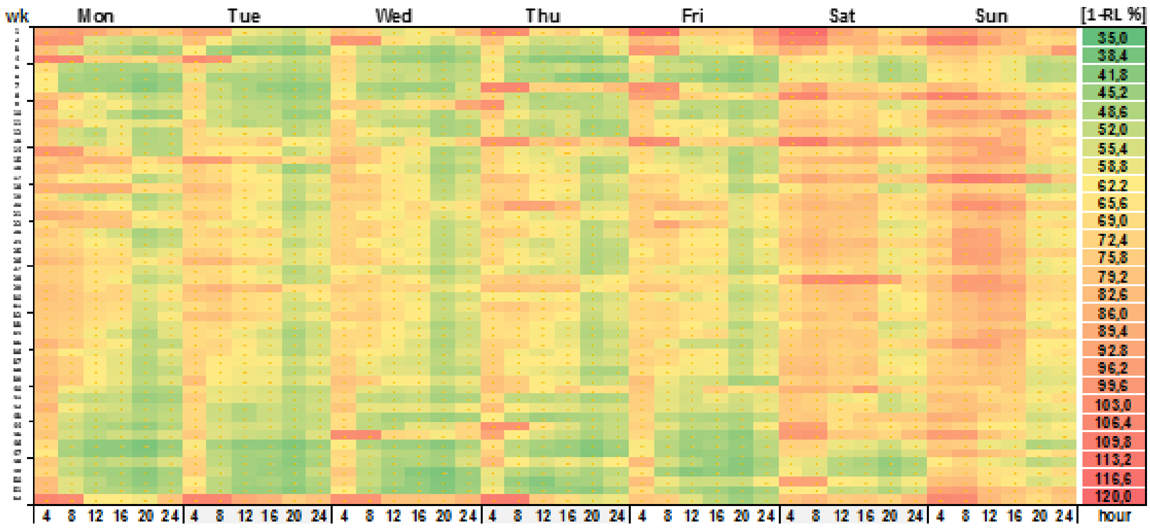

Figure 5.5.5.–Example of a chromatic graph for year 2020 Scenario B.

The chromatic graph shows the residual load in (100 – RL) form.

- **Red** indicates challenging hours/period because it highlights situations with i) high need for flexibility (high RES penetration) **and** ii) potential lack of available flexibility (low level of flexible dispatchable production).
- **Green** indicates situations where RL is the highest in relative terms. This indicates situations when the load is covered by RL [%] = 100 – VALUE [%] by flexible dispatchable generation (VALUE = value in the graph legend).

Schematically, the chromatic graph colour legend is related to typical residual load duration curves in the following way:

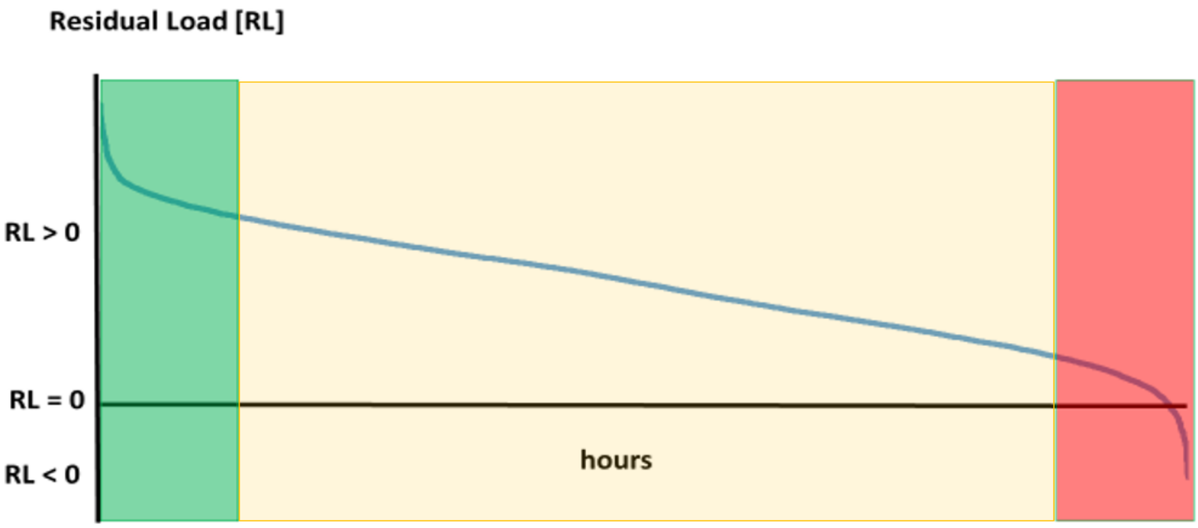

Figure 5.5.6. Explanation of the applied chromatic graph colour scheme.

Disclaimer: The choice of colours should, by no means, be associated with a position or statement by ENTSO-E or its members, and should be understood as a totally neutral choice.

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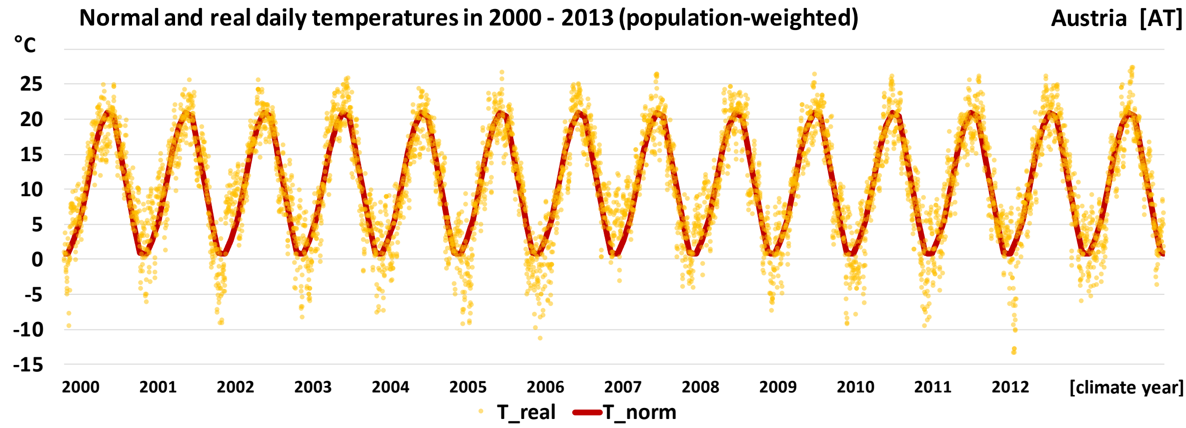
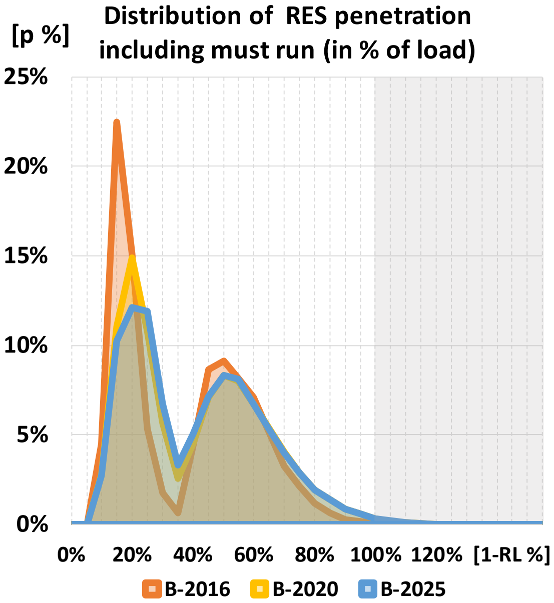
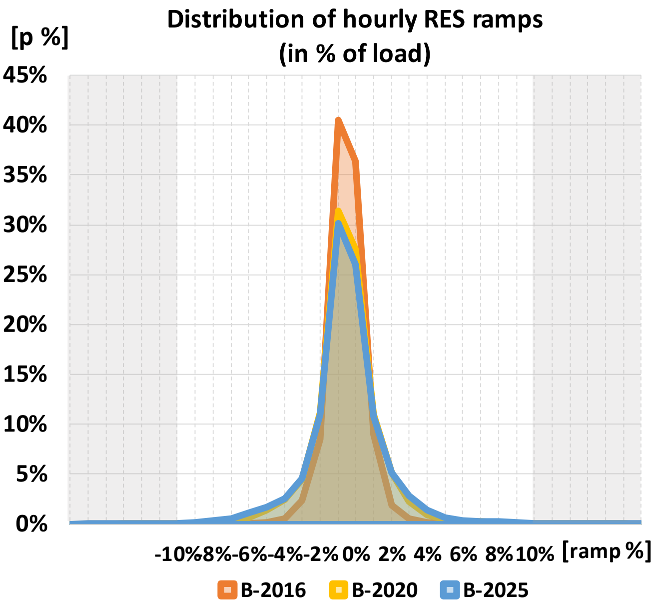
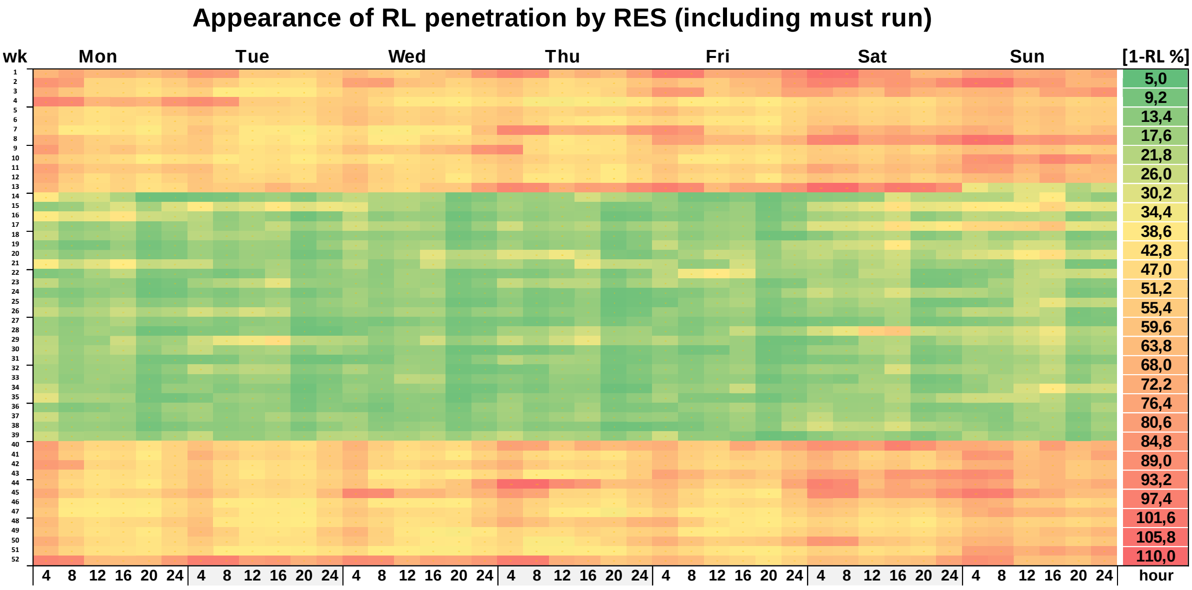
Austria

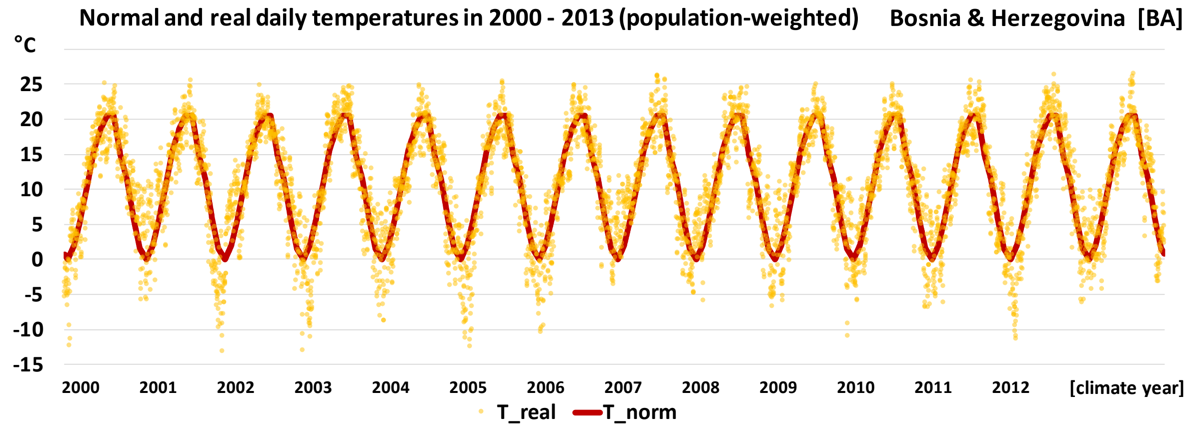

Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Austria [AT]
°C
25
20
15
10
5
0
-5
-10
-15
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 [climate year]
T_real
T_norm

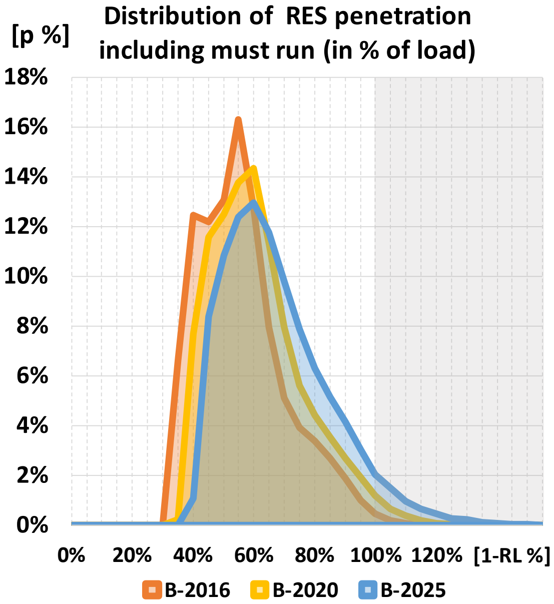

Distribution of RES penetration including must run (in % of load)
[p %]
25%
20%
15%
10%
5%
0%
0% 20% 40% 60% 80% 100% 120% [1-RL %]
B-2016 B-2020 B-2025

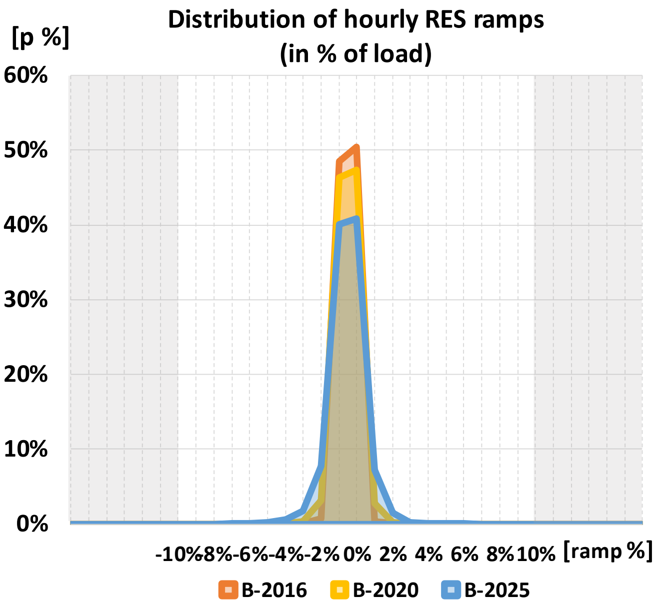

Distribution of hourly RES ramps (in % of load)
[p %]
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
-10%8%-6%-4%-2% 0% 2% 4% 6% 8% 10% [ramp %]
B-2016 B-2020 B-2025

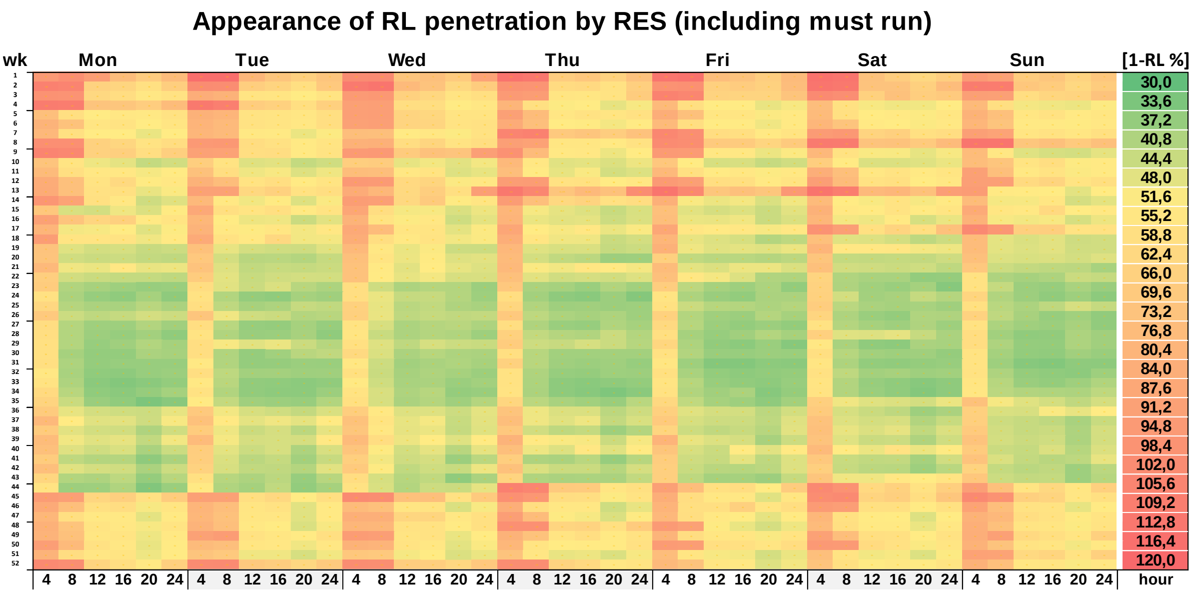

Appearance of RL penetration by RES (including must run)
wk
Mon Tue Wed Thu Fri Sat Sun
[1-RL %]
5,0
9,2
13,4
17,6
21,8
26,0
30,2
34,4
38,6
42,8
47,0
51,2
55,4
59,6
63,8
68,0
72,2
76,4
80,6
84,8
89,0
93,2
97,4
101,6
105,8
110,0
4 8 12 16 20 24
hour

Bosnia & Herzegovina









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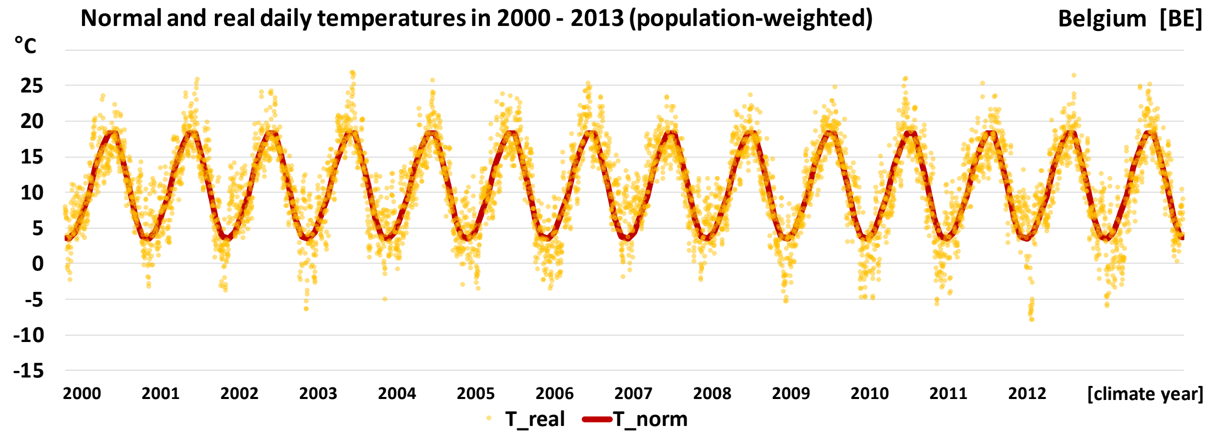
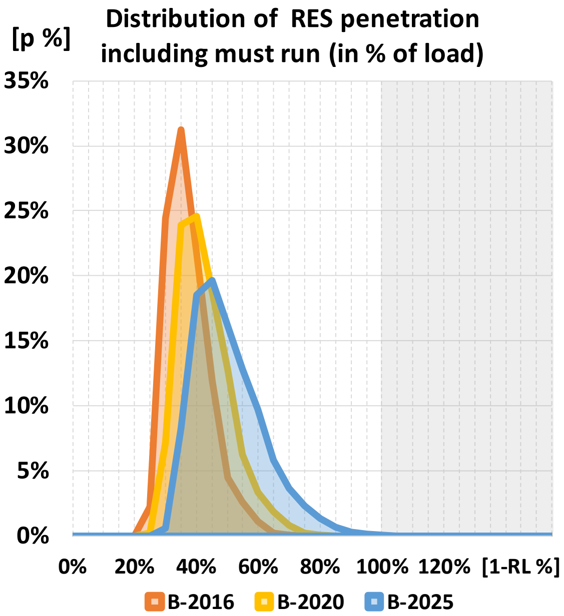
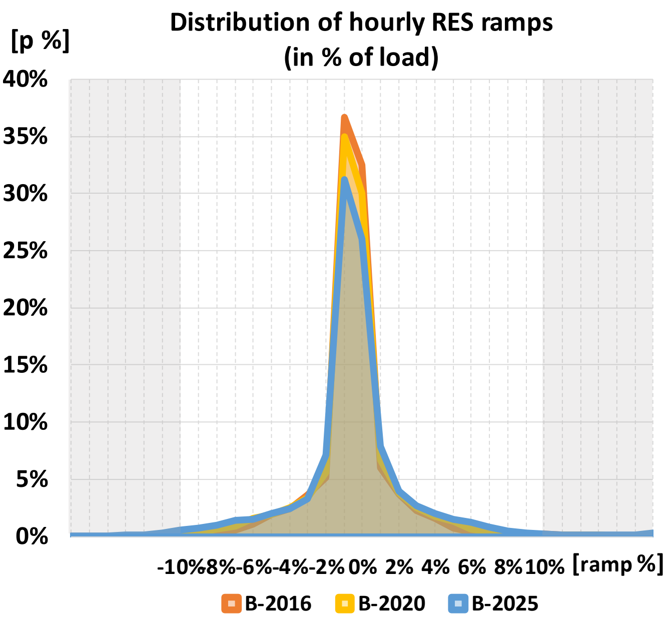
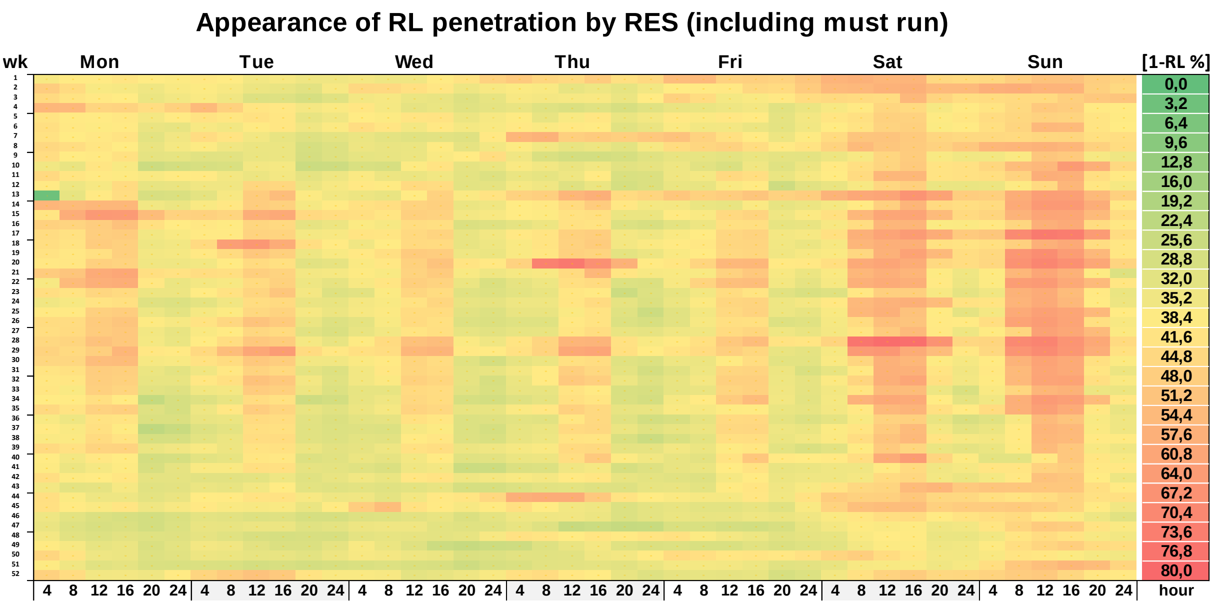
Belgium









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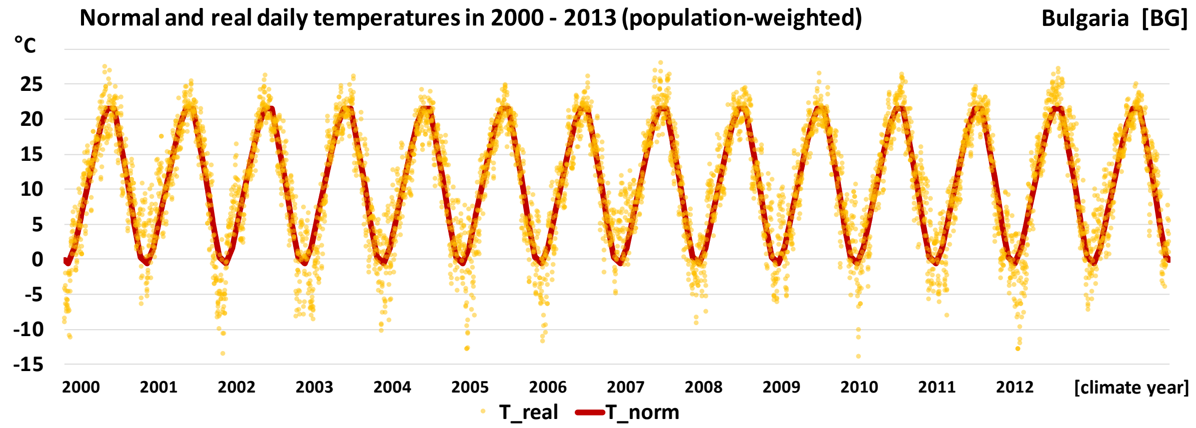
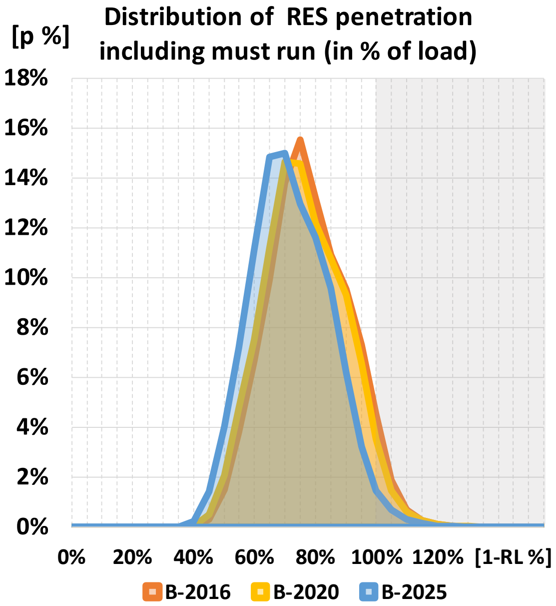
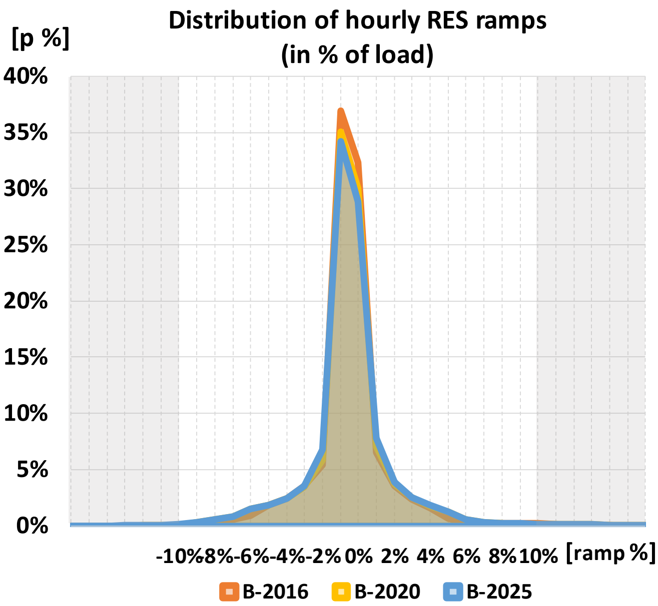
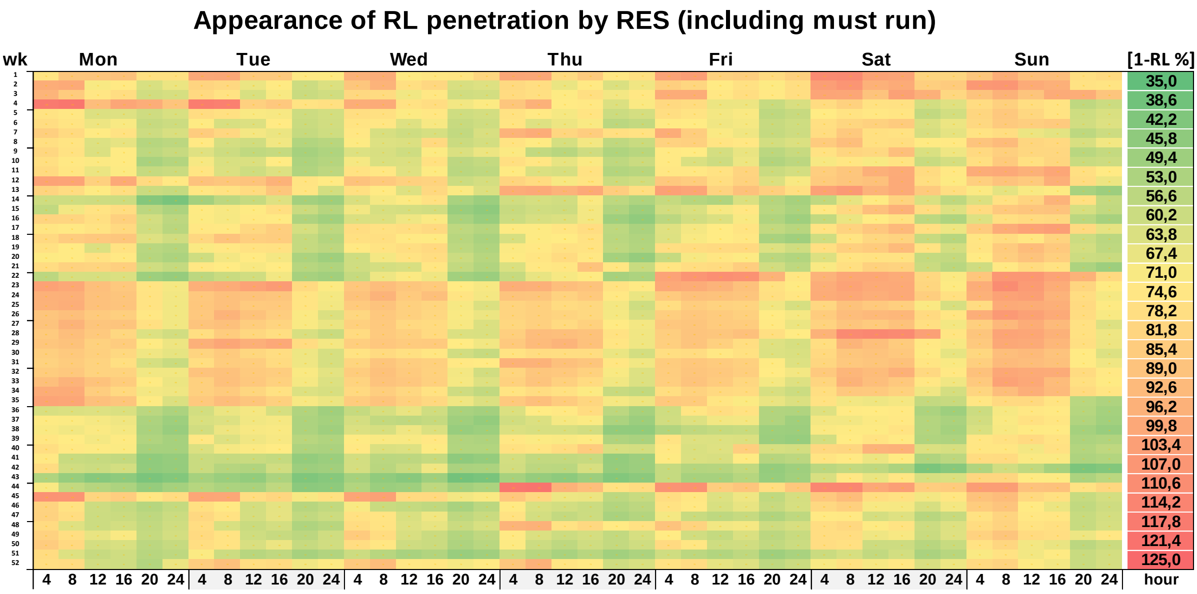
Bulgaria

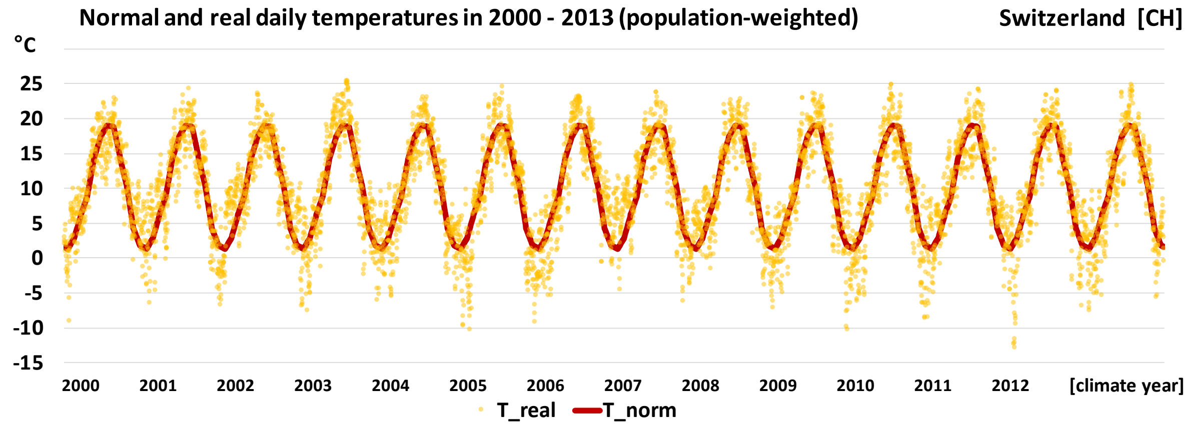

Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Bulgaria [BG]
°C
25
20
15
10
5
0
-5
-10
-15
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
[climate year]
T_real
T_norm

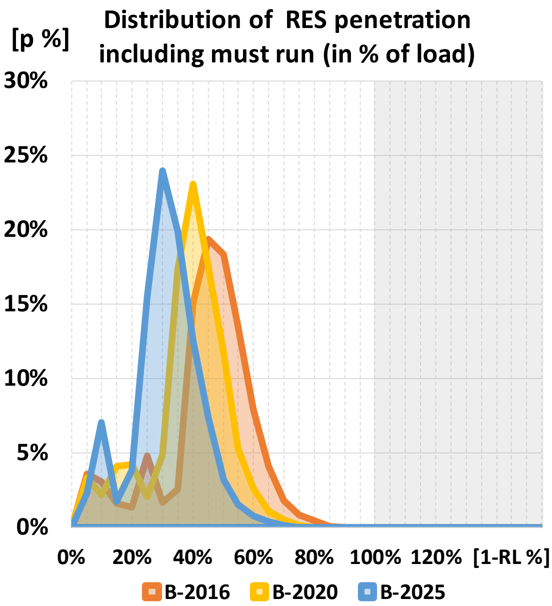

Distribution of RES penetration including must run (in % of load)
[p %]
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
0%
20%
40%
60%
80%
100%
120%
[1-RL %]
B-2016
B-2020
B-2025

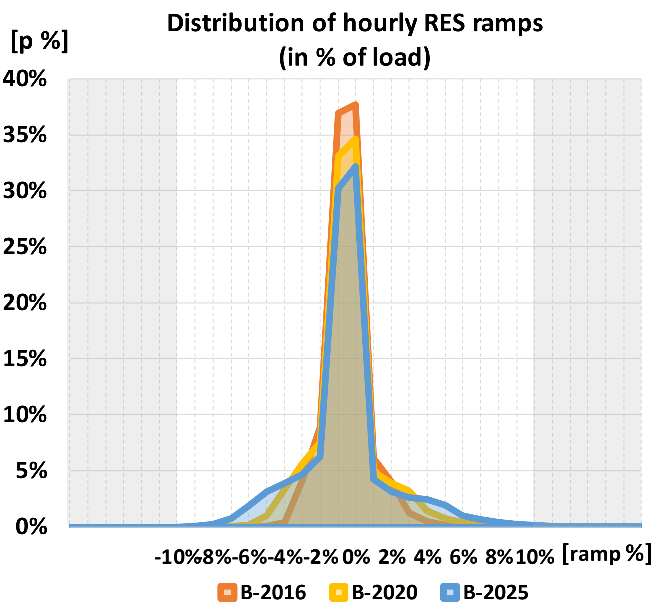

Distribution of hourly RES ramps (in % of load)
[p %]
40%
35%
30%
25%
20%
15%
10%
5%
0%
-10%8%-6%-4%-2%0% 2% 4% 6% 8%10%
[ramp %]
B-2016
B-2020
B-2025

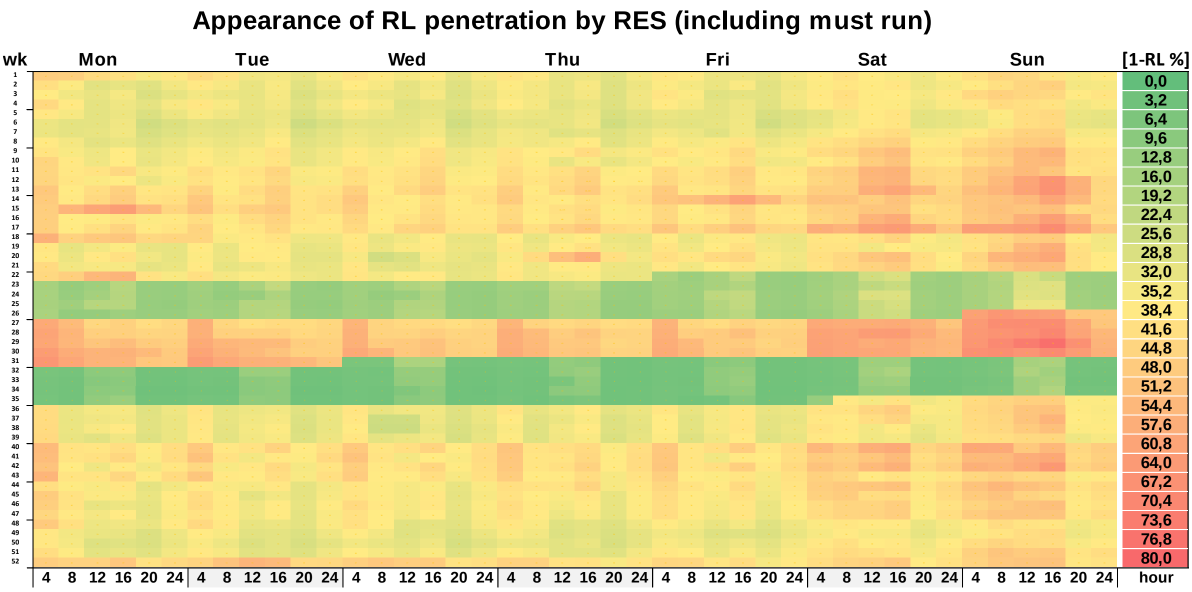

Appearance of RL penetration by RES (including must run)
wk
Mon
Tue
Wed
Thu
Fri
Sat
Sun
[1-RL %]
35,0
38,6
42,2
45,8
49,4
53,0
56,6
60,2
63,8
67,4
71,0
74,6
78,2
81,8
85,4
89,0
92,6
96,2
99,8
103,4
107,0
110,6
114,2
117,8
121,4
125,0
4 8 12 16 20 24
hour

Switzerland









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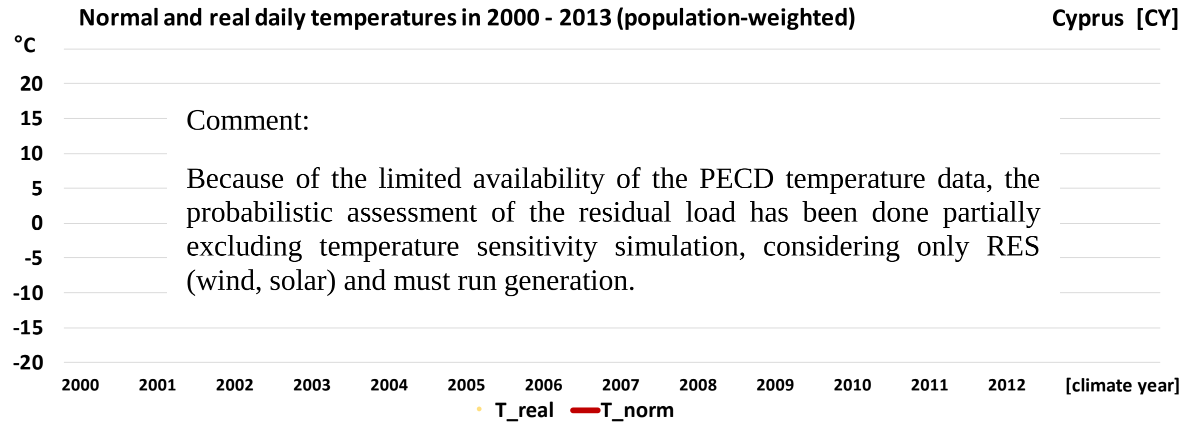
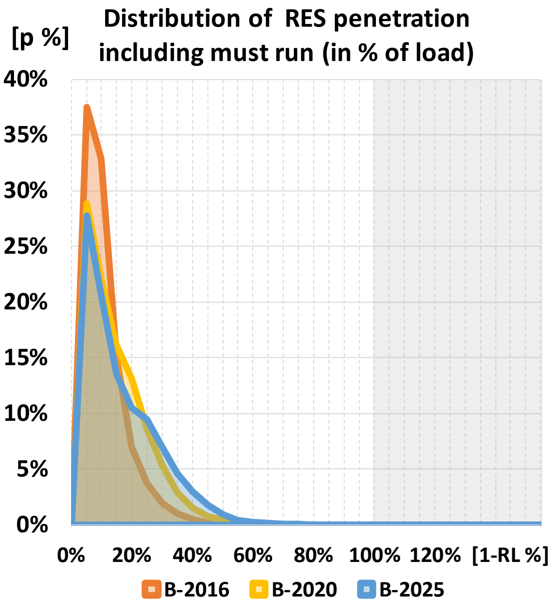
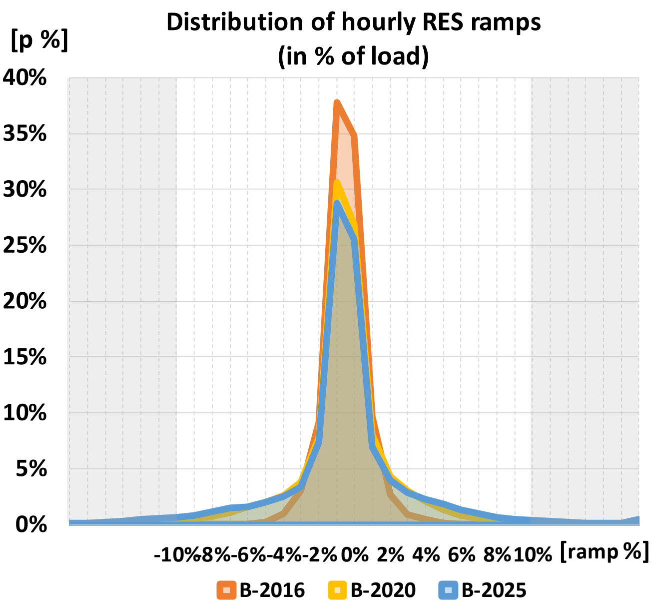
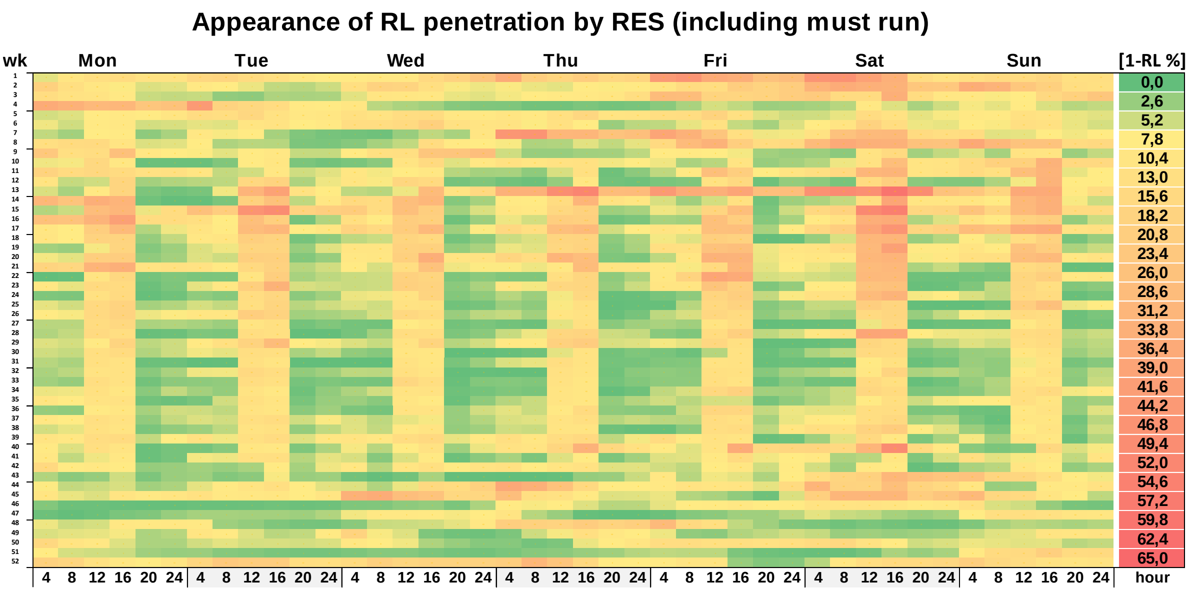
Cyprus









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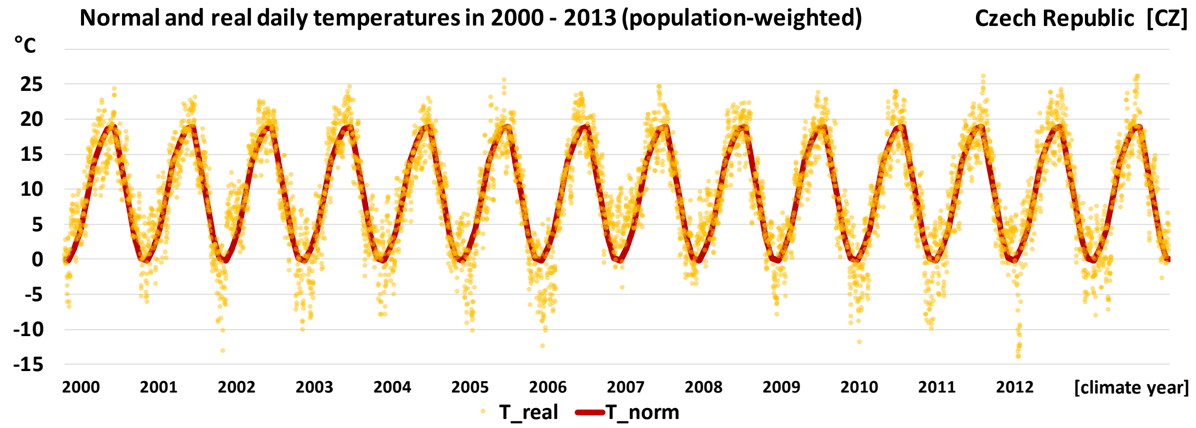
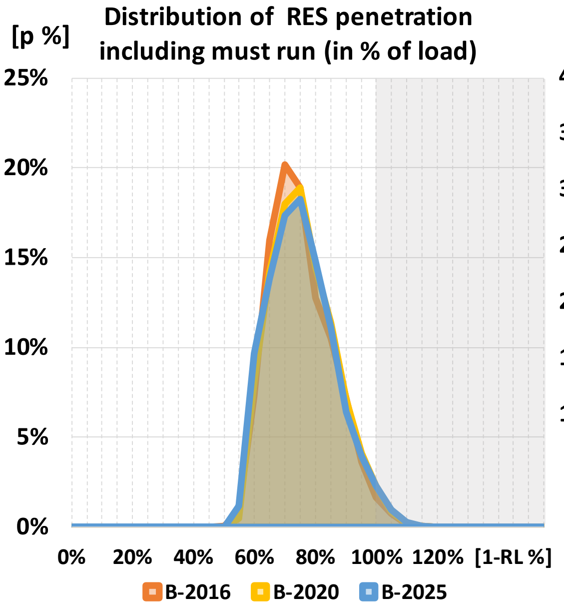
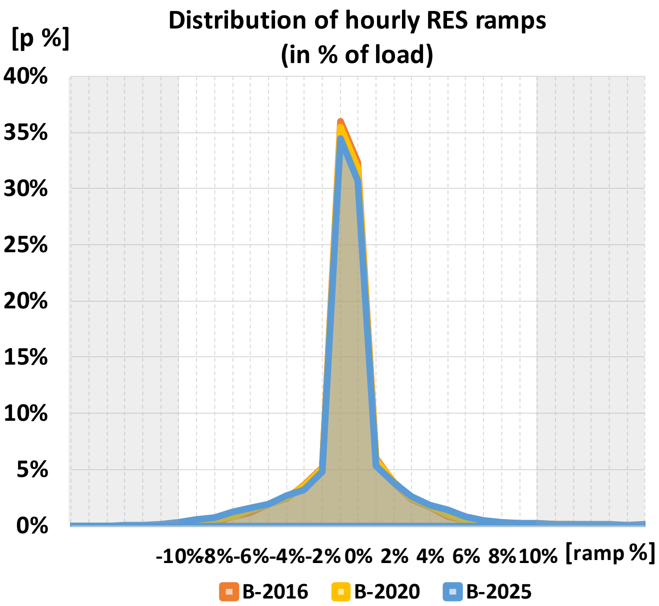
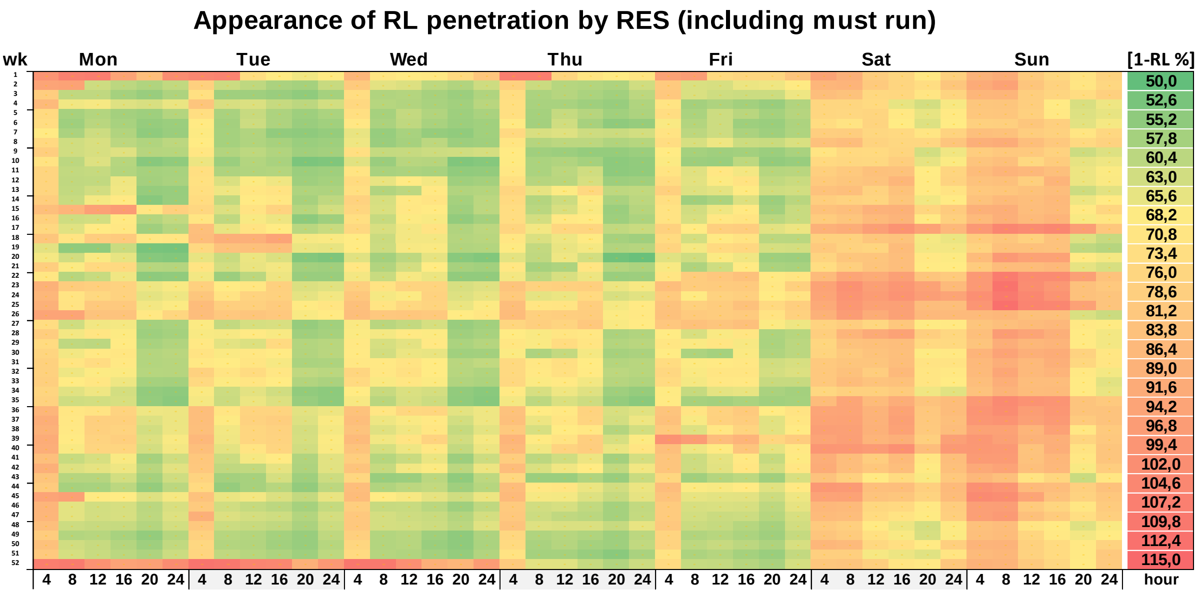
Czech Republic

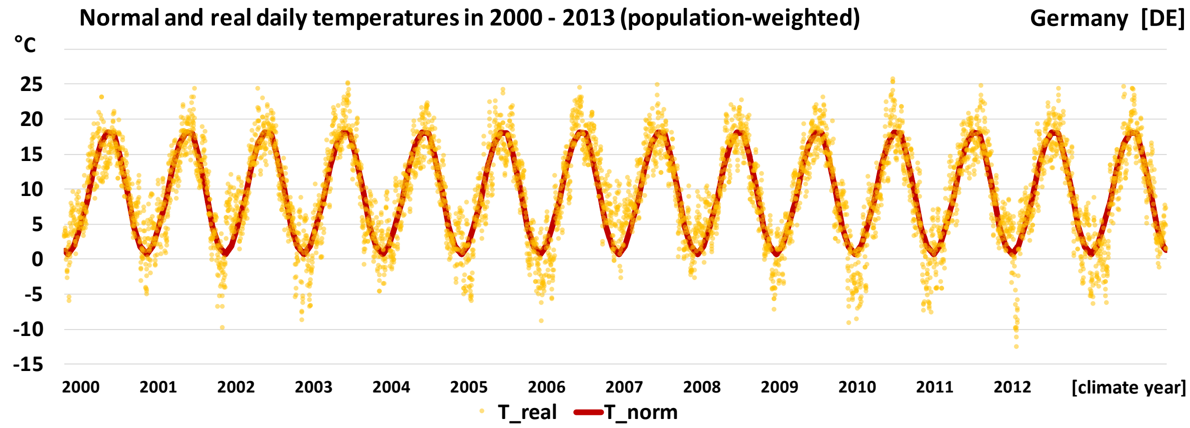


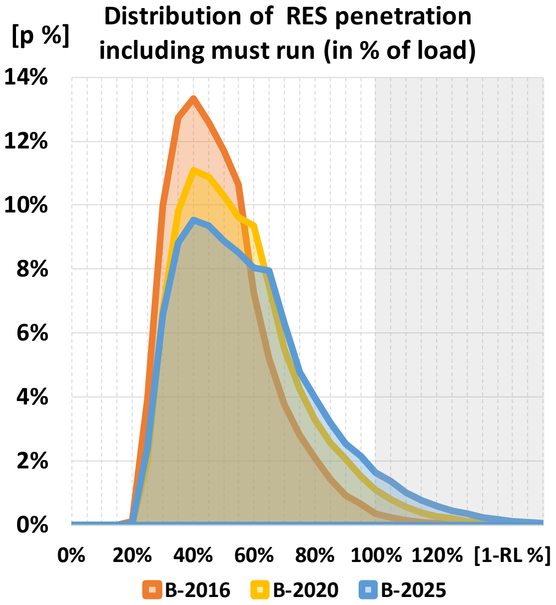


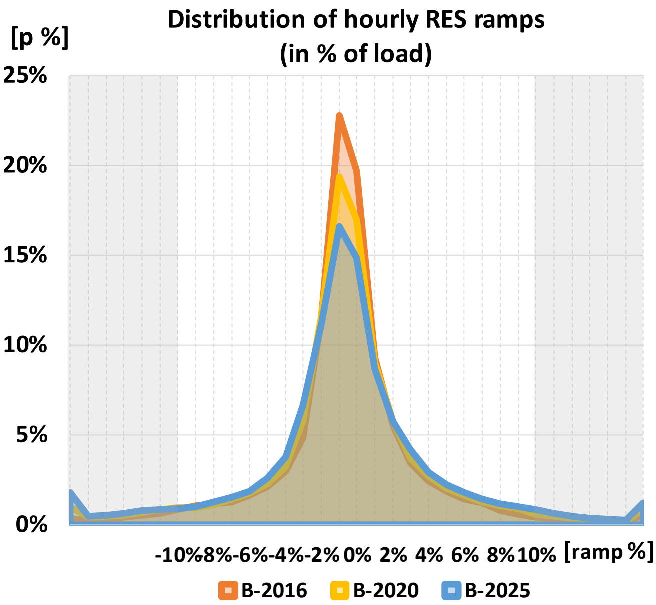


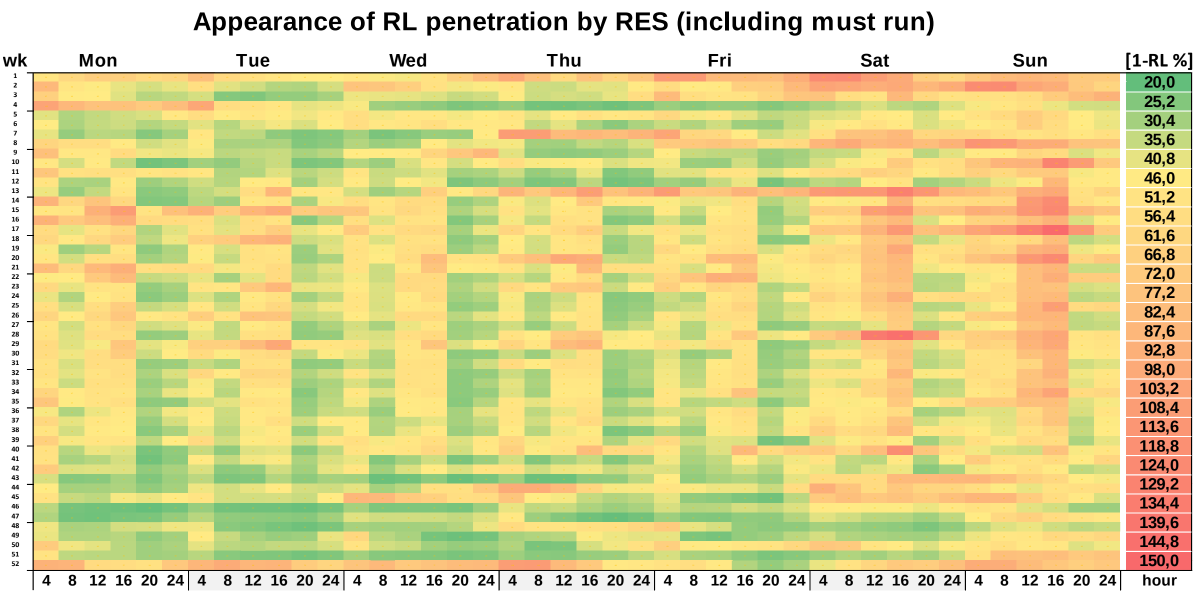


Germany









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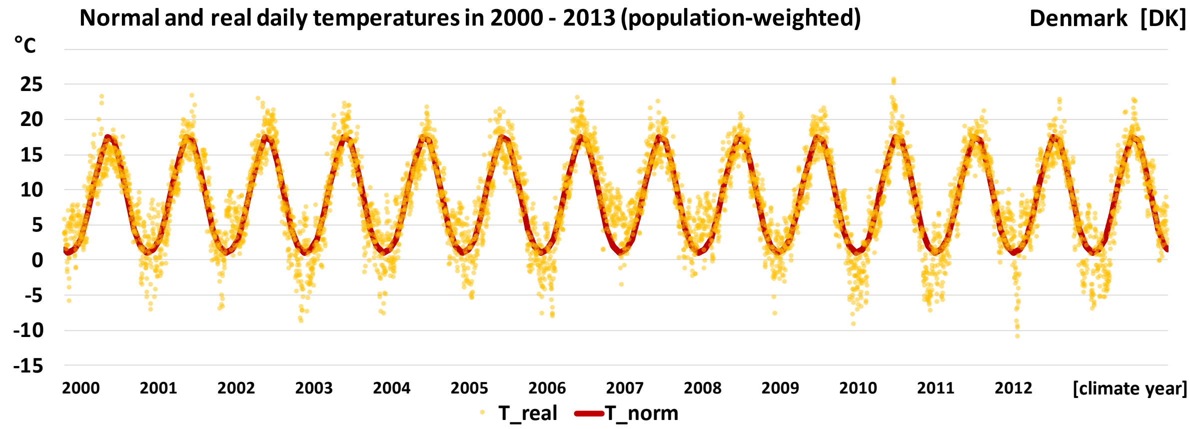
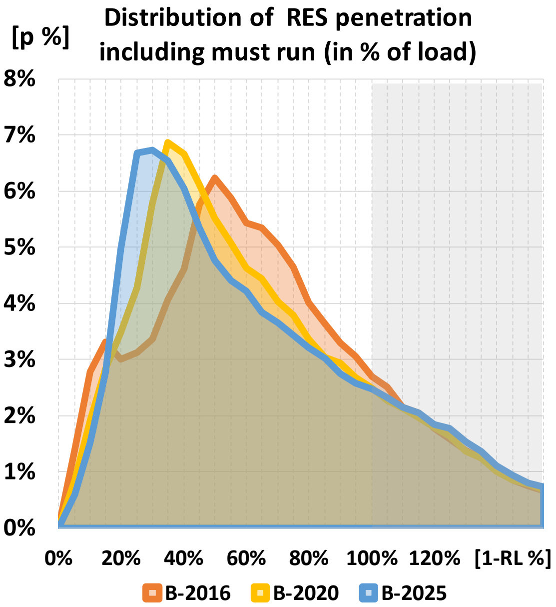
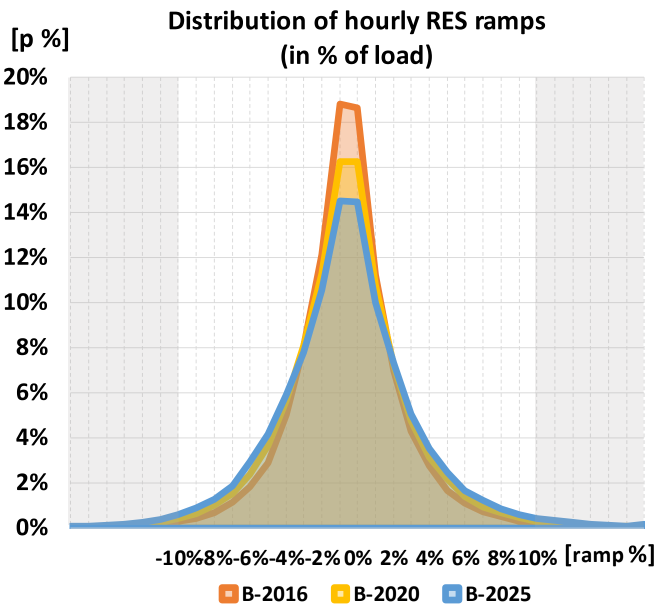
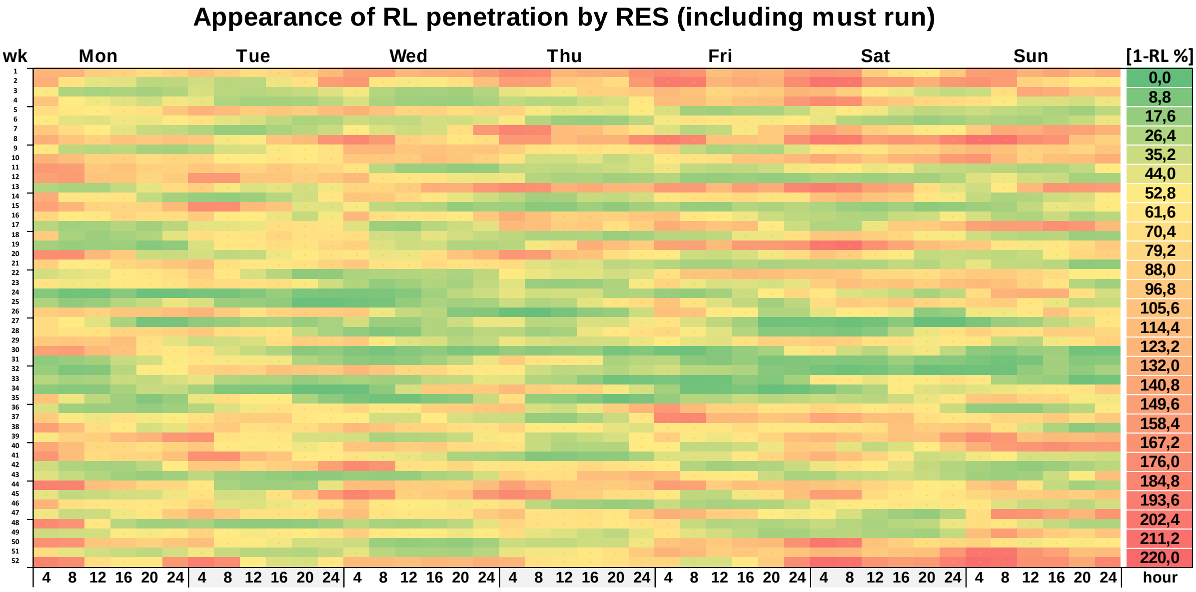
Denmark









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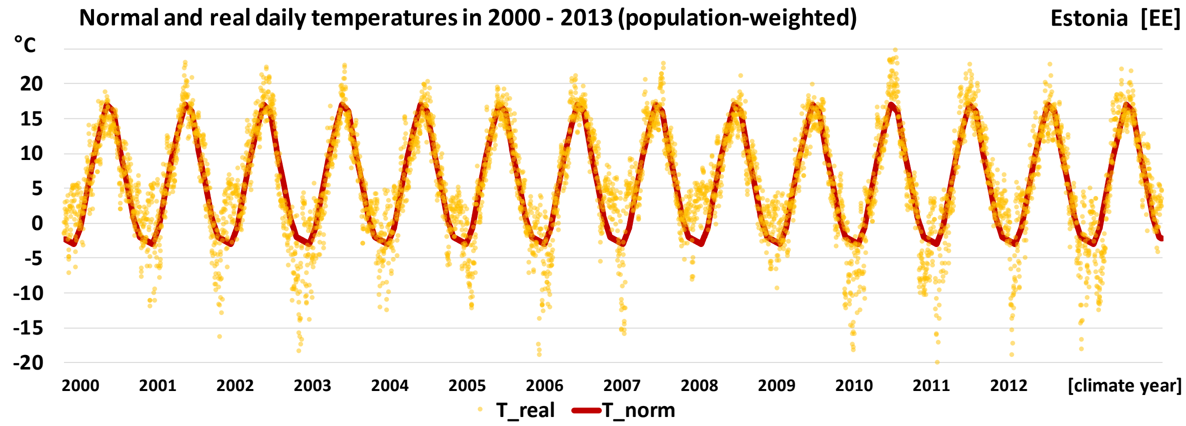
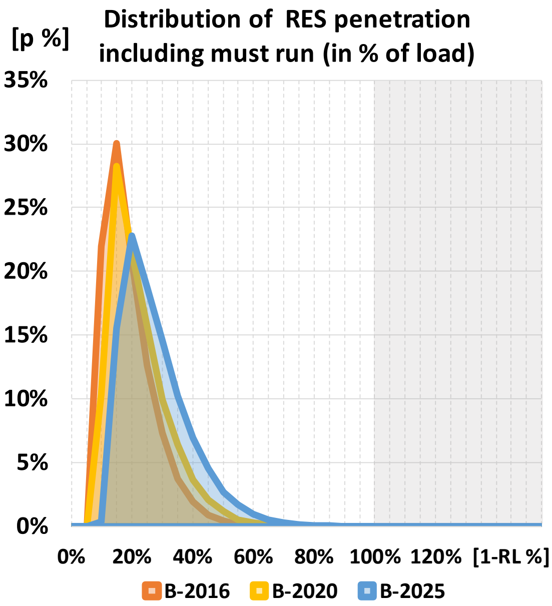
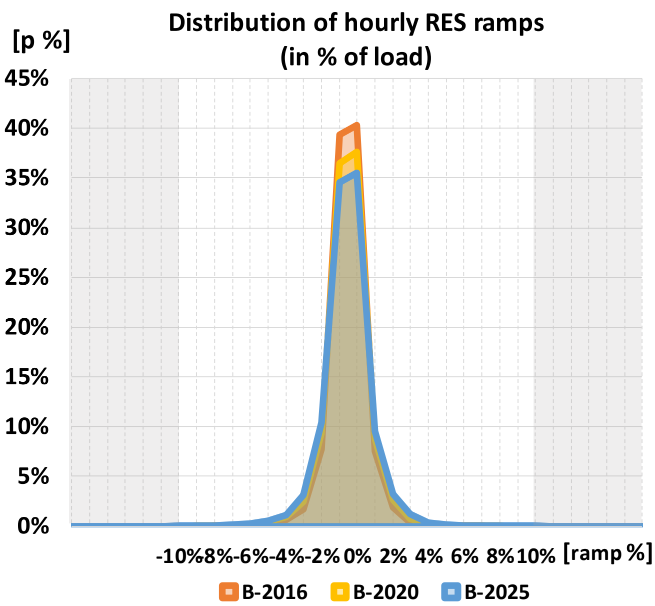
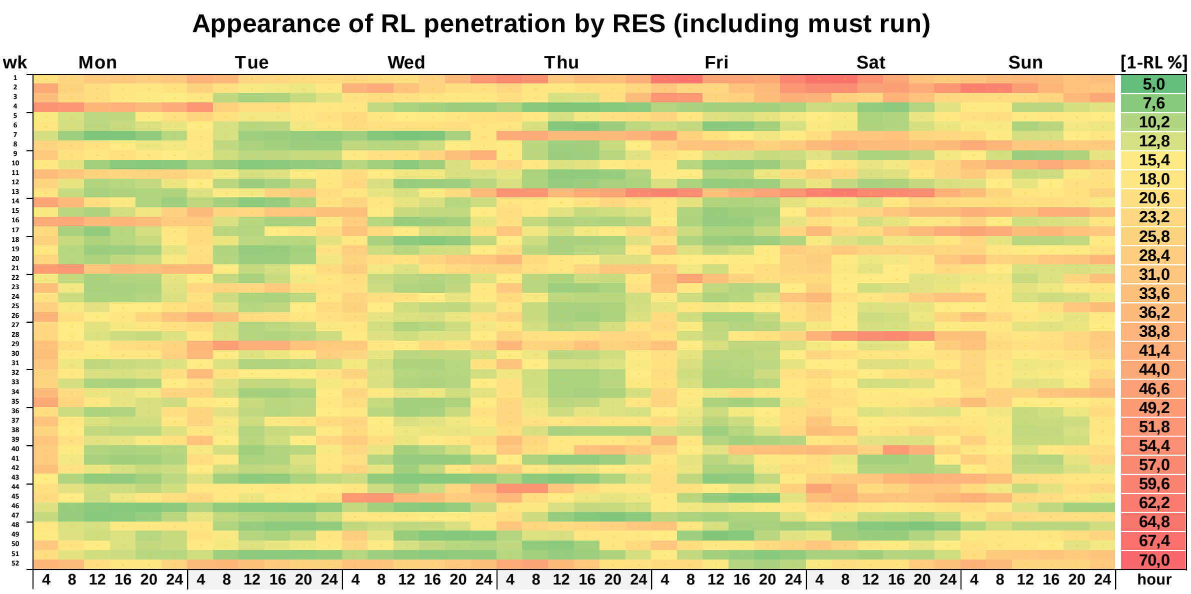
Estonia

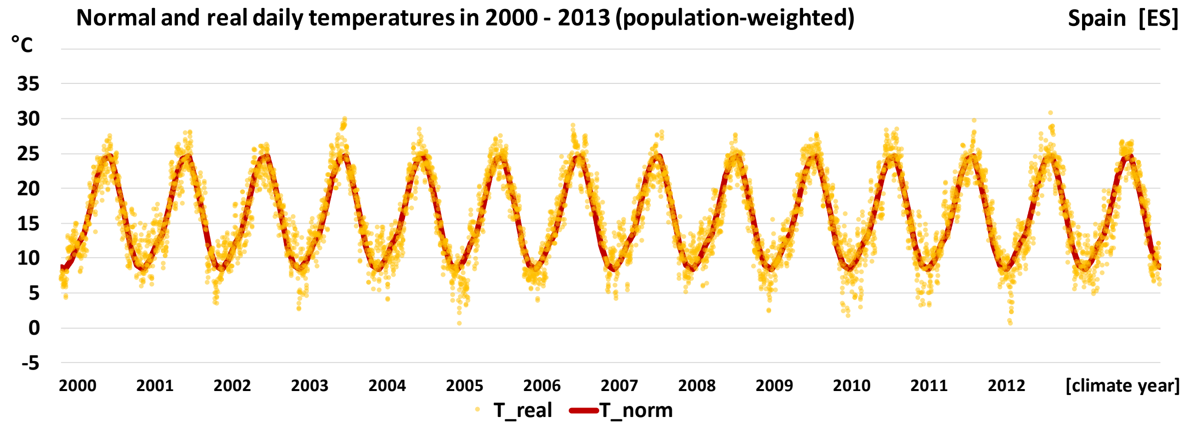

Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Estonia [EE]
°C
20
15
10
5
0
-5
-10
-15
-20
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
[climate year]
T_real
T_norm

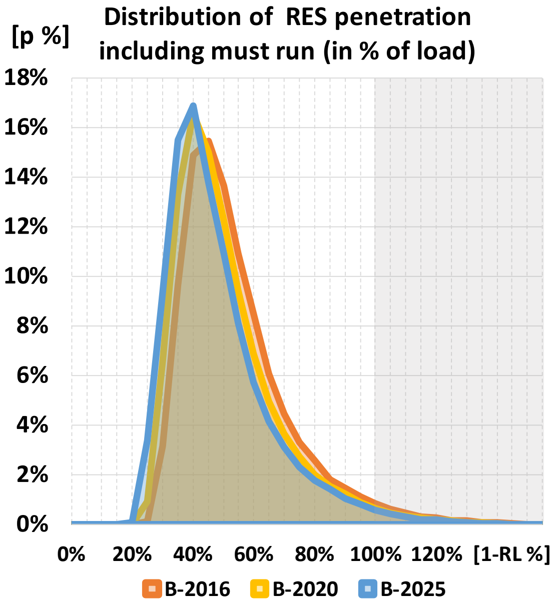

Distribution of RES penetration including must run (in % of load)
[p %]
35%
30%
25%
20%
15%
10%
5%
0%
0%
20%
40%
60%
80%
100%
120%
[1-RL %]
B-2016
B-2020
B-2025

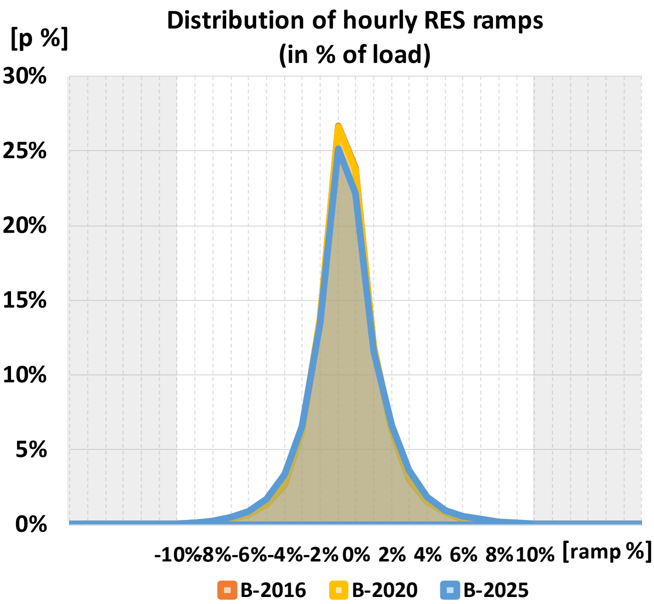

Distribution of hourly RES ramps (in % of load)
[p %]
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
-10%8%-6%-4%-2%0% 2% 4% 6% 8%10%
[ramp %]
B-2016
B-2020
B-2025

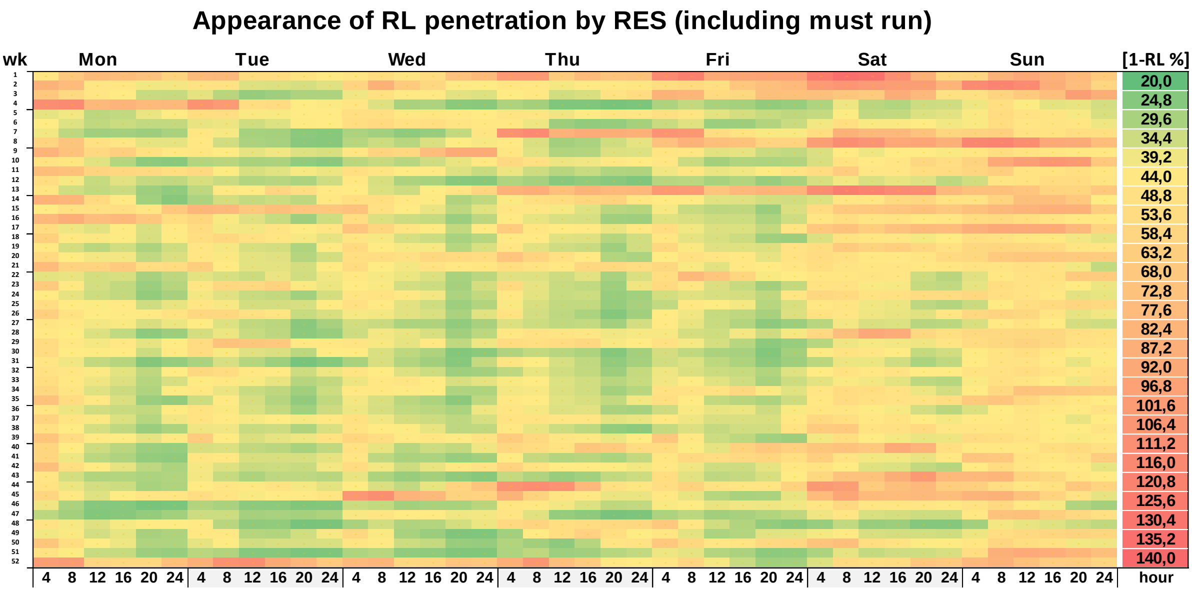

Appearance of RL penetration by RES (including must run)
wk
Mon
Tue
Wed
Thu
Fri
Sat
Sun
[1-RL %]
5,0
7,6
10,2
12,8
15,4
18,0
20,6
23,2
25,8
28,4
31,0
33,6
36,2
38,8
41,4
44,0
46,6
49,2
51,8
54,4
57,0
59,6
62,2
64,8
67,4
70,0
hour

Spain









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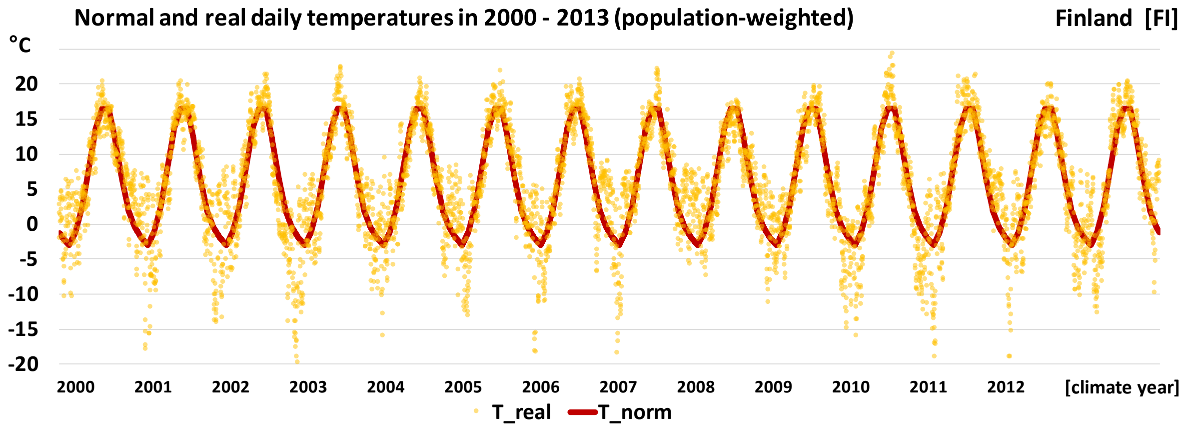
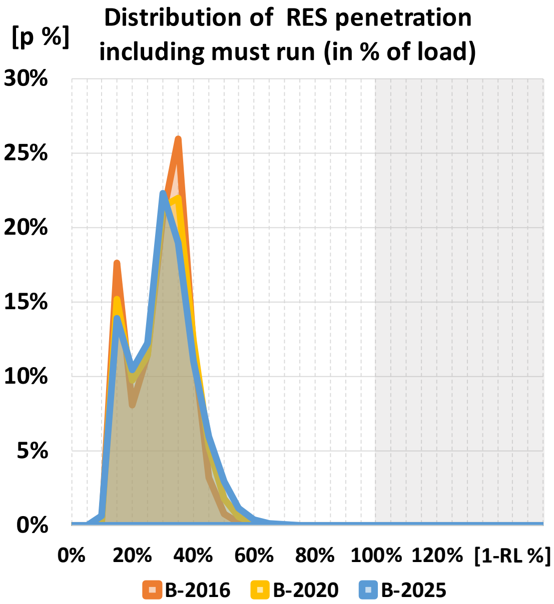
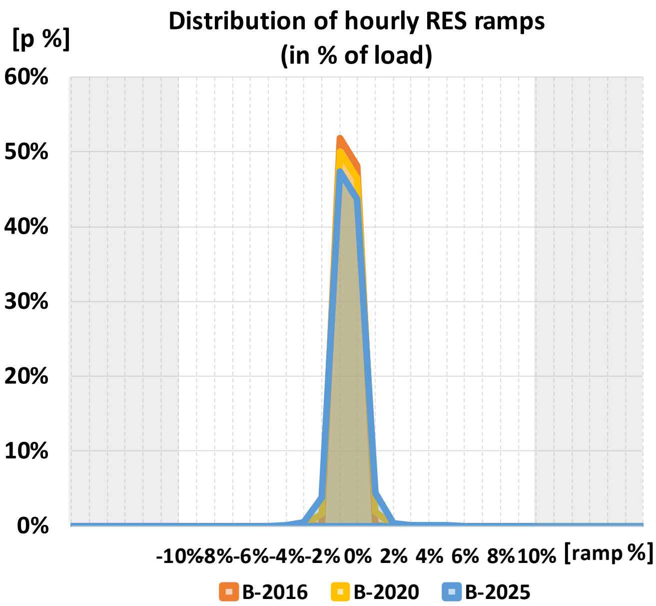
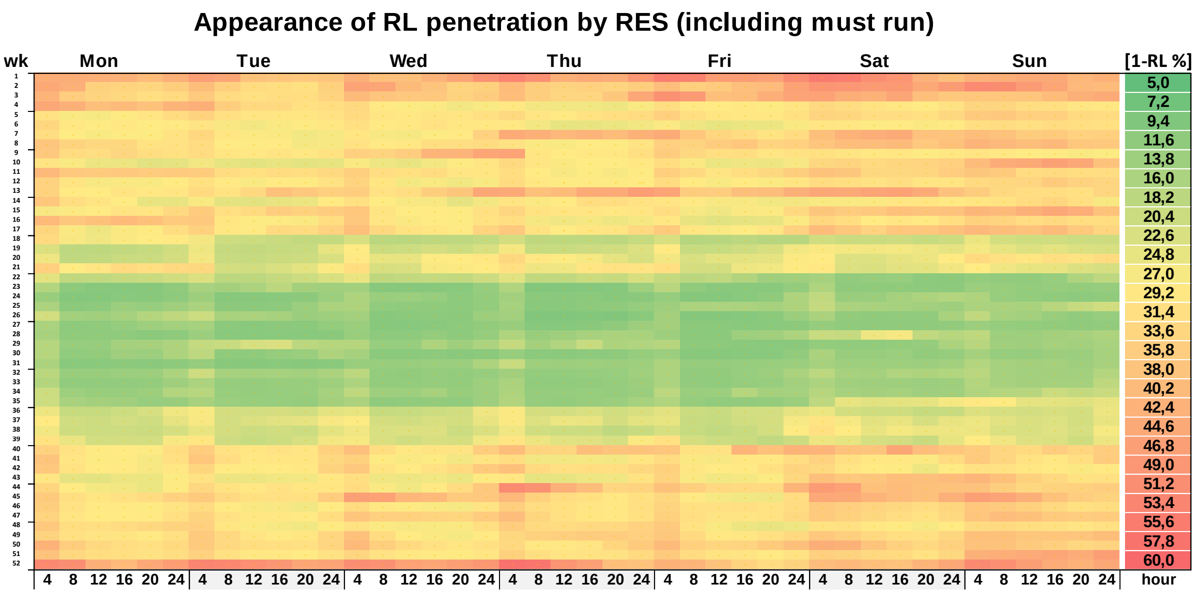
Finland









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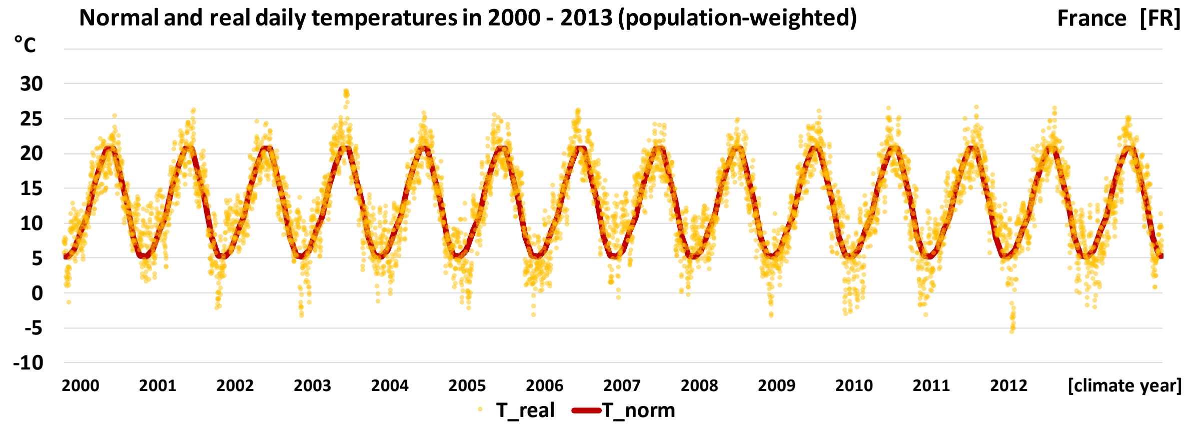
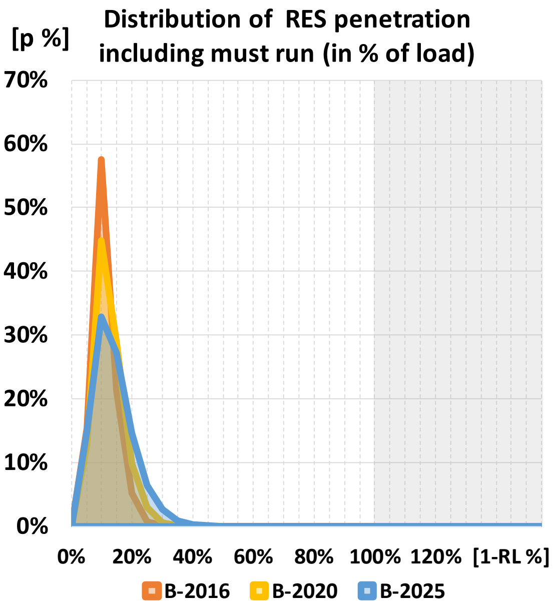
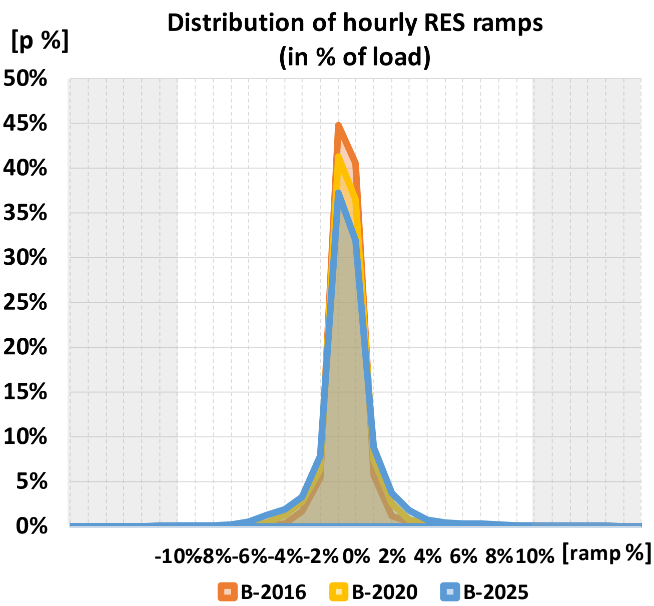
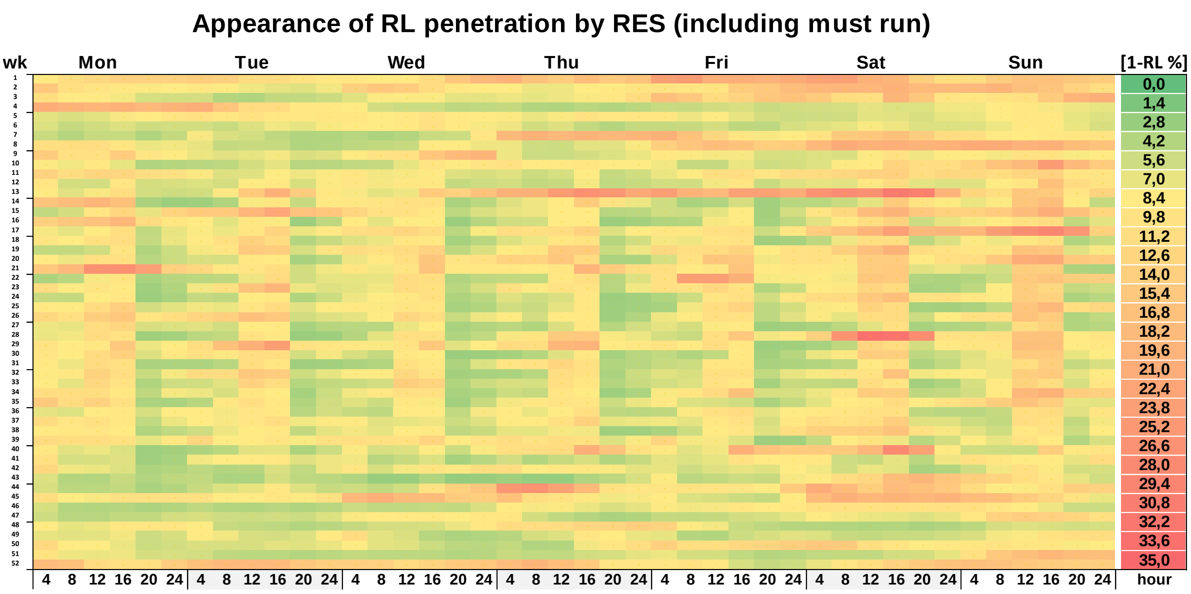
France









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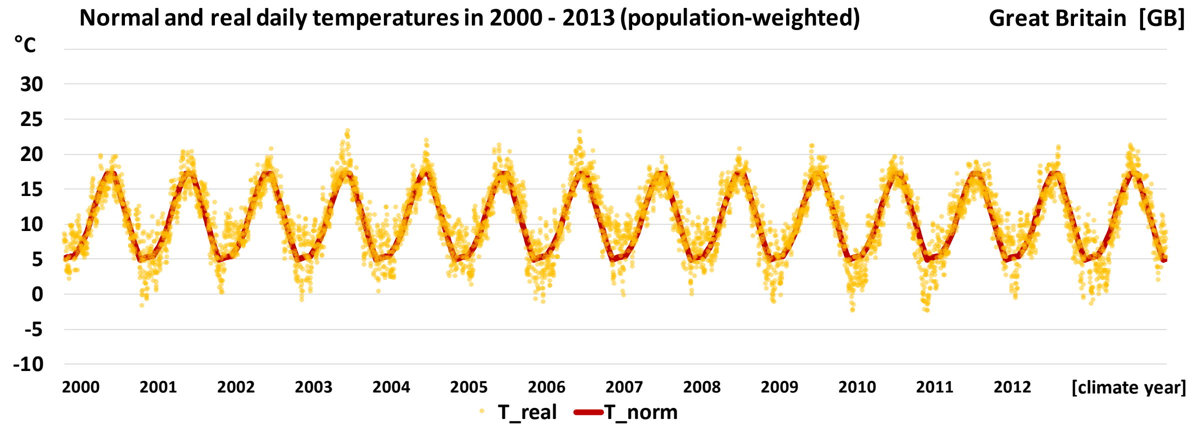
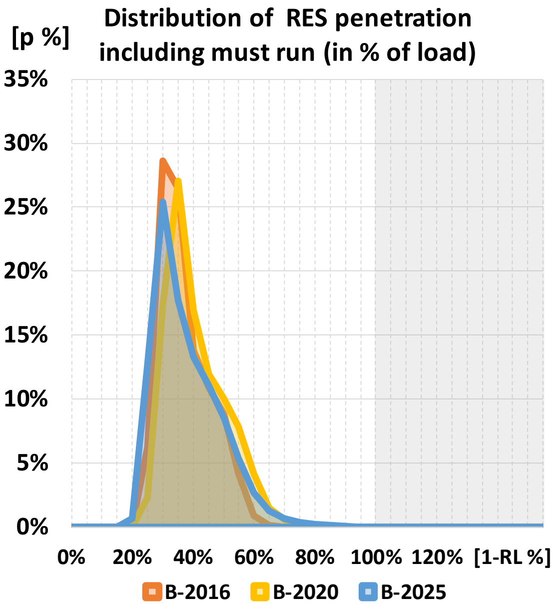
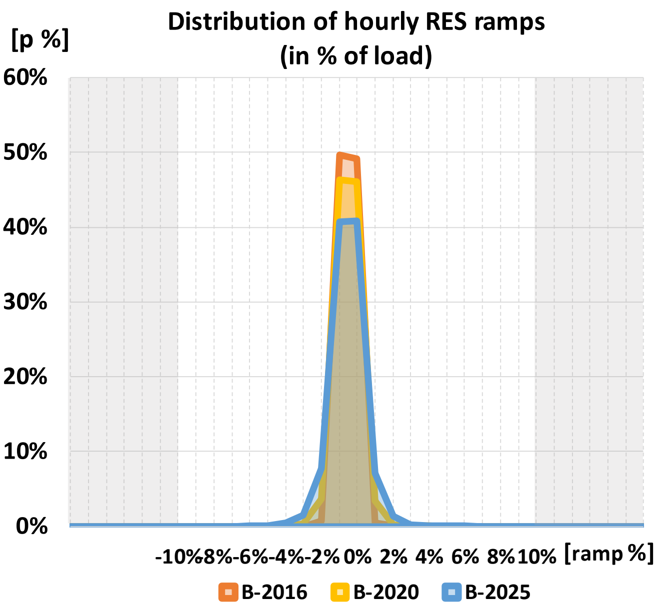
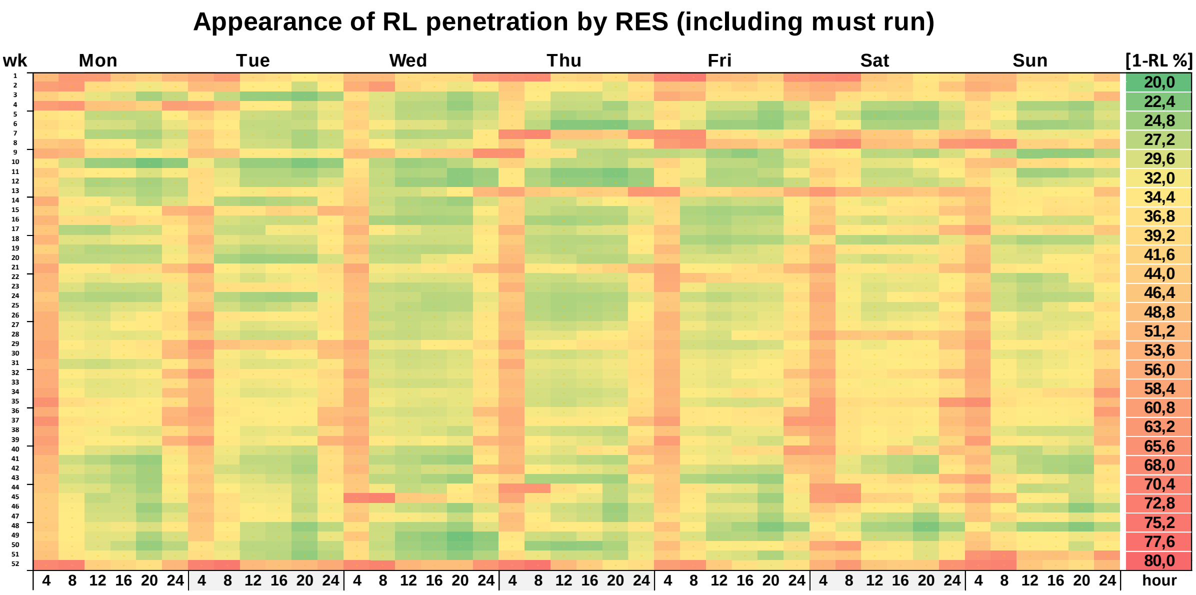
Great Britain









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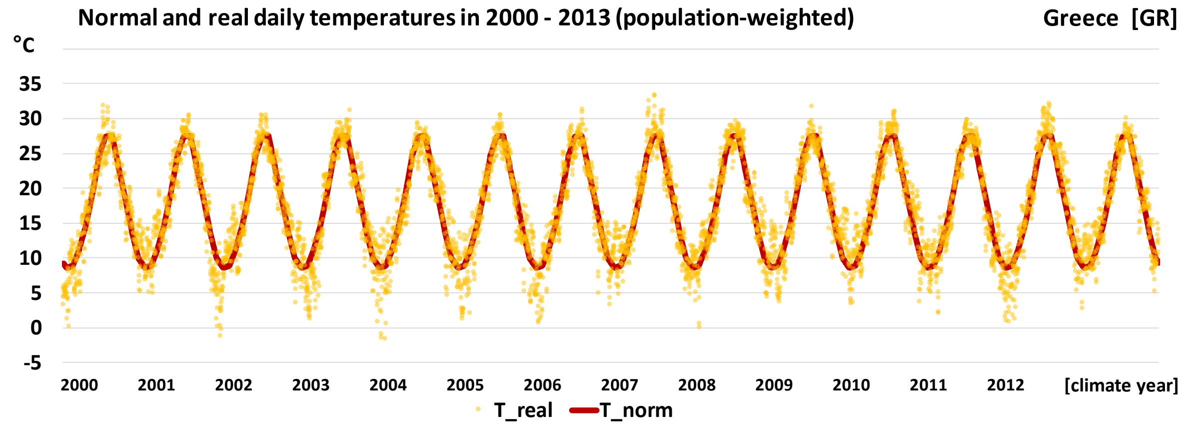
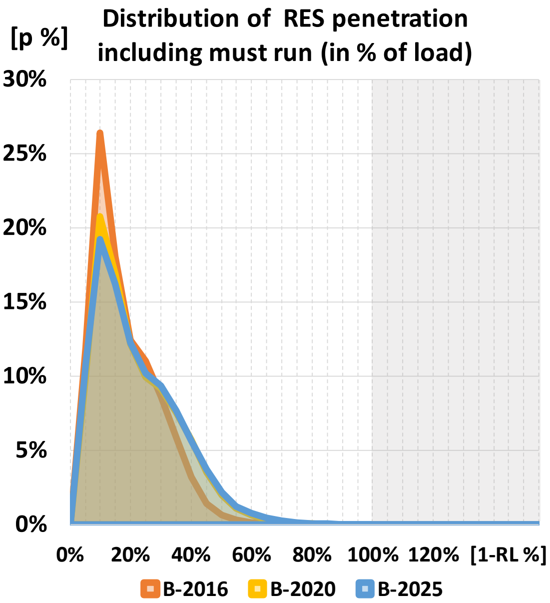
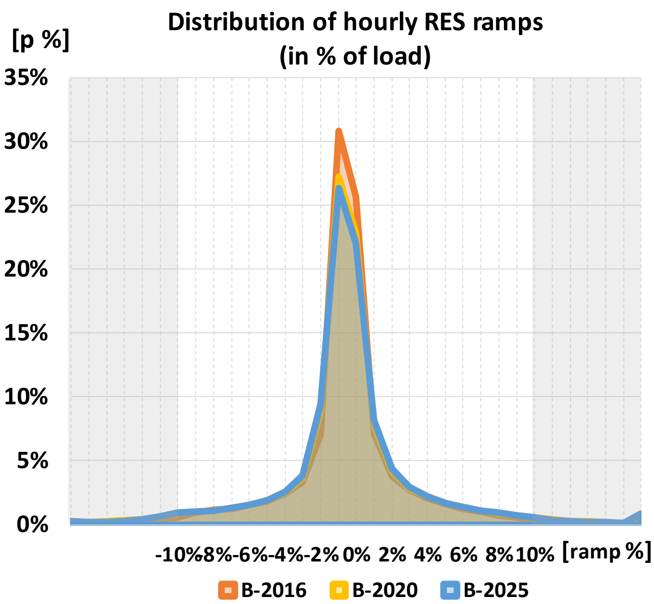
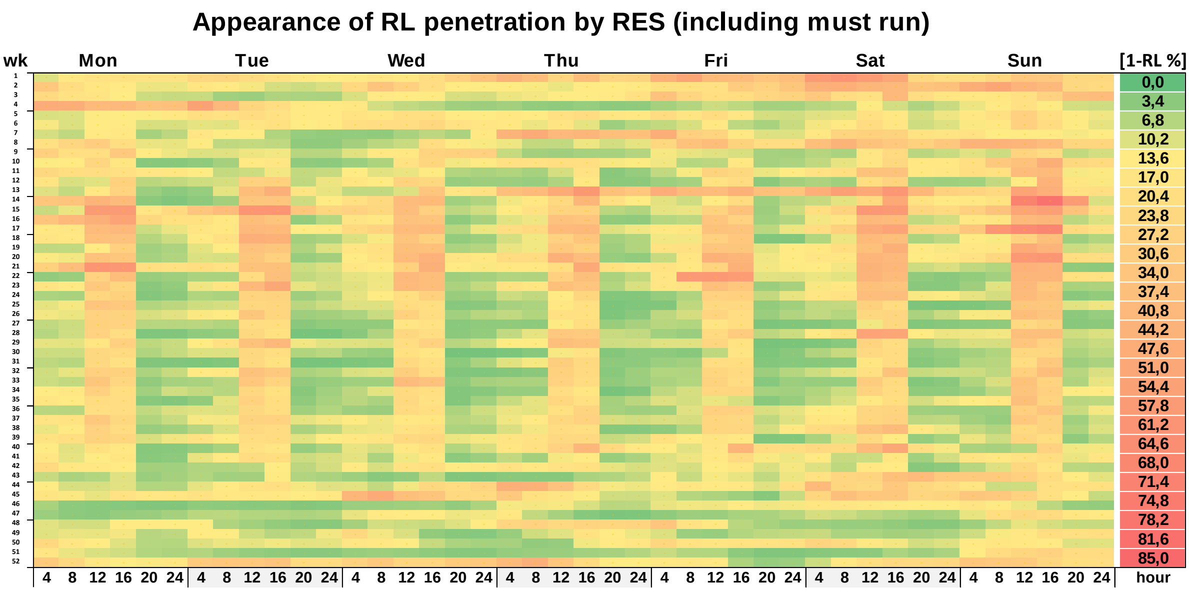
Greece









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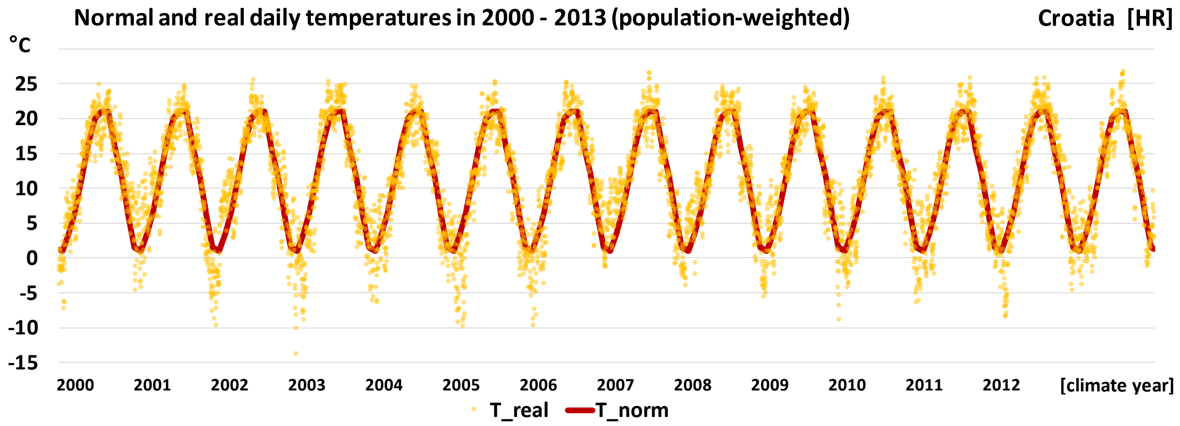
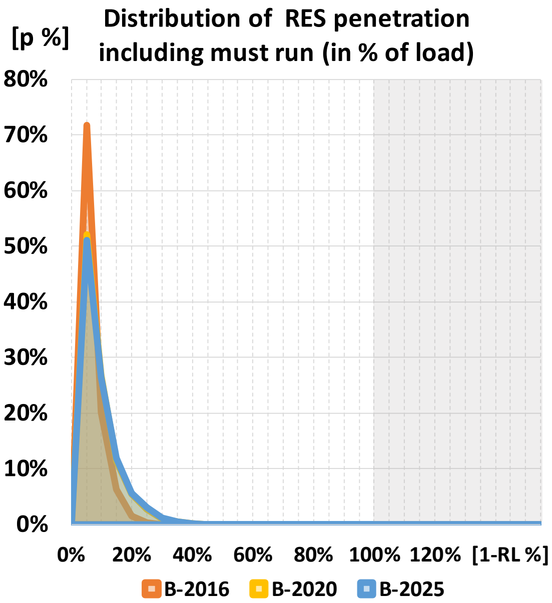
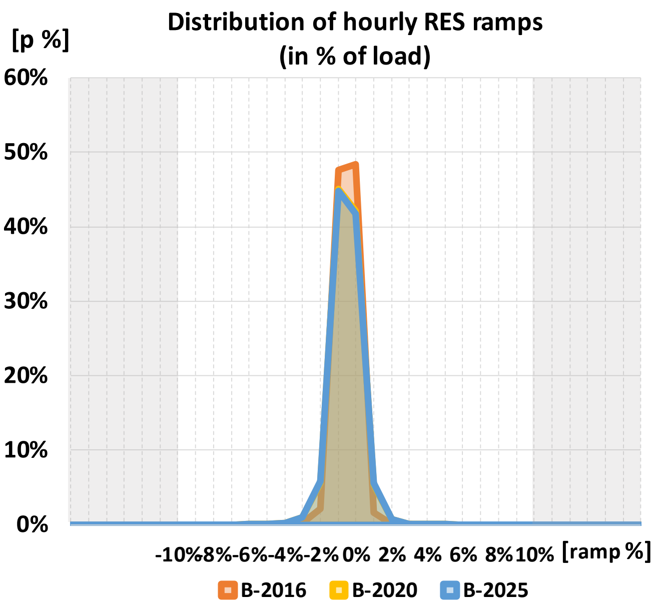
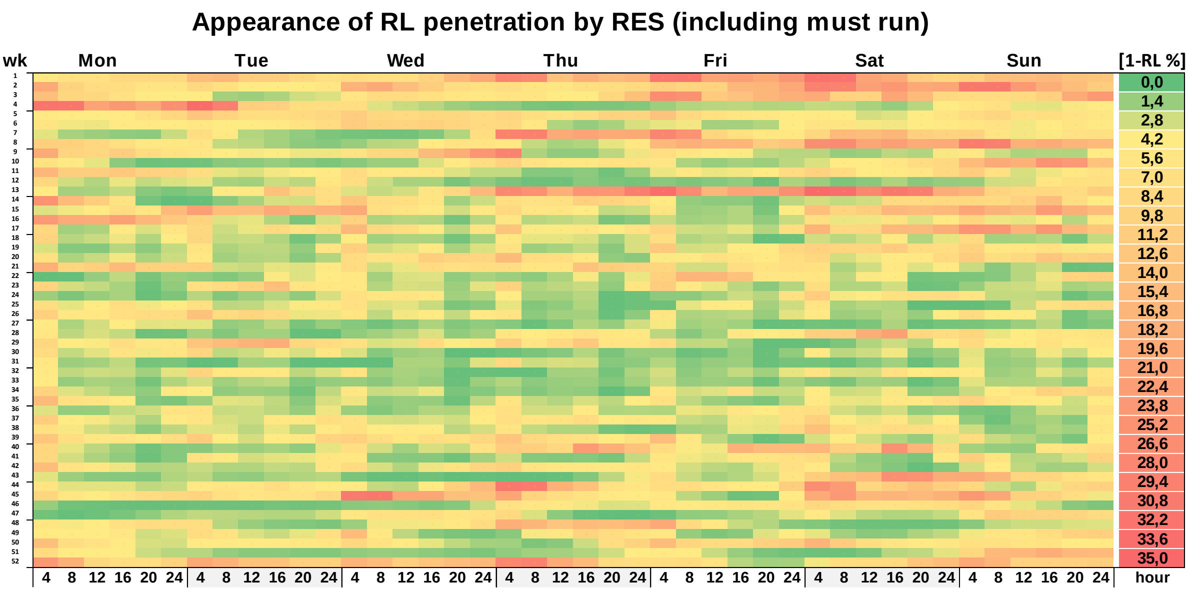
Croatia









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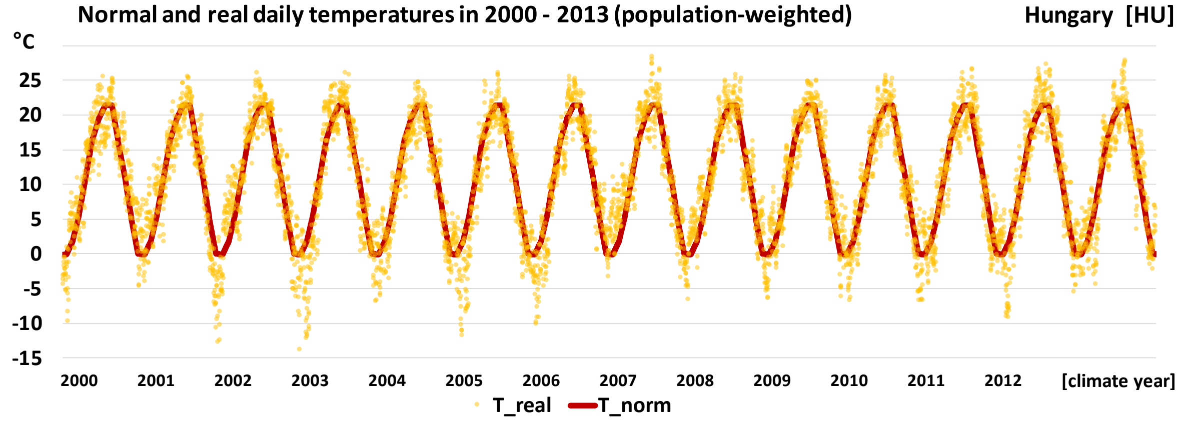
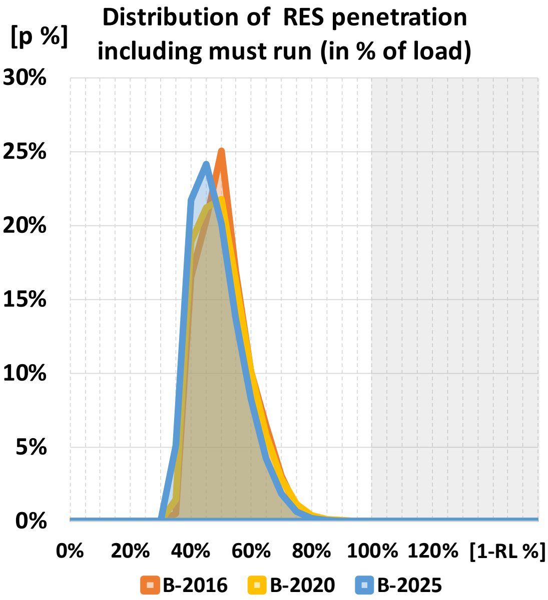
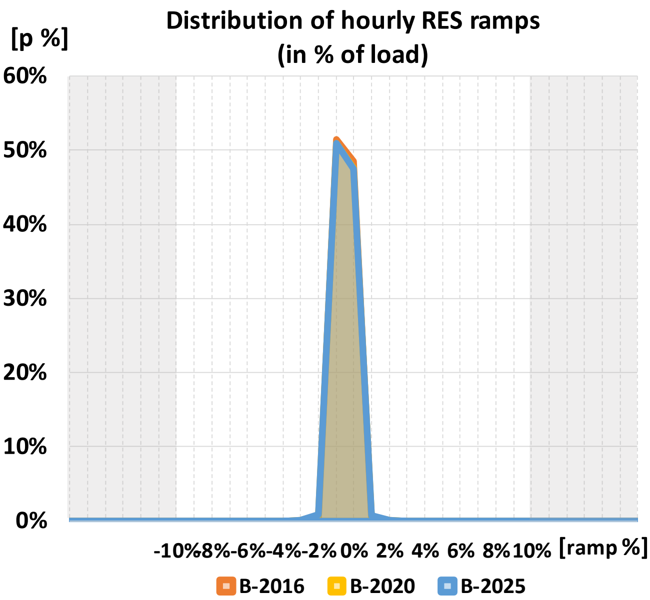
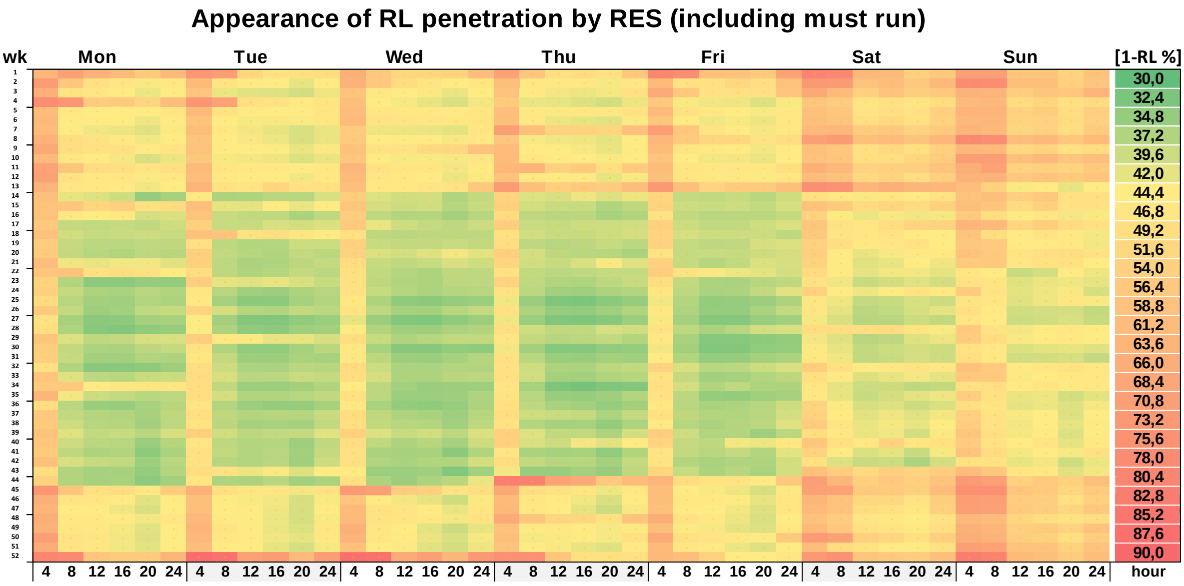
Hungary









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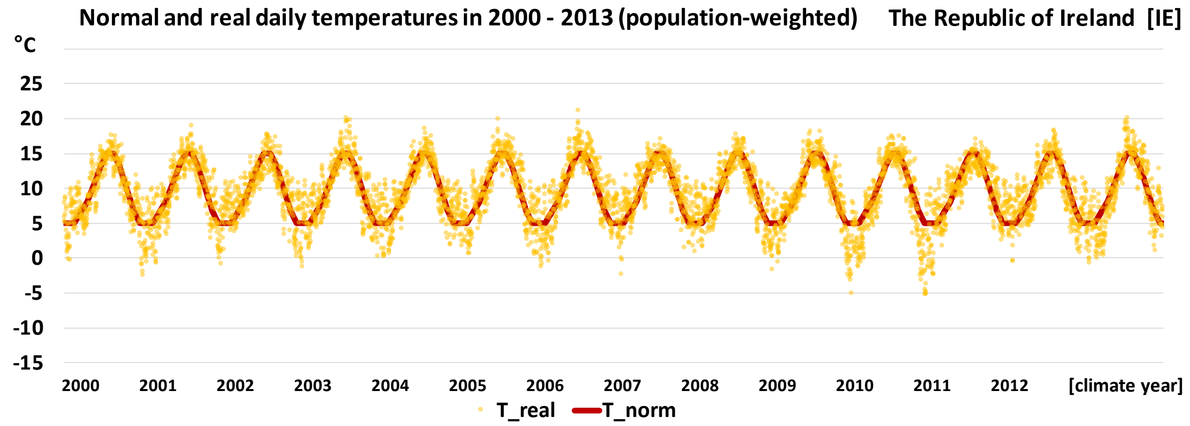
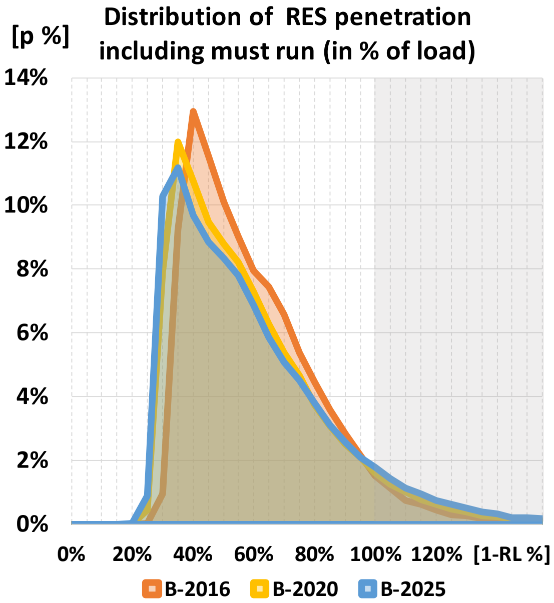
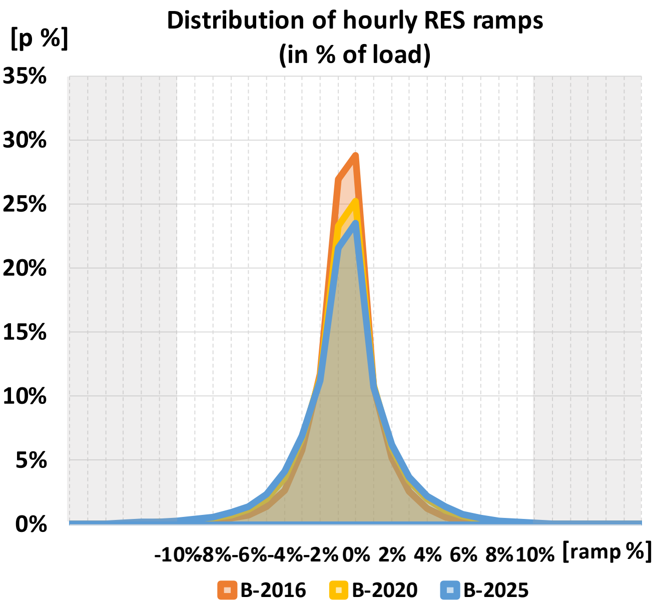
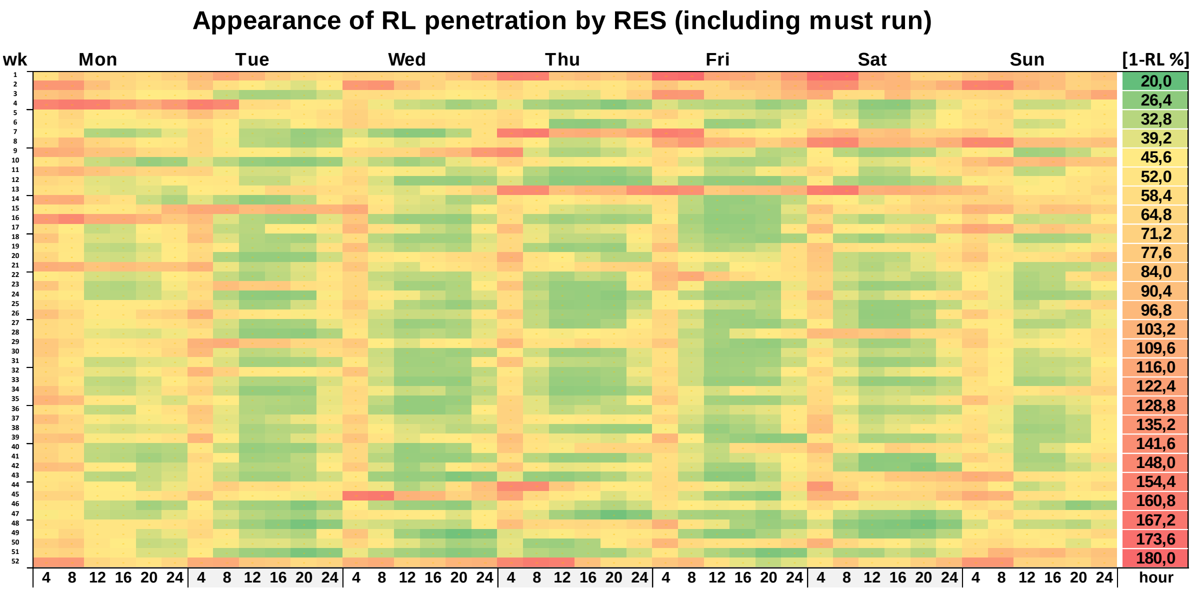
The Republic of Ireland









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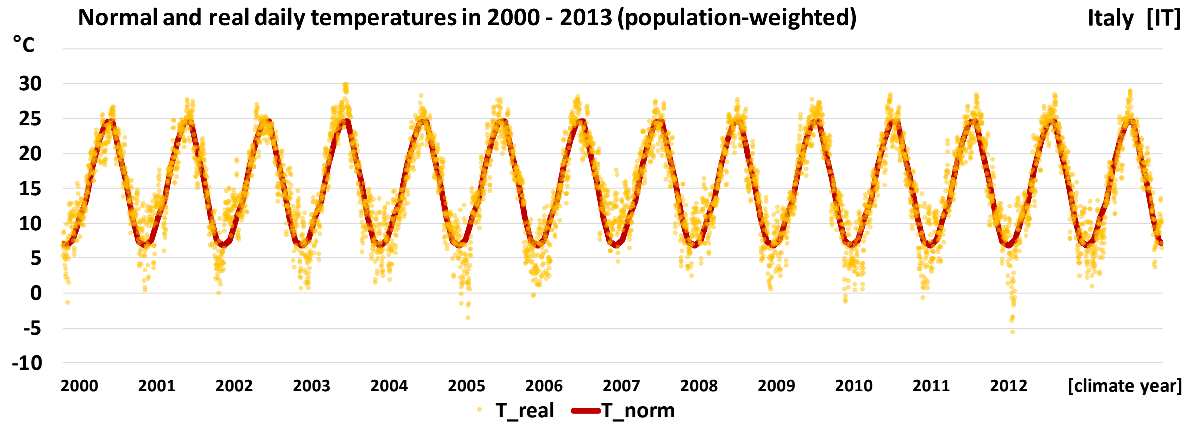
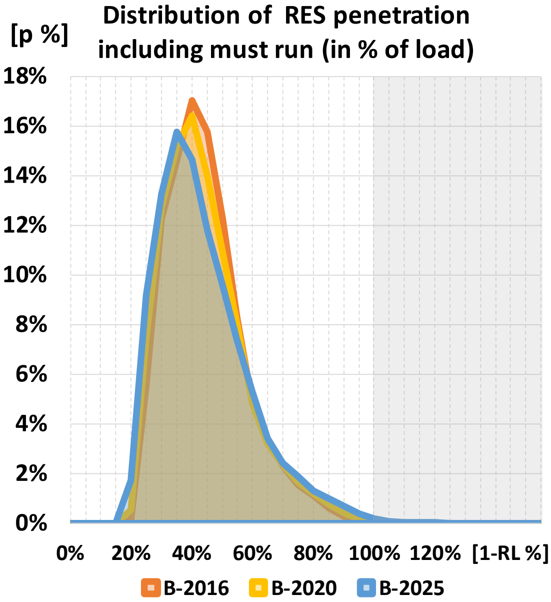
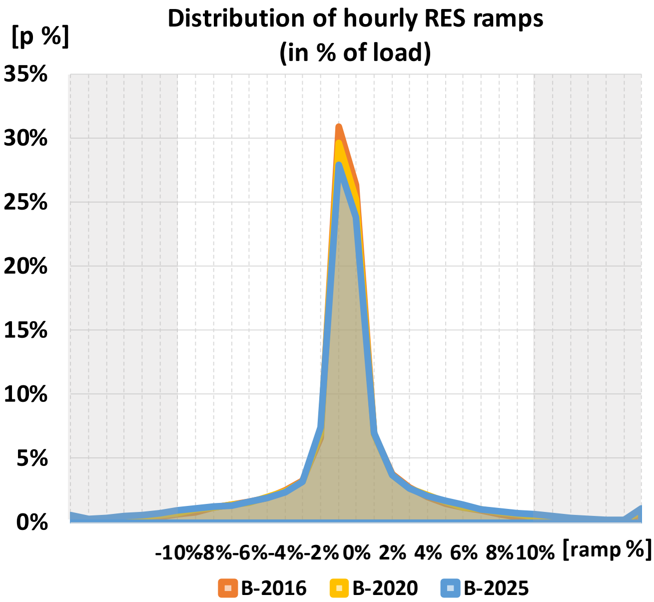
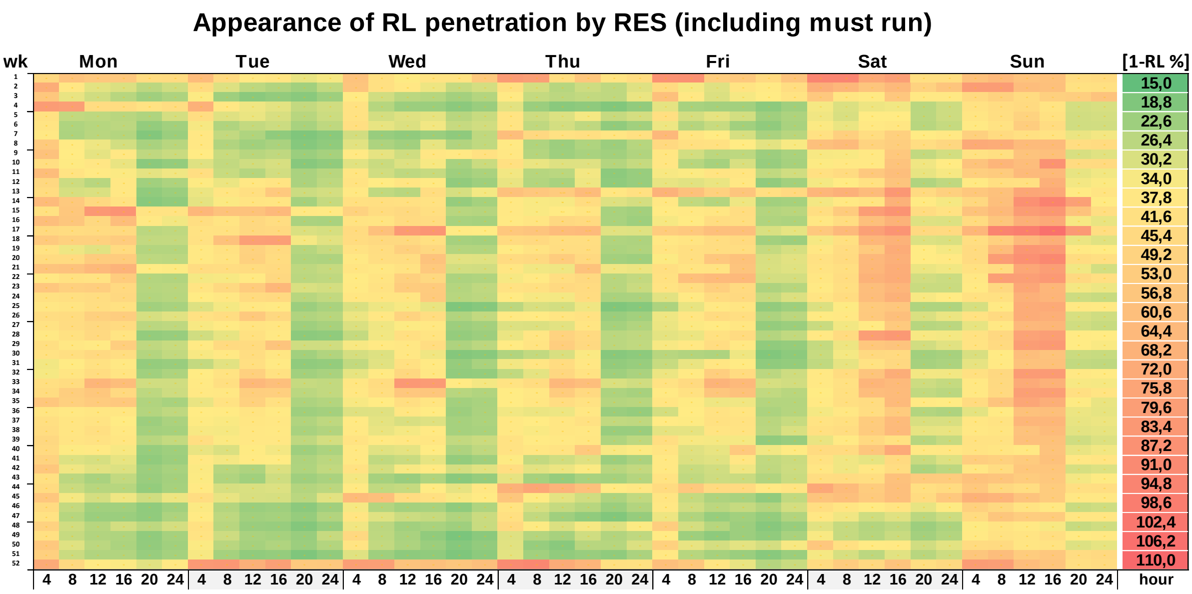
Italy









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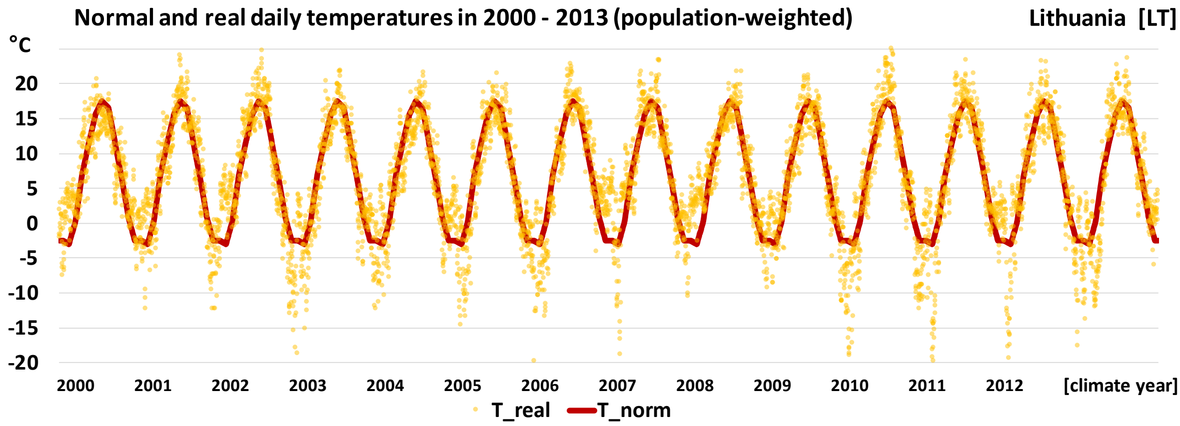
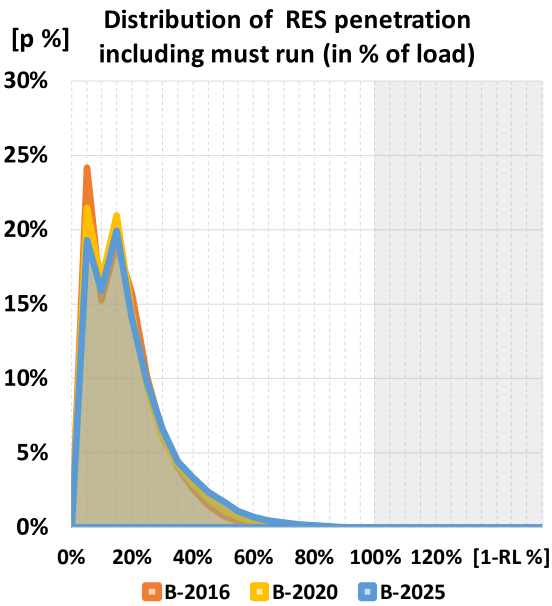
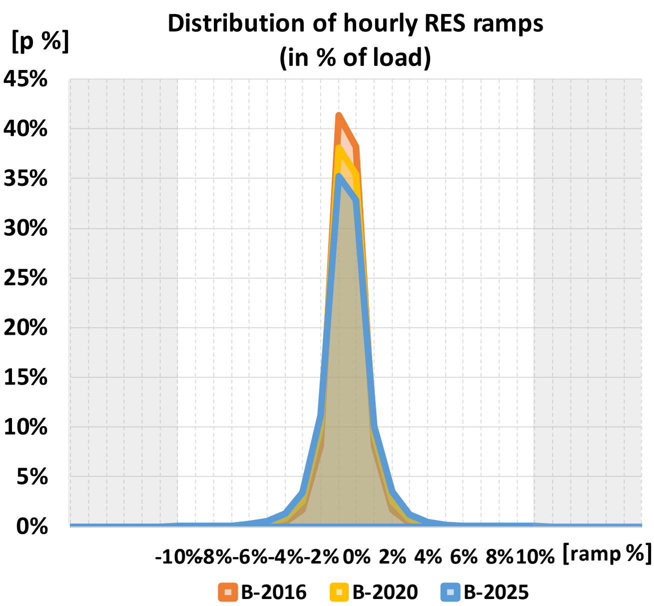
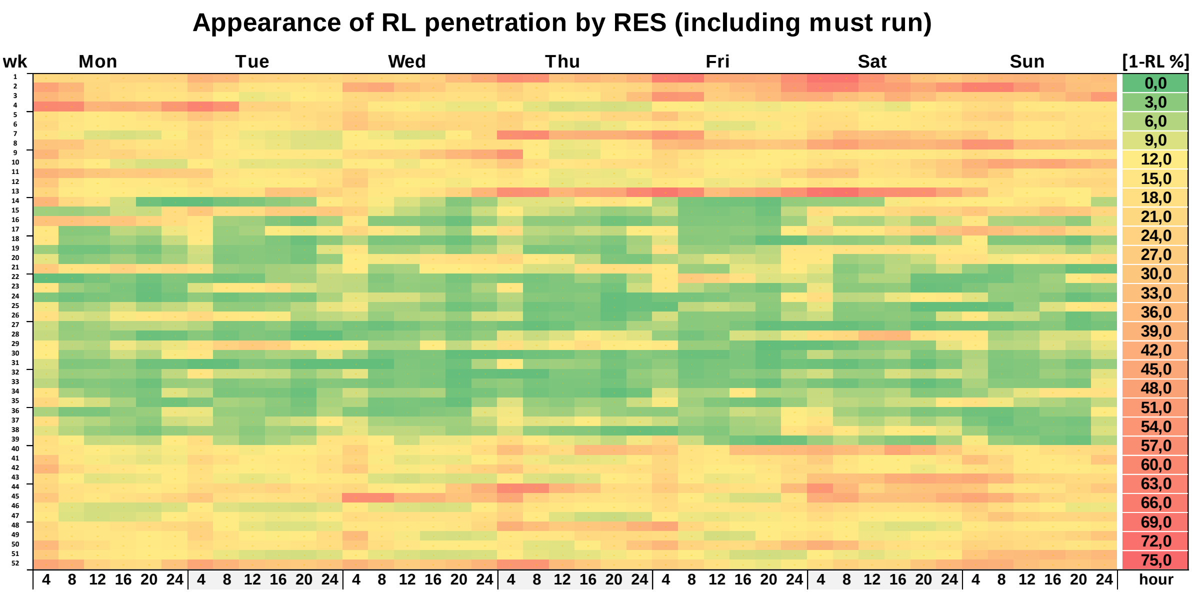
Lithuania

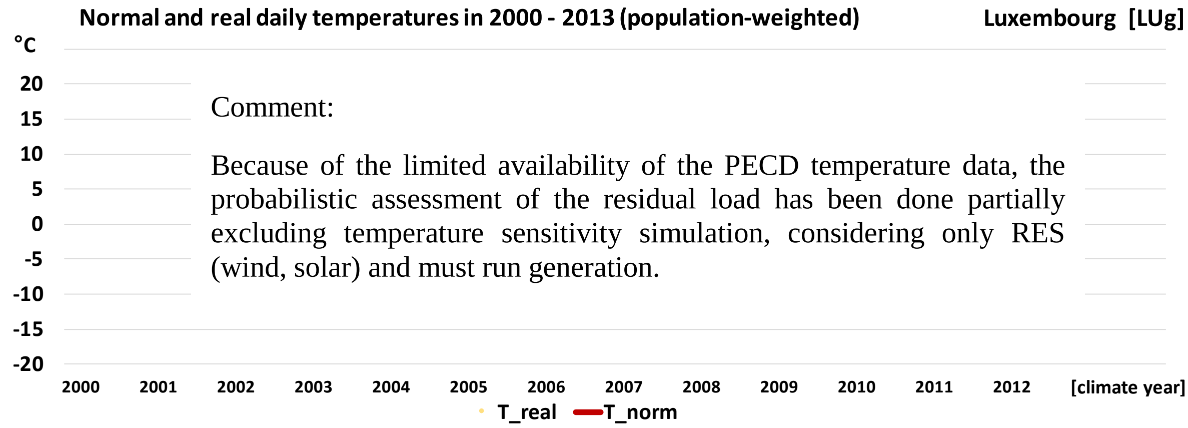

Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Lithuania [LT]
°C
20 15 10 5 0 -5 -10 -15 -20
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 [climate year]
T_real
T_norm

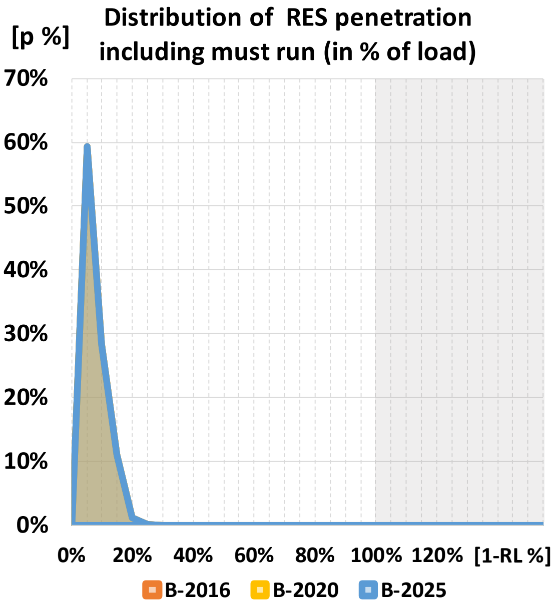

Distribution of RES penetration including must run (in % of load)
[p %]
30% 25% 20% 15% 10% 5% 0%
0% 20% 40% 60% 80% 100% 120% [1-RL %]
B-2016
B-2020
B-2025

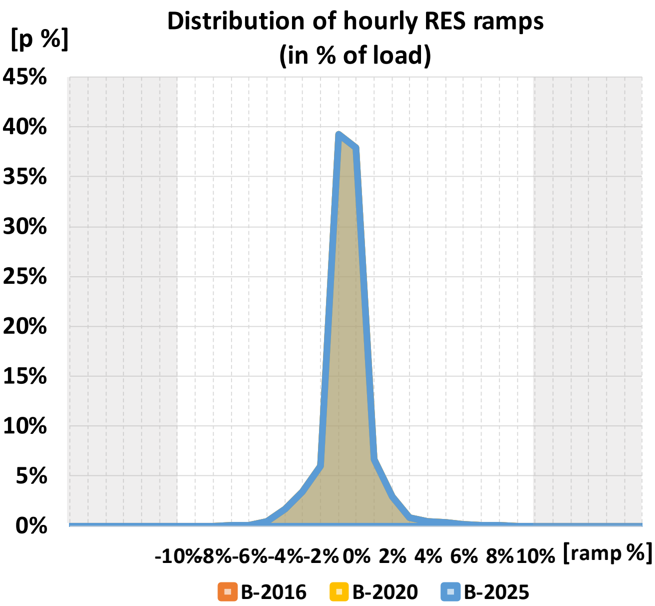

Distribution of hourly RES ramps (in % of load)
[p %]
45% 40% 35% 30% 25% 20% 15% 10% 5% 0%
-10%8%-6%-4%-2% 0% 2% 4% 6% 8%10% [ramp %]
B-2016
B-2020
B-2025

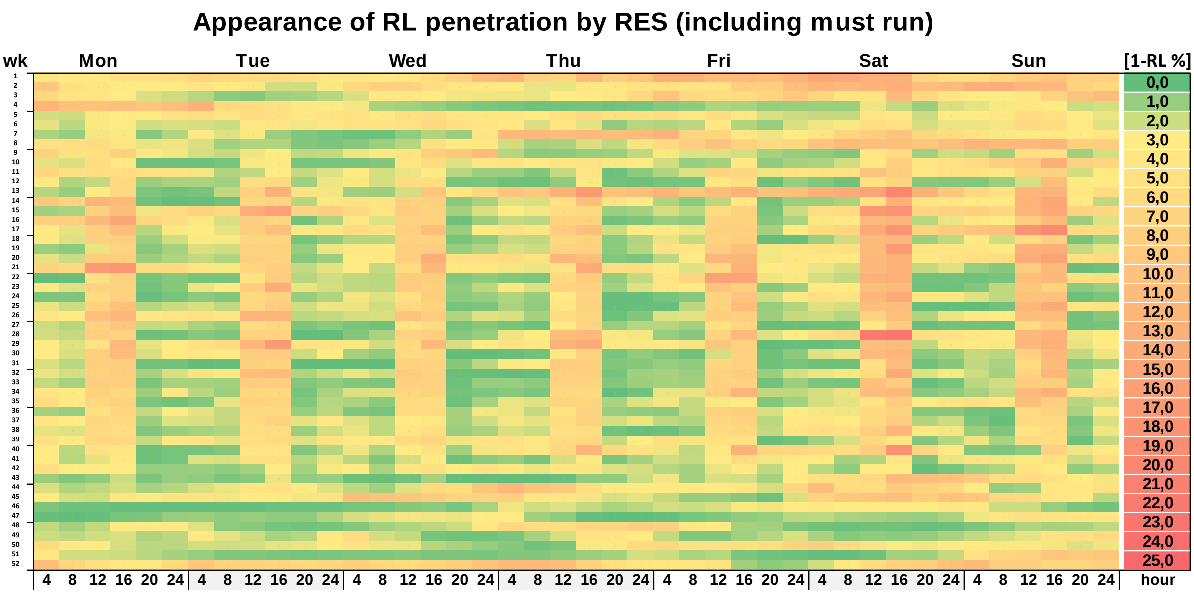

Appearance of RL penetration by RES (including must run)
wk
Mon Tue Wed Thu Fri Sat Sun
[1-RL %]
0,0 3,0 6,0 9,0 12,0 15,0 18,0 21,0 24,0 27,0 30,0 33,0 36,0 39,0 42,0 45,0 48,0 51,0 54,0 57,0 60,0 63,0 66,0 69,0 72,0 75,0
4 8 12 16 20 24
hour

Luxembourg

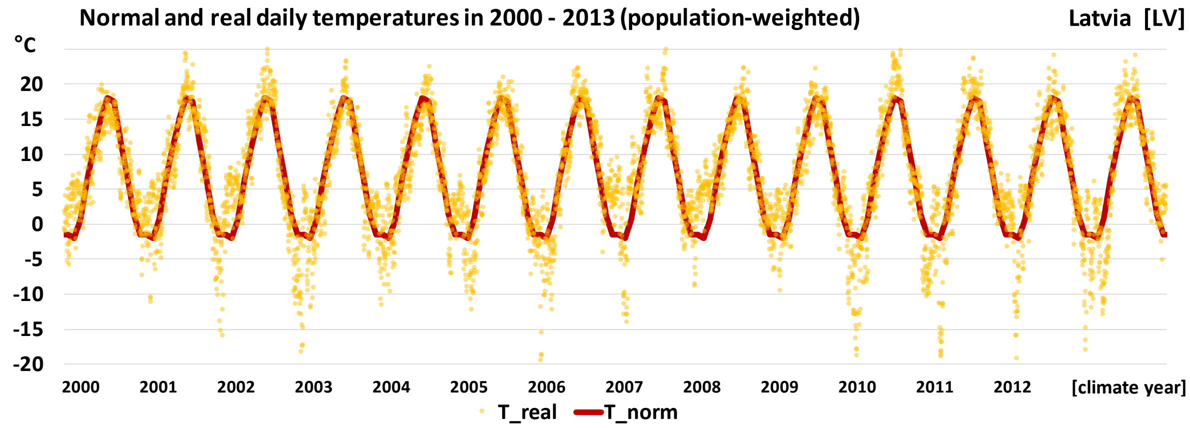

Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Luxembourg [LUg]
°C
20
15
10
5
0
-5
-10
-15
-20
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
[climate year]
T_real
T_norm
Comment:
Because of the limited availability of the PECD temperature data, the probabilistic assessment of the residual load has been done partially excluding temperature sensitivity simulation, considering only RES (wind, solar) and must run generation.

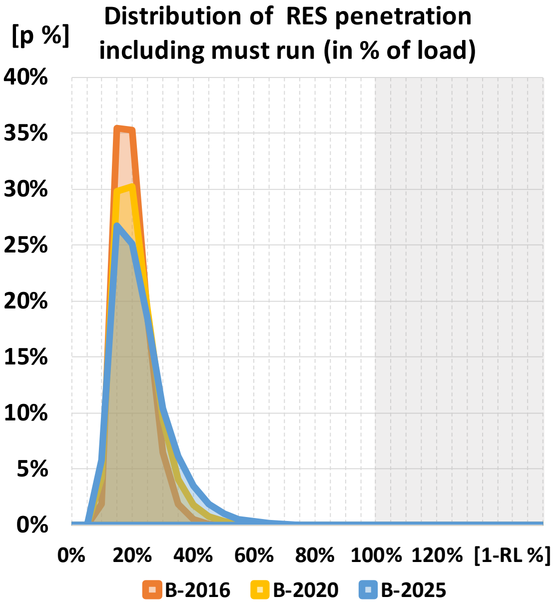

Distribution of RES penetration including must run (in % of load)
[p %]
70%
60%
50%
40%
30%
20%
10%
0%
0%
20%
40%
60%
80%
100%
120%
[1-RL %]
B-2016
B-2020
B-2025

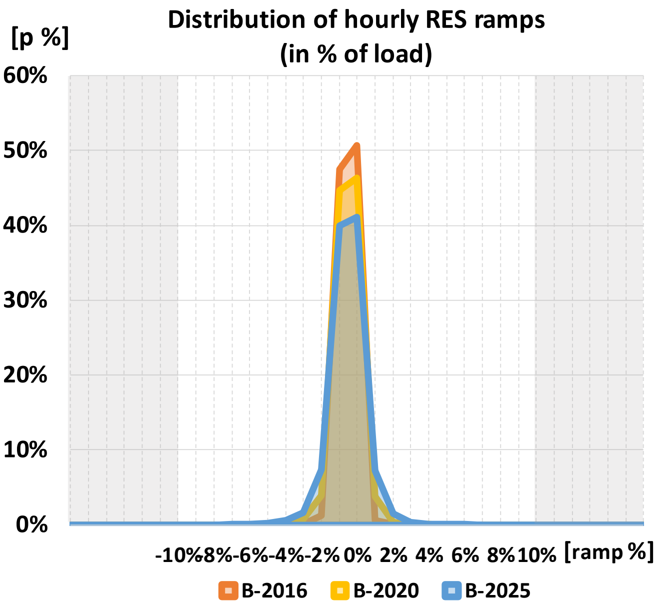

Distribution of hourly RES ramps (in % of load)
[p %]
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
-10%8%-6%-4%-2%0% 2% 4% 6% 8%10%
[ramp %]
B-2016
B-2020
B-2025

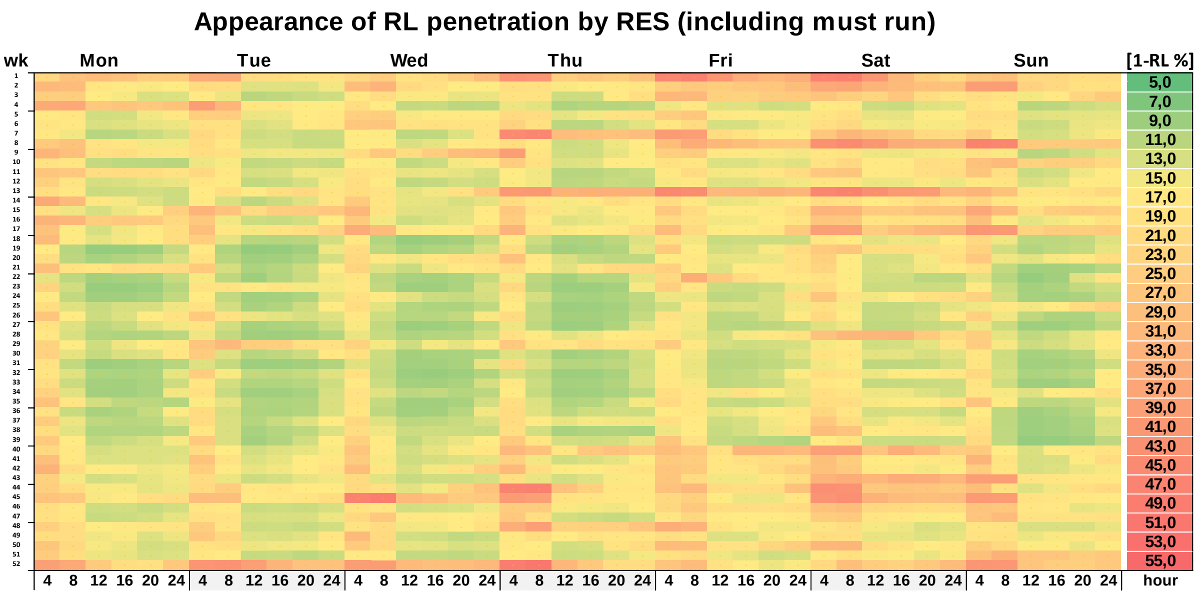

Appearance of RL penetration by RES (including must run)
wk
Mon
Tue
Wed
Thu
Fri
Sat
Sun
[1-RL %]
0,0
1,0
2,0
3,0
4,0
5,0
6,0
7,0
8,0
9,0
10,0
11,0
12,0
13,0
14,0
15,0
16,0
17,0
18,0
19,0
20,0
21,0
22,0
23,0
24,0
25,0
4 8 12 16 20 24
hour

Latvia

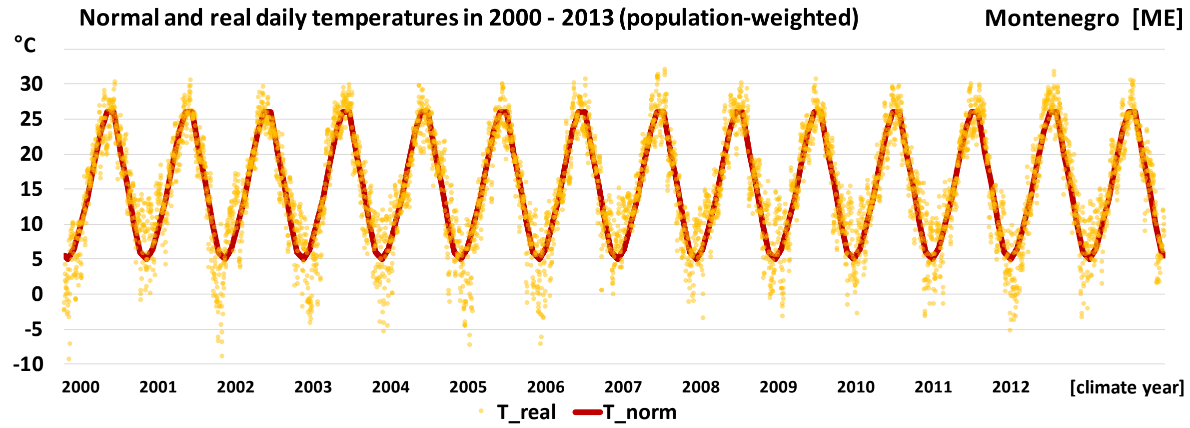

Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Latvia [LV]
°C
20
15
10
5
0
-5
-10
-15
-20
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 [climate year]
T_real
T_norm

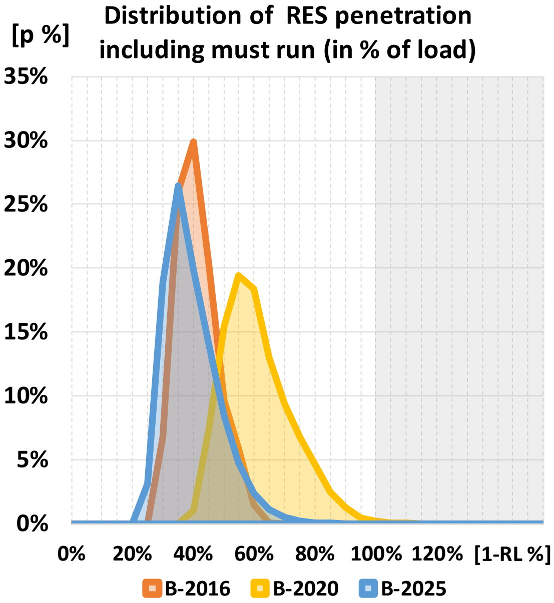

[p %]
Distribution of RES penetration including must run (in % of load)
40%
35%
30%
25%
20%
15%
10%
5%
0%
0% 20% 40% 60% 80% 100% 120% [1-RL %]
B-2016
B-2020
B-2025

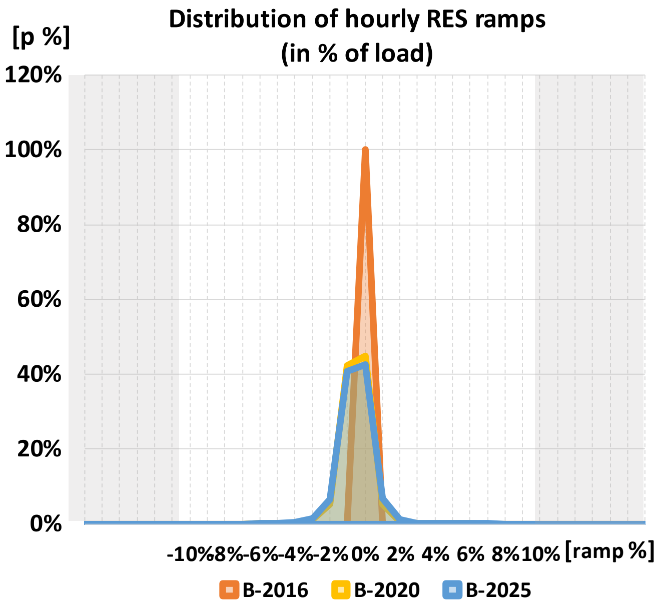

[p %]
Distribution of hourly RES ramps (in % of load)
60%
50%
40%
30%
20%
10%
0%
-10% 8% -6% -4% -2% 0% 2% 4% 6% 8% 10% [ramp %]
B-2016
B-2020
B-2025

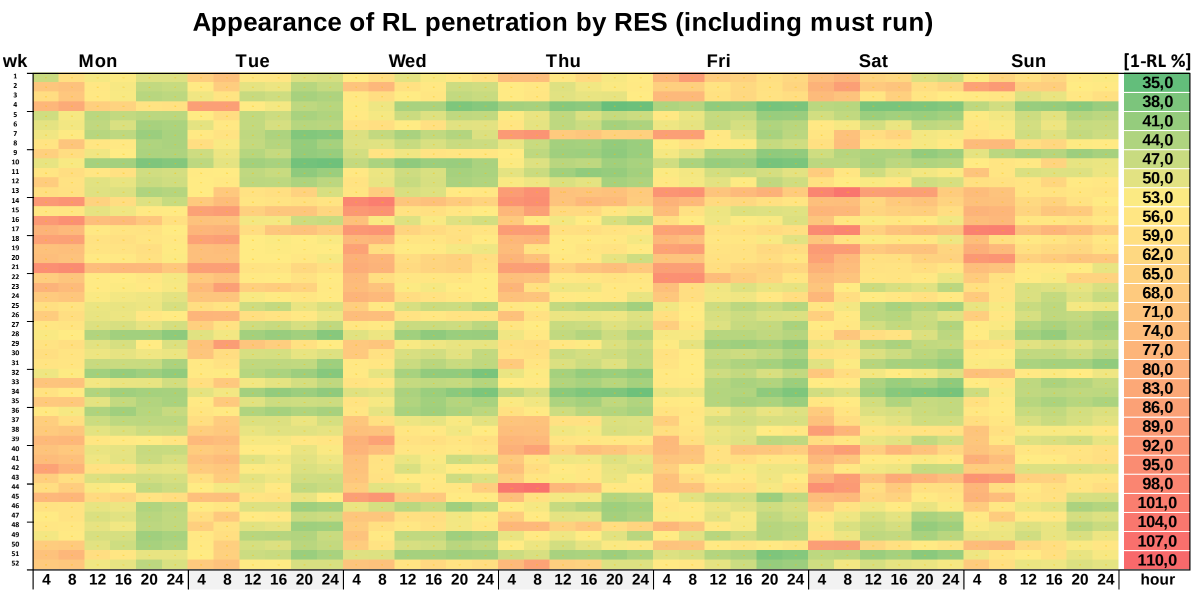

Appearance of RL penetration by RES (including must run)
wk
Mon Tue Wed Thu Fri Sat Sun
[1-RL %]
5,0
7,0
9,0
11,0
13,0
15,0
17,0
19,0
21,0
23,0
25,0
27,0
29,0
31,0
33,0
35,0
37,0
39,0
41,0
43,0
45,0
47,0
49,0
51,0
53,0
55,0
4 8 12 16 20 24
hour

Montenegro









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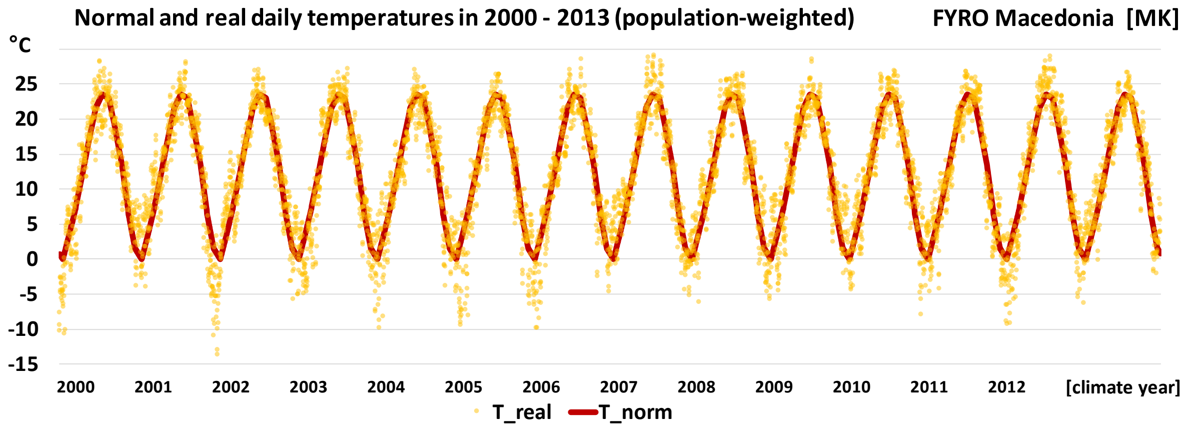
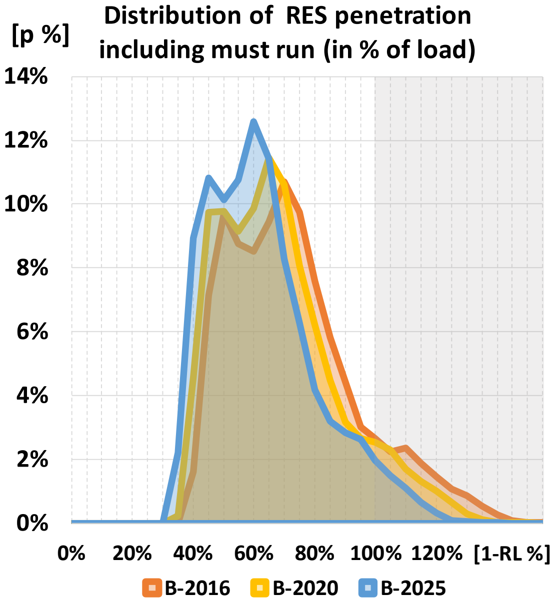
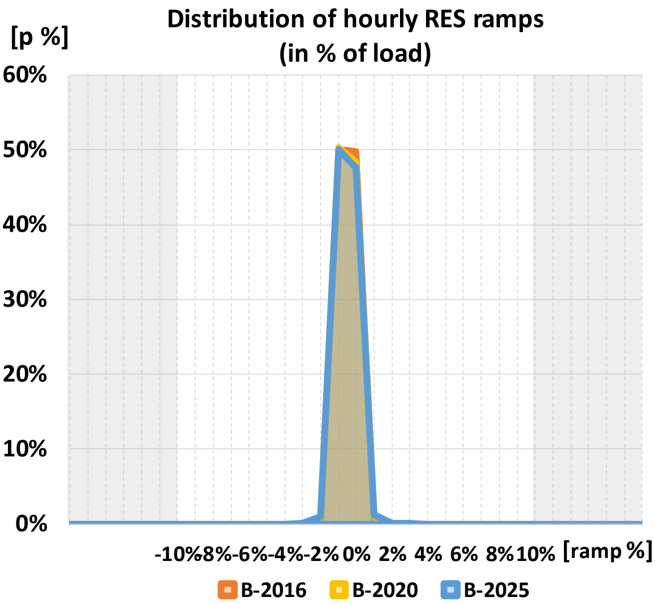
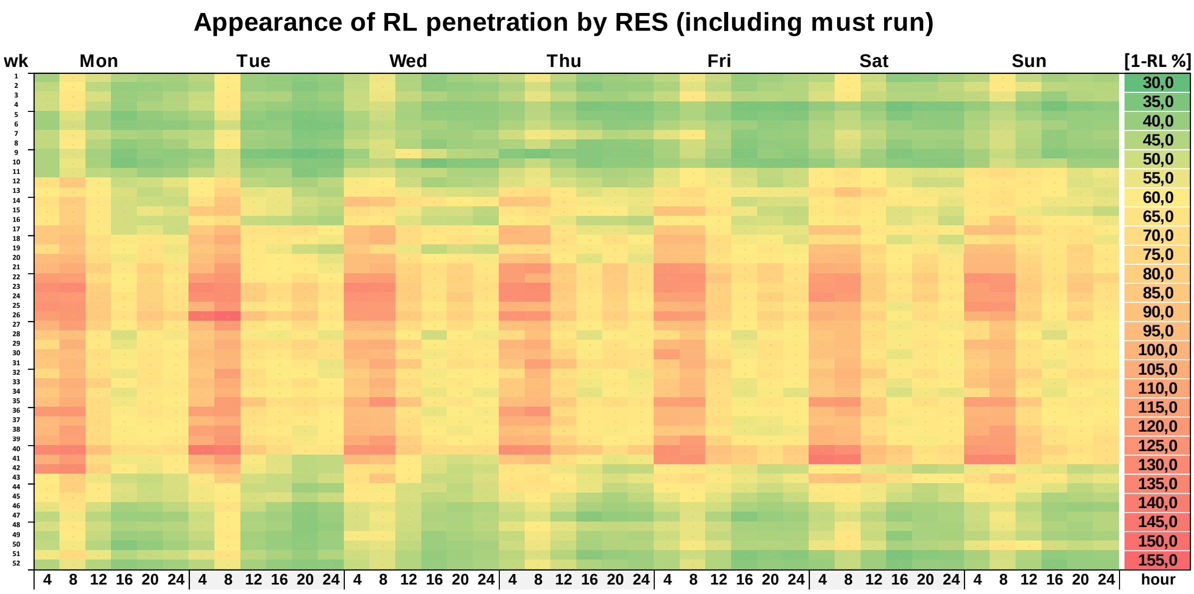
FYRO Macedonia

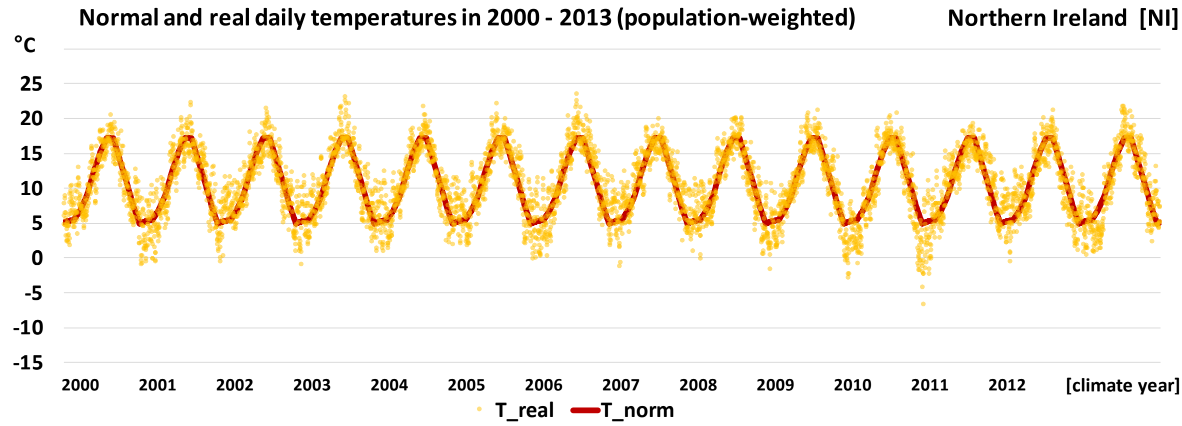


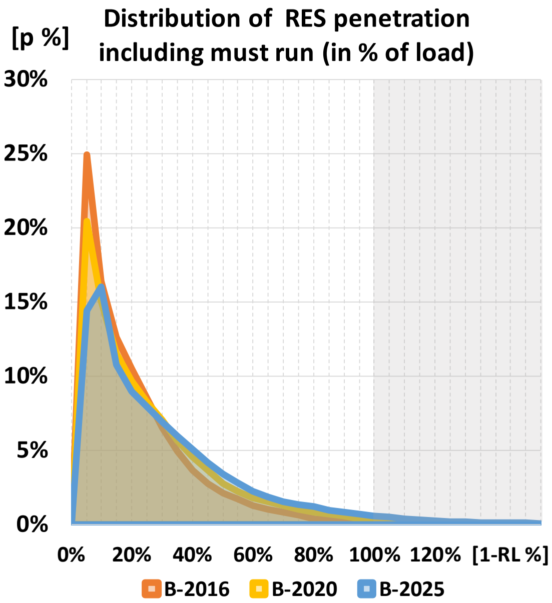


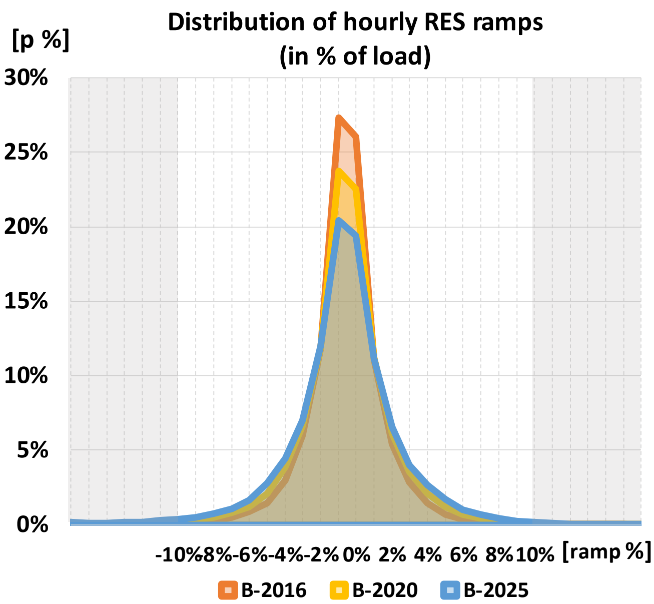


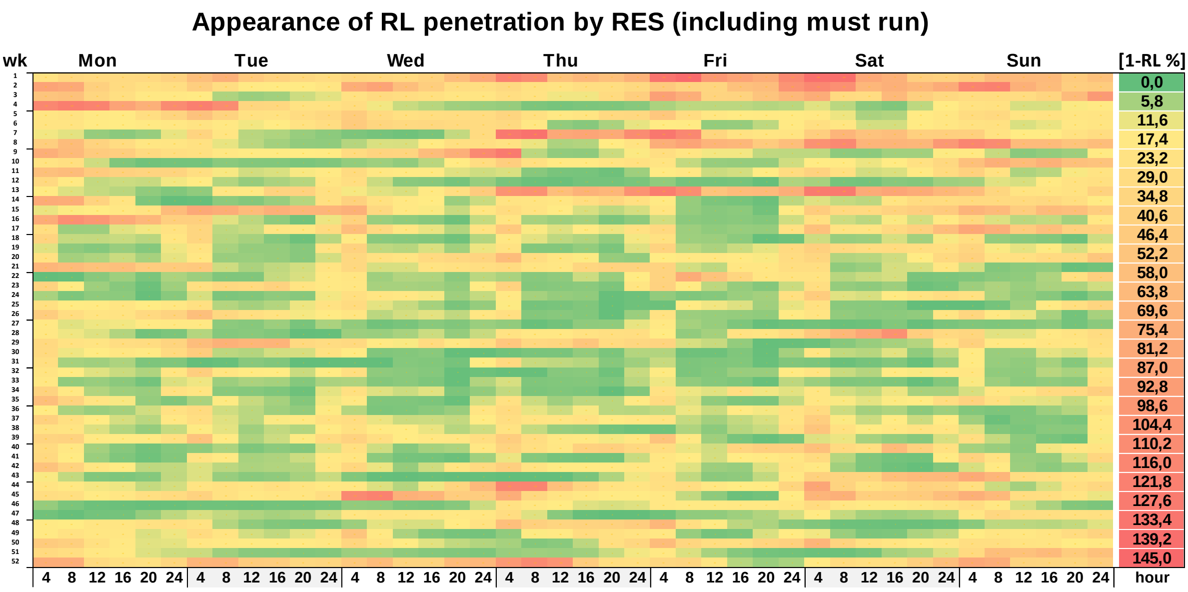


Northern Ireland

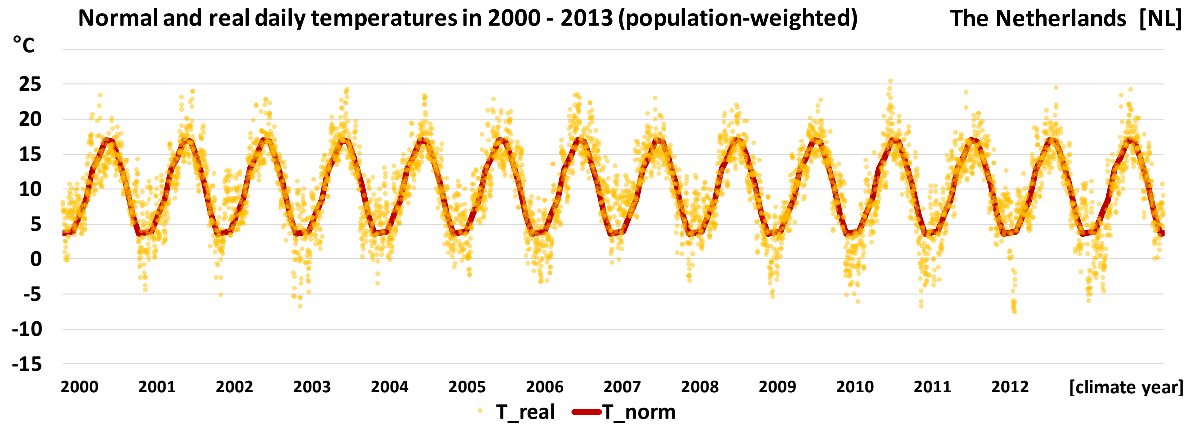


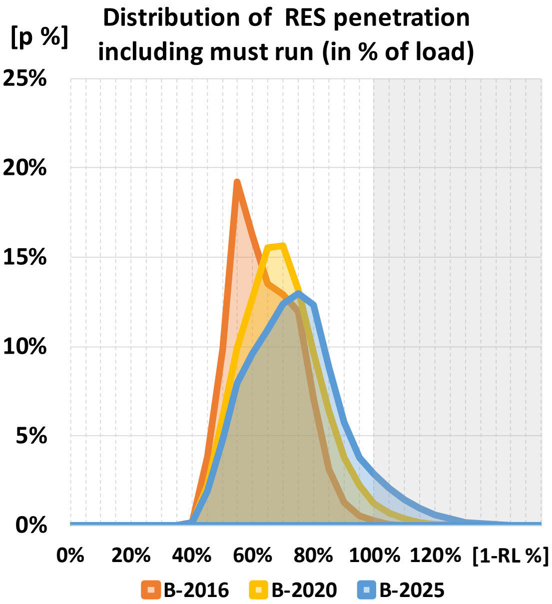


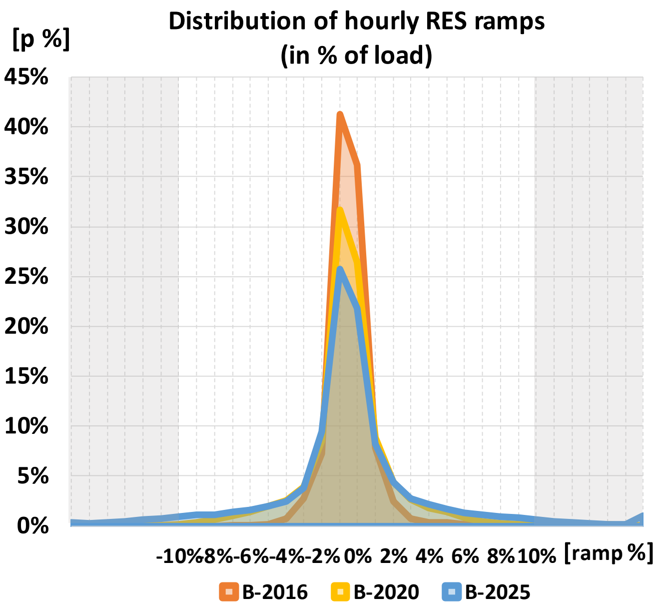


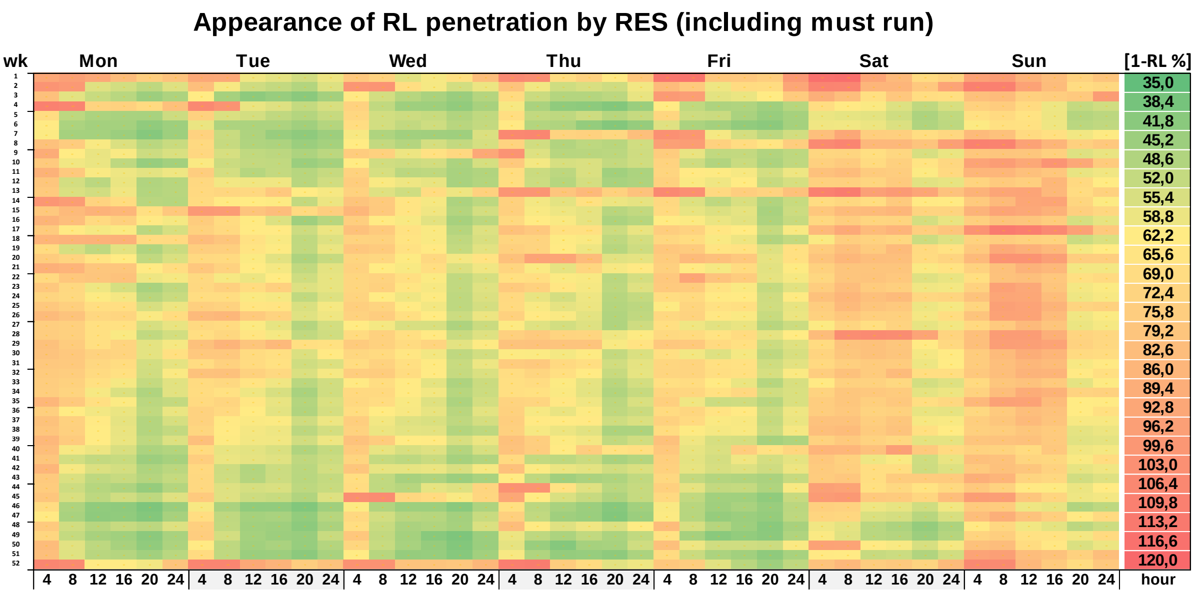


The Netherlands









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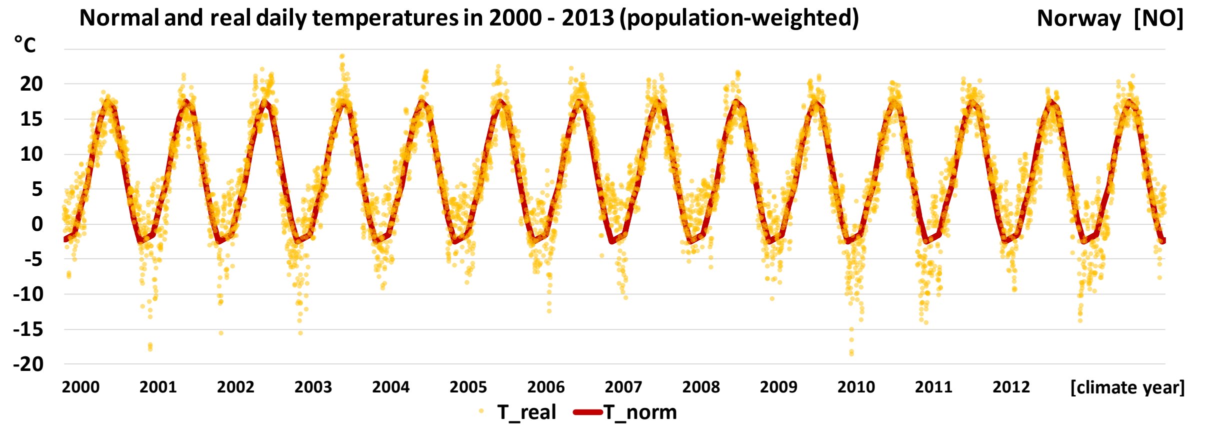
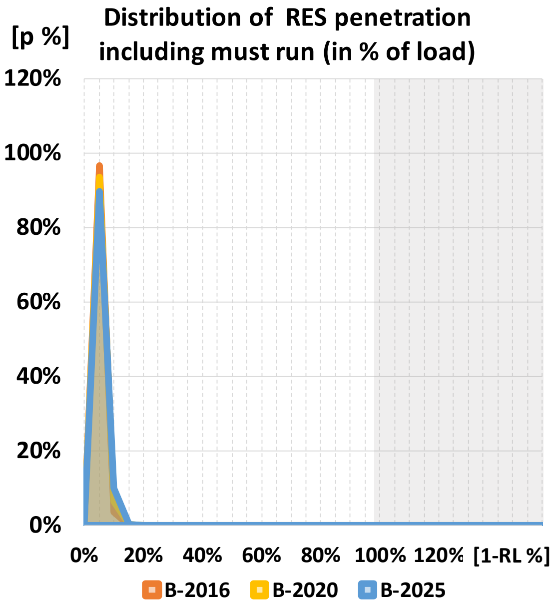
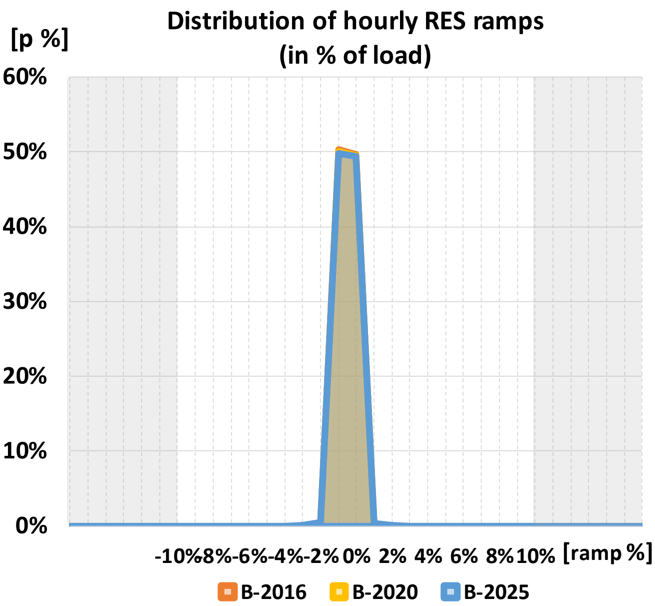
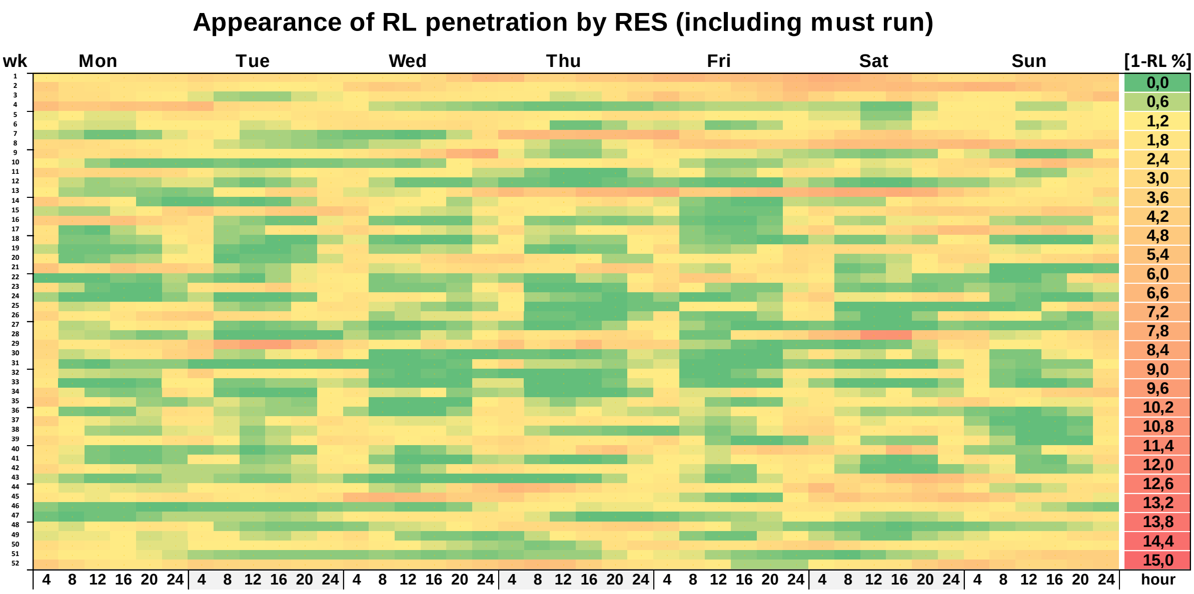
Norway

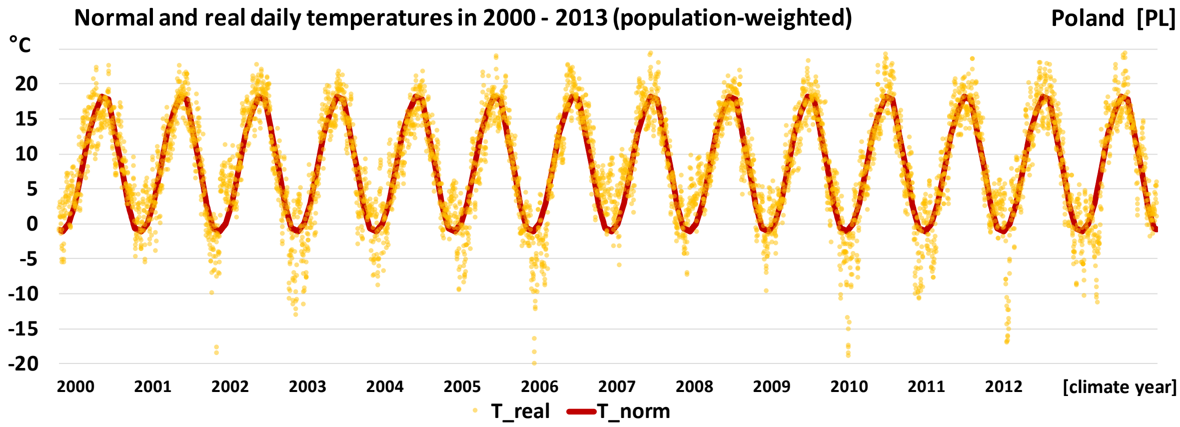

Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Norway [NO]
°C
20
15
10
5
0
-5
-10
-15
-20
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 [climate year]
T_real
T_norm

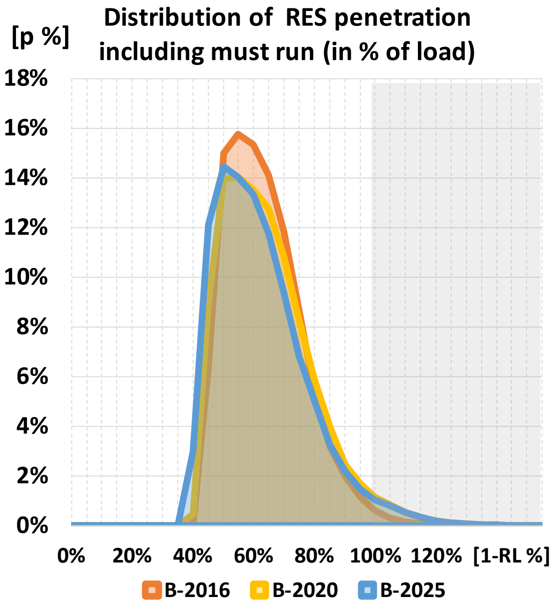

Distribution of RES penetration including must run (in % of load)
[p %]
120%
100%
80%
60%
40%
20%
0%
0% 20% 40% 60% 80% 100% 120% [1-RL %]
B-2016 B-2020 B-2025

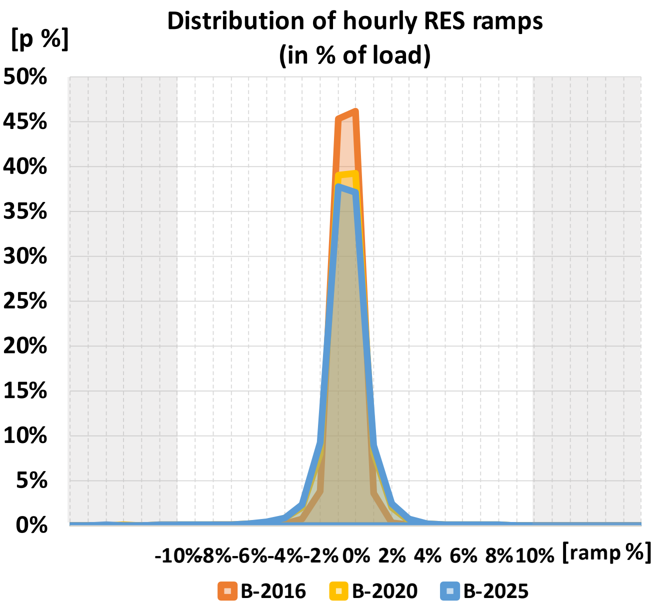

Distribution of hourly RES ramps (in % of load)
[p %]
60%
50%
40%
30%
20%
10%
0%
-10%8%-6%-4%-2%0% 2% 4% 6% 8%10% [ramp %]
B-2016 B-2020 B-2025

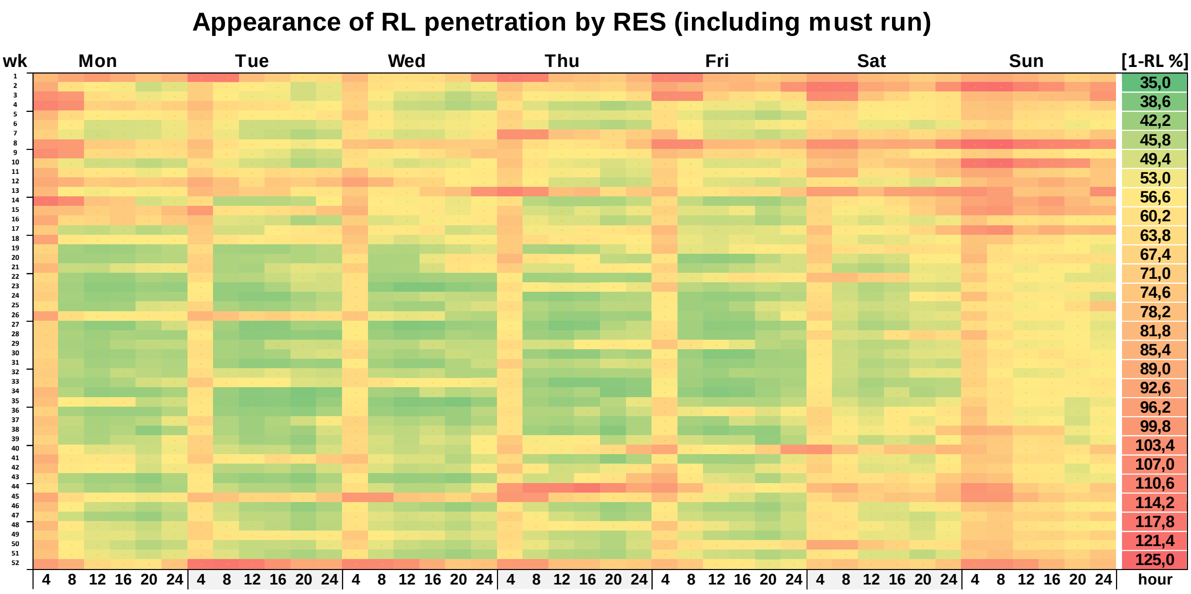

Appearance of RL penetration by RES (including must run)
wk
Mon Tue Wed Thu Fri Sat Sun
[1-RL %]
0,0
0,6
1,2
1,8
2,4
3,0
3,6
4,2
4,8
5,4
6,0
6,6
7,2
7,8
8,4
9,0
9,6
10,2
10,8
11,4
12,0
12,6
13,2
13,8
14,4
15,0
4 8 12 16 20 24 4 8 12 16 20 24 4 8 12 16 20 24 4 8 12 16 20 24 4 8 12 16 20 24 4 8 12 16 20 24 4 8 12 16 20 24
hour

Poland









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In spite of high RES development in Poland (by about 6 GW; mainly wind), the shape of curves on the figure showing distribution of RES penetration as part of load does not change significantly. The number of hours when RES infeed together with must run generation exceeds load (>100%) are negligible, nevertheless it is worth noting that this is 14 years' simulation (based on PECD), so the situation during high RES infeed conditions will be different and some measures will be required. The same situation refers to RES ramps, hourly changes in RES infeed looks to be not a problem for most cases.

The appearance of RL penetration by RES (including must run) quite well represents the present situation in Poland–in general the PSE can confirm that there can be some stress days during the year (especially during Christmas, Easter and holidays in May or November as well as in "bridge days"), when low demand and simultaneously high wind conditions could cause a balance problem in the Polish power system. Sundays and off peak hours are more difficult than rest periods. It is necessary to underline that the chromatic figure refers to climatic conditions in 2012 (appearance of RL penetration by RES is a kind of simulation for the year 2020 based on 2012 climatic conditions).

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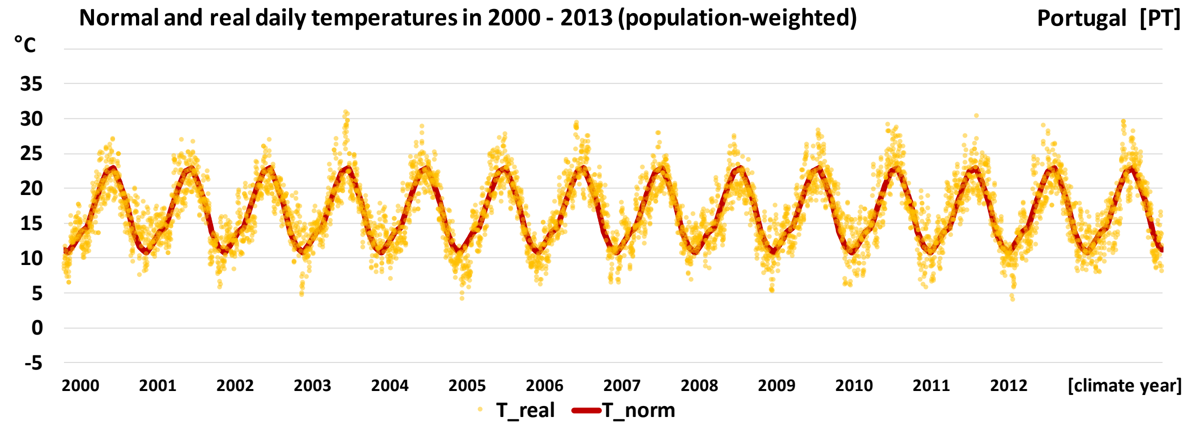
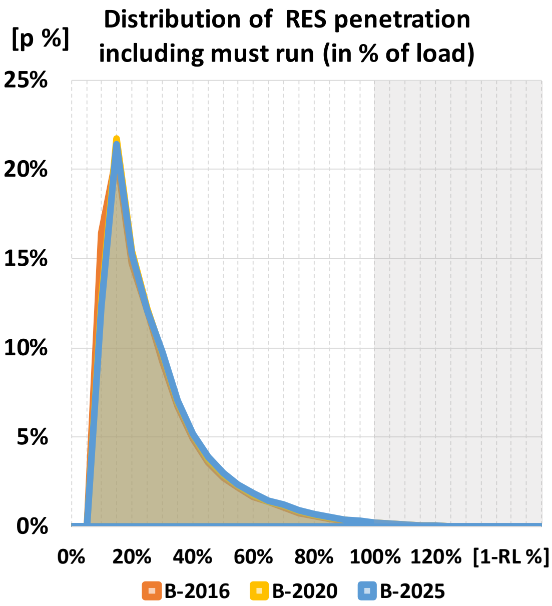
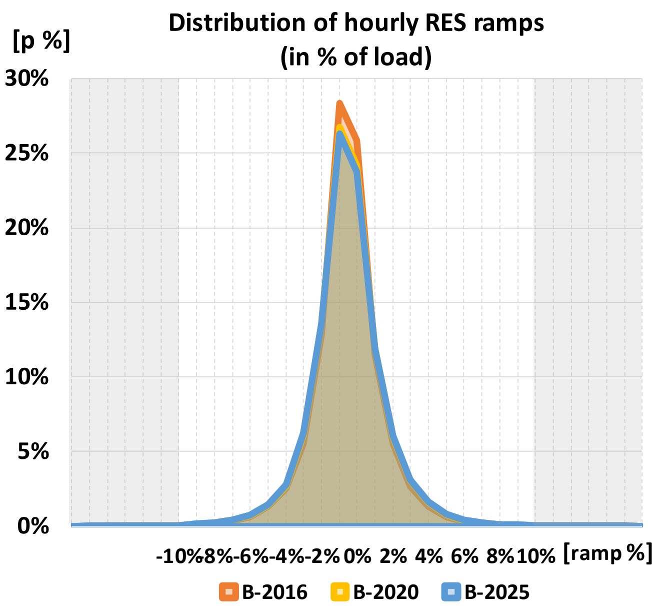
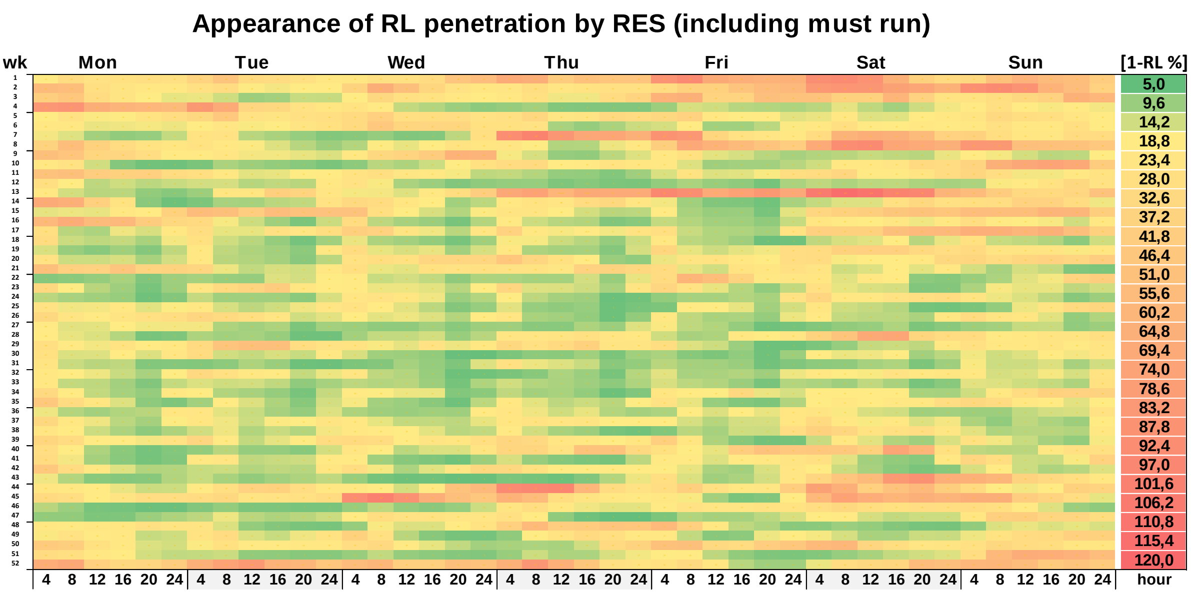
Portugal









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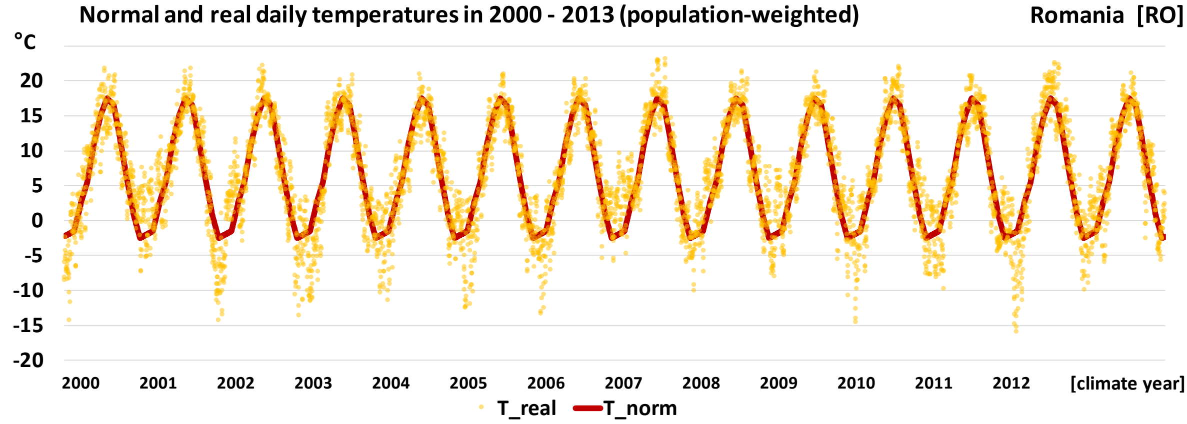
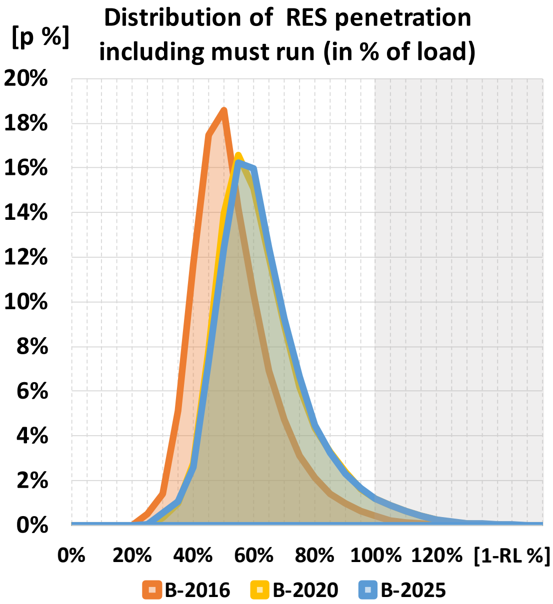
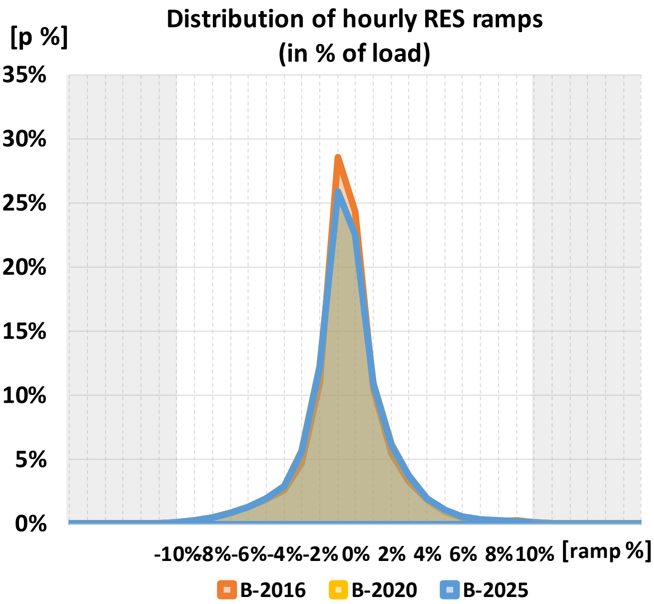
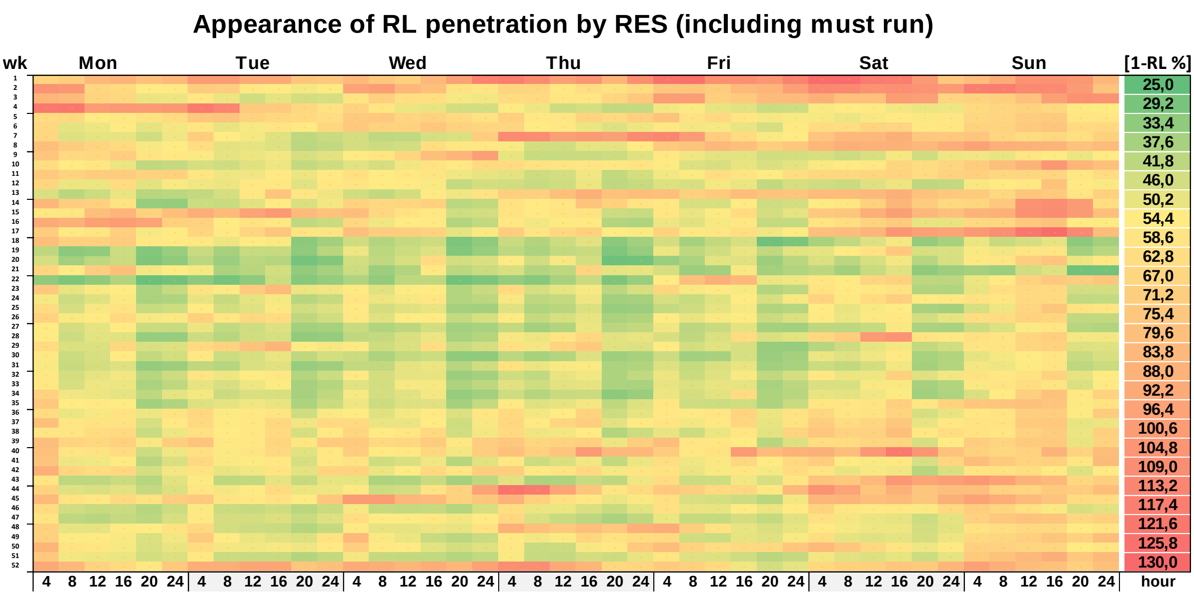
Romania









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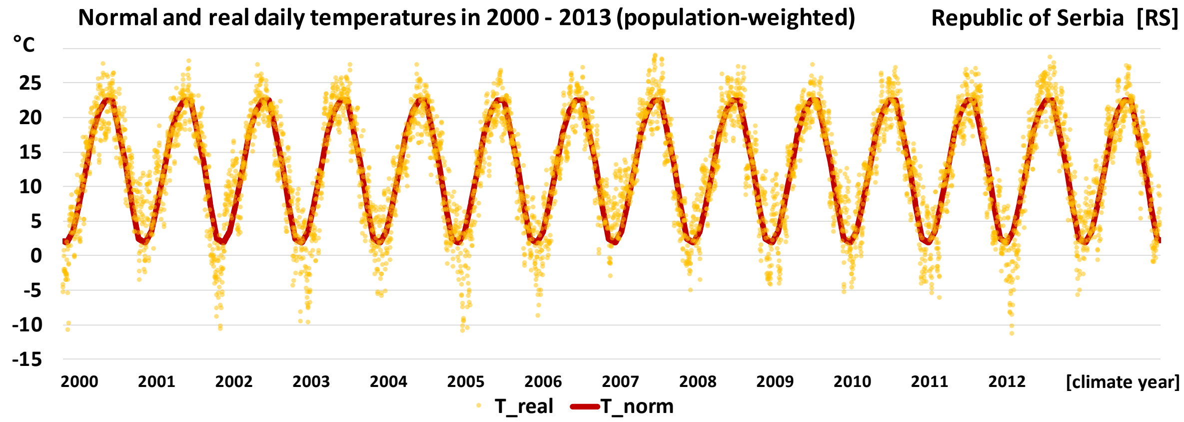
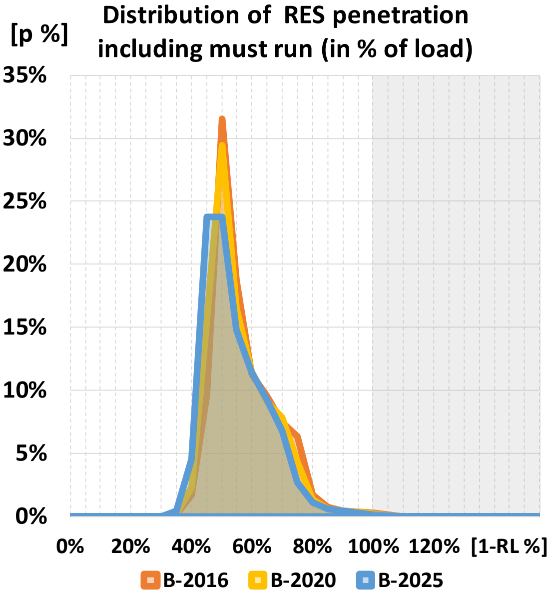
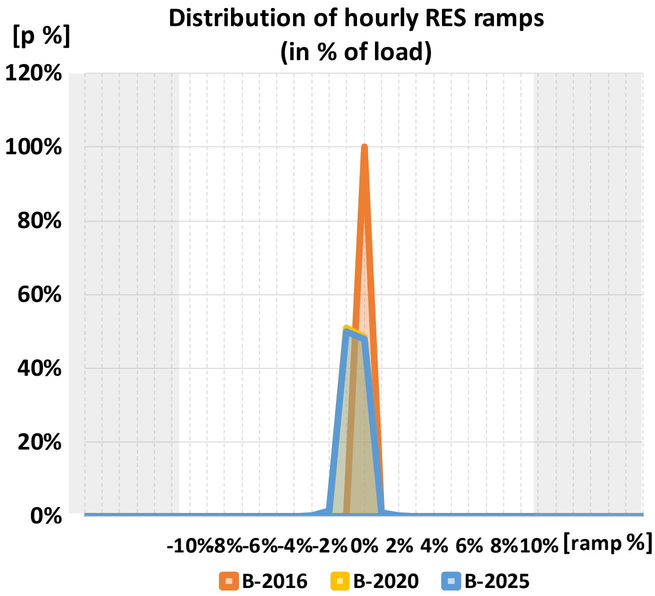
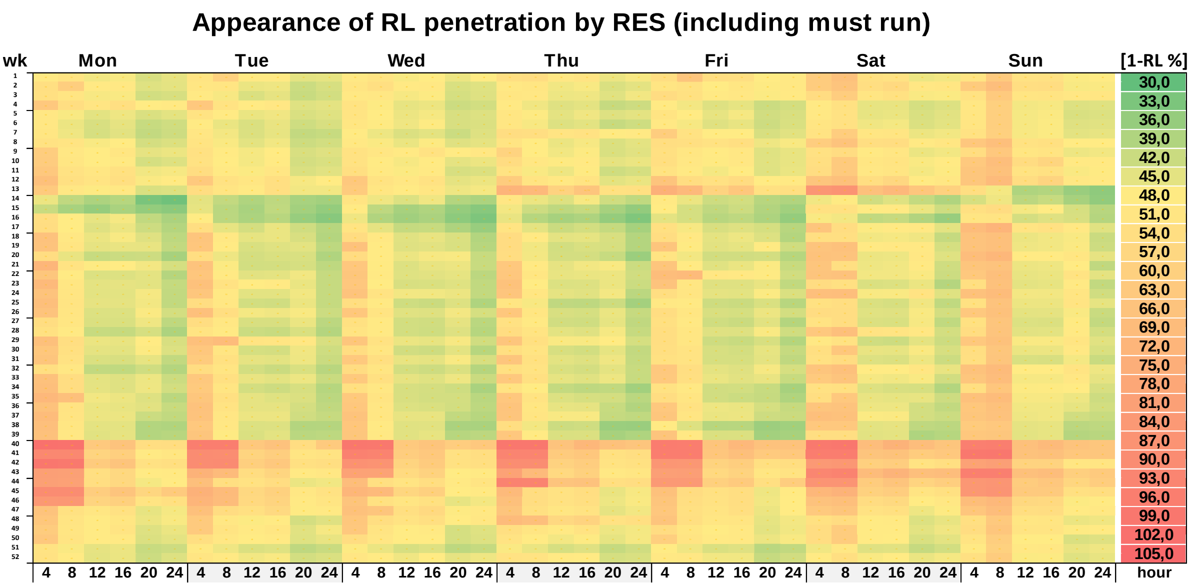
Republic of Serbia

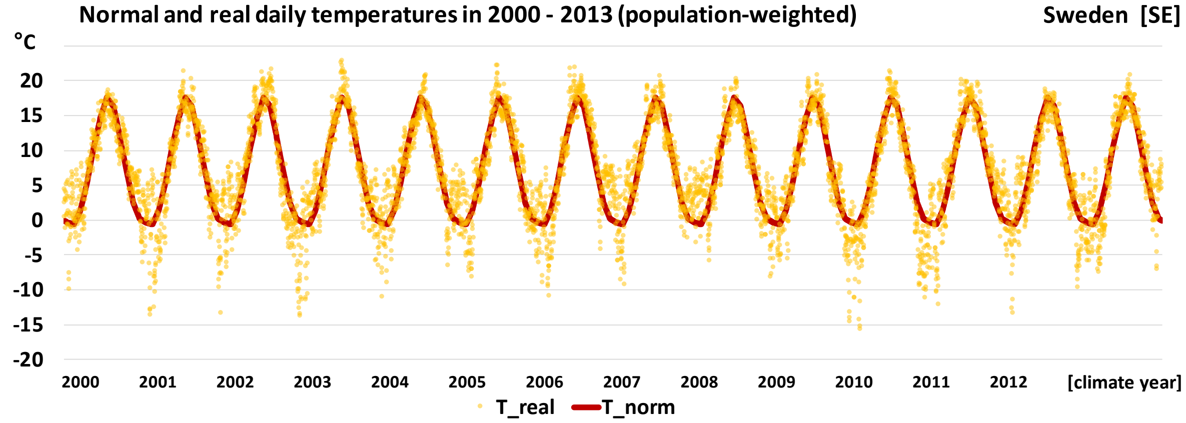


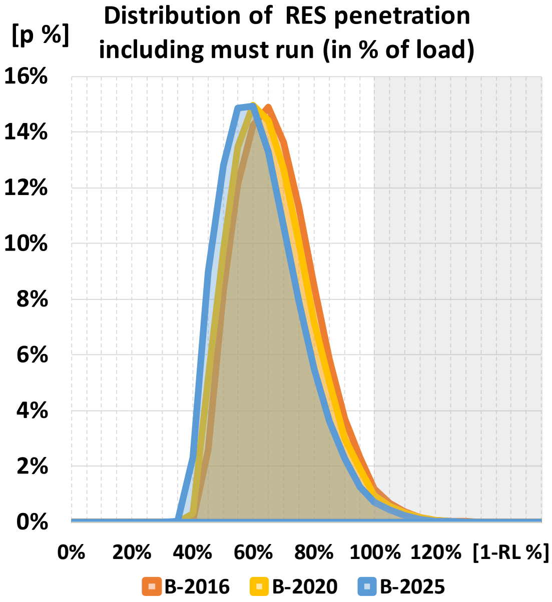


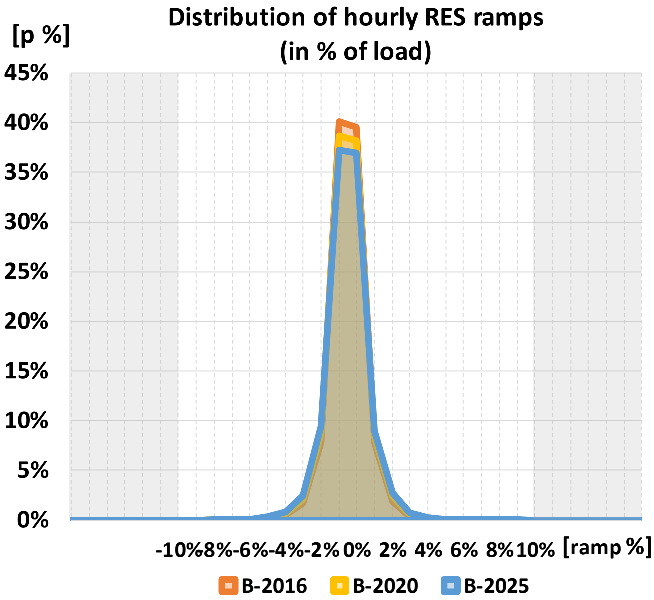


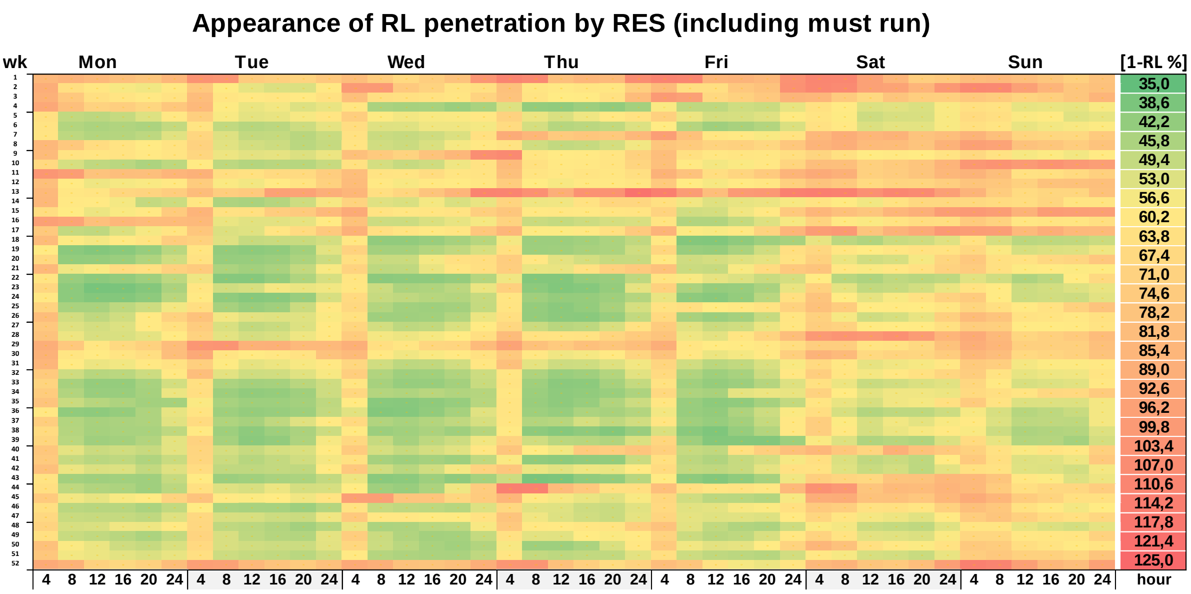


Sweden









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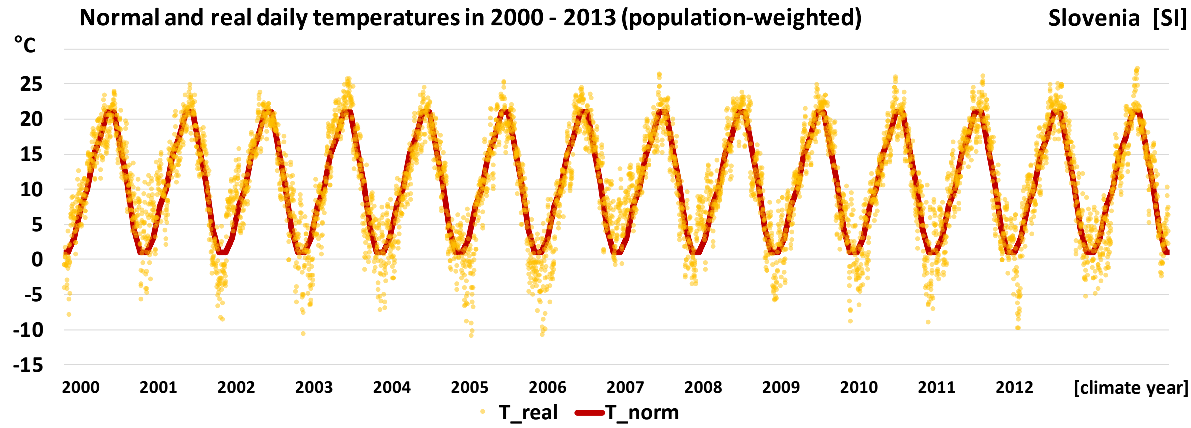
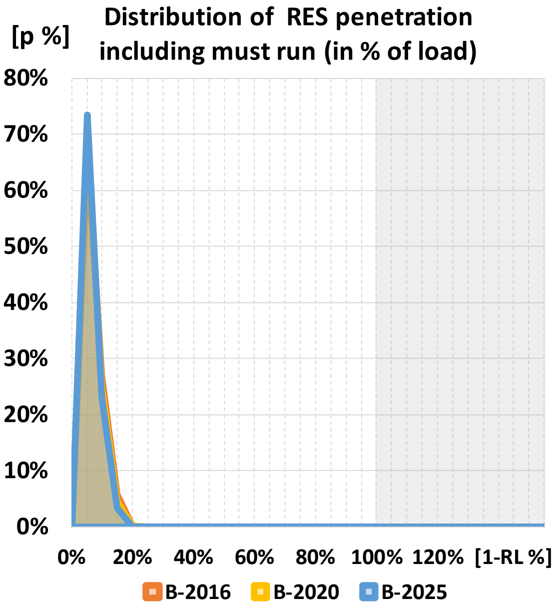
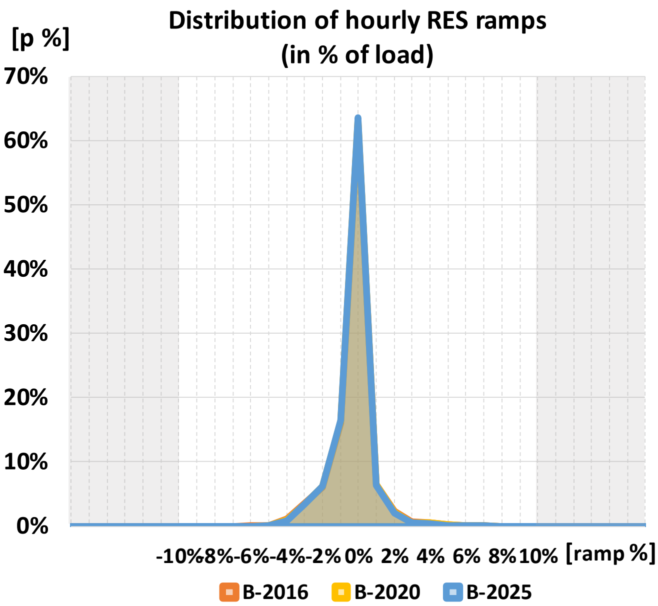
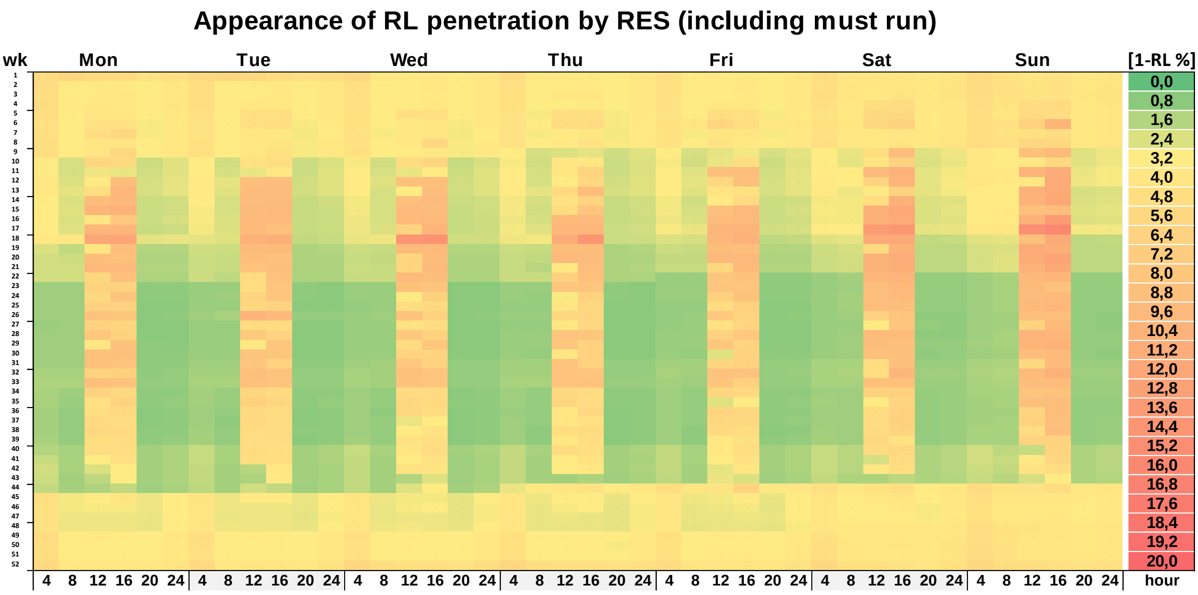
Slovenia

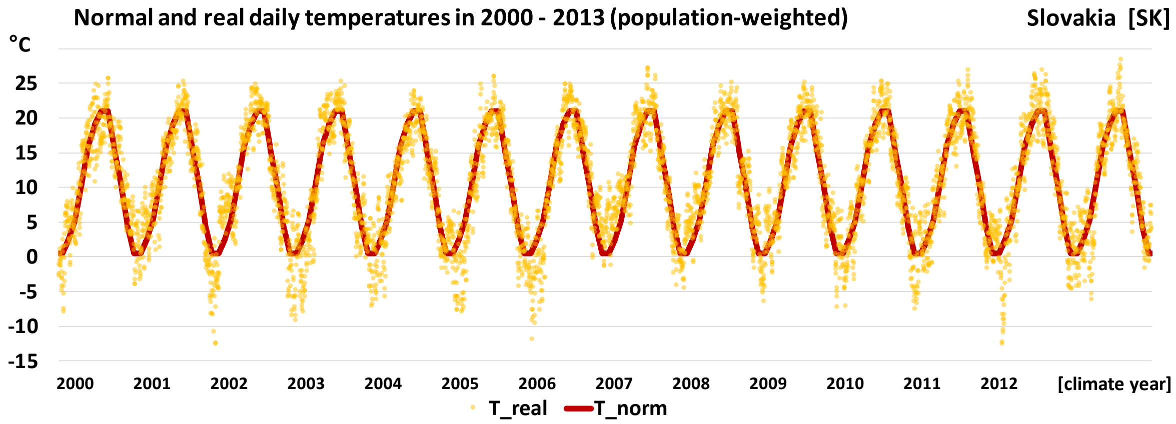

Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Slovenia [SI]
°C
25
20
15
10
5
0
-5
-10
-15
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 [climate year]
T_real
T_norm

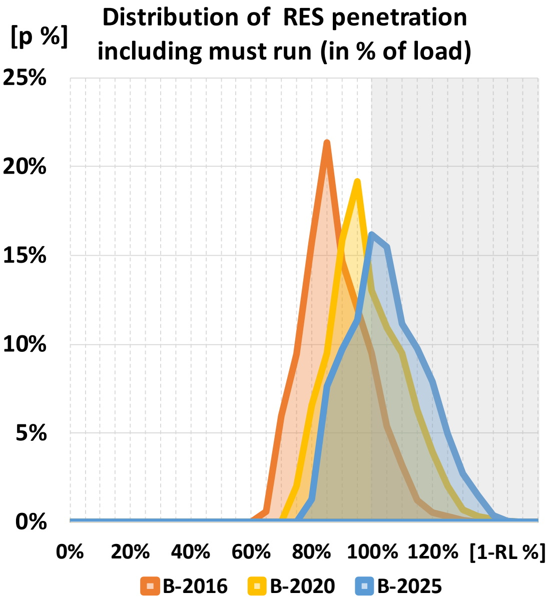

Distribution of RES penetration including must run (in % of load)
[p %]
80%
70%
60%
50%
40%
30%
20%
10%
0%
0% 20% 40% 60% 80% 100% 120% [1-RL %]
B-2016 B-2020 B-2025

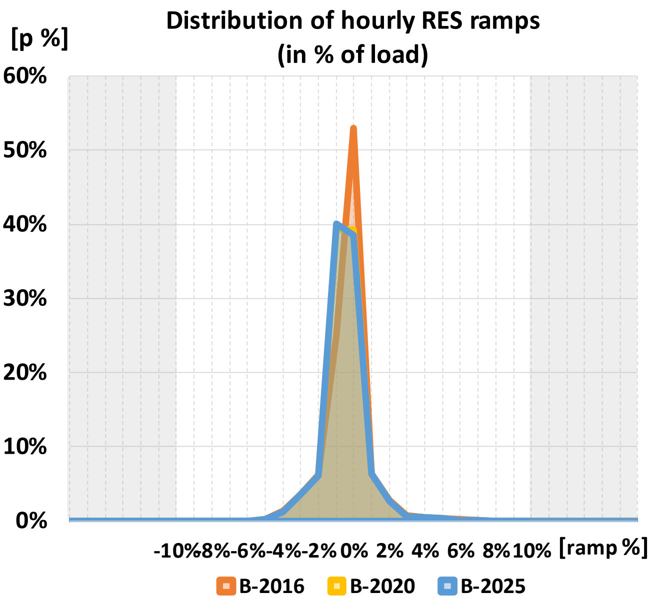

Distribution of hourly RES ramps (in % of load)
[p %]
70%
60%
50%
40%
30%
20%
10%
0%
-10%8%-6%-4%-2% 0% 2% 4% 6% 8% 10% [ramp %]
B-2016 B-2020 B-2025

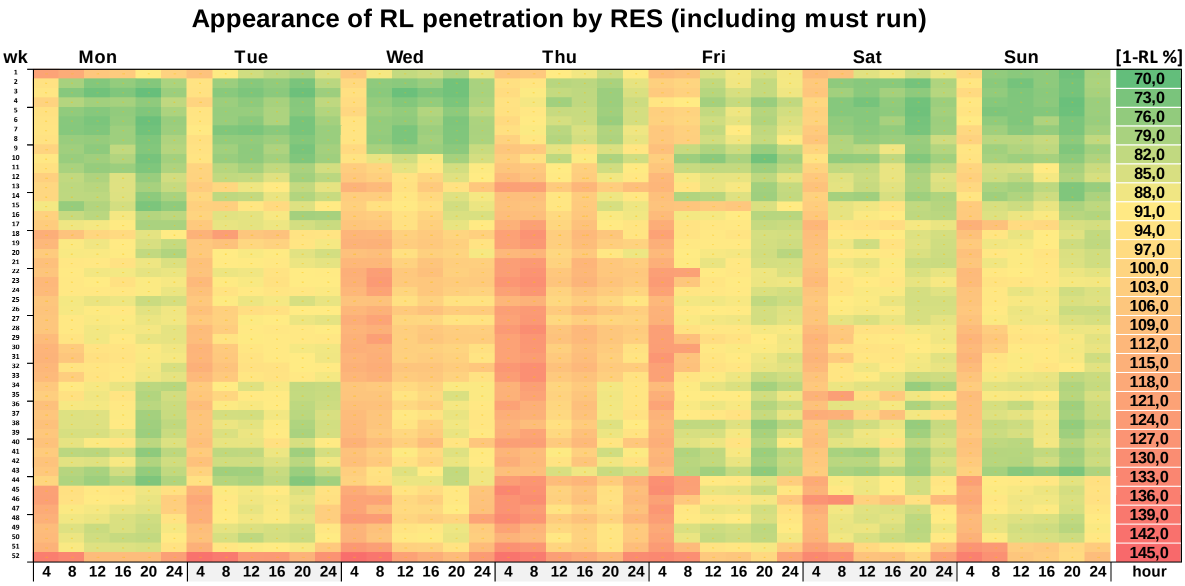

Appearance of RL penetration by RES (including must run)
wk
Mon Tue Wed Thu Fri Sat Sun
[1-RL %]
0,0
0,8
1,6
2,4
3,2
4,0
4,8
5,6
6,4
7,2
8,0
8,8
9,6
10,4
11,2
12,0
12,8
13,6
14,4
15,2
16,0
16,8
17,6
18,4
19,2
20,0
4 8 12 16 20 24
hour

Slovakia


Normal and real daily temperatures in 2000 - 2013 (population-weighted)
Slovakia [SK]
°C
25
20
15
10
5
0
-5
-10
-15
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
[climate year]
T_real
T_norm


[p %]
Distribution of RES penetration including must run (in % of load)
25%
20%
15%
10%
5%
0%
0%
20%
40%
60%
80%
100%
120%
[1-RL %]
B-2016
B-2020
B-2025


[p %]
Distribution of hourly RES ramps (in % of load)
60%
50%
40%
30%
20%
10%
0%
-10%8%-6%-4%-2%0% 2% 4% 6% 8%10%
[ramp %]
B-2016
B-2020
B-2025


Appearance of RL penetration by RES (including must run)
wk
Mon
Tue
Wed
Thu
Fri
Sat
Sun
[1-RL %]
70,0
73,0
76,0
79,0
82,0
85,0
88,0
91,0
94,0
97,0
100,0
103,0
106,0
109,0
112,0
115,0
118,0
121,0
124,0
127,0
130,0
133,0
136,0
139,0
142,0
145,0
4 8 12 16 20 24
hour

6 Pan-EU upward adequacy assessment: interconnection contribution to keep the balance

In this section, a regional assessment of generation adequacy is performed.

The target is to complement the national analysis of Chapter 4 to detect if problems can arise on a Pan-European scale because of a lack of available capacity and lack of available cross-border capacity to import the required power.

The basis of the regional analysis is a constrained linear optimization problem to minimise the deficit in power balance at the Pan-European level. The goal is to provide an indication of whether countries requiring imports will be able to obtain these across neighbouring regions under the conditions considered.

The regional analysis does not yet consider detailed market simulation or grid-model simulations. These features will be incorporated in future editions of the SO&AF report according to the roadmap for implementation of the ENTSO-E target methodology[21].

Therefore, the analysis presented here will only show if there is a shortage at the European or regional level, but it will not say which countries exactly will have a generation deficit, as this depends on the actual market price in all connected countries. In other words, the investigation carried out is purely a “feasibility” analysis.

It is important to underline that the scenarios evaluated in the regional assessment represent conditions that are significant and realistic for the European system as a whole. In this sense, the monthly reference point (3rd Wednesday of the month at 19:00) is chosen for the analysis, because this reference point has been identified as ENTSO-E peak load[22]. Therefore, the conditions considered here may differ from the conditions where the peak load occurs in each individual country, which correspond to conditions that are significant and realistic for each country.

Adequacy of a group of countries is assessed in the regional assessment by use of the provided Net Transfer Capacity (NTC) and Remaining Capacity (RC) minus Spare Capacity (SC). No Margin Against Monthly Peak Load (MaMPL), is used because it is relevant only to assess the distance to the referred reference point to national peak, which typically occurs at different non-simultaneous times in different countries. On the other hand, spare capacity constraints are considered. The spare capacity reflects the additional capacity that should be available on a power system to cope with any unforeseen extreme conditions. It comes in addition to system services reserves.

Spare Capacity should be sufficient to cover a 1% risk of shortfall on a power system, that is, to guarantee the operation on 99% of the situations considering random fluctuations of residual load and the availability of generation units.

6.1 Monthly import assessment

In the table below, the results of the feasibility assessments from the monthly regional analysis are shown. The analysis is performed for Scenario B and years 2016, 2020 and 2025, and:

- if a country does not need to import power to maintain adequacy**,** the table below shows a green for that month,
- if a country does need imports through the year to maintain adequacy, the table below shows yellow for that month.

[21] ENTSO-E Adequacy methodology https://www.entsoe.eu/about-entso-e/system-development/system-adequacy-and-market-modeling/adequacy-methodology/Pages/default.aspx

[22] ENTSO-E Statistical Factsheet 2014 https://www.entsoe.eu/Documents/Publications/Statistics/Factsheet/entsoe_sfs2014_web.pdf

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The results should be understood under the assumption that each month is represented by each reference point (3rd Wednesday of the month, 19:00 CET). Furthermore, identified import needs do not forecast commercial import needs. Commercial flow patterns depend on the actual market price structure in all connected countries. It should therefore be clearly understood that the investigation carried out is purely a "feasibility" analysis.

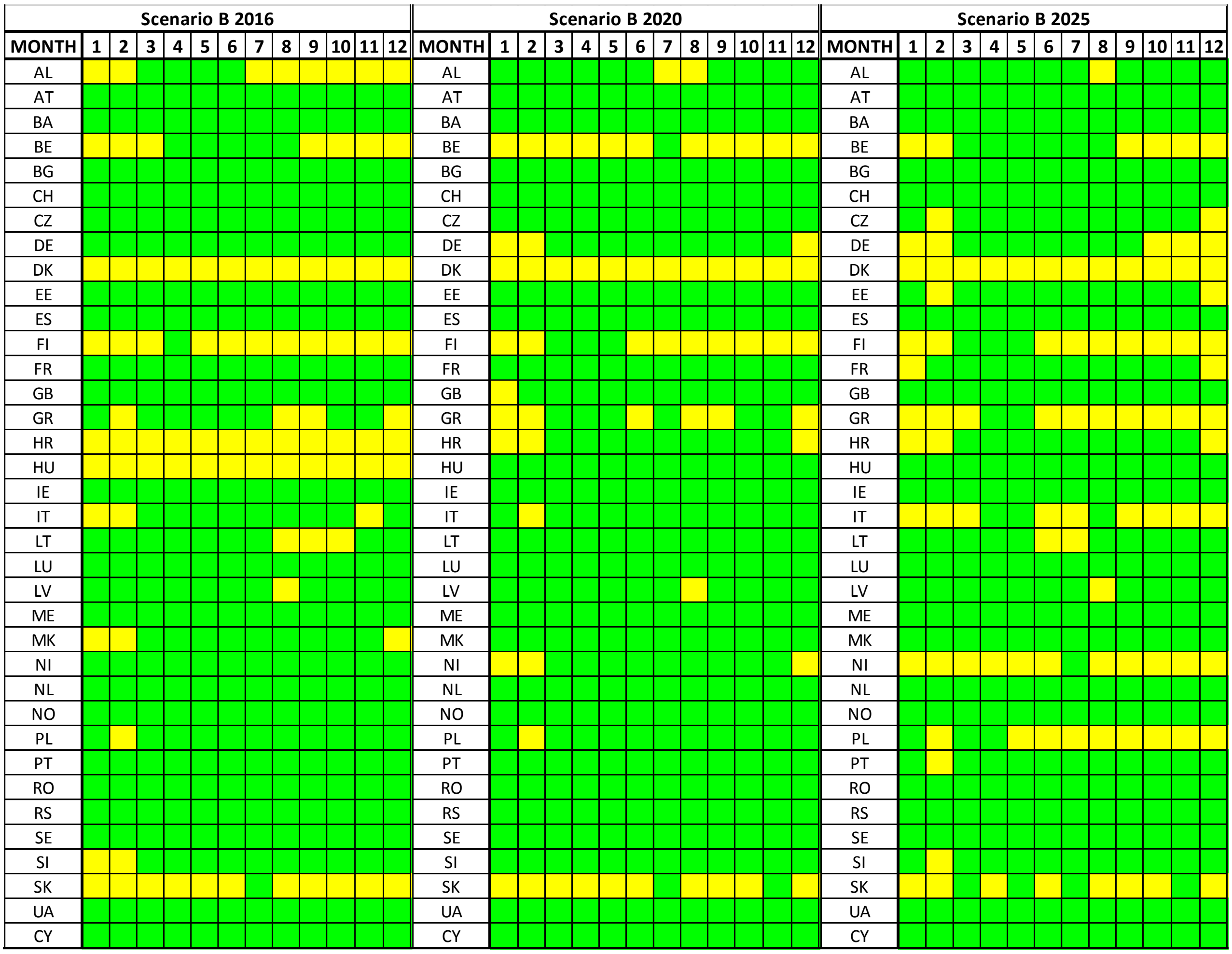
The analysis implicitly considers a perfectly functioning market, where all reliably available capacity at the hour of operation is properly delivered by all the different market sectors (spot, intraday, balancing, capacity). However, the feasibility analysis identifies situations where even perfect markets are no longer able to deliver because of physical unavailability of generation or transmission. TSOs subtract only the system services reserves as unavailable capacity for the 'feasibility' generation adequacy assessment, because these are fundamentally needed by the TSOs to provide operating response and to maintain system stability (e.g. voltage stability).

Discussion:

The main results are:

- Some countries, e.g. BE, DK, FI and SK, are structurally dependent on imports through the period analysed, 2016–2020–2025.
- Import needs appearing at the beginning and at the end of the year indicate the effect of low temperatures and a corresponding increase in demand.
- In 2020, DE will need imports during January, February and December under extreme conditions (when spare capacity is already used). This is a different trend from that in 2016, correlated with the expected close-downs of conventional power plants in 2020. Further, in 2025, imports are needed under less extreme conditions.

These results are direct consequences of the data presented in the national analysis, Chapter 4. The regional analysis shows that from a Pan-EU system point of view, the level of imports necessary to maintain adequacy is **feasible** and **within** the level of forecast cross-border interconnectivity for the period 2016–2025. These results rely on the assumption that the forecast cross-border interconnectivity is in place in 2020 and 2025.



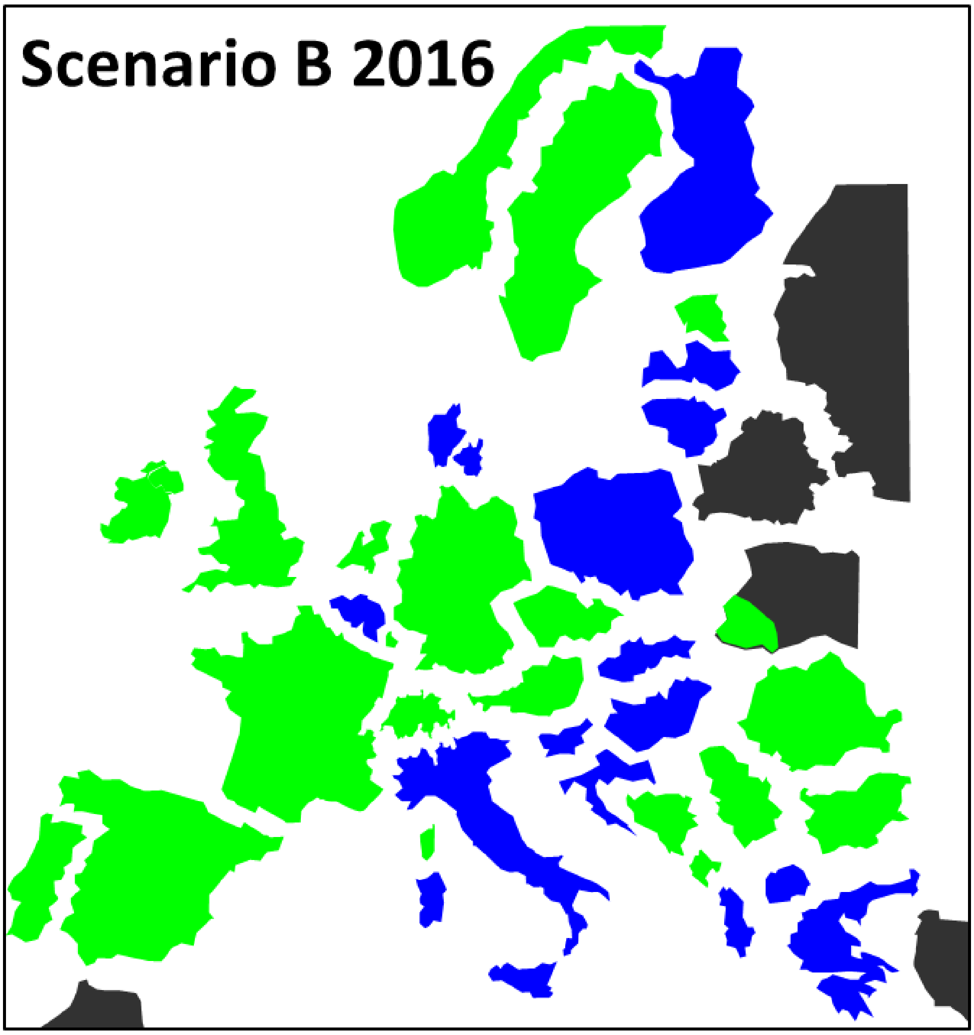
6.2 Overview of Pan-EU cross-border import needs

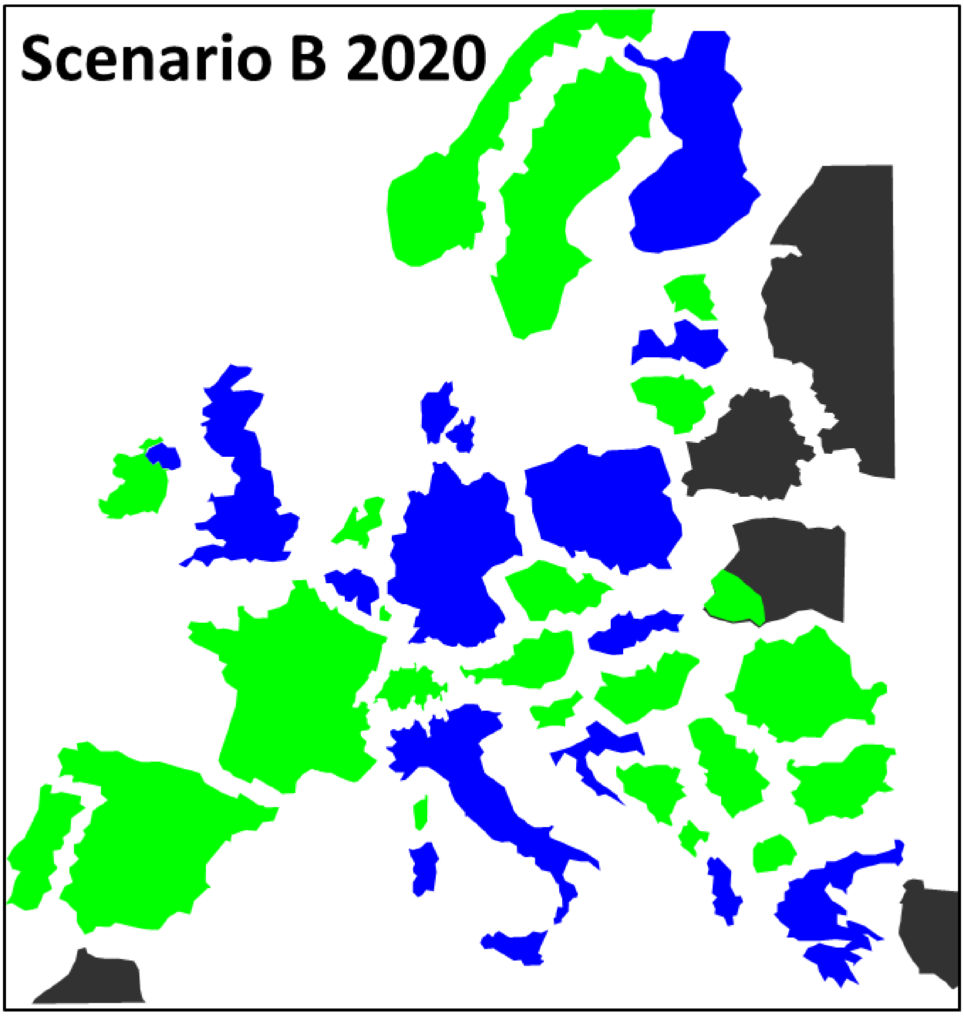
The above results show an increase in the cross-border imports to maintain adequacy from 2016 to 2025.

Below, an overview of the monthly result is summarized in the form of a coloured map, where:

- **Green** means a country does not need imports through the year to maintain adequacy;
- **Blue** means that a country needs imports (at least during one month or more) throughout the year to maintain adequacy.

The number of countries in blue increases between 2016 and 2025, showing the increasing role of cross-border imports in maintaining adequacy in the Pan-EU system.


Scenario B 2016



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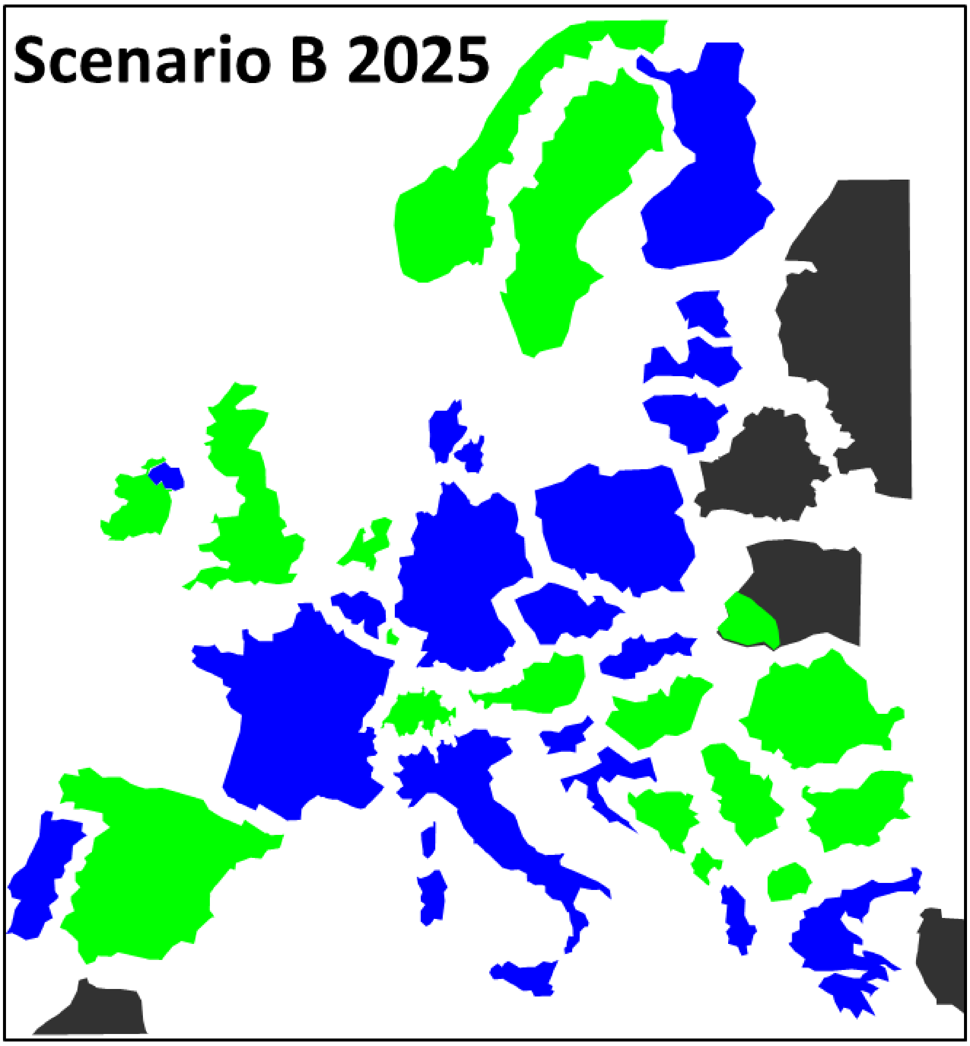
Scenario B 2025

7 Appendix I–Glossary/Data definitions

Adequacy Reference Margin: The part of Net Generating Capacity that should be kept available at all times to ensure the security of supply on the whole period that each reference point is representative of. Adequacy Reference Margin in an individual country is equal to the sum of the Spare Capacity and the Margin against Monthly Peak Load.

Load: Load on a power system is the net consumption corresponding to the hourly average active power absorbed by all installations connected to the transmission grid or to the distribution grid, excluding the pumps of the pumped-storage stations. "Net" means that the consumption of power plants' auxiliaries is excluded from the Load, but network losses are included in the Load.

Load Management: Load Management forecast is estimated as the potential load reduction under control of each TSO to be deducted from load in the adequacy assessment.

Maintenance and Overhauls: This category aggregates scheduled unavailability of generating capacity for regular inspection and maintenance.

Margin against Seasonal Peak Load: The difference between Load at the reference point and the Peak Load over the season (summer or winter) the reference point is representative of. It serves to extend the results from the single reference point to the whole investigated period.

Net Generating Capacity (NGC): The Net Generating Capacity of a power station is the maximum electrical net Active Power it can produce continuously throughout a long period of operation in normal conditions. "Net" means the difference between, on the one hand, the gross generating capacity of the alternator(s) and, on the other hand, the auxiliary equipment load and the losses in the main transformers of the power station.

> Remark: If the lowest voltage levels are not considered for load that is net of generation on these voltage levels, then the generation connected to these lowest voltage levels should not be reported. In this respect, the National Representativeness index is the estimation of the percentage of the national value that the collected data are representative of. As generation adequacy is based on the comparison of national load and generation, National Representativeness of load data and generation data should be identical in order to make the generation adequacy assessment reliable.

> Remark: The National Generating Capacity of a country is the sum of the individual Net Generating Capacity of all power stations connected to either the transmission grid or the distribution grid. The sum of the individual net generating capacity of all power stations connected to either transmission or the distribution grid.

Non-Usable Capacity: Aggregated reduction of the net generating capacities because of various causes, including, but not limited to

- Limitation because of intentional decision by the power plant operators
  - Power stations in mothballs that may be recommissioned if necessary
  - Power stations bound by local authorities that are not available for interconnected operation
  - Power stations under construction whose commissioning is scheduled for a certain date, but capacity is not firmly available because of delays or retrofitting
  - Power stations that are converted to other fuels or that are equipped subsequently with desulphurization and denitrification plants
  - Power stations in test operation
- Unintentional temporary limitation
  - Power stations whose output power cannot be fully injected because of transmission constraints
  - Power stations in multiple purpose installations where the electrical generating capacity is reduced in favour of other purposes, such as heat extraction in combined heat and power plants for example
- Temporary limitation because of constraints, such as power stations in mothballs or test operations, heat extraction for CHPs
- Limitation because of fuel constraints management

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- Nuclear power stations in stretch-out operation
- Fossil fuel power stations
  - Power stations with interruptible fuel supply
  - Power stations with poor quality fuel, such as unfit coal
- Limitation reflecting the average availability of the primary energy source
  - Hydro power stations
    - Run-of-river power stations with usual seasonal low upstream water flow
    - Tidal power stations
    - Storage power stations subject to usual limitation such as limited reservoir capacity, power losses because of high water, loss of head height or limitation of the downstream water flow
  - Wind power stations
  - Photovoltaic power stations
  - Geothermal power stations
- Power stations with output power limitation because of environmental and ambient constraints
- Limitation because of other external constraints
  - Hydro power stations with water flow regulation for irrigation, navigation, tourism
  - Power stations with output power limitation because of environmental constraints
  - Power stations with output power limitation because of external thermal conditions

Outages: This category aggregates forced—that is, not scheduled—unavailability of generating capacity.

Reference Points: Reference points are the dates and times data are collected for:

- Data collected for the hour *H* are the average value from the hour *H* – 1 to the hour *H*.
- Two annual reference points are defined in the SO&AF report:
- The 3rd Wednesday of January on the 19th hour (from 18:00 CET to 19:00 CET)
- The 3rd Wednesday of July on the 11th hour (from 10:00 CEST to 11:00 CEST)

Reliably Available Capacity (RAC): Part of the National Generating Capacity that is actually available to cover the Load at a reference point

Remaining Capacity (RC): The RC on a power system is the difference between the RAC and the Load. The RC is the part of the NGC left on the system to cover any unexpected load variation and unplanned outages at a reference point; RC is calculated in the SO&AF report including Load Management, which increases the amount of RC:

Remaining Capacity = Reliably Available Capacity – (Load – Load Management)

Simultaneous exportable/importable capacity: Transmission capacity available for exports/imports to/from other Control Areas.

Remark: The simultaneous importable/exportable capacity use in this report for adequacy assessment should not be confused with the *interconnection capacity*[23]. The simultaneous importable/exportable capacity taken into account in this framework could be lower than the sum of NTCs on each profile of a Control Area or country. It is calculated taking into account the mutual dependence of flows on different profiles because of internal or external network constraints, as well as the specific characteristics of the power system related to adequacy. For the interconnection level of countries, and checking the compliance with the *10% target requirement*, please refer to the TYNDP 2016[24] and the new Regional investment plans.

[23] http://ec.europa.eu/priorities/energy-union/docs/interconnectors_en.pdf
[24] https://www.entsoe.eu/major-projects/ten-year-network-development-plan/ten%20year%20network%20development%20plan%202016/Pages/default.aspx

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Spare Capacity: The spare capacity reflects the additional capacity that should be available on a power system to cope with any unforeseen extreme conditions. It comes in addition to system services reserves and margin against monthly peak load.

System Services Reserve: The capacity required to maintain the security of supply according to the operating rules of each TSO. It corresponds to the level required one hour before real time (additional short notice breakdowns are already considered in the amount of outages).

Time of Reference: Time in the outlook reports is expressed as the local time in Brussels.

Unavailable Capacity: Unavailable Capacity is the part of Net Generating Capacity that is not reliably available to power plant operators because of limitations of the output power of power plants. It is calculated by adding Non-Usable Capacity, Maintenance and Overhauls, Outages and System Services Reserves.

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