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Ten-Year Network Development Plan 2020

Electricity system needs factsheet: France

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

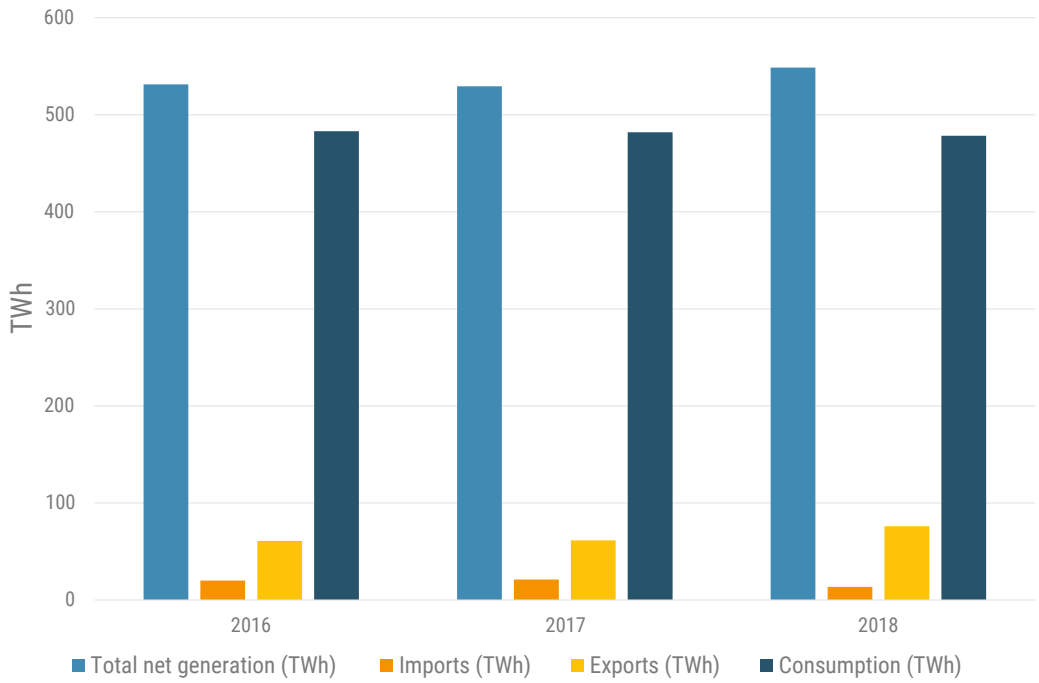


Figure 1.1: Yearly electricity demand, consumption and energy balance for the years 2016 – 2018. Values given in TWh.

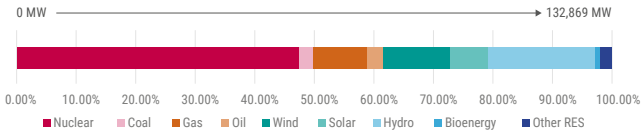


Figure 1.2: Share of installed capacity per generation category 2018.

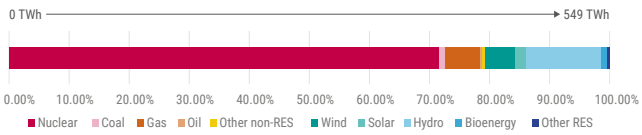


Figure 1.3: Share of generation mix by fuel category in 2018.

The climatic adjusted electricity demand in France follows a stable trend. The generation fleet is currently dominated by nuclear generation with around 75 % of the total generation in 2018. However, the energy transition is on track with the development of RES capacities, such as wind onshore and photovoltaic power generation, and the phase-out of coal-fired units by 2022. The first offshore wind farms are also expected to be commissioned in the coming years. Finally, the share of nuclear generation is planned to decrease down to 50 % of the generation mix by 2035.

The balance of exchanges is significantly positive (+60 TWh in 2018). This reflects the economic competitiveness of the nuclear generation.

From a market perspective, the average monthly price in the power spot trading shows a seasonality linked to the highly thermo-sensitivity of the French demand.

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.**

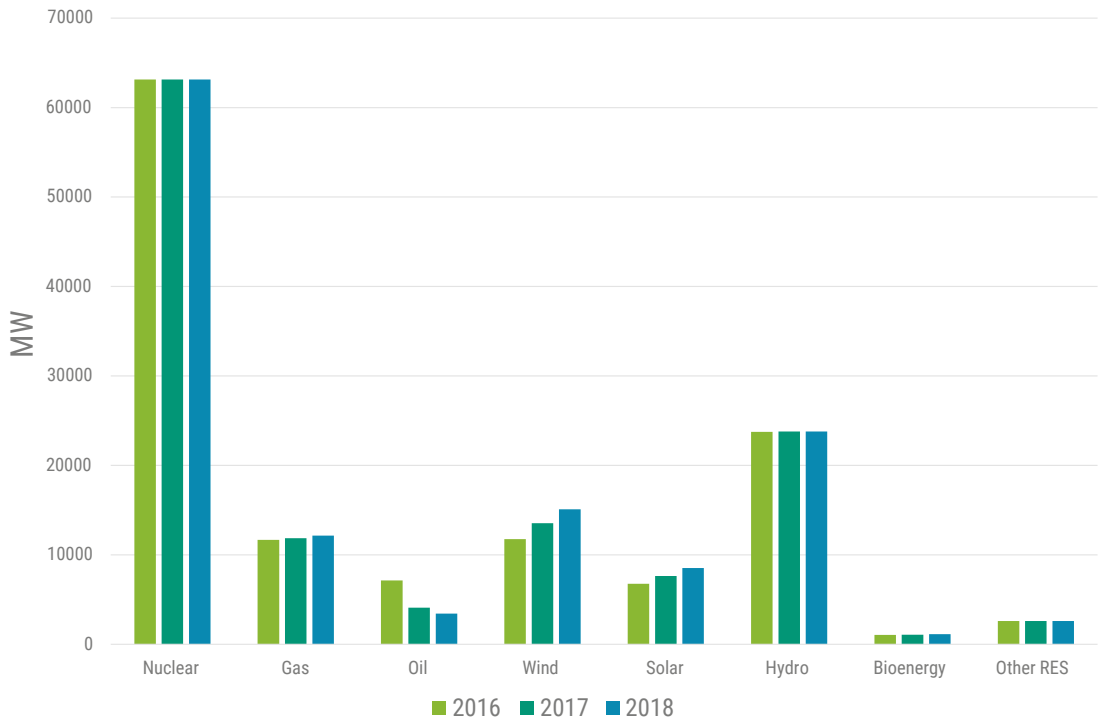


Figure 1.4: Net Generation Capacity evolution: 2016 – 2018 (MW).

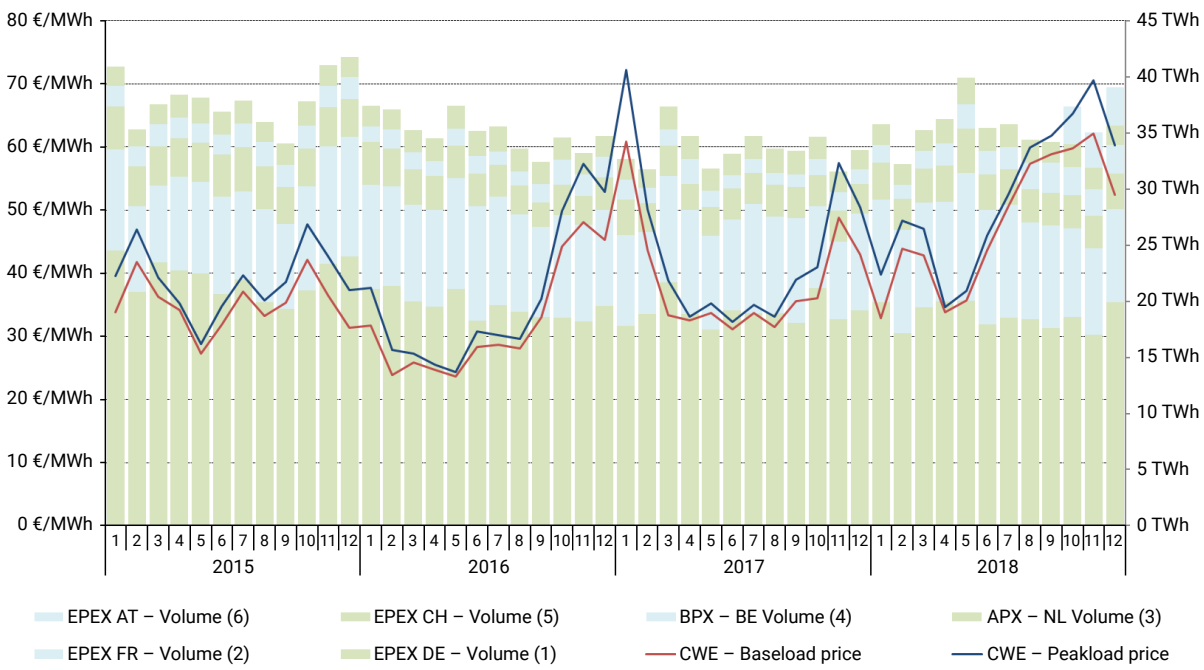


Figure 1.5: Monthly exchange traded volumes of day-ahead contracts and monthly average prices in the region in 2018 (Quarterly Report on European Electricity Markets Volume 11, Issue 4, Q4 2018).

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.

Investing in electricity interconnections on the French borders would increase the level of cross-border exchanges: France's position as an electricity exporter would be strengthened thanks to its nuclear generation and increasing RES generation. With the SEW-based needs network, the net electricity balance would reach +115 TWh by 2030 (170 TWh of exports/55 TWh of imports).

Depending on the borders, three behaviours stand out with future grid reinforcements:

- Electricity exports to eastern countries and Italy would rise by 2030 as a substitution of expensive thermal generation is these countries
- On the Spanish border higher RES-produced electricity imports would be enabled
- On the northern borders with Ireland and United Kingdom, the trend would be more balanced with higher imports of RES generation and higher exports to replace gas generation

Thus, new exchange capacities with France are justified by the high reduction of generation cost they would imply by replacing expensive coal and gas generation by nuclear and RES one. This higher level of exchanges would support market integration, with price convergence increasing with neighbouring bidding zones.

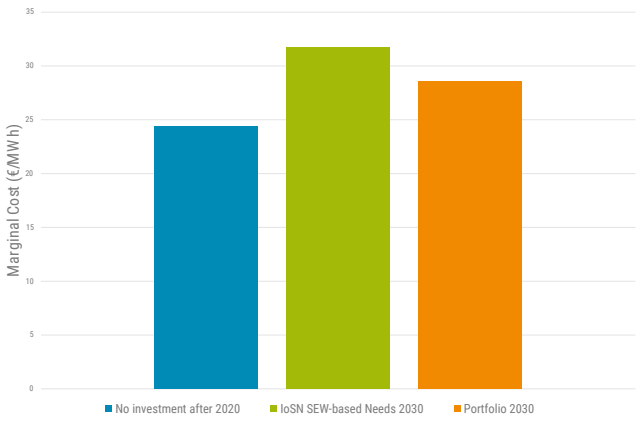
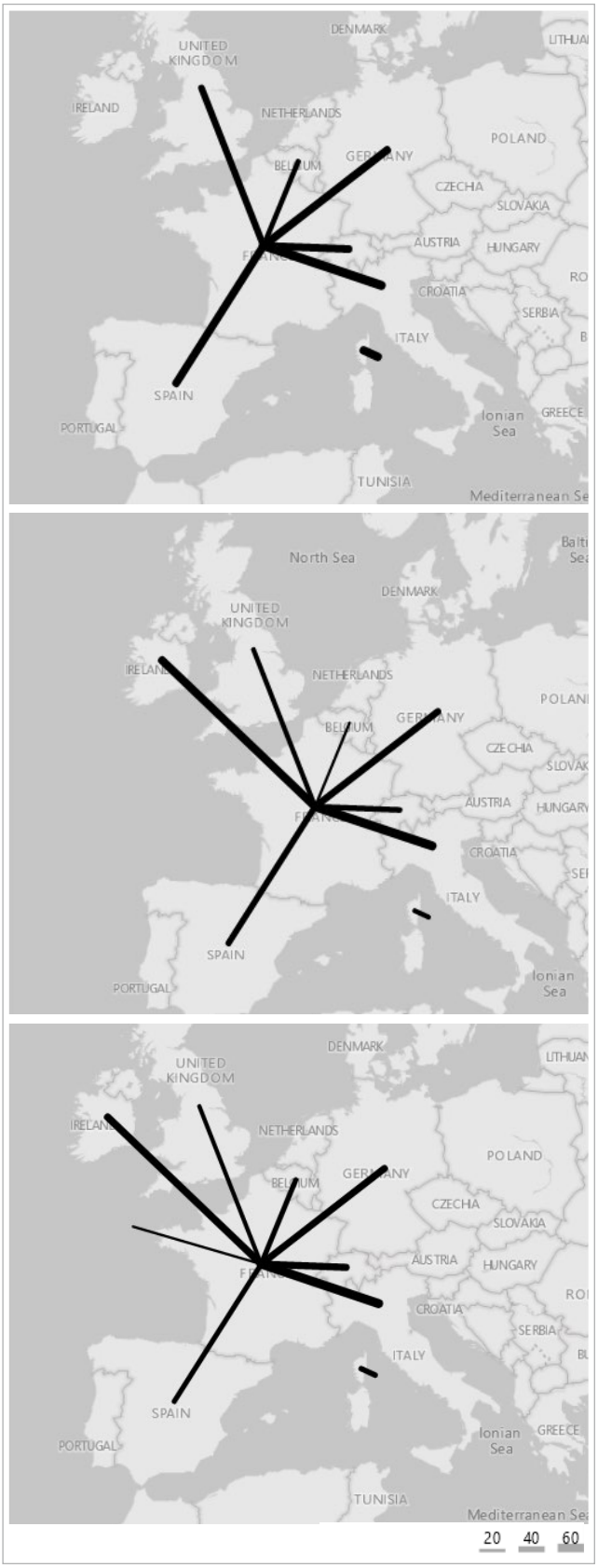


Figure 3.1: Marginal costs for the respective country for the grid sets No Investment after 2020, SEW-based needs 2030 and Portfolio 2030. These compare the differences between the marginal costs for each, hypothetical development pathway.

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.



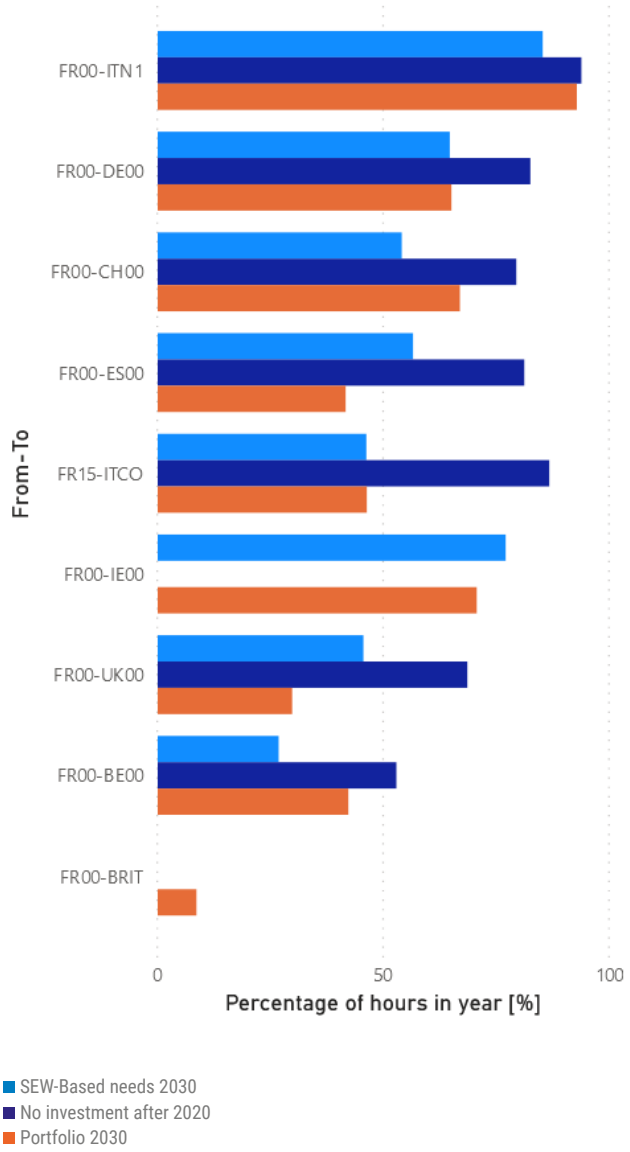


Figure 3.2: Constraint duration of connections between adjacent bidding zones in 2030. From top to bottom: No investment after 2020, SEW-based needs 2030 and TYNDP Portfolio 2030. Network constraint duration, given as the percentage of hours where each line is congested, are shown on the right. Congestion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

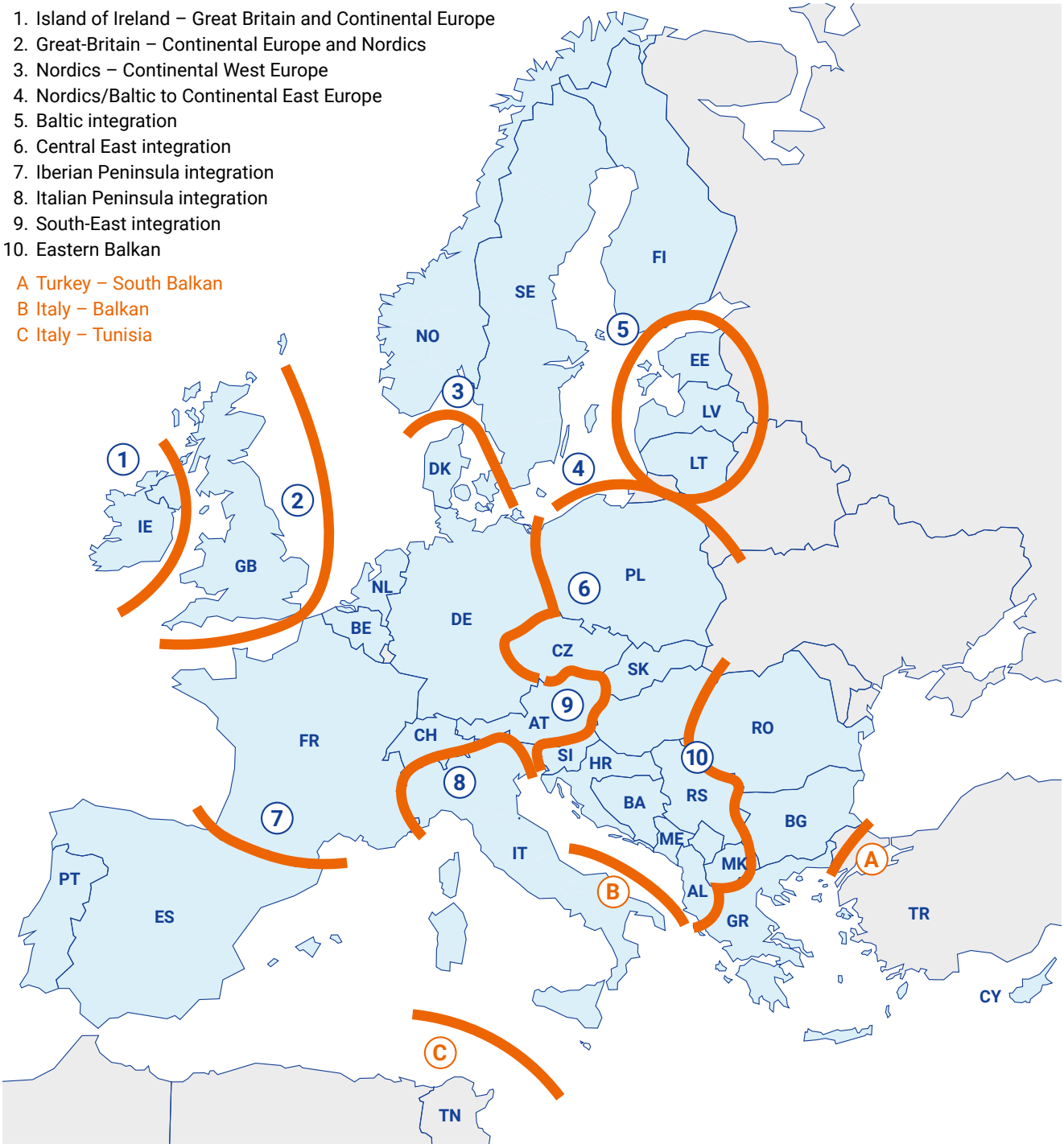


Figure 3.3: Map showing the main boundaries considered in the TYNDP 2020.

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.

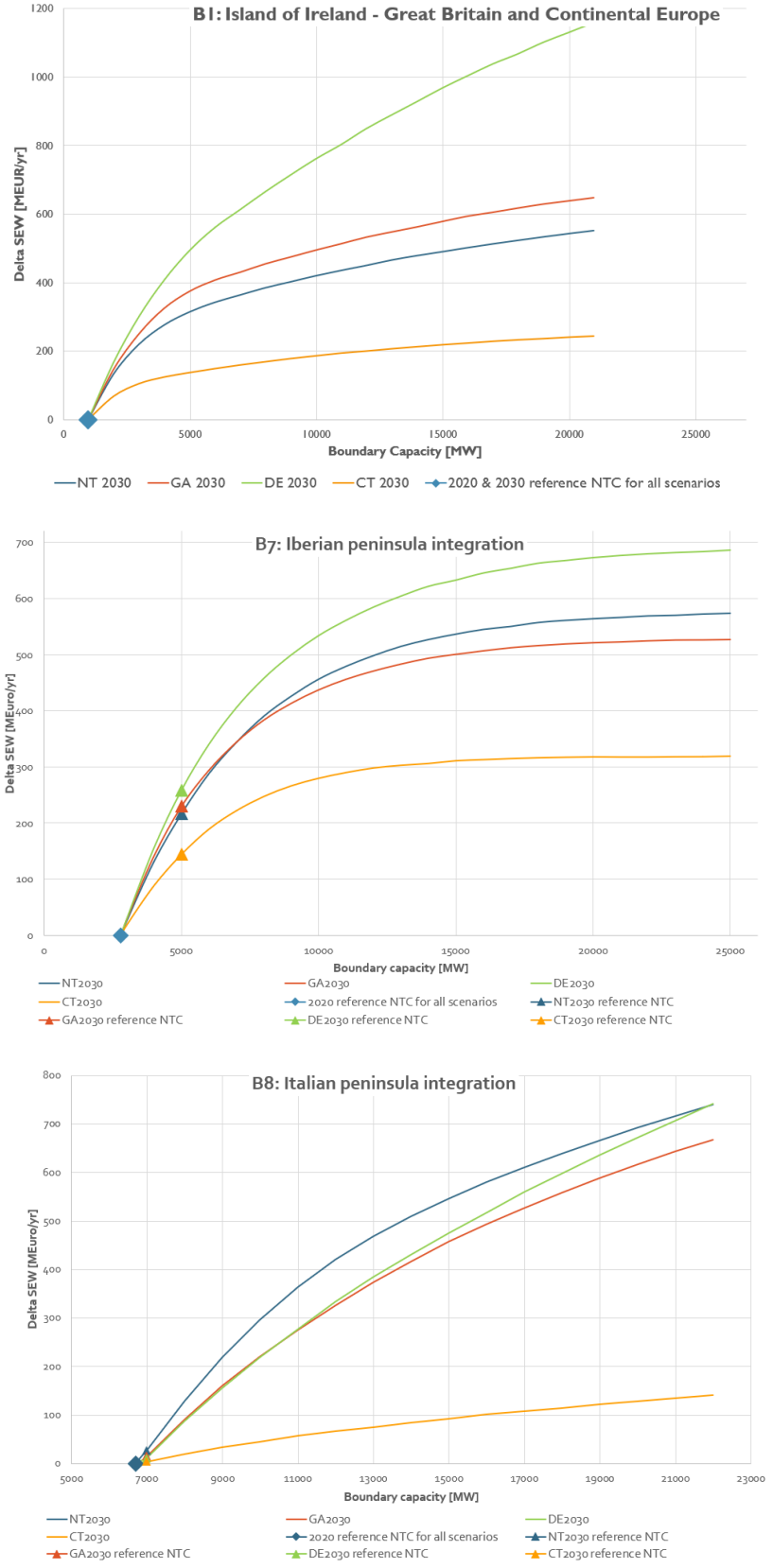


Figure 3.4: Relevant country boundaries indicating socio-economic growth (millions of EUR per year) with each stepped increase in each boundaries' grid transfer capacity (in MW).

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

4. Sustainability in 2030

The French generation fleet is characterized by a high level of low carbon power generation thanks to its nuclear power units. With the development of RES capacities, France would increase even more the volumes of competitive and CO_2-free electricity. As a result CO_2 emission in France due to electricity generation is already very low and is not the main challenge for developing interconnectors. The reinforcement of cross-border capacity with Spain would allow additional imports of RES generation from the Iberian Peninsula. Indeed, France is the only access of Iberian energy to the rest of Europe. This connection would result in reducing curtailed energy in the Iberian Peninsula.

Cross-borders reinforcements with other countries would allow the French low carbon generation and Spanish RES imports to replace CO_2-emitting thermal generation in the other European countries. This would result in a considerable reduction of European CO_2 emissions. Thus, while interconnections development by 2030 would have a limited effect on already low national CO_2 emissions, it is a prerequisite for an increased role of France (and Iberian Peninsula) in the reduction of CO_2 emission across the European electric system.

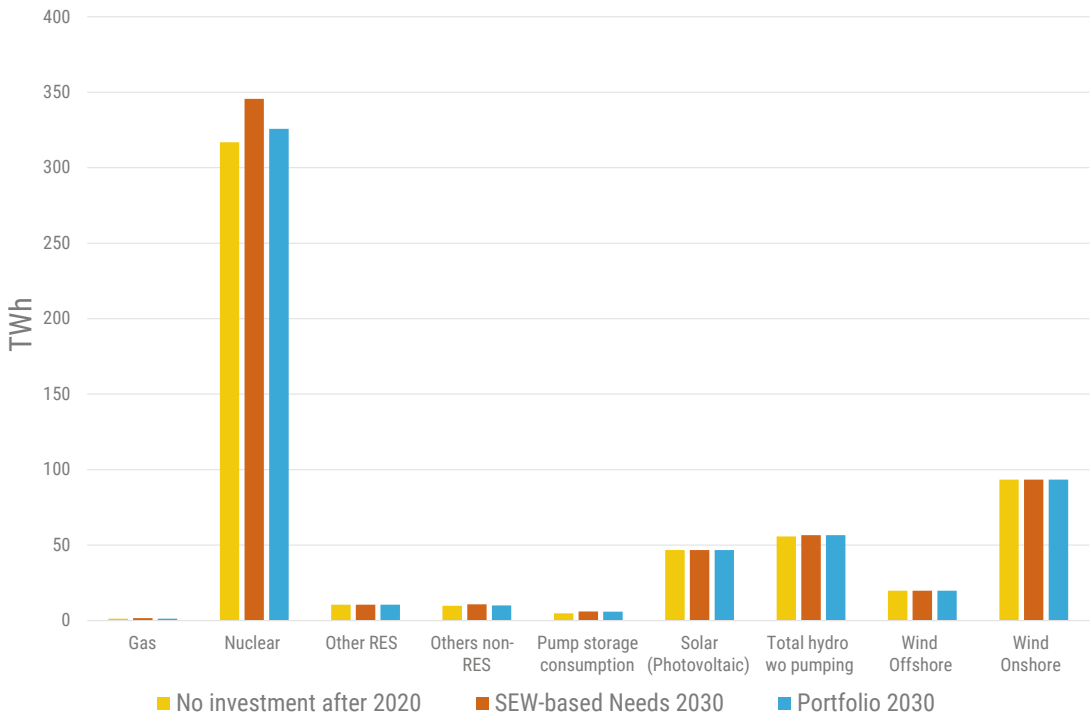


Figure 4.1: Comparison between the generation mix for National Trends 2030 for the 3 grid types: No investment after 2020, IoSN SEW-based needs 2030 and Portfolio 2030.

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
39	37	39

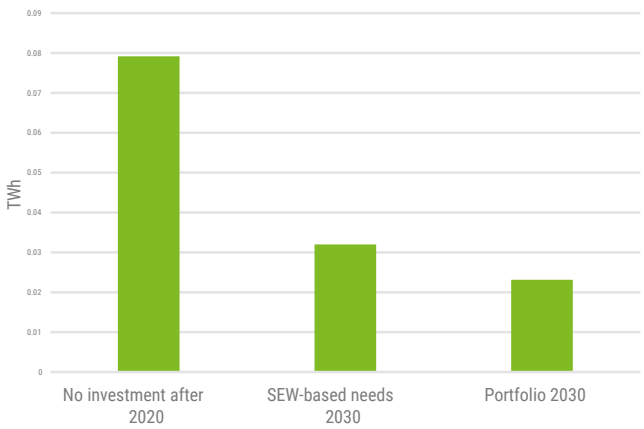


Figure 4.2: Yearly curtailed energy in National Trends 2030 (TWh/year), with 3 different grid sets: No investment after 2020, SEW-based needs 2030 and TYNDP Portfolio 2030.

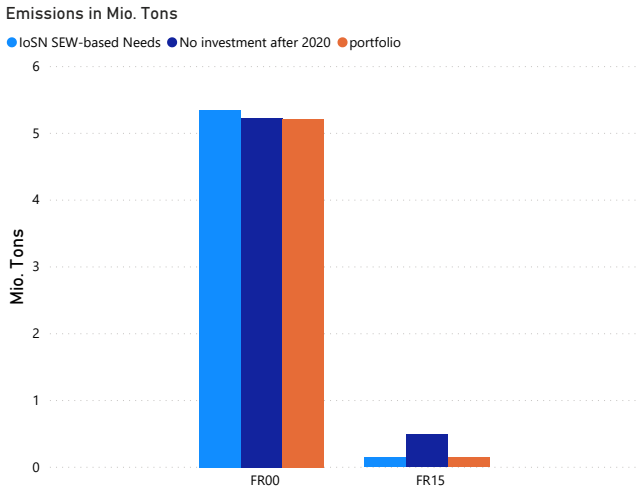


Figure 4.3: Total CO_2 emissions in National Trends 2030 for three different grid types: No investment after 2020, IoSN SEW-based needs 2030 and Portfolio 2030.

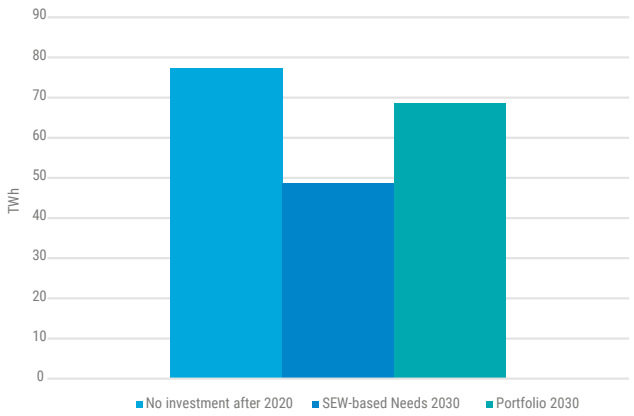


Figure 4.4: The total, available CO_2-free dispatchable energy from nuclear and biofuel generation (in TWh) for each grid case. Illustrates how much CO_2-free thermal generation a country has left after dispatch.

Hydro was not included as it is impossible to distinguish which part of hydro generation is spilled. Thus, even though hydro is CO_2-free and dispatchable source it was excluded from this calculation. As explained in the PCI 4-pagers, more low-emission, biofuel generators can be recruited as more cross-border capacity becomes available reducing network emissions.

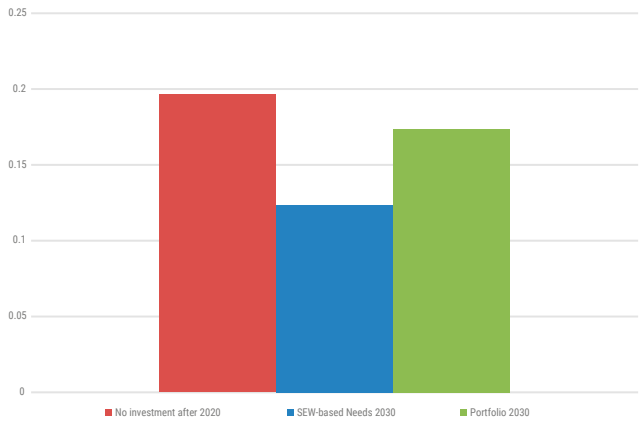


Figure 4.5: Ratio between available CO_2-free dispatchable energy and the total available energy of the country, for the IoSN SEW-based needs 2030, No investment after 2020 and Portfolio 2030 grids.

The ratio shows how much of the available generation, after dispatch, is low-emission synchronous generation. Depending on the grid configuration and the availability of cross-border generation, the dispatch profile and the available generation pool can change, as stated for Figure 4.4.

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
0.01	0.01	0.01

5. Security of Supply in 2030

With a significant RES share in the mix, generation volatility would increase and thus, the French adequacy could be at risk under a wider range of situations not only resulting from demand thermo-sensitivity. Interconnectors could help mitigating this risk. Within the TYNDP 2020 framework, interconnection projects have been assessed according to an additional security of supply criterion. This new indicator assesses the reduction of energy not supplied brought by a new project. It also estimates roughly the reduction in the need for peaking generation. For projects on the French borders, this adequacy valuation represents a significant share of projects' benefits: it is in the order of tens of millions of euros per year and per project.

These findings show that interconnections would play a major role regarding security of supply in France and its neighbouring countries by enabling solidarity between countries to take place.

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.

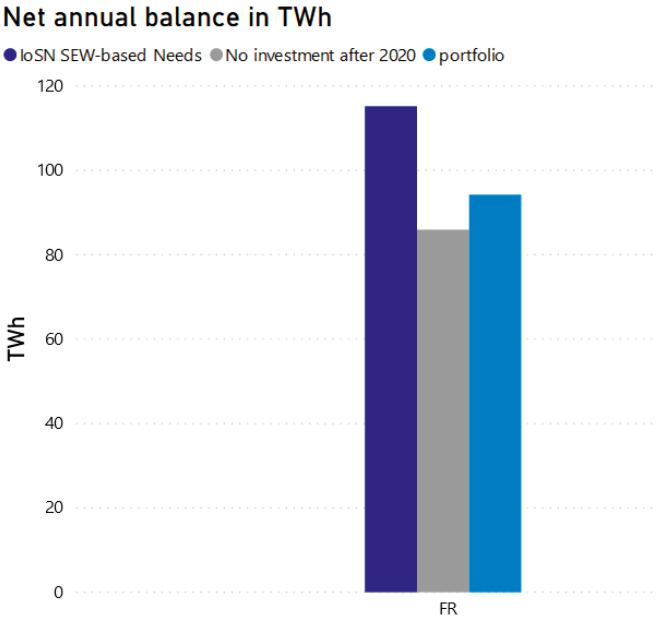


Figure 5.1: Net energy balance (TWh) for 3 grid sets considering the National Trends 2030 scenario.

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

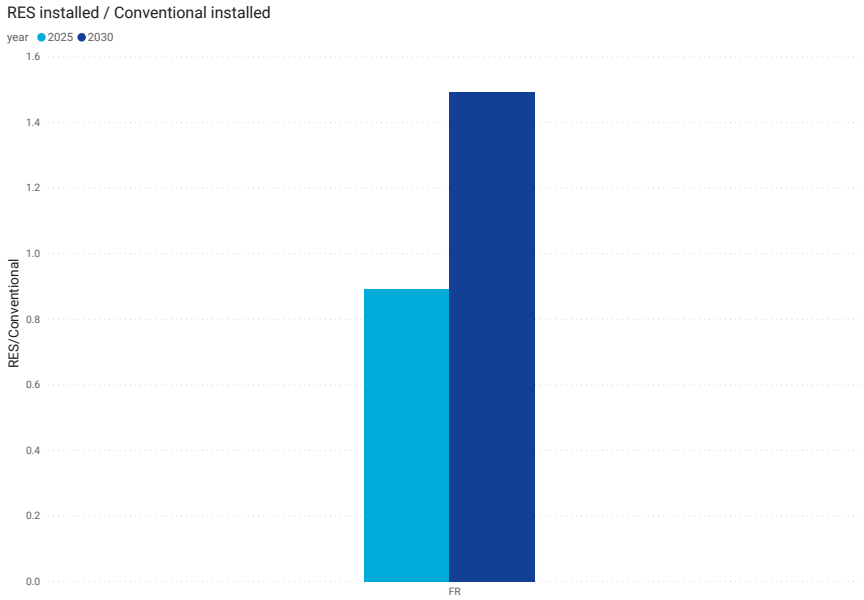


Figure 5.2: Ratio of the installed RES generation capacity to the installed conventional generation capacity in the years 2025 and 2030.

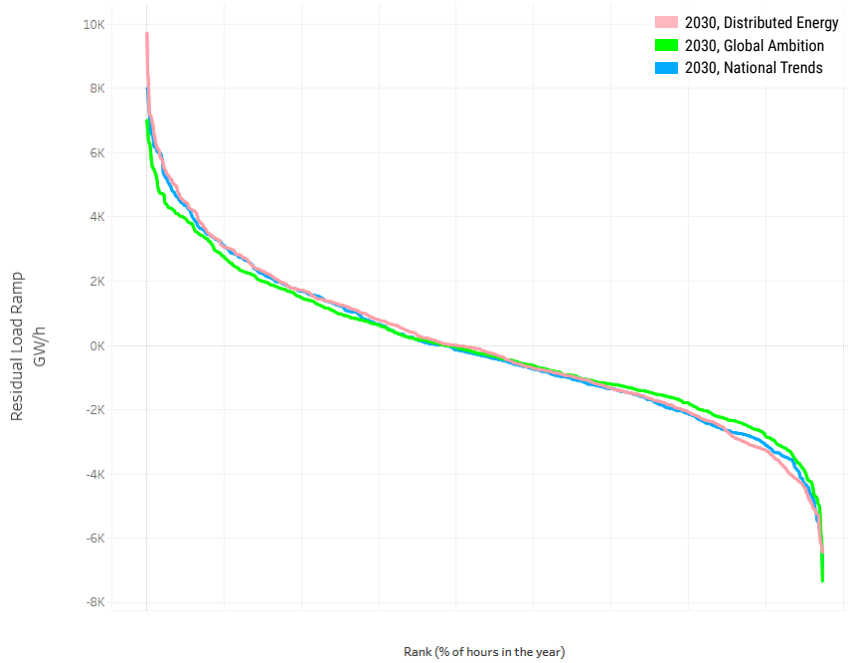


Figure 5.3: Residual load ramp duration curve for 2030 scenarios. (includes Corsica)

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.

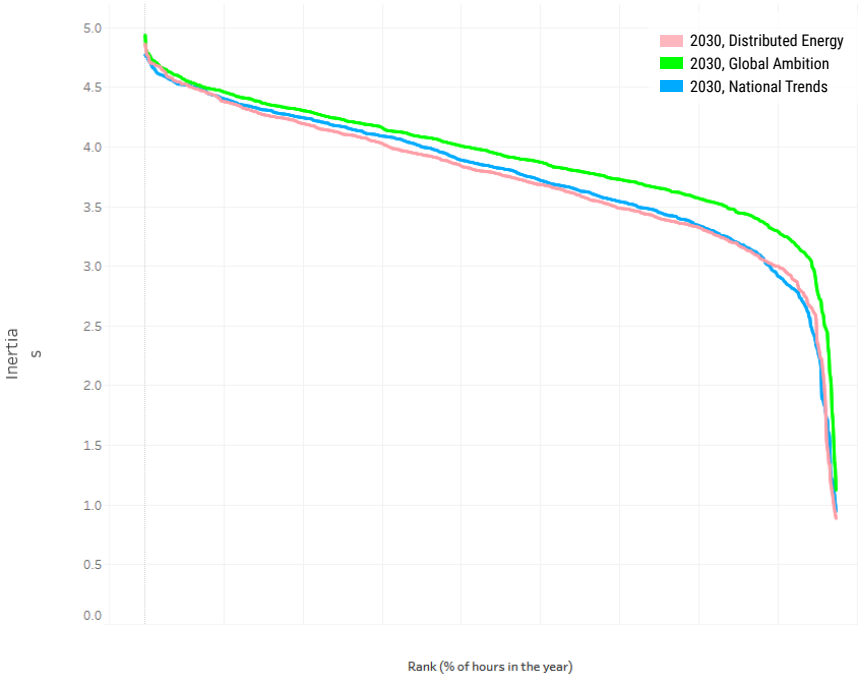
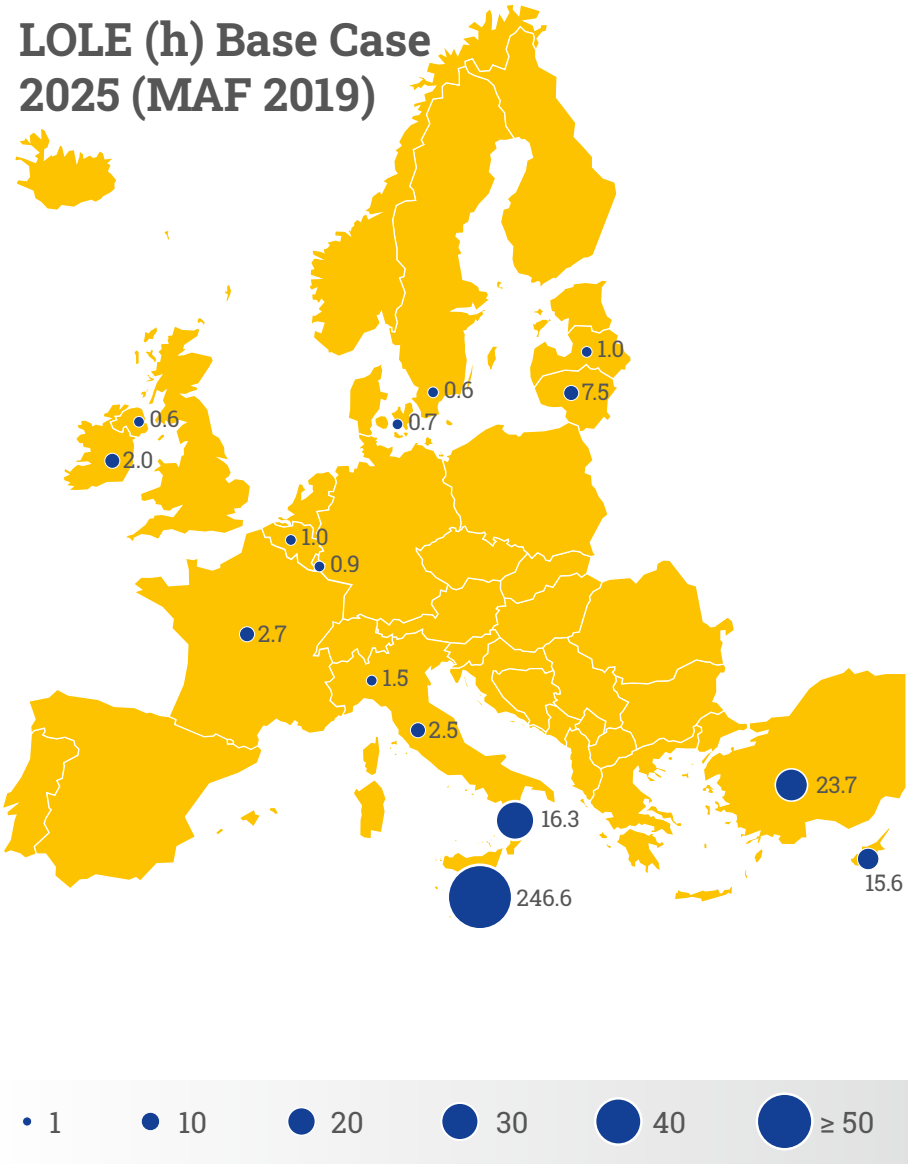


Figure 5.4: Inertia duration curve for 2030 scenarios. (includes Corsica)

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.

The ITEG criteria show the need to consider reinforcements on each French border:

- The spread of marginal prices exceeds 2 euros/MWh with all of its neighbouring countries and even reaches more than 20 euros/MWh with Italy.

- The two ratios of nominal transmission capacities over peak load and of nominal transmission capacities over RES installed capacities are in the low range of acceptability.

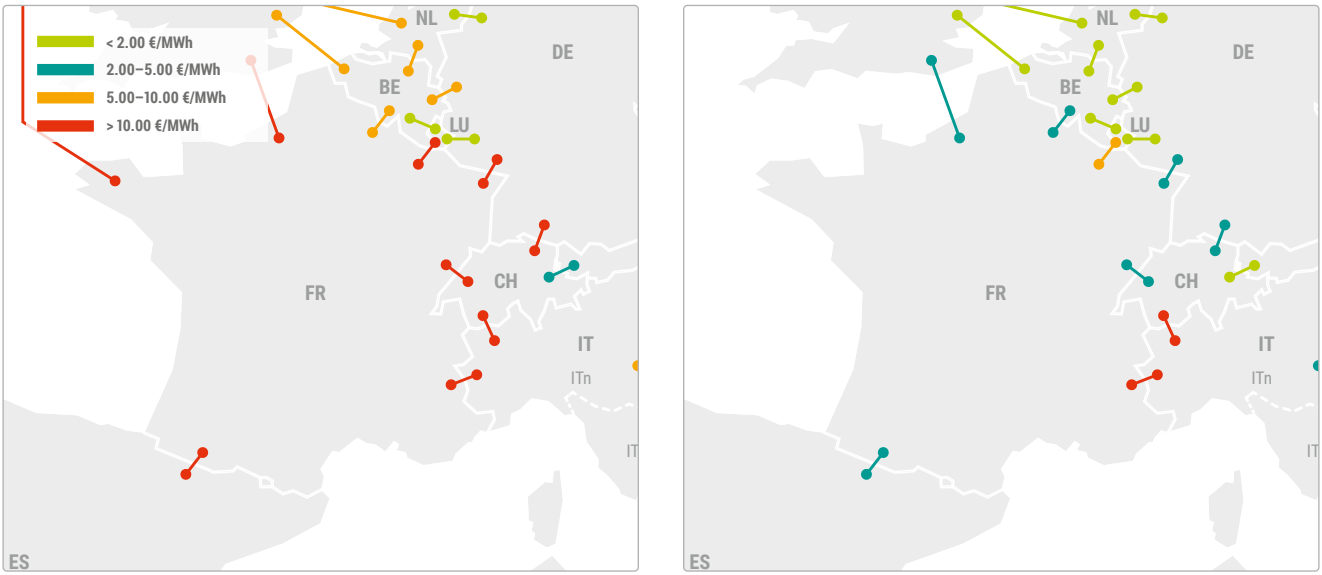


Figure 6.1: Yearly average difference in the marginal cost of electricity between neighbouring bidding zones in EUR/MWh in the cases where Europe would stop investing in the grid after 2020 (left) and with the expected grid in 2025 (right).

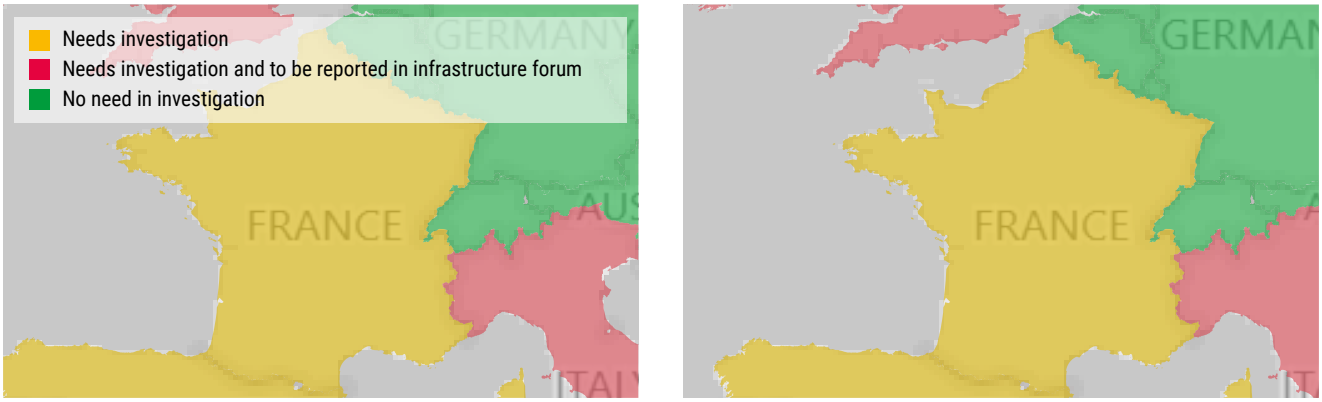


Figure 6.2: Ratio of nominal transmission capacity to the peak load in 2030, in the situation where Europe would stop investing in the grid after 2020 (left) and in the expected grid in 2025 (right).

Ideally, the demand in a country should be met exclusively through native and imported generation. This means the country should be able to ensure it has sufficient cross-border capacity to support its own demand and, when necessary, sell its generation to its neighbours. Countries in green have met the interconnection target while countries in red require substantial investment to expand cross-border capacity.

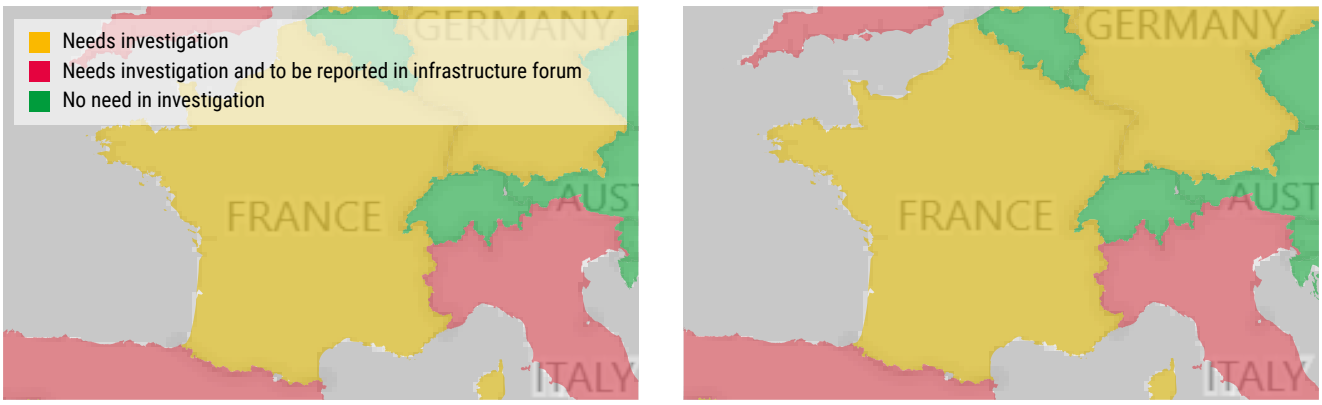


Figure 6.3: Ratio of nominal transmission capacity to the installed RES generation in 2030, in the situation where Europe would stop investing in the grid after 2020 (left) and the expected grid in 2025 (right).

Countries with a low ratio of nominal transmission capacity to installed RES capacity require increased cross-border capacity to ensure they can export this additional energy and not have to resort to curtailment. Countries in green have met the interconnection target while countries in red require substantial investment to expand cross-border capacity.

7. Perspectives on 2040

By 2040, France will have significant volumes of low carbon electricity: the strong growth of RES generation added to the remaining nuclear power plants create a significant cheap and CO_2 free generation fleet. As a result, France would stay a large exporter within Europe. However, the evolution of the European energy mix at that time horizon would change the drivers of new interconnectors' development compared to the 2030 situation:

- First, the development of interconnections would support the integration of RES capacity in France by offering more opportunities to this generation and then reducing the spilled energy.
- But, the interconnectors would mainly allow to connect renewable energy produced in the Iberian Peninsula and in the United-Kingdom to the continental Europe.

As a result, France would be at the cross road of low carbon electricity transits, which may raise significant needs for internal network reinforcements.

	Curtailed Energy* (TWh)	CO_2 emissions (MTonnes)	Energy Balance (TWh)	Average marginal cost (EUR/MWh)
IoSN SEW Based Needs 2040	6.71	4.47	69.97	29.68
No investment after 2025	11.73	4.26	63.47	30.77

* 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)

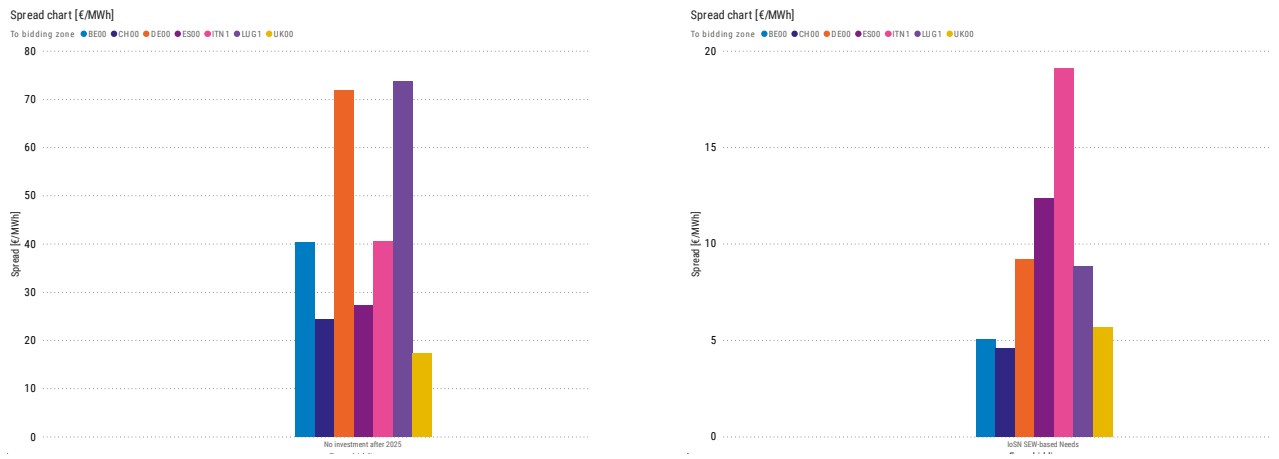


Figure 7.2: Average spread of marginal costs between this and neighbouring countries' bidding zones for the cases where Europe would stop investing in the grid after 2025 (left) and the SEW-based needs grid in 2040 (right).

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