January 2021 · Version for ACER opinion

Ten-Year Network Development Plan 2020

Electricity system needs factsheet: Serbia

Based on findings published in the TYNDP 2020

These **Electricity System Needs factsheets** present an overview of the electricity landscape in each European country for the next decades, with a focus on the 2030 time horizon, and providing a first look at the possible 2040 landscapes. They provide the essential information allowing to understand so-called "system needs": how the electricity system should be reinforced throughout Europe to deliver on the climate agenda while keeping the bills as low as possible and maintaining the reliability standards of European electricity systems. The data and analysis presented in this document is extracted from ENTSO-E's TYNDP 2020 package.

What is ENTSO-E's System Needs study

ENTSO-E's system needs study investigates where improving cross-border electricity flow throughout Europe could bring benefits to Europeans. The study finds needs everywhere in Europe, with a total of 50 GW of needs on close to 40 borders in 2030 and 43 additional GW on more than 55 borders in 2040. This is in addition to the 35 GW of cross-border transmission capacity reinforcements by 2025 that are already under construction or in permitting phase.

What technologies should address the needs?

Many of the studies presented in this document focus on the development of interconnection levels. However, these findings can be extrapolated to identify specific projects aimed at solving interconnection barriers through other technologies (including demand response, generation, storage, etc.). The solution to tomorrow's challenges will be the parallel development of all possible solutions, including on the role of prosumers and historic generators, and the development of new interconnections.

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For full details on the system needs identified for 2030 and 2040

tyndp.entsoe.eu/system-needs

entsoe

1. Current electricity landscape

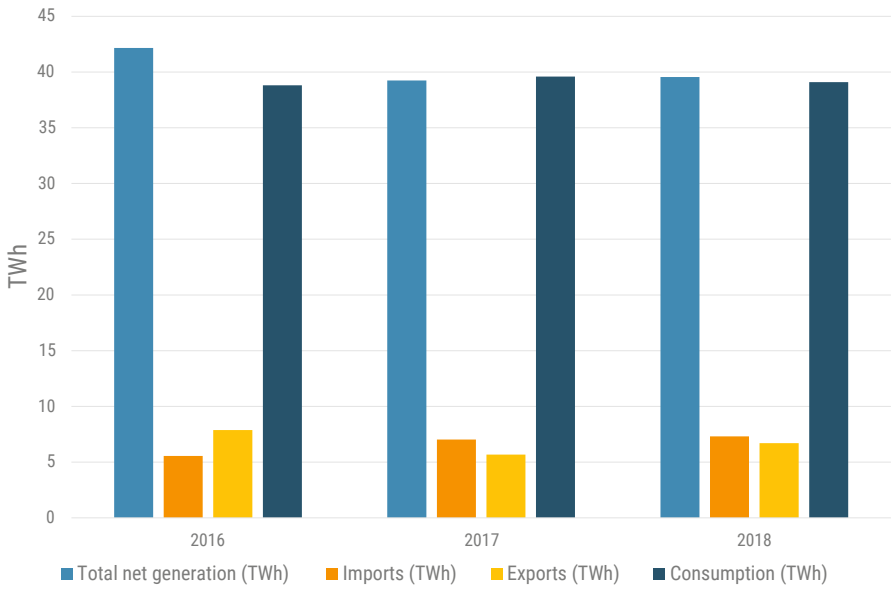


Figure 1.1: Yearly electricity demand, consumption and energy balance for the years 2016 – 2018. Values given in TWh.

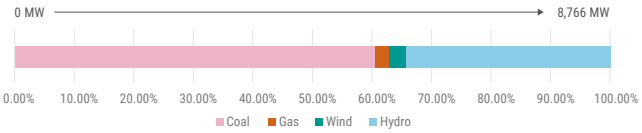


Figure 1.2: Share of installed capacity per generation category 2018.

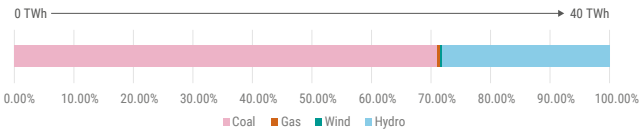


Figure 1.3: Share of generation mix by fuel category in 2018.

At the very beginning, it is fitting to enclose the brief overview of the current electricity landscape of Serbia, where particular attention should be paid to the current generation mix, both to obtain the satisfactory understanding of the present situation of the system-of-interest for this document and to foster comprehension of the changes, through which this system is poised to go through in the coming years, easier. Even though the graphs provided in the upper part of this page inevitably lead to the conclusion that the coal-fired power plants have dominated the generation mix of the Serbian system in 2018 (time horizon for which the collection of data was conducted), the encouraging signs can be spotted if the segment of Fig. 1.4 dedicated to the onshore wind power production was observed, with the bar declaring the wind capacities in Serbia first appearing in 2018, marking the introduction of this type of sources to the Serbian system. Of course, this can only be seen as the start of a lengthy and difficult process of turnabout in the entire Serbian power sector, with much more prominent roles expected to be given to the environmentally acceptable renewable energy sources without undermining the system's reliability. This will, however, be covered in-depth in one of the following chapters, dealing specifically with that aspect of the system's operation.

Generation technologies have been grouped for legibility:

- **Coal:** Hard coal, soft coal and Lignite
- **Gas:** Coal-derived gas and Fossil gas
- **Oil:** Fossil oil and Oil shale
- **Other non-RES:** non-RES waste, Other non-RES, peat, Mixed Fuels and Other Fossil Fuels
- **Wind:** Offshore and Onshore
- **Solar:** Solar PV and Solar Thermal
- **Bioenergy:** Biomass and Biogas
- **Hydro:** All hydro categories including marine

Generation categories were taken directly from the **ENTSOE Statistical Factsheets 2016 – 2018.**

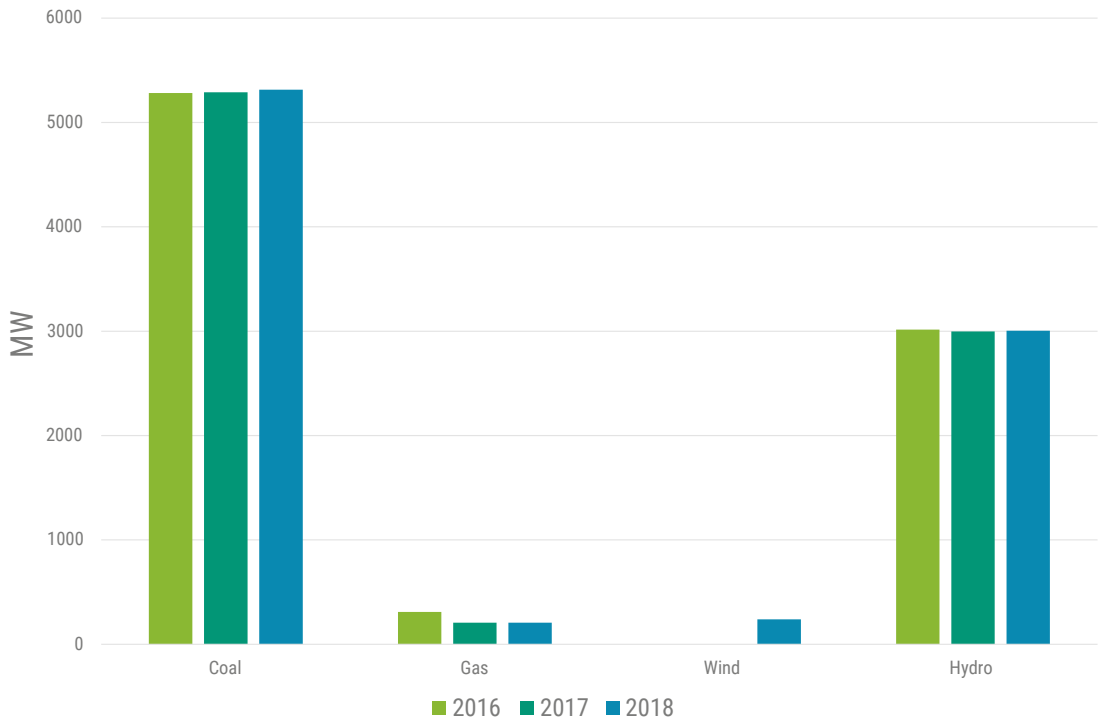


Figure 1.4: Net Generation Capacity evolution: 2016 – 2018 (MW).

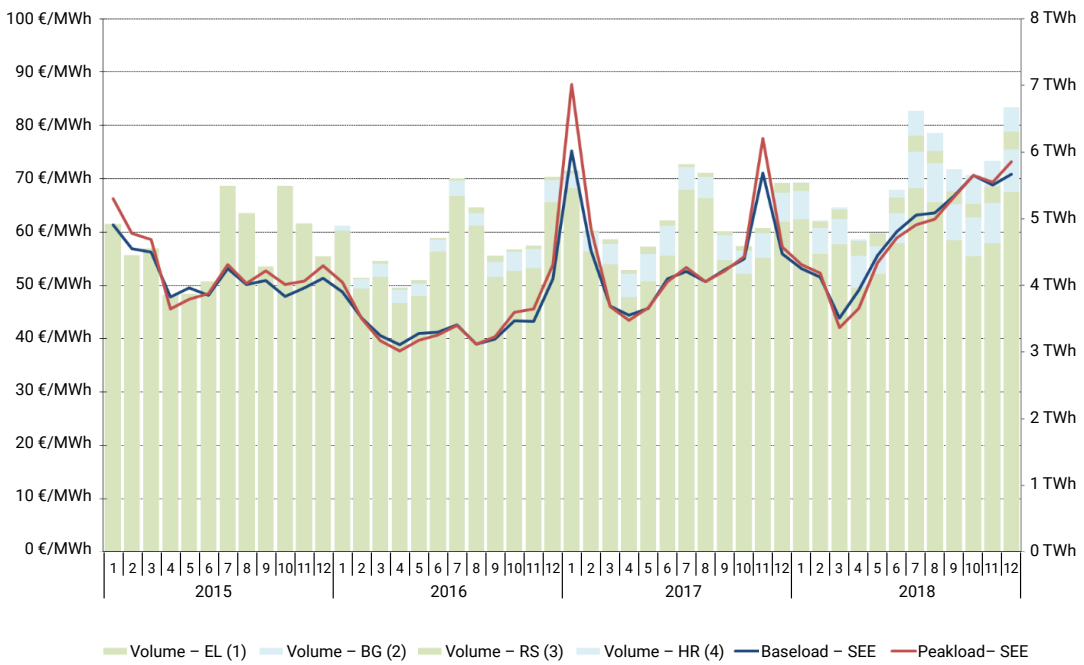


Figure 1.5: Monthly exchange traded volumes of day-ahead contracts and monthly average prices in the region in 2018 (Quarterly Report on European Electricity Markets Volume 11, Issue 4, Q4 2018).

2. About the scenarios

The TYNDP 2020 scenarios describe plausible and technically sound electricity futures for 2025, 2030 and 2040. They were jointly built with ENTSO-G, from storylines co-constructed with stakeholders. All scenarios head towards a decarbonised future and have been designed to reduce GHG emissions in line with EU targets for 2030 or the United Nations Climate Change Conference 2015 (COP21) Paris Agreement objective of keeping temperature rise below 1.5° C.

National Trends (NT) is the central scenario based on draft National Energy and Climate Plans in accordance with the governance of the energy union and climate action rules, as well as on further national policies and climate targets already stated by the EU member states. The present Country factsheet focuses on the National Trend 2030 scenario, because it has been identified as the reference scenario for the 2020 PCI process.

Global Ambition (GA) is a scenario compliant with the 1.5° C target of the Paris Agreement also considering the EU's climate targets for 2030. It looks at a future that is led by development in centralised generation.

Distributed Energy (DE) is a scenario compliant with the 1.5° C target of the Paris Agreement also considering the EU's climate targets for 2030. It takes a decentralised approach to the energy transition.

	2020	2025	2030	2040	2050
BEST ESTIMATE					
RES-E wind	n/a	19 %			
RES-E solar	n/a	8 %			
RES-E hydro	n/a	20 %			
Direct electrification	n/a	n/a			
Domestic RES Gas Biomethane	1 %	1 %			
Domestic RES Gas Power-to-gas					
Decarbonisation of gas supply	1 %	1 %			
Gas import share	78 %	85 %			
NATIONAL TRENDS					
RES-E wind			29 %	42 %	n/a
RES-E solar			12 %	15 %	n/a
RES-E hydro			21 %	16 %	n/a
Direct electrification			n/a	n/a	n/a
Domestic RES Gas Biomethane			4 %	12 %	n/a
Domestic RES Gas Power-to-gas			0 %	1 %	n/a
Decarbonisation of gas supply			4 %	13 %	n/a
Gas import share			84 %	83 %	n/a
DISTRIBUTED ENERGY					
RES-E wind			29 %	42 %	54 %
RES-E solar			14 %	18 %	19 %
RES-E hydro			21 %	21 %	23 %
Direct electrification			29 %	45 %	54 %
Domestic RES Gas Biomethane			6 %	18 %	33 %
Domestic RES Gas Power-to-gas			3 %	17 %	32 %
Decarbonisation of gas supply			12 %	47 %	86 %
Gas import share			79 %	60 %	35 %
GLOBAL AMBITION					
RES-E wind			32 %	45 %	50 %
RES-E solar			10 %	13 %	15 %
RES-E hydro			21 %	16 %	29 %
Direct electrification			27 %	35 %	41 %
Domestic RES Gas Biomethane			5 %	12 %	19 %
Domestic RES Gas Power-to-gas			0 %	6 %	11 %
Decarbonisation of gas supply			11 %	46 %	86 %
Gas import share			83 %	78 %	70 %

Percentages indicate by how much the technology total capacity has grown since the current year.

Readers who are interested are referred to the Scenarios 2020 report.

3. Market integration in 2030

About the grid configurations presented in this document

Each grid configuration corresponds to a vision of the year 2030:

- **No investment after 2020:** a hypothetical year 2030 where Europe stopped all cross-border grid development after mid-2020.
- **Portfolio 2030:** a hypothetical year 2030 where all projects of the TYNDP 2020 Portfolio that are foreseen to commission until 2030 have been built.
- **SEW-based needs 2030:** a hypothetical year 2030 where the needs for capacity increases after 2025 identified by ENTSO-E's System needs study have been addressed. These needs represent the combination of cross-border capacity increases that minimises overall system cost. Only part of these needs are addressed by existing projects.

Analysis: Market integration needs across relevant European boundaries in 2030

Ten **main boundaries to electricity exchanges** (groups of borders between countries) have been identified in ENTSO-E's TYNDP, where important barriers exist preventing optimal power exchanges between countries or market nodes from occurring. Electricity flows are highly sensitive to initial system conditions, which are impossible to forecast precisely on the long term. Considering boundaries instead of individual borders allows to focus on large systemic flows which can be seen in all scenarios, whatever the actual path of electrons.

Boundary studies investigate how SEW increases with increasing grid transfer capacity. These curves are included for those countries that sit on one or more of the boundaries identified in Figure 3.3. If a country does not sit on one of these boundaries then these figures are not included. For those countries with boundary curves, the steeper the SEW increases the higher the marginal benefit for society. As stated in the IoSN, addressing the needs identified through studies like this are not limited to transmission lines but can also include additional generation, storage options, demand side technologies and a host of other technologies.

As the market integration represents one of the primary pillars around which the heavily interconnected power systems of the future are to be woven, it should come as no surprise that the development of the Serbian transmission system also strongly leans in that direction, with the numerous projects submitted for consideration in the scope of TYNDP 2020 only serving as further argumentation for the aforementioned claim. These projects were seen as optimal way of increasing the transfer capacities across the Serbian borders that were shown to need future strengthening, with the potential effects of these actions presented in the Fig. 3.2, located on the next page, that shows the anticipated constraint durations of Serbian cross-border connections for each of the three grid sets encompassed by this report (the darker shade of blue used for the line, alongside the thickness of the line itself, indicates the longer lasting of the expected congestions on the border). If this diagram was carefully analysed, it would become clear that the constraint duration values are way higher in the case illustrating in the case of the "No investment after 2020" grid than in either of the other two cases, especially when compared to the "SEW-based needs 2030" results. This conclusion merely amplifies the importance of honouring the market integration principles by ensuring the high-enough transfer capacities across each of the Serbian boundaries for which the potential congestions were foreseen, all of that in a timely and effective manner.

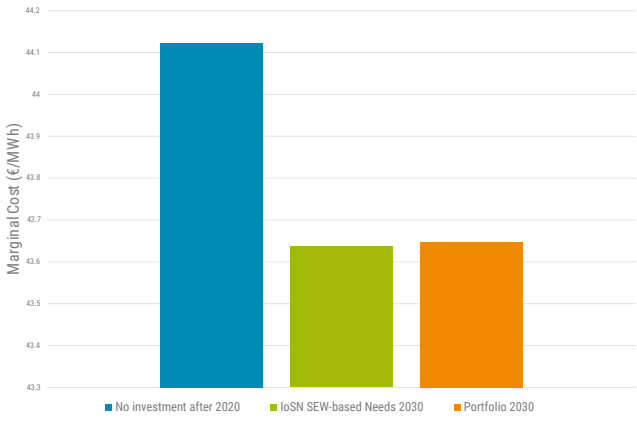
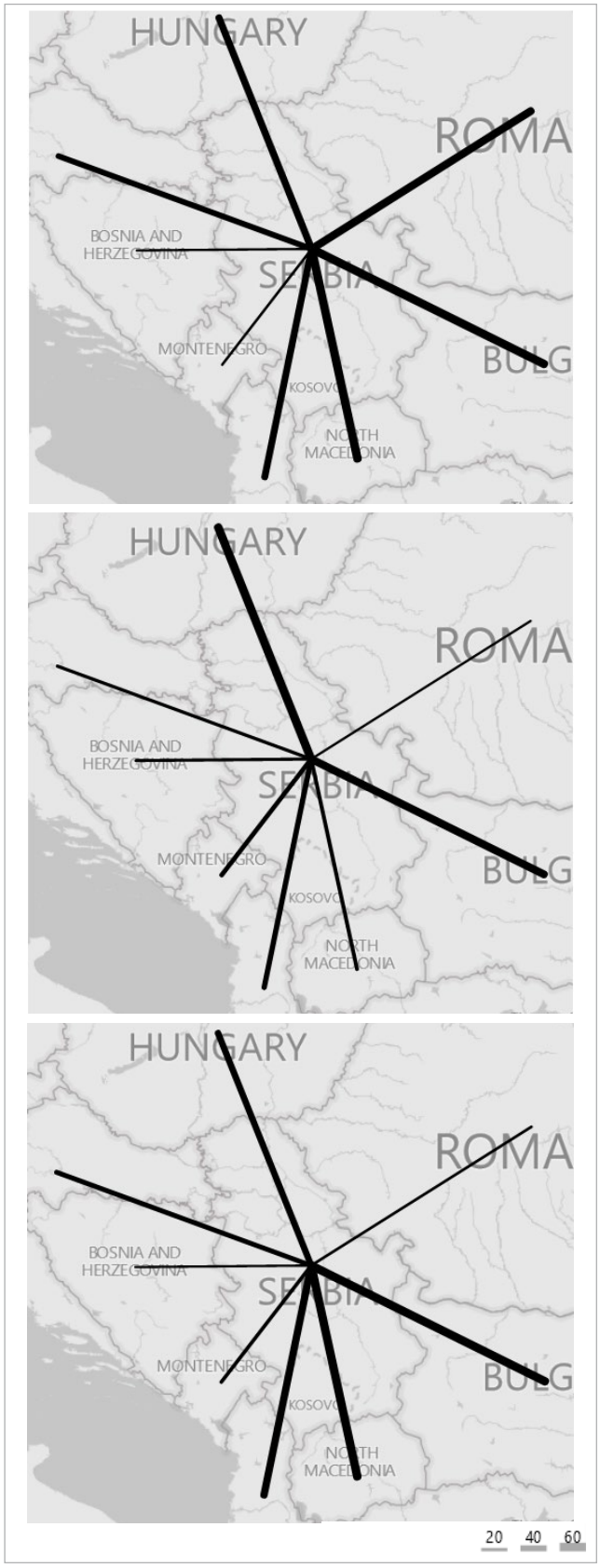


Figure 3.1: Marginal costs for the respective country for the grid sets No Investment after 2020, SEW-based needs 2030 and Portfolio 2030. These compare the differences between the marginal costs for each, hypothetical development pathway.

Marginal prices can be heavily impacted by cross-border congestions: a well-integrated market allows cheaper generation to be recruited by neighbouring countries, including low-emission sources such as wind and solar. Greater interconnections thus help reduce both electricity costs for consumers in all countries and also the carbon emissions the European grid generates.



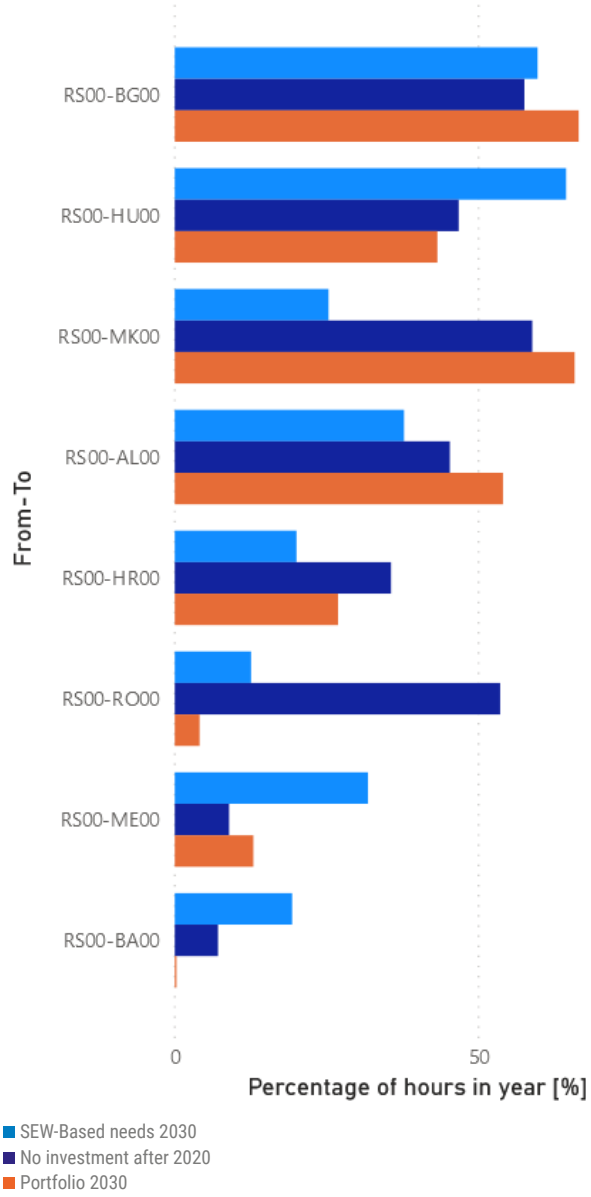


Figure 3.2: Constraint duration of connections between adjacent bidding zones in 2030. From top to bottom: No investment after 2020, SEW-based needs 2030 and TYNDP Portfolio 2030. Network constraint duration, given as the percentage of hours where each line is congested, are shown on the right. Congestion percentages are totalled for both A > B and B > A directions.

Power lines allow for bi-directional power flows. The directional capacity of a line can be heavily dependent on the network conditions of the country or region the line is connected to. Hence, Congestion in one direction can be different to the other. Here, we are reporting the total congestion for the line in both directions. A and B refer to the *From* and *To* countries that are connected via a cross-border transmission line respectively.

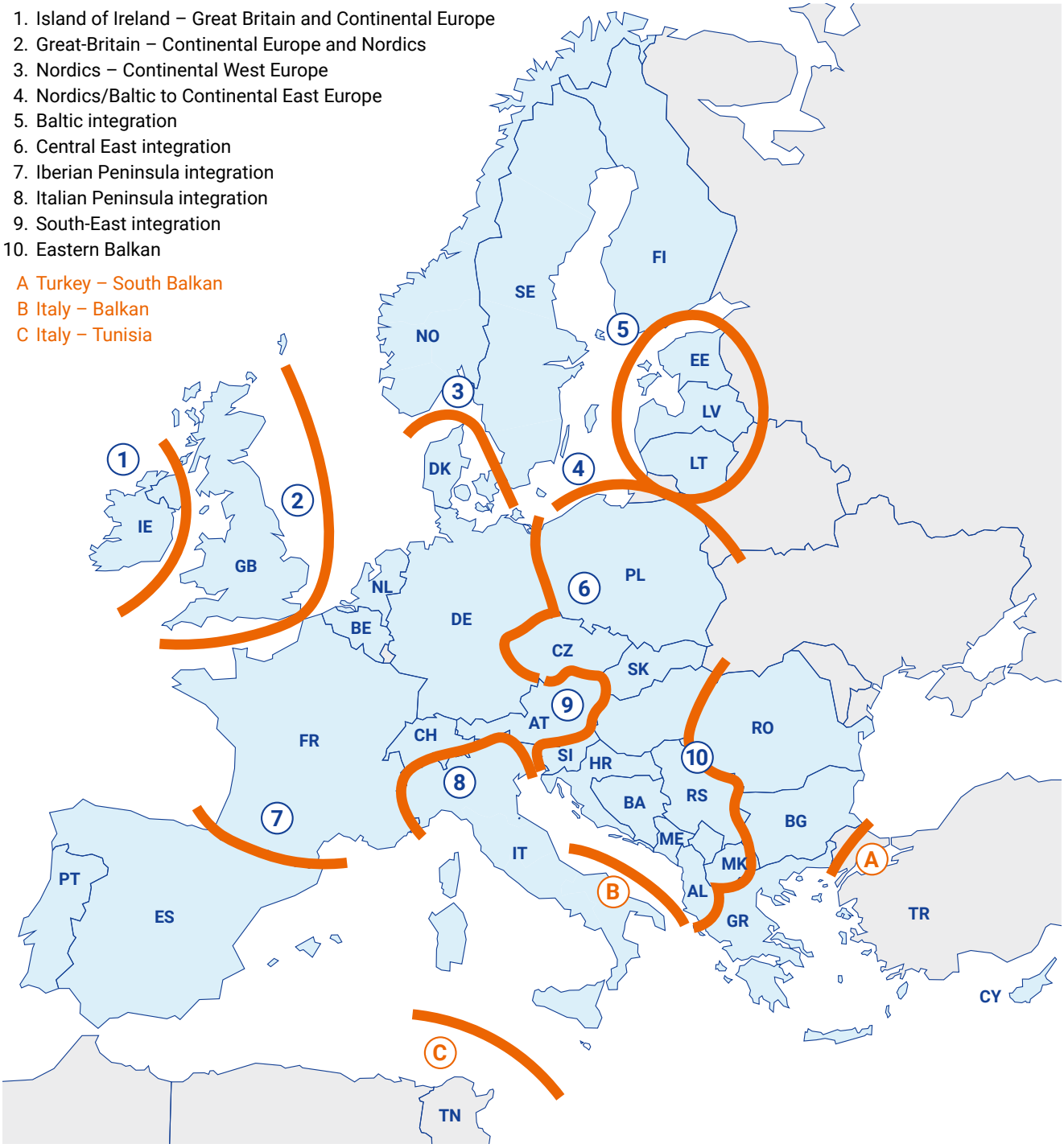


Figure 3.3: Map showing the main boundaries considered in the TYNDP 2020.

Boundaries are areas between transmission grid regions where a significant need for transmission capacity has been identified and greater grid transmission capacity is required to increase overall social welfare.

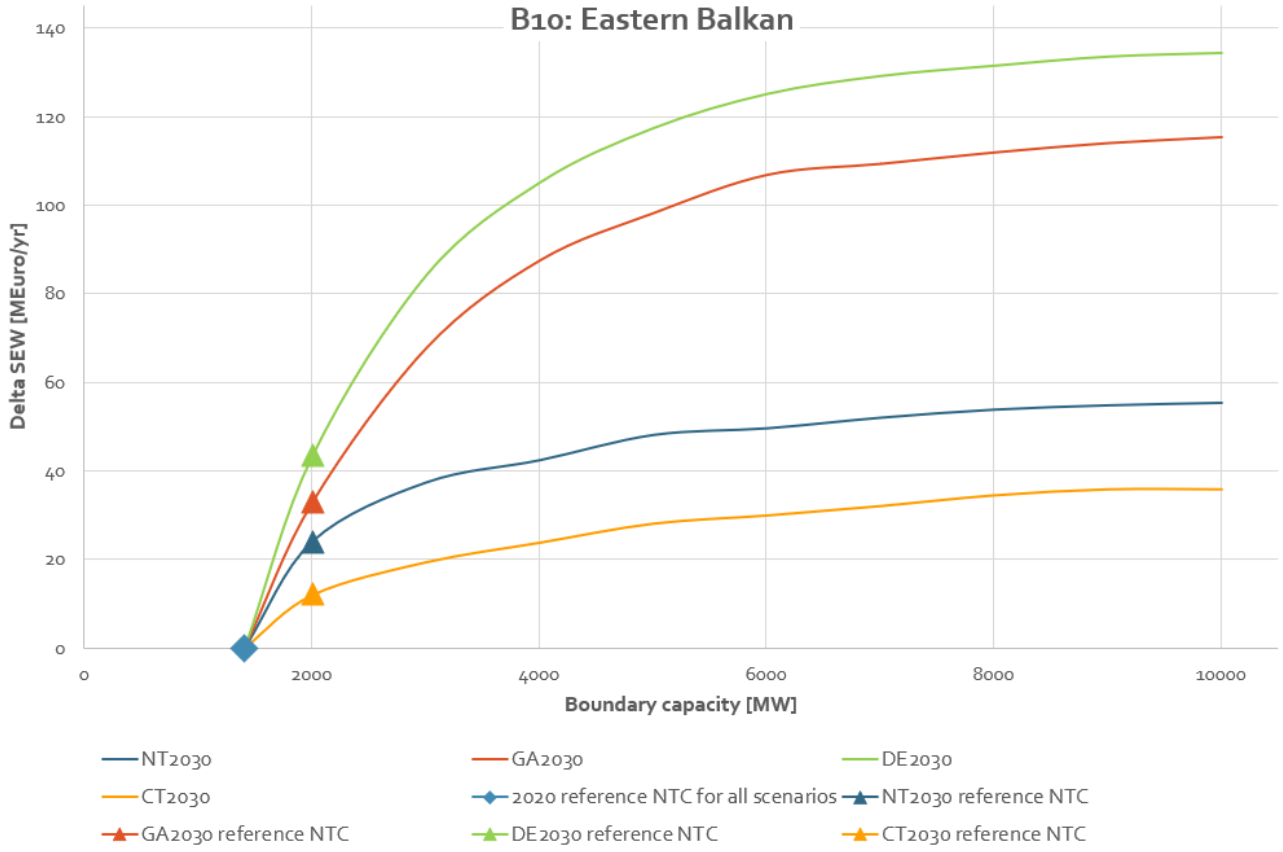


Figure 3.4: Relevant country boundaries indicating socio-economic growth (millions of EUR per year) with each stepped increase in each boundaries' grid transfer capacity (in MW).

Steeper SEW increases point to greater gains in socio-economic welfare.

4. Sustainability in 2030

It is already well-known that the widespread usage of the conventional power sources based on fossil fuels bears a significant share of blame for the emission of the greenhouse gases into the atmosphere, the recognition of which has given birth to the ever louder, but still perfectly justified, public propaganda that insists on the sustainable renewable energy sources taking the place in the generation mix previously occupied by the thermal units. Albeit it cannot be denied that Serbia was a bit late to initiating this process, especially when compared to some of the countries of Western Europe, it should also be underlined that, once this switch begins, it is expected to happen in a rather rapid fashion, with several GW of installed onshore wind capacity already envisaged only in the Banat region, positioned in the close vicinity of the border between Serbia and Romania. This leads to the conclusion that renewable energy sources are, according to currently available information, expected to take over a mighty part of the Serbian generation mix in the upcoming ten-year period, with the emissions of CO_2 in Serbia set to drop once the new mix begins taking shape (this can also be seen in Fig. 4.2, showing the reduction of CO_2 emission if the grid is developed properly until 2030), bringing Serbia to the level of some European countries that boasted a noteworthy head-start in the renewables integration race.

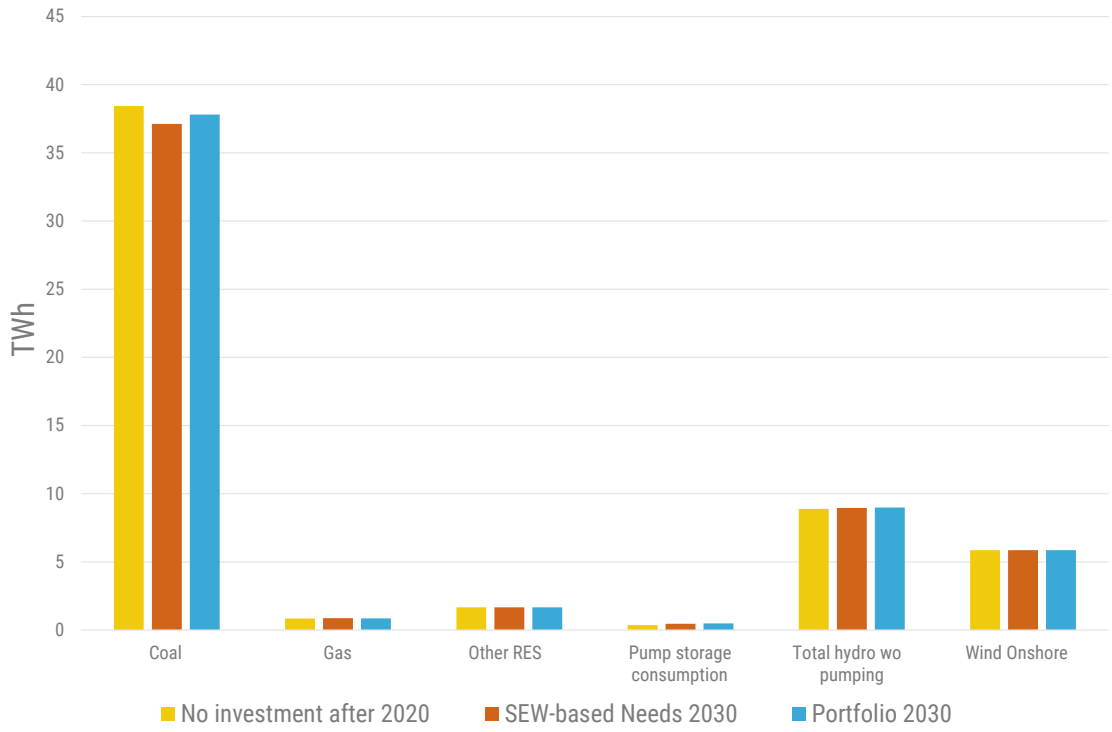


Figure 4.1: Comparison between the generation mix for National Trends 2030 for the 3 grid types: No investment after 2020, IoSN SEW-based needs 2030 and Portfolio 2030.

Generation categories are grouped for legibility:

- **Coal:** Lignite, Lignite CCS, Hard coal, Hard Coal CCS, Light oil, Heavy oil, Oil shale
- **Gas:** Closed Cycle Gas turbine, Open Cycle Gas Turbine and Open Cycle Gas Turbine CCS
- **Total hydro wo pumping:** Run-of river and pondage, Reservoir, Pumped Storage Open Loop (turbine) and Pumped Storage Closed Loop (turbine)
- **Pump storage consumption:** Pumped Storage Open Loop (pump) and Pumped Storage Closed Loop (pump)
- **Other RES:** Co-fired and biofuel thermal plants
- **Battery:** battery discharge i.e. generation from battery
- **Battery charge:** i.e. battery consumption from grid
- **Power to gas:** generation and load

% RES generation of total generation in 2030

IoSN SEW-based Needs 2030	No investment after 2020	Portfolio 2030
29	28	29

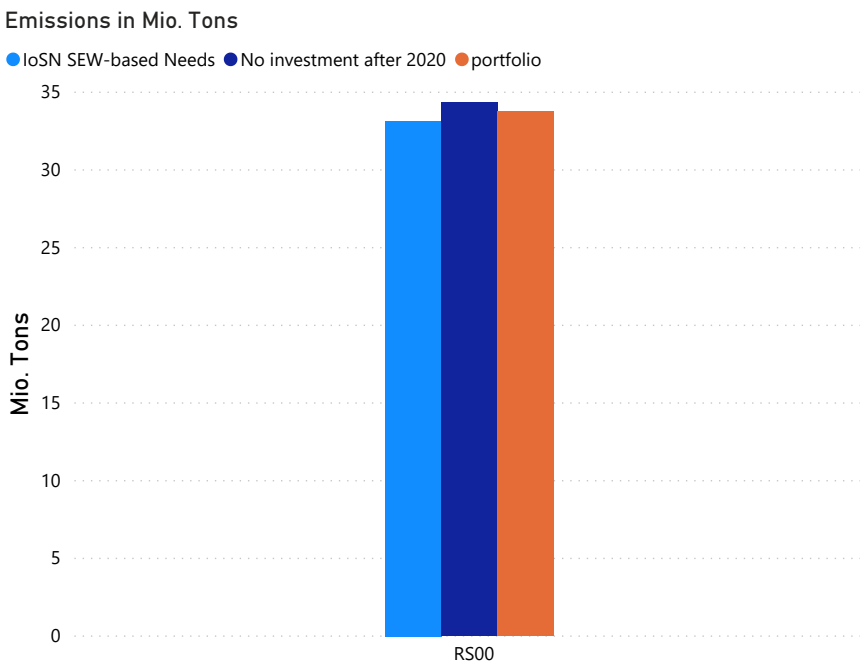


Figure 4.2: Total CO_2 emissions in National Trends 2030 for three different grid types: No investment after 2020, IoSN SEW-based needs 2030 and Portfolio 2030.

Ratio of curtailed RES production (TWh) to total RES production (TWh)

IoSN SEW-based Needs 2030	No investment after 2020	Portfolio 2030
0	0	0

Ratio of total CO_2 emissions (MTonnes) to the country's total electricity production (TWh)

IoSN SEW-based Needs 2030	No investment after 2020	Portfolio 2030
0.62	0.63	0.61

5. Security of Supply in 2030

Just like the remainder of countries that are currently preparing to go through the already elaborated generation mix transition and turn towards the sustainable energy production, Serbia is laboriously bracing itself for the potential challenges that might arise from the steps necessary for the planned changes to take place. As foreseen, significant part of these challenges will be related to the issues of system flexibility once the generation power of renewable sources nearly starts dictating the operational conditions of the system, especially because the mentioned power could suffer unexpected variations due to the stochastic nature of wind speed or solar irradiance affecting wind and solar units respectively. In order to cope with this problem, the Serbian TSO has planned an adequate number of interconnections with the neighbouring systems, with each of the newly commissioned tie-lines guaranteeing the additional reserve to the system in case of the sudden lack of energy and, therefore, mitigating the consequences of the highlighted events on the functioning of the system itself and, hence, the process of the unbothered energy delivery towards the consumers. The confirmation of these statements is also witnessed by the value of LOLE (explained below) for the 2025 time-horizon, where Serbia was assigned values less than 0.5 hours per year, proving the reliability of its system and verifying the previously described course of actions that the Serbian TSO is willing to take and is, to a certain extent, already taking.

Beyond adequacy: future challenges in Security of supply

Beyond the necessity to efficiently ensure balance between production and demand at any time, **the future system will also need to be operable in real time by TSOs.** The changing environment radically transforms the way this will be done, leading to new technical needs for the system. Transmission systems in Europe are increasing in complexity. Conventional generation is being displaced by new generation technologies that have different performance capabilities, generation is moving from the higher voltage levels to the distribution networks, and there is an increased level of interconnection between different synchronous areas. Many of the system services cannot be performed by solar or wind installations, because they do not include synchronous rotating masses. This increases both the interdependency of TSO processes to operate the system in a secure and efficient manner, and the need to take into account the challenges associated with the operation of the future system when designing the transmission network.

The **inertia duration** curve and residual load ramp curve present the situation created by the future energy landscape. Future studies will be necessary to clearly understand the scale and nature of measures to be taken by system operators in order to adapt to the situation of the 2030 and 2040 scenarios. Some of the needs may be addressed through the specification of capabilities and services that users (generation or demand) are expected to provide as part of their connection. However, additional nationally and regionally defined network reinforcement projects can also be expected to address the specific dynamic stability needs.

The inertia duration curve presents the percentage of hours in a full year where, for the synchronous area of the country, the intrinsic inertia (expressed in seconds) from generators is above a given value. The larger the area, the more stored energy in the rotating masses of the synchronous generating units is available (inertia), which the system can benefit from. When unexpected frequency variations occur in power systems, the energy stored in the rotating masses of the synchronous generating units, by virtue of their inertia, is released providing instantaneously balancing of any mismatch between generation and supply. **The level of inertia provides a useful assessment of the emerging challenges to system operability.**

The high variability of renewable energy sources will increasingly result in larger and faster imbalances in the electricity system. In this context, there is need to guarantee the necessary volume of reserves, in all time scales, as cases of unforeseen imbalances of generation and demand is increasing.

The Residual Load Ramp is an indicator used to highlights this impact: the response (in MW/hour) that has to be provided by controllable generating units, in order to maintain the balance between generation and demand. The residual load duration curve depicts the percentage of hours in a year where, the residual load ramps are above a given value. In order to cope with this situation, new sources of flexibility stronger interconnection will be necessary, for safe and secure operation of the power system.

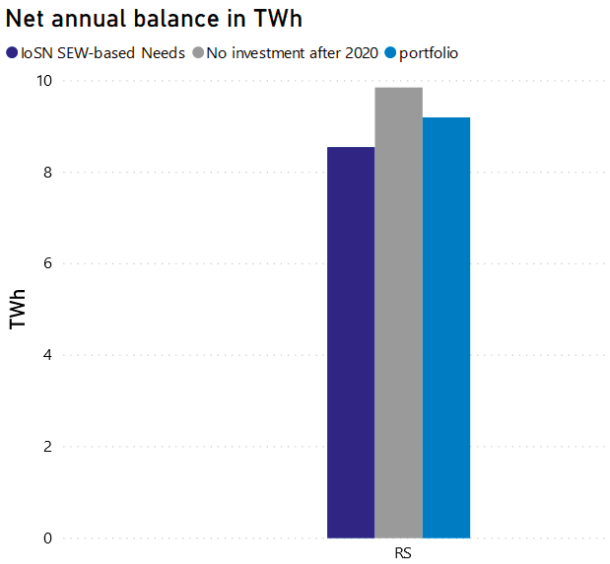


Figure 5.1: Net energy balance (TWh) for 3 grid sets considering the National Trends 2030 scenario.

Positive energy balance indicates the country is an exporter. Negative means the country is an importer.

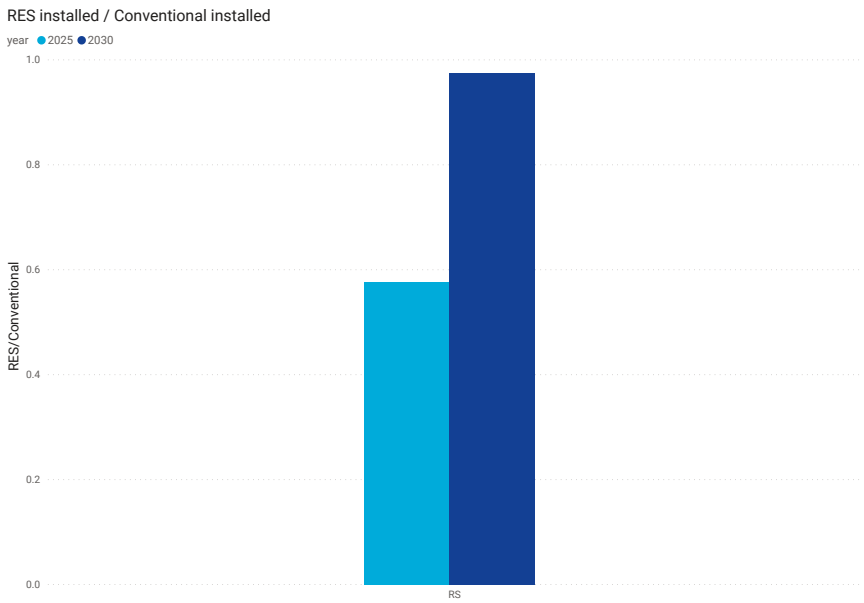


Figure 5.2: Ratio of the installed RES generation capacity to the installed conventional generation capacity in the years 2025 and 2030.

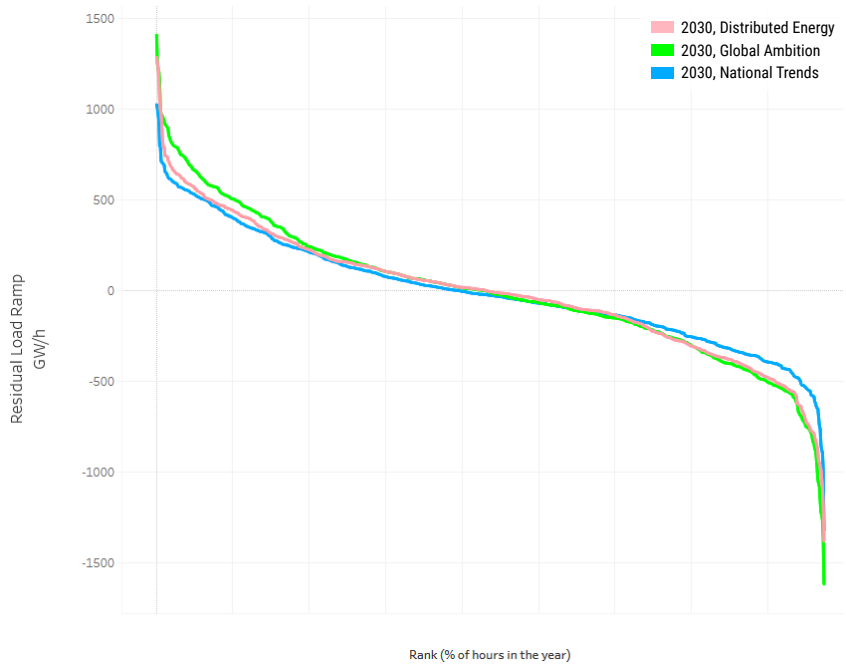


Figure 5.3: Residual load ramp duration curve for 2030 scenarios.

Hourly residual load ramp is one parameter showing the challenges of operating a system with reduced amount of controllable units, high flexibility needs in normal operation, and a requirement to guarantee the necessary volume of frequency reserves for cases of unforeseen imbalances between active power generation and demand. The curves show the changes of residual load (demand minus RES) from one hour to the following hour. These curves thus express the response (in MW/hour) that needs to be provided by controllable generating units or through interconnectors in order to maintain balance between generation and demand.

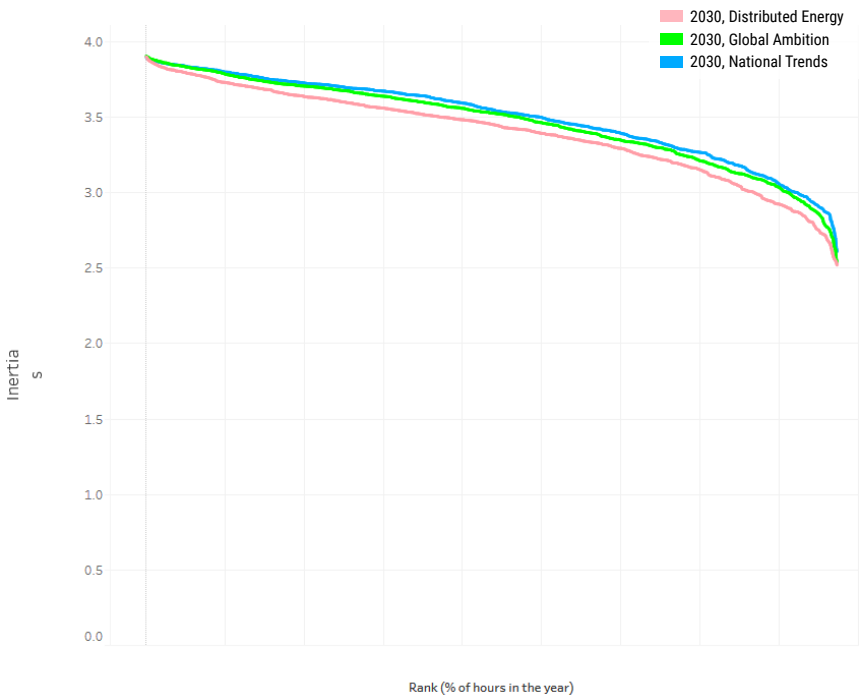
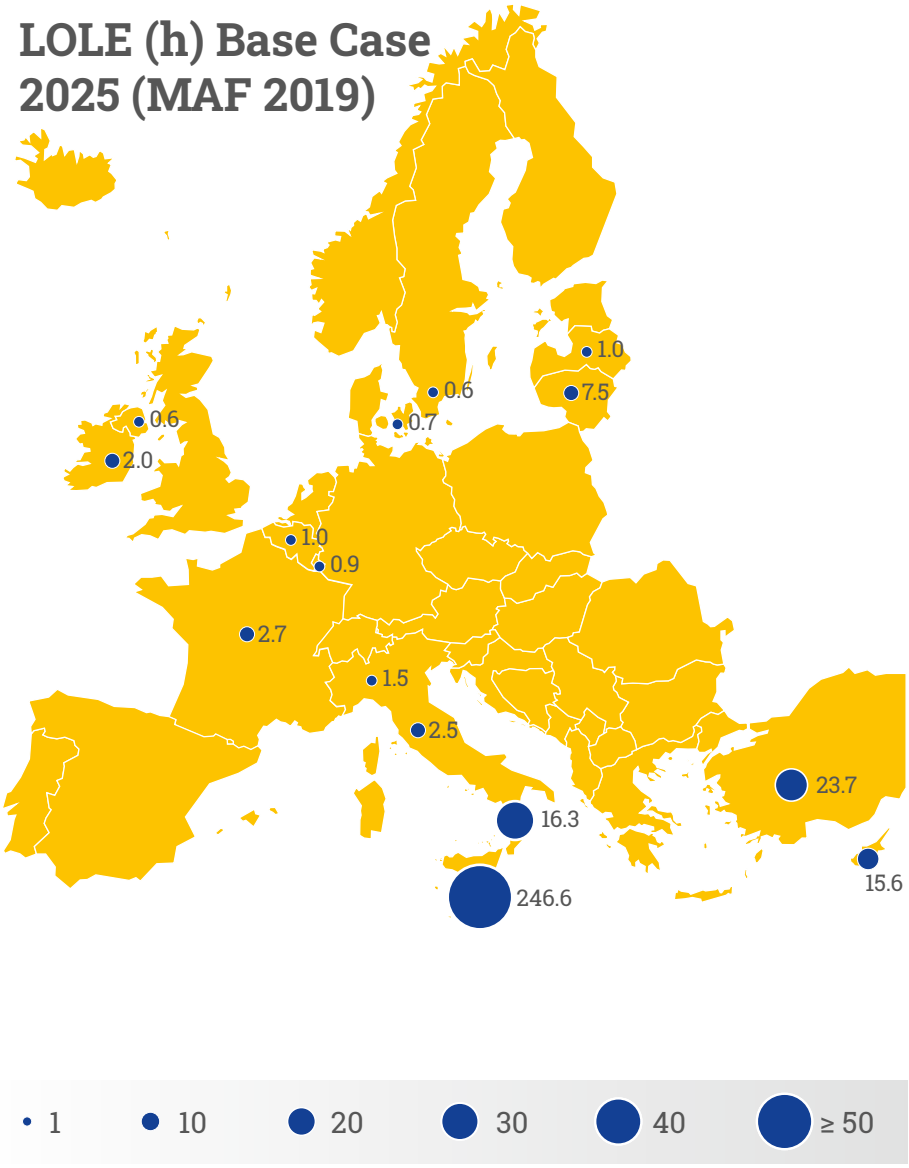


Figure 5.4: Inertia duration curve for 2030 scenarios.

Inertia is the estimated kinetic energy stored in the rotational masses of synchronous generators. The more RES penetration a system has the less inertia is available. The curve above illustrates how much inertia is available to the country as a percentage of hours during the year. Inertia determines how resistant a network is to sudden changes in the energy balance: higher inertia means higher stability. As RES penetration increases, system operators are beginning to explore new options to address this issue. Interested readers are directed towards ENTSO-e's Inertia insight report, published on the **TYNDP website**.

Brief explanation on the meaning of LOLE

The **Loss of Load Expectation (LOLE)** is the expected number of hours in which the hourly load exceeds the available generating capacity and available imports. This leads to hours wherein the supply cannot be met and load will have to be curtailed.



A non-zero value of LOLE indicates only a resource inadequacy in the market. It does not indicate a risk of blackout or load shedding, because ENTSO-E observes only the day-ahead situation, while TSOs have various tools to resolve situations of scarcity within the day. Circle radii reflect the magnitudes of the LOLE values for the corresponding zones. Zones without circle have LOLE values of less than 0.5 h.

Figure 5.5: Loss of Load Expectation in 2025 (ENTSO-E's Mid Term Adequacy Forecast 2019)

6. Interconnection targets in 2030

In 2017, the Interconnection Target Expert Group (ITEG) proposed alternative indicators to the European Commission 15 % interconnection criteria of every country and electrical island, developed collaboratively between the EC, ENTSO-E and ENTSOG, industry, universities and other experts.

The methodology is based on the TYNDP Cost Benefit Analysis Methodology from 2018 and is based on 3 concepts:

1. efficient internal energy market should be interpreted in competitive electricity costs throughout the EU. Member States should strive to minimise differences in wholesale market costs. New interconnectors will be prioritised on borders with a wholesale marginal cost difference greater than 2 EUR/MWh. This difference may be calculated at the borders of either member states, regions or bidding zones. This change may be calculated on borders of Member States, regions or bidding zones. **The higher the cost difference, the higher the interconnection needs.**

2. The peak demand shall be met through the combination of national capacity and imports for every Member State. **Member States should investigate options for additional interconnectors where its interconnectors' nominal transmission capacities are below 30 % of their peak load.**

3. The further integration of RES shall not be blocked by insufficient export capacity. RES for any Member State should be optimally integrated on a pan-European level. **Countries for which the interconnectors' nominal transmission capacity is below 30 % of installed renewable capacity should study the options for electricity infrastructure development.**

In addition to the 3 indicators, as a condition sine qua non, each new interconnector must be subject to a socioeconomic and environmental cost-benefit analysis and implemented only if the potential benefits outweigh the costs.

It is probably even excessive to repeat the overt fact that Serbia is, at the moment, not a country that possesses an EU-membership, which further implies that it is not obliged to follow all of the regulations and norms set before the EU-countries. What should be emphasized, however, is that Serbia nonetheless does its best to honour these standards as this is considered to be a responsible approach, particularly when it comes to some of the modern tendencies in the power engineering, such as the market integration and introduction of renewable energy sources. Of course, building and commissioning a sufficient number of new interconnections is tightly bundled with each of these aspects of system planning, with the geographical position of Serbia, in the very centre of the Balkan Peninsula, making it a notable participant in the energy flow across the region both in the North-South and the East-West corridors. Serbia has, as far as it is concerned, taken this matter rather seriously, with the projects submitted for the assessment in the scope of TYNDP 2020 encompassing both the new ties with the EU-countries (Romania, Bulgaria, etc.) and the non-EU countries (Montenegro and Bosnia and Herzegovina) in the region and vouching for the ability of Serbian system to take the energy produced in the generation-heavy parts of the Southeast Europe and forward it towards the countries that are, according to the forecasts, expected to be in the dire need of it in the not-so-distant future.

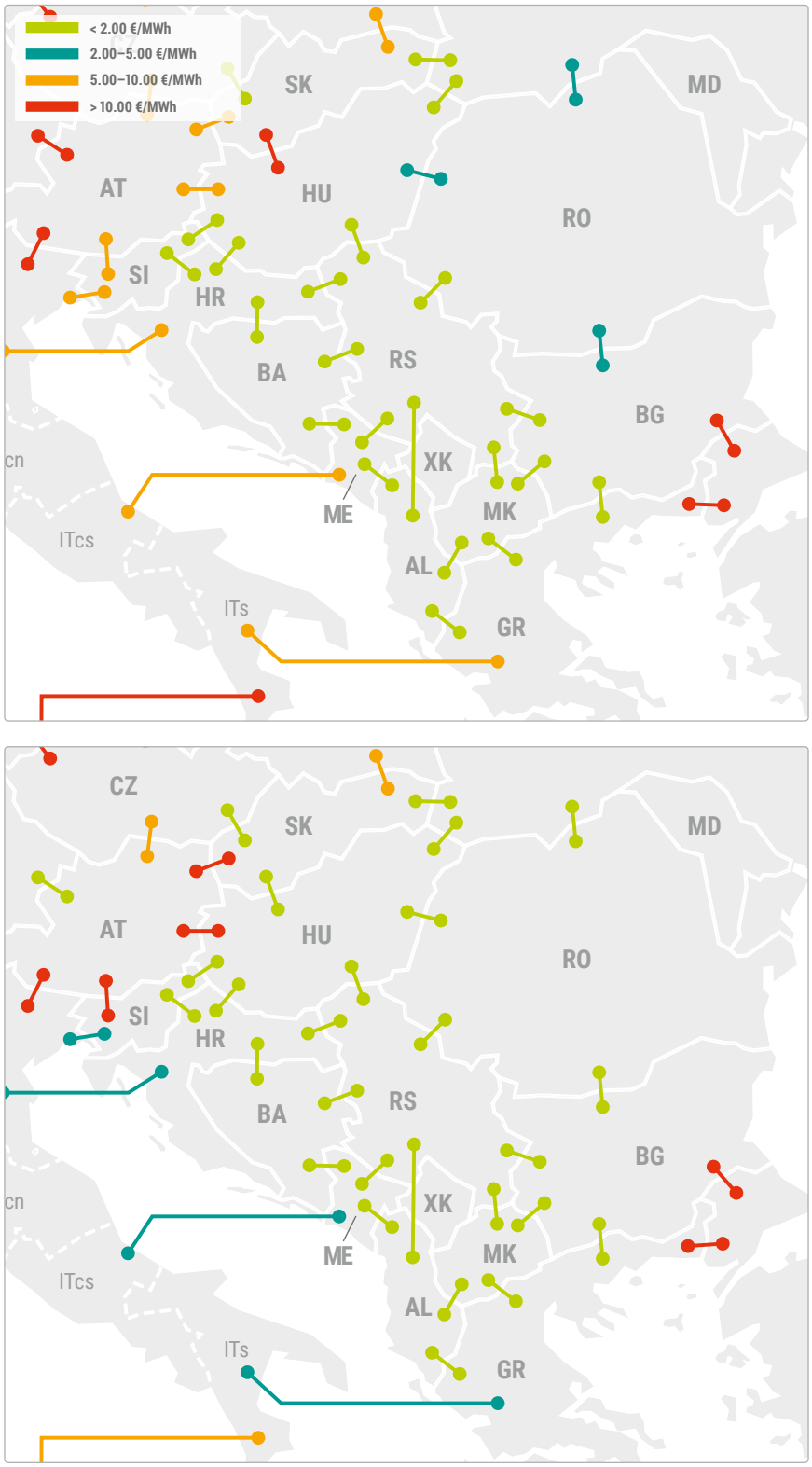


Figure 6.1: Yearly average difference in the marginal cost of electricity between neighbouring bidding zones in EUR/MWh in the cases where Europe would stop investing in the grid after 2020 (top) and with the expected grid in 2025 (bottom).

7. Perspectives on 2040

To close this document, it is only appropriate to provide the reader with a brief insight into the principles that the Serbian TSO takes into account when looking toward 2040, with market integration and the strengthening of the interconnections in order to reach the sufficient flexibility level kept among the priorities. This approach could be simplified into the "if it works, don't fix it" principle, where the ideas behind the system's desired development for the long-term horizon almost mirror the practices utilized for the upcoming ten-year time frame. The results stemming from the IoSN process, obtained during the TYNDP 2020 process, could also be seen as guidelines when determining the borders across which the additional capacities are needed before 2040 in order to ensure maximal benefits to both the society and, to narrow it down, the power sector. The impact of implementation of the suggestions included in the IoSN reports can also be seen on this page, where the values of some of the more prominent indicators were included in the table below. Here, it is clear that the system development that fits the outlines given in the IoSN reports could result in the remarkable decrease of the marginal energy cost and the reduction of the CO_2 emissions, thus steadily aligning the characteristics of the Serbian system with those of more technologically advanced ones and confirming that the direction in which this system is heading can, by all means, be seen as proper and rational.

	Curtailed Energy* (TWh)	CO_2 emissions (MTonnes)	Energy Balance (TWh)	Average marginal cost (EUR/MWh)
IoSN SEW Based Needs 2040	0	20.88	– 9.36	56.39
No investment after 2025	0	21.55	– 8.34	71.09

* Curtailed energy calculated only at the country level, not bidding zone level

Figure 7.1: Curtailed energy, CO_2 emissions, marginal price of the country's bidding zone(s), and energy balance (in SEW-based needs 2040 and in the case where Europe would stop investing in the grid after 2025)

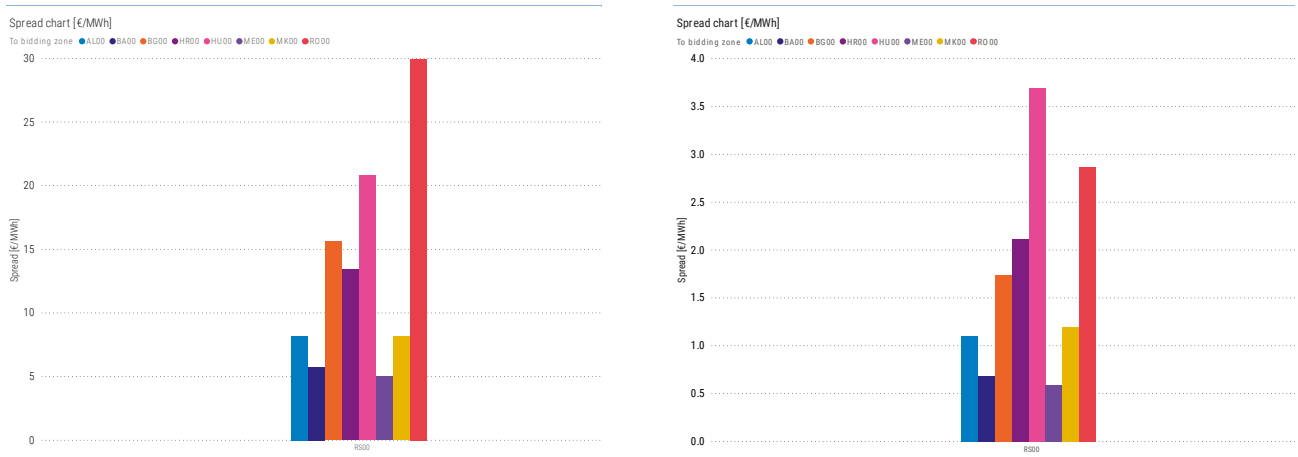


Figure 7.2: Average spread of marginal costs between this and neighbouring countries' bidding zones for the cases where Europe would stop investing in the grid after 2025 (left) and the SEW-based needs grid in 2040 (right).

8. Read more

Find out more about the European and regional context and the details on the studies, methodologies, results and data source presented in this country factsheet on the TYNDP website.

http://tyndp.entsoe.eu