TYNDP 2022

Regional Investment Plan

Continental South West

Final Version · May 2023

entsoe

ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the association for the cooperation of the European transmission system operators (TSOs). The 39 member TSOs, representing 35 countries, are responsible for the secure and coordinated operation of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E brings together the unique expertise of TSOs for the benefit of European citizens by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the security of the inter-connected power system in all time frames at pan-European level and the optimal functioning and development of the European interconnected electricity markets, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first climate-neutral continent by 2050 by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires sector integration and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources. ENTSO-E acts to ensure that this energy system keeps consumers at its centre and is operated and developed with climate objectives and social welfare in mind.

ENTSO-E is committed to using its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in solidarity as a community of TSOs united by a shared responsibility.

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by optimising social welfare in its dimensions of safety, economy, environment and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and innovative responses to prepare for the future and overcome the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with transparency and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its legally mandated tasks, ENTSO-E's key responsibilities include the following:

› Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy;

› Assessment of the adequacy of the system in different timeframes;

› Coordination of the planning and development of infrastructures at the European level (Ten-Year Network Development Plans, TYNDPs);

› Coordination of research, development and innovation activities of TSOs;

› Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the implementation and monitoring of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

1. EXECUTIVE SUMMARY

The historical main drivers for grid development of European significance in the region have been reported in every release of the Regional Investment Plan (RgIP) and Ten-Year Network Development Plan (TYNDP):

- On the one hand, the insufficient cross border capacity, in order to allow:
  - the completion of the Iberian Electricity Market (MIBEL) through the reinforcement of the Portugal–Spain interconnection, and
  - the integration of the Iberian Peninsula into the European continental market, through the development of the France–Spain interconnection.
- On the other hand, the Renewable Energy Sources (RES) integration. The Iberian Peninsula has been a forerunner in the installation of renewable energy (hydro, onshore wind and solar), and in the integration of this production into the system, with significant investments in new network infrastructure in Portugal and Spain and smart management such as the Spanish renewable control centre (CECRE).

As the region advances towards a decarbonised power system, both issues remain a challenge in the short and long term, as the most recent studies demonstrate.

In this TYNDP edition, a very detailed identification of system needs was performed. This analysis focuses on the years 2030 and 2040. Based on the National Trend (NT) scenario from the Scenario Report published in April 2022, it includes an assessment of what would happen with the system in the event of encountering A 2040 NT and 2030 NT scenario while retaining the 2025 grid (that is, a no investment grid after 2025 – called 'no grid').

The main findings of this analysis are as follows:

- **Change in the generation portfolio towards a more carbon-free system**

  The 2030 and 2040 scenarios show a transition from thermal to renewable generation, including the partial phase-out of nuclear in France and a complete phase-out of nuclear in Spain. In addition, a complete phase-out of coal in the Iberian Peninsula is expected. The optimisation of RES performed in the 2030 and 2040 top-down scenarios resulted in the assignment to the Continental South West (CSW) region of very significant increases in RES technologies, primarily solar energy in the Iberian Peninsula (based on its high potential) and France, in addition to a significant increase in wind energy, even offshore wind energy, especially in France, and other RES technologies in the region.

- **The need for a further market integration in the region, with a special focus on the isolation of the Iberian Peninsula**

  Despite the strong efforts from Transmission System Operators (TSOs) and the support from Member States and European Commission (EC) through the Madrid and Lisbon Declarations and the High Level Group monitoring[1], Spain has not fulfilled the

[1] *EC communication dated 23 November 2017 on strengthening European energy networks, addressed to the European Parliament, the Council and the European Economic and Social Committee, and the Committee of the regions* *https://ec.europa.eu/energy/sites/ener/files/documents/communication_on_infrastructure_17.pdf*

10% interconnection ratio objective for 2020 as recommended and will be unable to fulfil it in the midterm. Moreover, this objective has been increased to 15% for the 2030 horizon.
The current analysis also reveals relevant needs in the 2030 and 2040 horizons related to cross border development based on socioeconomic welfare, especially regarding reinforcing the Iberian Peninsula with the remainder of Continental Europe, that should be carefully analysed in the future.

- **The RES integration will pose a challenge, and it will not have a unique solution**
  The market analysis of 2040 scenarios reveals a high amount of RES curtailment in the region in the event of no grid development beyond 2025 and even an important volume with the 2040 grid.
  In the face of the 2040 NT scenario, the network as it will exist by 2025 will not be able to accommodate the high RES potential. This is because the renewable curtailed energy could amount to around 10.0 TWh in Spain, 4.2 TWh in Portugal and 2.8 TWh in France without new network reinforcements beyond those included in the 2025 reference grid ('no grid' investment after 2025).
  In fact, enabling future RES integration will represent a key challenge. The solution for this RES integration challenge will not be unique. Rather, it should be a mixture of internal reinforcements, development of interconnections, new storage, power to gas, and so forth.

- **The system will experience new power flow patterns and important investment needs**
  The high use of RES technologies (mainly solar power) in the Iberian Peninsula (mainly in the south) and in the south of France and high exports from CSW to the rest of Europe create higher flows and new flow patterns for which the grid was not designed. Therefore, these new flows incorporating higher volumes and variable directions, which may be opposite to those currently known, result in cross-border and internal congestions in the long term. On the one hand, there will be structural needs for internal reinforcement derived from the new demand and generation scenarios. On the other hand, in light of the 2040 scenarios, we can foresee higher and longer transit flows and more influence than today between the France–Iberian Peninsula border and the France–Central Europe border.
  If these long-term scenarios materialise, cross-border and important internal reinforcements of today's grid will be required to ensure the safe operation of the power system.
  Nevertheless, to determine whether each investment need is sufficiently robust and whether the benefits to socioeconomic welfare (SEW) and other areas are sufficient to compensate the costs, these identified potential needs for the 2040 horizon should be further investigated in future TYNDPs with a view to determining whether it would be adequate to propose additional projects to fulfil these needs.

- **The security of supply will have a new dimension**
  Ensuring security of supply in the future will not only be a matter of checking conventional system adequacy (to ensure sufficient generation capacity to meet demand) and avoiding structural transmission congestions (to ensure the fulfilment

of the N-1 conditions stated in the network codes in order to avoid energy not supplied), but it will need to reach beyond these issues. For instance, flexibility, dynamic behavior, system inertia and demand-side response will gain importance in the security of supply.

The first phases of the TYNDP 2022 process consisted in building new scenarios for 2025, 2030 and 2040 and assessing system needs for the long-term horizons 2030 and 2040. As part of this work, grid reinforcements (interconnections) and other flexibility solutions[2] (storage and CO_2 free peaking units) which have a positive impact on the system were identified[3] for the 2030 and 2040 NT scenarios. A European overview of these needs is presented in the European System Need report developed by ENTSO-E, in parallel with the Regional Investment Plans 2022. Identified needs at the countries of the CSW-region are presented in the maps below (Figure 1).

The overall needs for capacity increases identified in the analysis in the 2040 horizon are +4500 megawatts (MW) on the Spain–France border and +1000 MW on the Portugal–Spain border in addition to the 2025 reference grid (9500 MW in total in France–Spain and 4500/5200 MW in total in Portugal–Spain). These identified needs showed potential economically viability because the benefits obtained (only SEW in this assessment) outweigh the estimated costs. The estimated costs also affect the results within the region, such as on the France–Spain border, where the cost of an underground high-voltage direct current (HVDC) potential project has been considered.

On the 2040 time horizon, optimisations were performed considering other flexibility solutions: storage to optimise interconnectors / curtailment and peaking units to solve the detected risks of ENS. On the CSW region, around 18 GW (14 GW, 1.5 GW and 2.5 GW respectively in Spain, France and Portugal) of additional storage needs were identified as valuable on top of the starting point (capacities in 2030 in the NT scenario). The highest storage needs were found in countries with high RES curtailment. No needs of peaking units were identified for the CSW region.

The needs for transmission capacity increases identified across Europe in such scenarios from 2025 onwards would have a significant impact on the electrical system and on society as a whole in 2040:

- They would enable a reduction of the generation costs in the CSW region by 878 M€/year;
- They would reduce the cost spread between France and Spain by around 24 €/MWh and between Portugal and Spain by around 2 €/MWh;
- They would enable an integration of an additional 9.7 TWh/year of renewable energy in the CSW region which would otherwise be curtailed. This value represents 1.1% of the total demand in the CSW region or 1.5% of the total production from wind and solar energy in the CSW region in the 2040 NT; and
- They would enable an overall reduction of CO2 emissions in Europe of up to 3.7 Mtons/year of CO_2 emissions in CSW.

Although the quantified benefits for the CSW region presented in this report result from a Europe-wide increase for grid reinforcements (interconnections) and other flexibility solutions (storage and

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[2] Storage and CO2 free peaking units needs were accessed only for 2040 horizon

[3] For a description of the methodology used, see chapter 3.

CO_2 free peaking units), the role of the increases inside the countries in the CSW region are, of course, essential to realise most of these benefits.

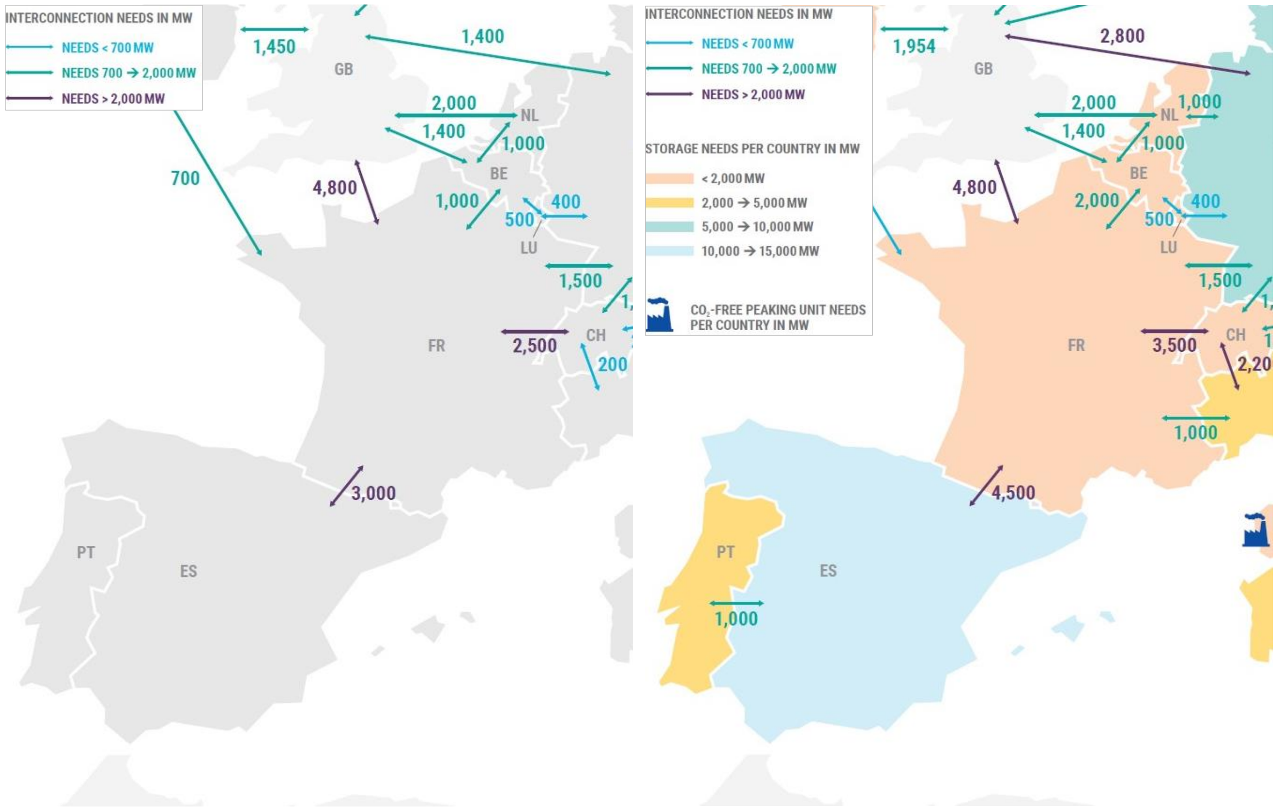

Figure 1: Identified grid reinforcements and other flexibility solutions needs for 2030 and 2040

The IoSN results confirm that projects already included in the TYNDP 2020 respond to a real system need for greater cross-border capacity and reflect the fact that ambitious RES scenarios – such as the ones used for TYNDP 2022 – could require more cross-border exchange capacity.

Here are the cross-border projects which already address the identified needs in the 2022–2040 horizon and that will be analysed in the TYNDP 2022:

- New northern interconnection between Portugal and Spain in Minho/Galicia regions, due to be commissioned by 2024 as part of the TYNDP 2022 Reference Grid (PCI 2.17 in the 2021 PCI list);
- Biscay Gulf project between Spain and France, due to be commissioned by 2027 as part of the TYNDP 2022 Reference Grid, which should generate 2.2 GW extra capacity (PCI 2.7 in the 2021 PCI list) allowing 5 GW to be reached on the France–Spain border; and
- Navarra Landes and Pyrénées Atlantiques-Aragon between Spain and France, which together could generate up to 3 GW extra cross-border capacity beyond the 2027 horizon (PCI 2.27 in the 2021 PCI list) allowing 8 GW to be reached on the France–Spain border.

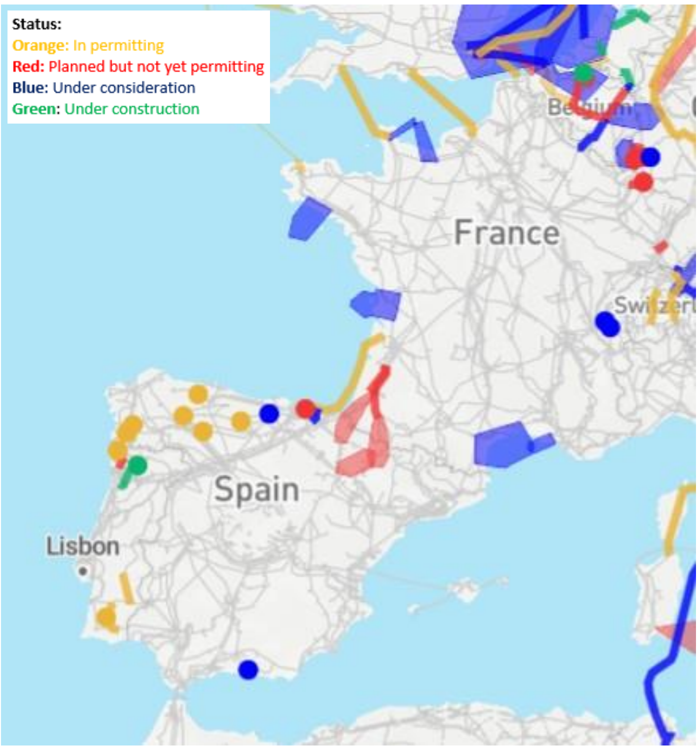

Figure 2: Projects to be assessed in the TYNDP CBA analysis

The Cost–Benefit Analysis (CBA) assessment will be performed for those cross-border projects previously mentioned and some internal projects as well as some storage projects that have fulfilled the criteria for inclusion in the TYNDP 2022:

- Purifying Pumped Hydroelectric Energy Storage (P-PHES), Navaleo, in León (PCI 2.28 in the 2021 PCI list)
- Purifying Pumped Hydroelectric Energy Storage (P-PHES), Cúa, in León (PCI 2.28 in the 2021 PCI list)
- Reversible Hydraulic Power Plant Los Guajares, Andalucía
- Purifying – Pumped Hydroelectric Energy Storage 'Velilla del Río Carrión' (P-PHES VELILLA), Castilla y León
- Reversible Hydraulic Power Plant Aguayo, Cantabria
- Purifying Pumped Hydroelectric Energy Storage (P-PHES), Buseiro, Asturias

In addition to these projects above, there are still gaps to reach the identification of a system needs optimum in the CSW region. Regarding the gaps identified on both the Spain–France and Spain–Portugal borders, the effective needs still require further investigation in future TYNDP releases. As of now, such gaps still need to be investigated further; therefore, it seems too soon to propose any additional projects on the borders of the region. In addition, any proposal would need to cope with the evolution of already-planned projects as there would be interactions between them. To summarise, some additional projects could be considered in the future if the trends identified in the scenarios are confirmed in the coming years.

2. Introduction and regional context

2.1 About Regional Investment Plans

2.1.1 Legal requirements and link to the TYNDP package

The RgIPs are part of the TYNDP package and comply with Regulation (EU) 2019/943 (Article 34 and Article 48), which requests TSOs to establish regional cooperation within ENTSO-E and publish an RgIP biennially. In addition, TSOs may take investment decisions based on that Plan.

RgIPs are part of the TYNDP 2022 package, which also includes the Scenario report and the System Needs Study. The **Scenario Report** describes possible European energy futures up to 2050 and is used to test potential electricity and gas infrastructure needs and projects. Scenarios serve as a basis for the RgIPs to describe the future challenges of the region. The System Needs Study investigates system gaps in the mid-and long-term time horizons (2030 and 2040) in the NT scenario. The present Plan further analyses at regional and country levels the capacity increases identified in the System Needs Study.

Figure 3: ENTSO-E's System Development regions. Each region is covered by one RgIP.

2.1.2 Scope of the RgIPs 2022

RgIPs describe the present situation in each region as well as future regional challenges, considering the 2030 and 2040 time horizons. The Regional Investment Plan 2022 also investigates solutions that can help to mitigate future challenges as well as the projections regarding internal network reinforcements. In addition, this edition of the Plan includes a study roadmap for the region with ongoing and future studies that cover the priorities stemming from the 2040 System Needs Analysis.

The present document comprises the following chapters:

1. **Chapter 1** gathers the key messages of the region.
2. **Chapter 2** outlines the legal requirements and scope of the RgIPs. An overview of the present situation of the regions is also presented.
3. **Chapter 3** covers a description of the identified regional system needs depending on the regional challenges.
4. **Chapter 4** is dedicated to additional analyses specific to the region.
5. **Chapter 5** presents the future challenges in the region and what the necessary mitigation steps are as well as the projections in terms of internal reinforcements. The study roadmap for the region is also included.
6. The Appendix includes the abbreviations and terminology used in the report as well as the list of projects relevant to the region, the links to National Development Plans, the links to simulation results, and additional content depending on the region.

2.2 Overview of the region and present situation

2.2.1 Overview of the region

The CSW regional group, under the scope of the ENTSO-E System Development Committee, includes the following countries and TSOs (Figure 4 and Table 1).

Figure 4: ENTSO-E (System Development Committee Continental South West region)

Country	Company/TSO
France	RTE - Réseau de Transport d'Electricité
Portugal	REN - Rede Eléctrica Nacional, S.A.
Spain	Red Eléctrica - Red Eléctrica de España S.A.U

Table 1: ENTSO-E Regional Group Continental South West membership

2.2.2 Present situation

The interconnected network in the CSW Region is synchronous with the remainder of the Central Europe. The principal issue at stake concerns the low interconnection capacity of the Iberian peninsula with France compared to the overall interconnection capacity of the CSW region with its continental neighbouring countries (Belgium, Germany, Switzerland and Italy), which are themselves interconnected through the European 400 kilovolts (kV) grid.

Due to this low interconnection capacity, the Iberian Peninsula has been historically considered an electric 'island'. Consequently, while its isolation is being reduced through new reinforcements in the interconnection with France, the peninsula has also developed a highly meshed internal system in an effort to strengthen its capacity to withstand potential incidents.

Within the CSW Region, the main alternating current (AC) transmission voltage levels are 400 kV (380 kV in France) and 220 kV (225 kV in France), while voltages below 220 kV are in general considered distribution. In Portugal, 150 kV is considered transmission and in the Spanish Canary and Balearic islands 132 kV and 66 kV are also considered transmission, as is the case in France for 150 kV, 90 kV and 63 kV. There are two HVDC connections in the region; one that has been in service since 2010 and connects the Spanish mainland with Mallorca (the main island of the Balearics in the Mediterranean Sea), and another one that has been in service since 2015 between Spain and France on the eastern part of the border.

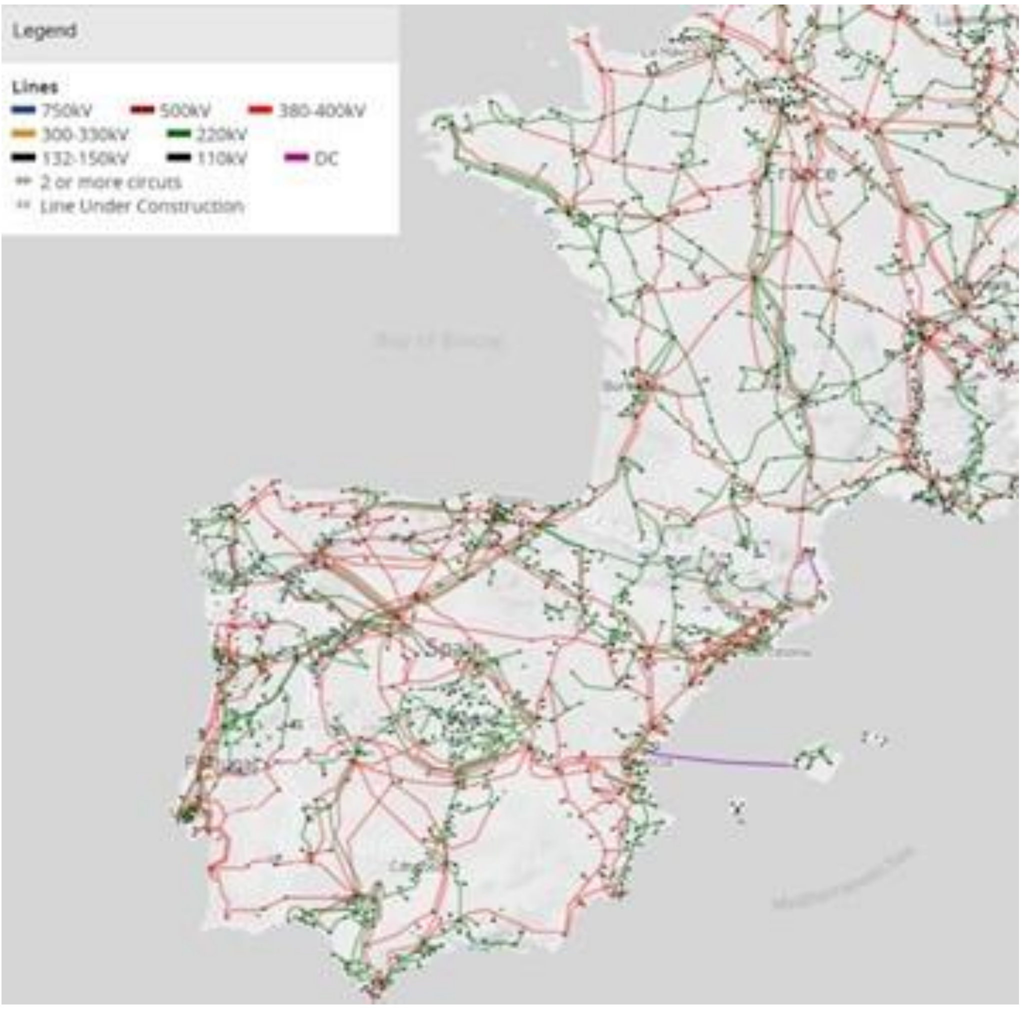

Figure 5: Interconnected network of the CSW Region

The following map shows the reference Net Transfer Capacities (NTC) in the CSW Region. The NTC is the maximum exchange programme between two adjacent control areas that is compatible with security standards and applicable in all control areas of the synchronous area, whilst considering the technical uncertainties regarding future network conditions. In real time operation, these values can vary from hour-to-hour based on the availability of grid elements and changes in generation portfolio due to unbalances, for example.

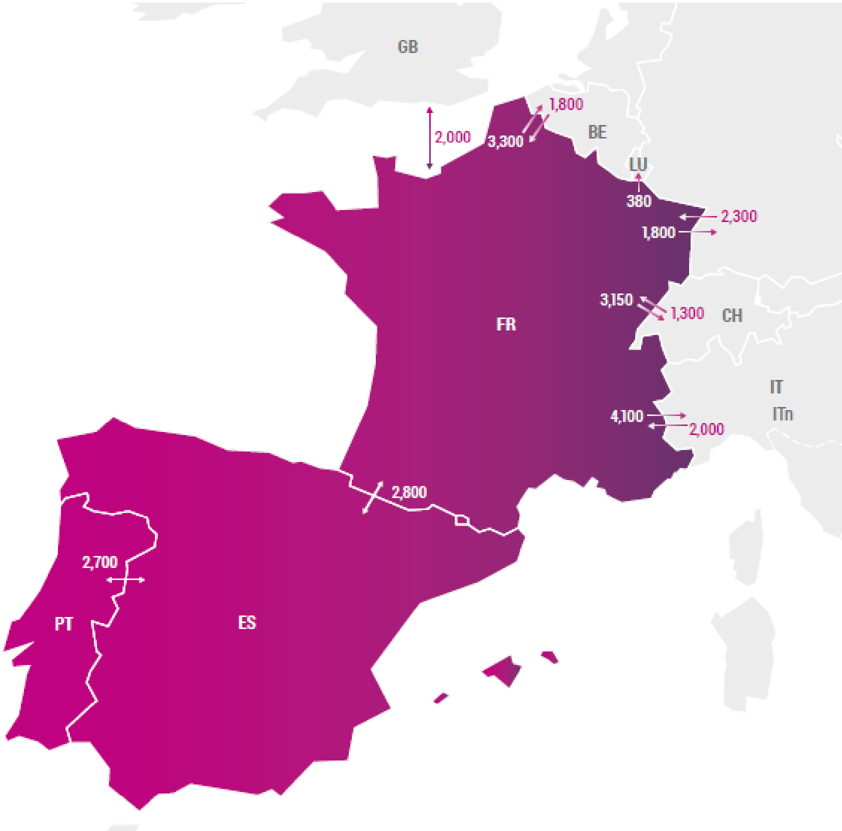

Figure 6: Reference commercial exchange capacities in the CSW Region 2020[4]

[4] The values presented in the map show the reference NTC for 2020 used in MAF 2018

2.2.3. Generation, consumption and exchange physical flows in the region

The following figures show the generation mix in terms of installed capacity, annual generation and balances in 2019 and 2020 and its comparison to 2010.

Peak load in the region decreased in 2019 and 2020 compared to 2010 values. The main reasons for this decrease were the financial crisis after 2008 and energy efficiency measures and, in the case of 2020, the Covid-19 pandemic. The total installed capacity increased in the three countries mainly driven by new RES generation: wind (21 GW in 2020), solar (20 GW in 2020) and other RES technologies (1.5 GW in 2020). On the other hand, fossil fuels installed capacity decreased by 16.2 GW.

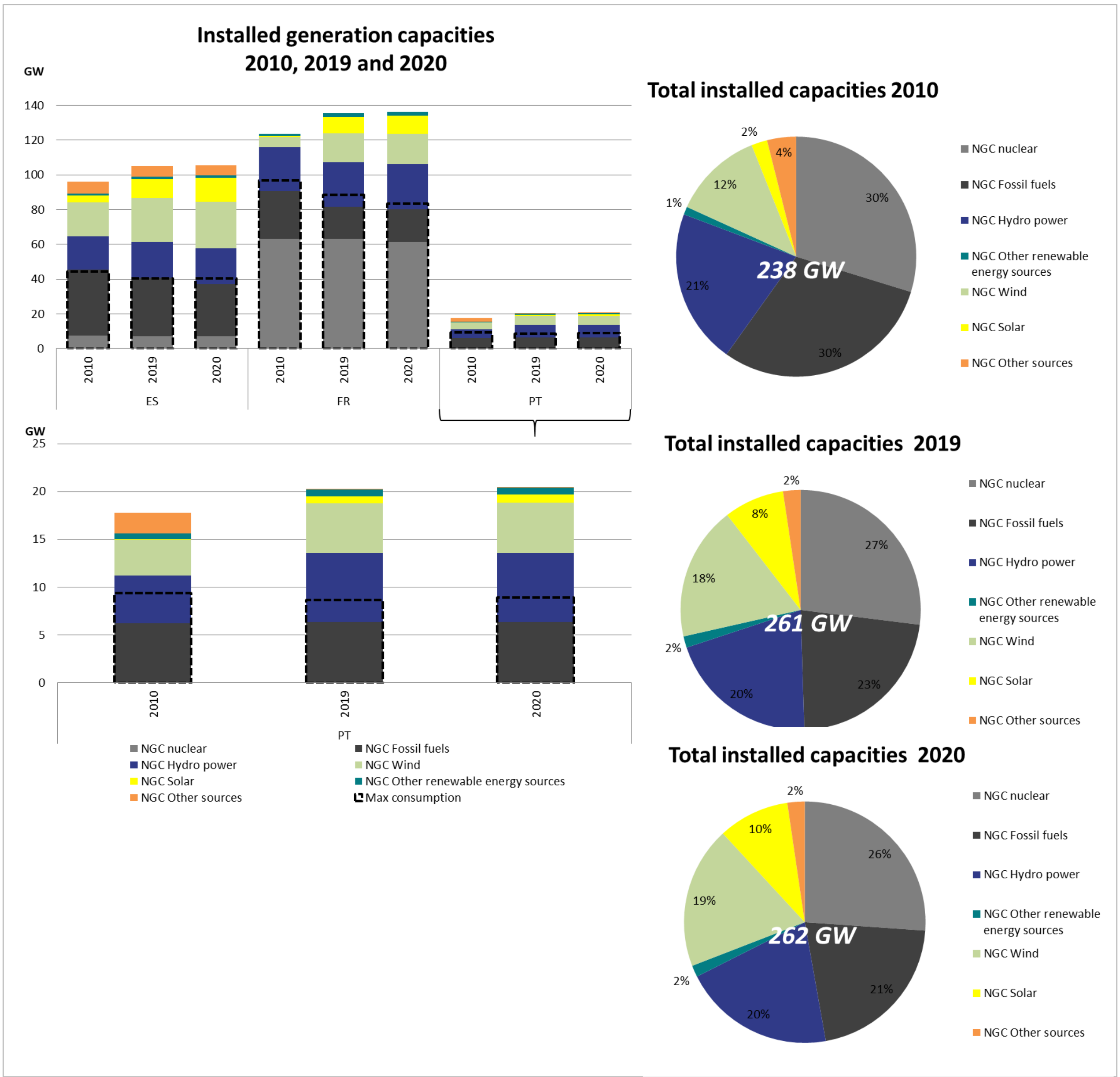

Figure 7: Installed generation capacities by fuel type in the CSW Region 2010–2020

Consumption reduced in all three countries in 2019 and 2020 compared to 2010. In the case of 2020, the reduction was bigger due to the COVID-19 pandemic and totalled 9.1% in Spain, 10.4% in Portugal and 6.5% in France.

In line with the reduction in the demand, net generation also decreased in the region by 10.3% for that year. The most significant reductions appear in nuclear (-76 TWh/y) and thermal generation with fossil fuels (-75.5 TWh/y), while RES generation increased both in wind (43.7 TWh/y) and solar (25.7TWh/y). Even though nuclear is the generating technology with the biggest decrease, it remained the main contributor in 2020, covering half of the total demand in the region. Wind and solar increased their share to 17.8% of the total demand and total RES, including hydro and other RES, totalled 33.6% in 2020.

In 2019 and 2020, France was a net exporter of electricity whereas Portugal was a net importer. Both countries had the same behaviour as in 2010. Spain changed the sign of its net balance, being a net exporter in 2010 and a net importer in 2019 and 2020.

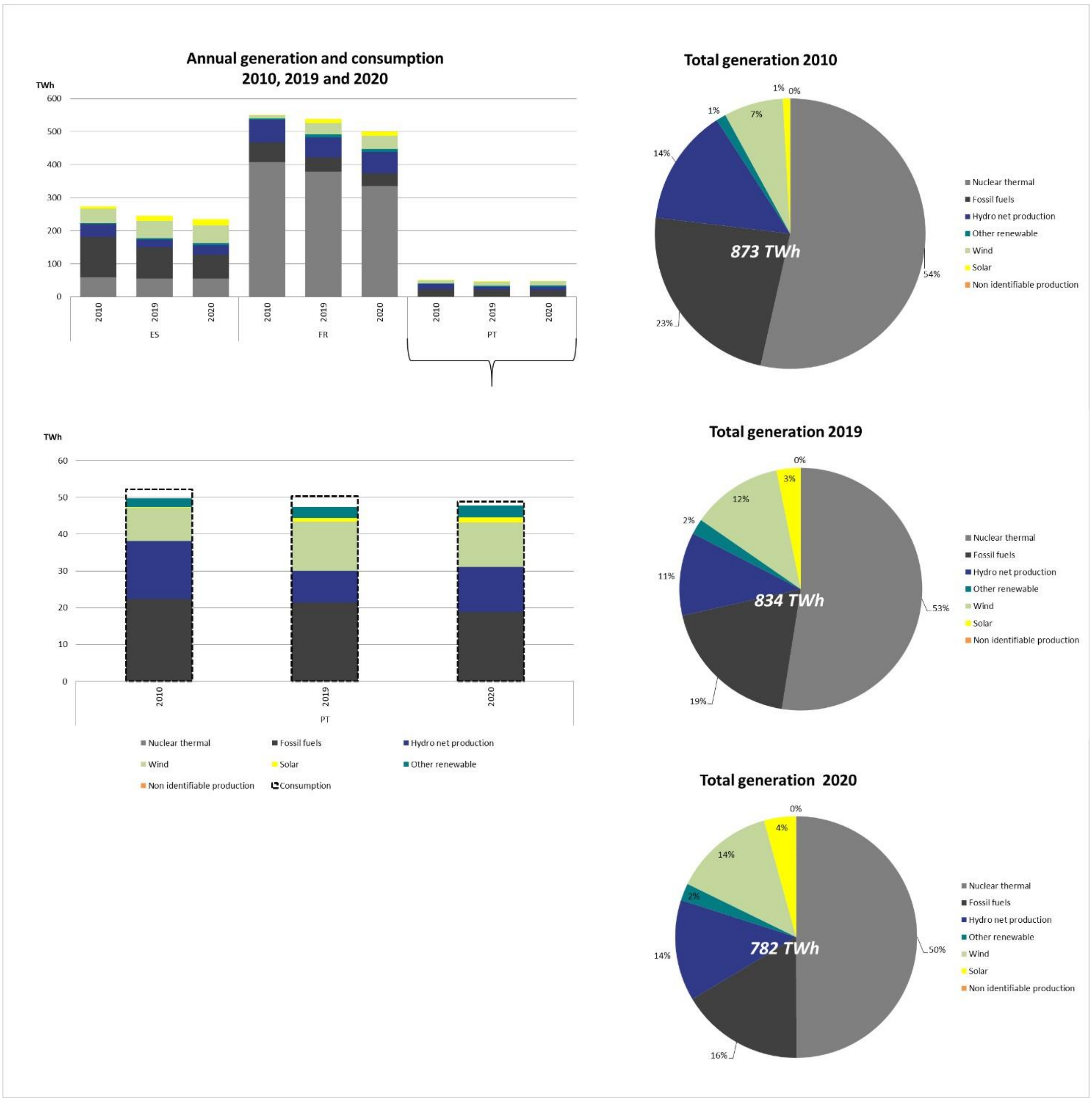

Figure 8: Annual generation by fuel type and annual consumption in the CSW Region in 2010, 2019 and 2020

Physical flows in the borders between countries in the region have increased from 2010. On the Portugal–Spain border, flows increased in both directions due to the commissioning of the southern interconnection between Algarve and Andalucía in 2014. Similarly, on the Spain–France border flows also increased in both directions compared to 2010 due to the commissioning in 2015 of the HVDC line Baixas–Santa Llogaia that doubled the exchange capacity between the two countries. Exchanges from Spain to France approximately doubled in these 10 years and France to Spain had a much stronger increase of around 6 times.

Regarding exchanges with third countries, in the border between Spain and Morocco the pattern changed significantly, with a large reduction of flows in the direction of Spain to Morocco and flows in the opposite direction. These were insignificant until 2019. French exports increased to Italy, Belgium and Great Britain and reduced to Germany and Switzerland; imports reduced with all of them except Germany.

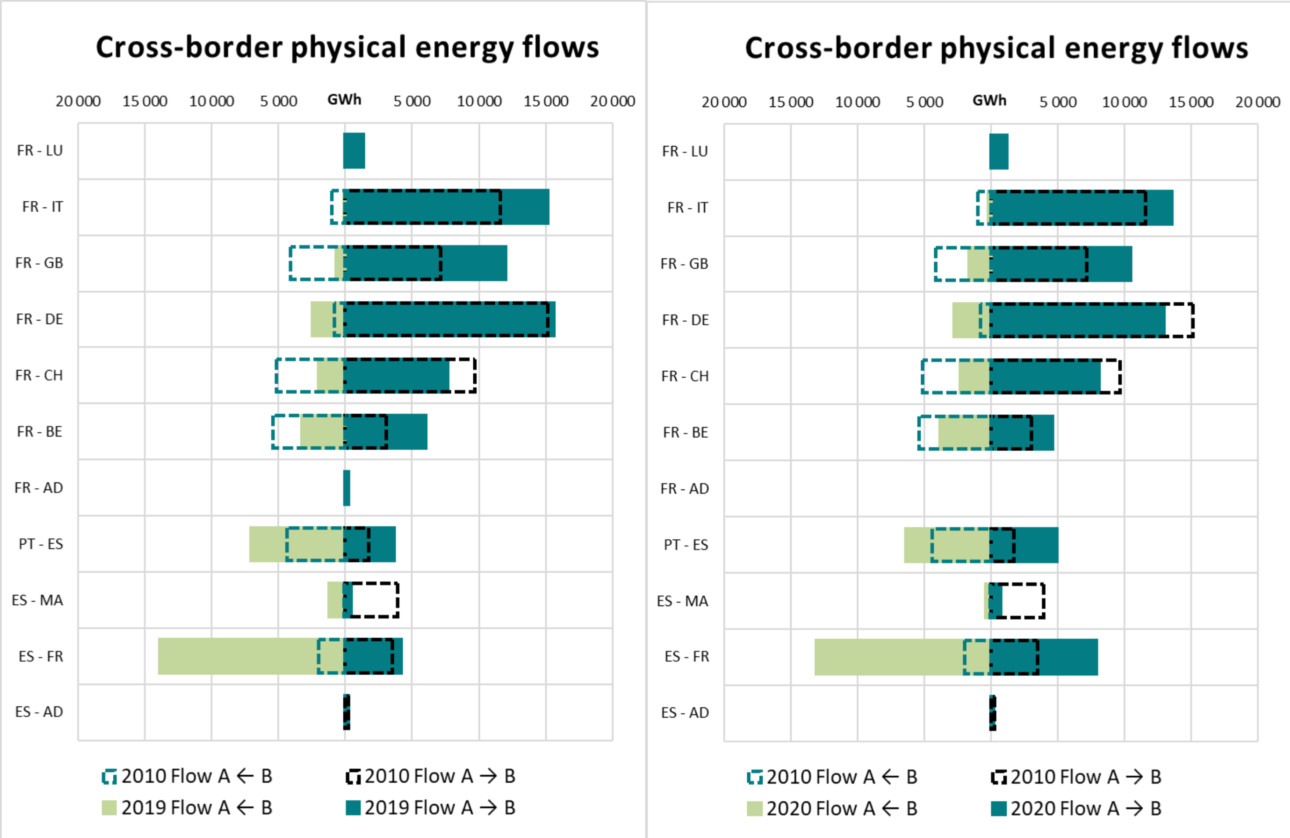

Figure 9: Cross-border physical flows (GWh) in the CSW Region in 2010–2019 and 2010–2020

Regarding adequacy and the possibility of suffering from energy not supplied situations, ENTSO-E Winter Outlook 2021-2022[5] reports:

- The current surge of prices on the gas market may have an impact on electricity prices but should not pose additional adequacy risks under reference and severe scenarios.
- Risks have been identified in France in January and February in the event of extreme cold weather events due the low availability of nuclear power plants.
- Non-market resources do not notably decrease the risk in France as resources in neighbouring countries cannot be reached due to interconnection limitations.

[5] *https://www.entsoe.eu/outlooks/*

2.2.4. Grid Constraints

The average NTC values between Portugal and Spain in 2020 were 2,920 MW from Portugal to Spain and 2,970 MW from Spain to Portugal. The exchange capacity value has increased significantly (mainly in the direction Portugal-to-Spain) due to the commissioning, in 2014, of a new interconnection between Tavira in the Algarve area in Portugal and Puebla de Guzman in the Huelva area in Spain.

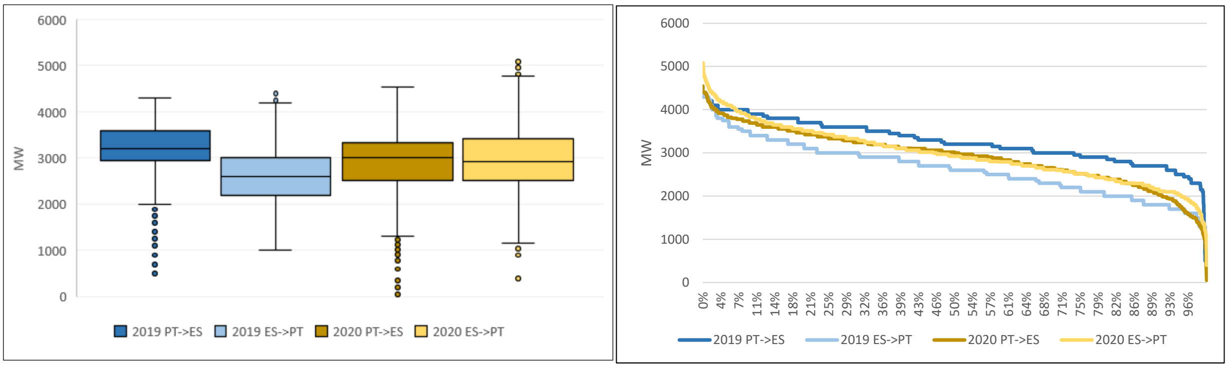

Figure 10: Commercial Exchange Capacities in the Portuguese–Spanish border – 2019 and 2020[6] – distribution of values

On the Portugal–Spain border, NTC values enable a high level of integration. Some constraints, however, still impede the achievement of the main political goal of 3,000 MW NTC, established for reaching a complete operational Iberian Electricity Market (MIBEL). Moreover, in 2020 the congestion rate was 4%, and the average day ahead market prices differences was 0.12€/MWh, with some maximum values above 10€/MWh.

The average NTC values between France and Spain in 2020 were 2,592 MW from France-to-Spain and 2,427 MW from Spain-to-France. The exchange capacity value has increased due to the commissioning, in 2015, of a new HVDC interconnection between Santa Llogaia in the Girona area in Spain and Baixas in the Perpignan area in France.

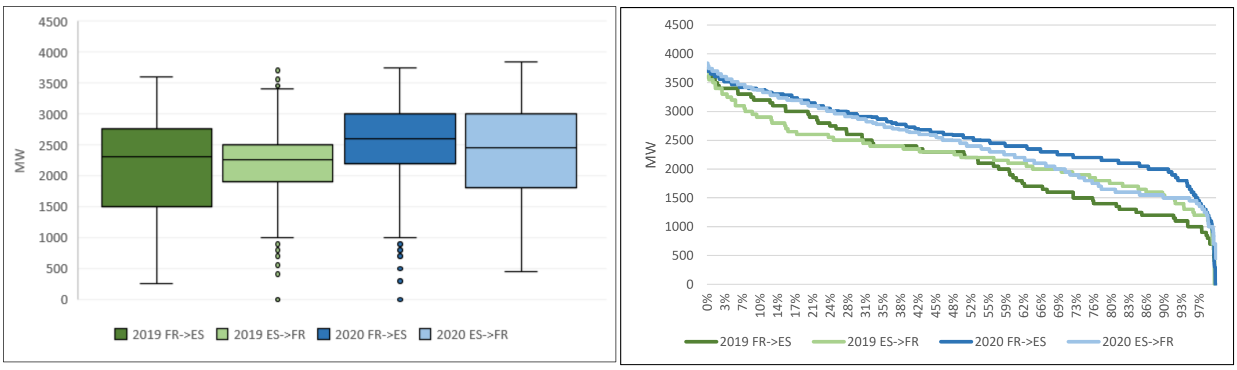

Figure 11: Commercial Exchange Capacities in the France–Spain border – 2019 and 2020[7]– distribution of values

[6] *Source: https://www.iesoe.eu*
[7] *Source: https://www.iesoe.eu*

Commercial exchanges between France and Spain are lower from 2019 due to a reduction of ratings on the Hernani-Argia-Cantegrit lines. Some planning outages occurred in 2019 on the Hernani-Argia-Cantegrit 400kV lines to increase the capacity of these lines at least to previous levels. Although in 2021 congestion—that is, the percentage of the hours in which the market agent's interest reaches the maximum NTC—still occurs around 65.2% of the time France to Spain, and the average price differences are still in the order of 20 €/MWh, the congestion on the border has decreased by around 12% compared to 2019. 2020 values are atypical due to the impact of the pandemic. Furthermore, congestion income is now almost twice as high as it was before the HVDC (178 M€ in 2019, 135 M€ in 2020 and 318 M€ in 2021), primarily due to a doubling of cross-border capacity. Meanwhile the cross-border balancing energy is now almost three times as high as it was before the interconnection.

The CSW Region is also interconnected with Morocco—which is a non-ENTSO-E country—through two submarine AC cables of 400kV with a thermal capacity of 700 MW each. The NTC values between Spain and Morocco have not changed since the commissioning of the second cable in 2006. These NTC values are 600 MW Morocco-to-Spain and 900 MW Spain-to-Morocco (the average NTC values in 2020 were 545 MW Morocco-to-Spain, and 763 MW Spain-to-Morocco). This border usually had high flows Spain-to-Morocco but, starting in 2018, this situation has changed, and Spain has begun to import energy from Morocco during some hours of the year.

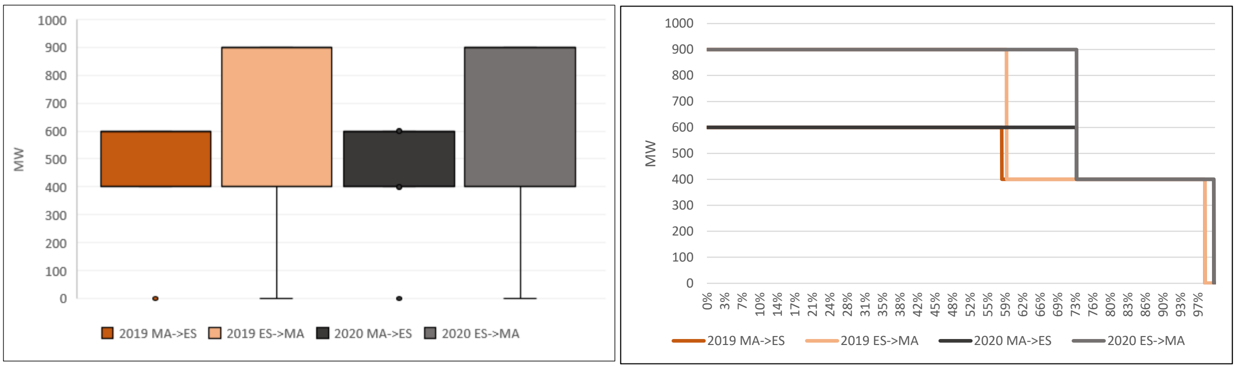

Figure 12: Commercial Exchange Capacities in the Spain–Morocco border – 2019 and 2020[8]

[8] *Source: https://www.iesoe.eu*

2.2.5. Interconnection ratio in the region

The CSW regional group faces two main challenges relating to the transmission infrastructure development currently being addressed by the three countries involved: the completion of the Iberian Electricity Market (MIBEL) through reinforcing the Portugal–Spain interconnection, and the integration of the Iberian Peninsula into the European internal market, through the development of the France–Spain interconnection. This existing challenge will remain in the future, independently of the generation scenarios considered.

There is political support for these cross-border reinforcements, both at European and national levels. Within the European approach, the support is embodied in the following Regulations:

- The European Council established on 15 and 16 March 2002 the objective of reaching a minimum interconnection ratio of at least 10% of the installed generation capacity in every Member State.[9] In the case of Spain, this ratio is expected to amount to around 7% by 2022.
- The European Council of October 2014[10] endorsed the proposal by the EC of May 2014[11] to extend the current electricity interconnection target of 10% (defined as import capacity over installed generation capacity in a Member State) to 15% by 2030 "*while taking into account the cost aspects and the potential of commercial exchanges in the relevant regions".*

  To achieve the 15% target, the EC decided to establish a Commission Expert group on electricity interconnection targets to provide technical advice. Its conclusions were published in November 2017 in the report entitled 'Towards a sustainable and integrated Europe'.[12]

  At the same time, EC showed the expectation for 2020 (based on TYNDP 2016 data): Portugal and France would meet the 10% objective, while Spain would remain in a range of 6–7%, still some distance from the 10% threshold.

[9] *The COM (2001) 775 establishes that "all Member States should achieve a level of electricity interconnection equivalent to at least 10% of their installed generation capacity". This goal was confirmed at the European Council of March 2002 in Barcelona and chosen as an indicator the EU Regulation 347/2013 (annex IV 2.a) The interconnection ratio is the sum of importing GTCs/total installed generation capacity.*

[10] *Council Conclusions of 23 and 24 October 2014* http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf

[11] *COM(2014) 330 final.*

[12] https://ec.europa.eu/energy/sites/ener/files/documents/report_of_the_commission_expert_group_on_electricity_interconnection_targets.pdf

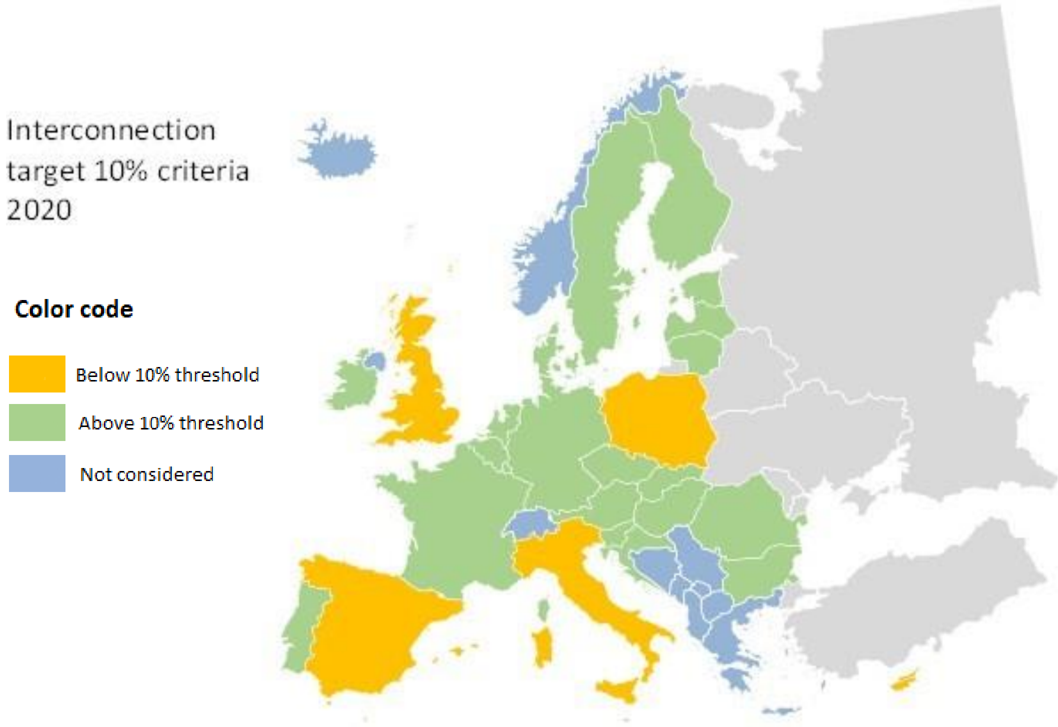

Figure 13: Fulfilment of the 10% interconnection target in 2020 (source EC)

- The Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 has set an interconnection target of at least 15% for 2030, while defining several urgency indicators (based on price differential in the wholesale market and nominal transmission capacity of interconnectors in relation to peak load and to the installed renewable generation capacity resulting on the outcomes from the Expert group on electricity interconnection targets[13]). The regulation also reminds us that '*each new interconnector shall be subject to a socioeconomic and environmental cost-benefit analysis and implemented only if the potential benefits outweigh the cost'.*

Within a regional approach, the support involves governmental commitments and facilitation groups:

- In March 2015, the Declaration of Madrid of the Energy Interconnection Links Summit between the governments of Spain, France, and Portugal, the EC and the European Investment Bank gave support to TSOs' ongoing regulations and studies. The Declaration of Madrid highlights the urgency of fulfilling the 10% objective and conducting further investigations aimed at developing and following up on the electrical interconnection projects required to reach 8 GW capacity on the France–Spain border.
- A high-level group on interconnections for South-West Europe, established following the Madrid Summit, featuring representatives from the EC, national governments, national regulatory authorities and the TSOs to closely monitor the progress of the works.

[13] *ITEG (Interconnection Target Expert Group) Indicators*

- In July 2018, the Lisbon Declaration of the second Energy Interconnections Summit among the governments of Portugal, France and Spain, the EC and the European Investment Bank. The declaration aimed to strengthen regional cooperation in the framework of the Energy Union and better integrate the Iberian Peninsula into the internal energy market.

All this support paved the way, for example, for French and Spanish regulators to agree – on 21 September 2017 – to a proposal for financing a new interconnector via the Biscay Gulf; this agreement constituted an important boost for cross-border development.

Following the proposal from the French and Spanish regulators in January 2018, the EC has granted 578 M€ in the Biscay Gulf project, through the Connecting Europe Facility (CEF Energy) programme.

Nowadays, Spain has still an interconnection ratio of 5.7% while Portugal and France have already passed the 10% objective. At the same time, due to the peripheral nature of the region, it is also relevant to report that the interconnection ratio of the Iberian Peninsula as a whole – currently in the range of 3% – is a very low value, and one which will not improve for the next few years until the commissioning of the Gulf of Biscay project. The Iberian Peninsula will still be viewed as an electrical 'island', and reinforcements with central Europe are necessary.

2.2.6. Evolution compared to RegIP 2020

Since the publication of RegIP 2020, which was published for public consultation in August 2020, progress of the projects included in TYNDP 2020, regarding grid development and storage, are presented in the next table.[14] The table also includes the new projects in this TYNDP 2022.

Project nº	Project Name	TYNDP 2020 Commissioning Date	TYNDP 2020 Status *	Current Commissioning Date	Current Status *	Progress
1	RES in north of Portugal	2021-2024	Planned but not yet Permitting	2021-2029	Planned but not yet Permitting	On time
4	Interconnection Portugal-Spain	2022	In Permitting	2024	In Permitting	Delayed
16	Biscay Gulf	2027	In Permitting	2027	In Permitting	On time
85	Integration of RES in Alentejo	2023	Planned but not yet Permitting	2023	In Permitting	On time
233	Connection of Aragon Pumping hydro	2027	Under consideration	-	Not included in TYNDP 2022[15]	Desestimated
270	FR-ES project -Aragón-Atlantic Pyrenees	2030	Planned but not yet Permitting	2030	Planned but not yet Permitting	On time
276	FR-ES project -Navarra-Landes	2029	Planned but not yet Permitting	2030	Planned but not yet Permitting	Re-scheduled
296	Britib	2026	Under consideration	-	Not included in TYNDP 2022[16]	Desestimated
378	Transformer Gatica	2025	Planned But Not Yet Permitting	2027	Planned but not yet Permitting	Re-scheduled
379	Uprate Gatica lines	2025	Under consideration	2026	Planned but not yet Permitting	Re-scheduled
1012	P-PHES Navaleo	2024	In permitting	2026	In permitting	Delayed
1027	P-PHES Cúa	2028	In permitting	2028	In permitting	On time
1039	Pumped hydro Los Guajares	2026	Under consideration	2026	Under consideration	On time
1041	Pumped hydro Velilla	2026	In permitting	2028	In permitting	Delayed
1011	Pumped hydro MontNegre	2025	In Permitting	-	Not included in TYNDP 2022	Desestimated
1019	Pumped hydro Gironets & Raimats	2028	In Permitting	-	Not included in TYNDP 2022	Desestimated
1036	Pumped hydro Mar de Aragón	2025	Under consideration	-	Not included in TYNDP 2022	Desestimated
1042	H2 storage and production through a fleet of FC-Electric Vehicles	2022	Under consideration	-	Not included in TYNDP 2022	Desestimated

* Status of the least advance investment

Table 2: Progress of the TYNDP projects from the CSW region

[14] *For regional investments, more detailed information is provided in the Appendix*

[15] *This project intended to ensure the connection to the network and proper performance of a set of new pumping hydro storage plants that have a PCI label in the Aragón region. Those plants are no longer PCIs and are not in the TYNDP, so this Project does not resolve any need.*

[16] *This Project has not fulfilled the criteria for inclusion in the TYDNP 2022*

3. Regional System Needs (or Regional System Opportunities)

This chapter presents and explains the results of the studies and is divided into four sections. Subchapter 3.1 presents a comparison of what would happen in a hypothetical situation where Europe ceases investment in the grid ('no grid' investment after 2025) with the 2040 NT scenario; this analysis allows future challenges in the region to be identified. Subchapter 3.2 provides the future capacity needs highlighted by the identification of system needs process. Subchapter 3.3 examines the regional market analysis results in detail, showing a comparison between the 'no grid' investment after 2025 and the 'economic grid' for 2030 and 2040 in order to show the potential benefits, whereas subchapter 3.4 focuses on the network analysis results.

3.1 'No Grid' analysis

An analysis of the 2040 NT scenario with the expected grid of 2025 (reference grid; for more details, readers should refer to the System Needs Study main report) revealed the following future challenges:

- Insufficient integration of renewables (large amounts of curtailed energy);
- High price differences between bidding areas;
- Unused potential to further reduce high CO_2 emissions; and
- Bottlenecks between and inside market areas.

Challenges from market studies approach

For the horizon 2040, the IoSN study used a standard NTC model, with a model that only considers one zone per country; the cross-border capacity is the NTC. An expansion algorithm has been used to optimise the total system costs based on the optimal grid reinforcements (interconnections) and other flexibility solutions (storage and CO_2 free peaking units) increases. For more details on the zonal model methodology, readers should refer to the System Needs Study main report.

The figures below describe the regional challenges identified by the simulations described above. They present the results of simulations for the long-term 2040 NT scenario, with a hypothetical situation where Europe ceases investment in the grid ('no grid' investment after 2025). The results could be compared with the similar figures in chapter 3.3, which show the 2040 market data simulations combined with an appropriate 2040 scenario grid ('economic grid').

Figure 14 presents the annual generation by fuel type in the region for the 2040 NT scenario with the 'no grid' investment after 2025. It is possible to see that wind and solar energy (excluding the curtailed energy) will contribute 72.9% of the generation required to satisfy the native consumption in the region.

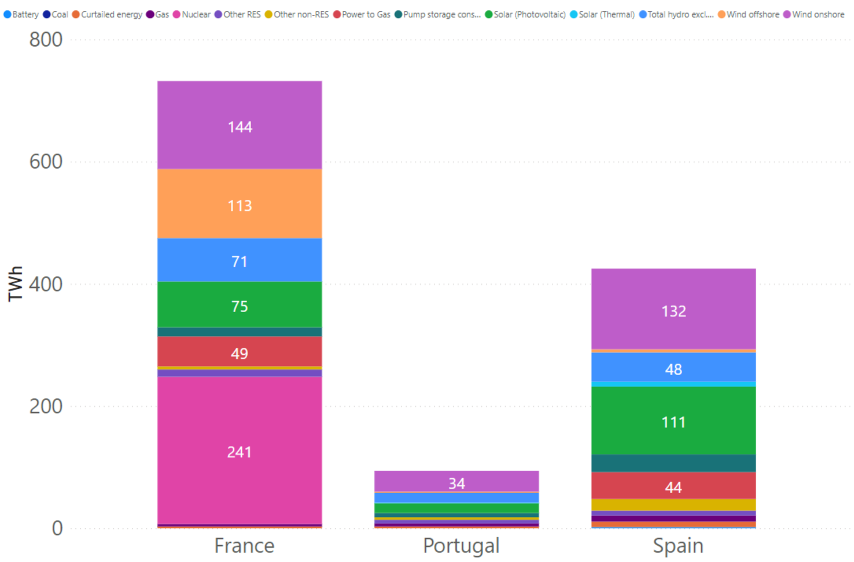

Figure 14: Annual generation by fuel type in the region for 2040 NT scenario with 'no grid' investment after 2025

Regarding RES integration, Figure 15 indicates a high level of curtailed energy in 2040 in the Iberian Peninsula – particularly in Spain – with the 2025 network, for which the future projects (particularly those to be commissioned 2025–2040) would help to mitigate the situation, although they would not permit avoiding all generation curtailment. The curtailed energy would represent around 3.2%, 0.5% and 5.3% of the expected consumption in Spain, France and Portugal respectively in the 2040 NT scenario.

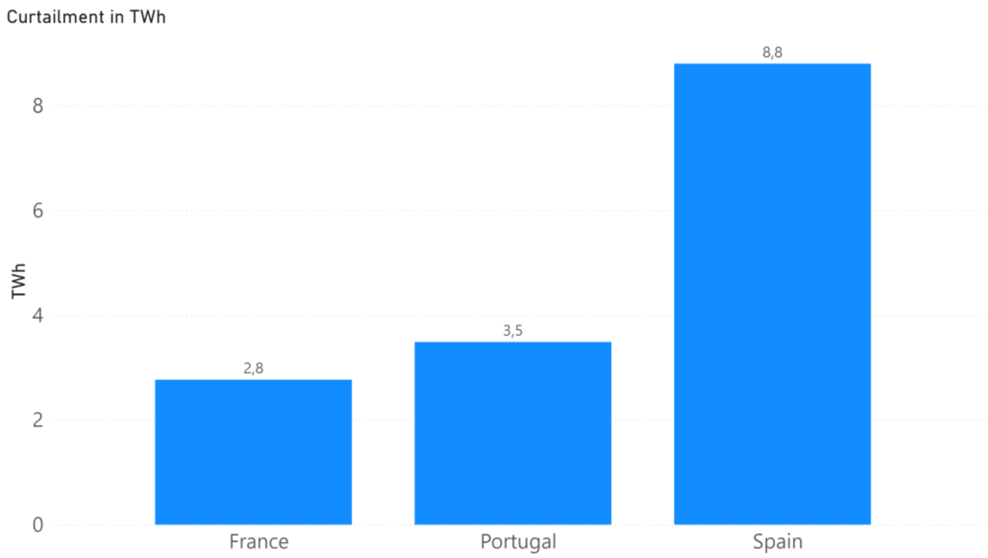

Figure 15: Yearly curtailed energy in the region for 2040 NT scenario with 'no grid' investment after 2025

With the 2040 NT scenario in terms of load and generation and the 2025 network, the level of CO_2 still reflects an imperfect level of RES integration. At the same time, as a result of the scenario, a high reduction of CO_2 is expected in the region.

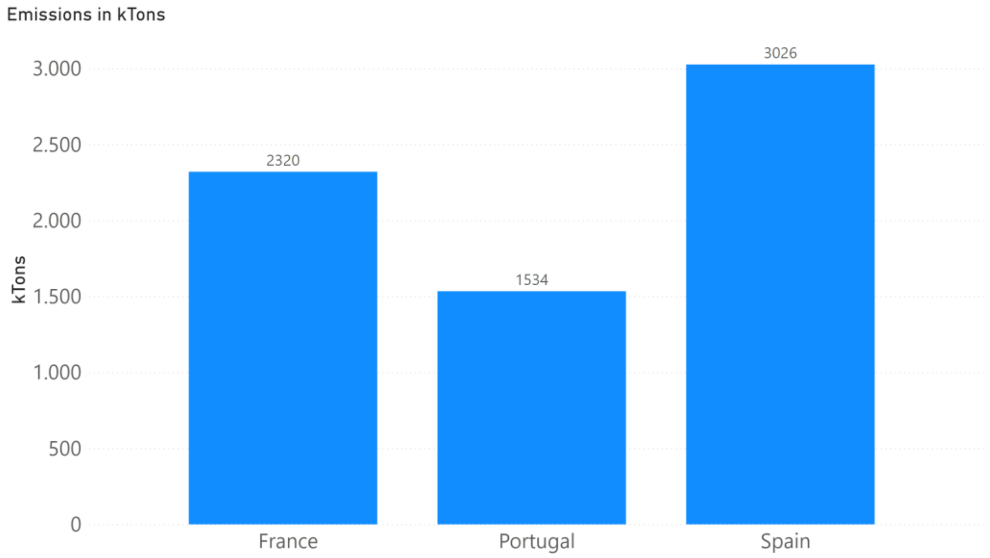

Figure 16: Yearly CO_2 emissions in the region for the 2040 NT scenario with 'no grid' investment after 2025

Figure 17 shows the marginal cost yearly average with the 2040 NT scenario in terms of load and generation and the 2025 network. The value for Portugal is 53 €/MWh, while the values for Spain and France are 56 €/MWh and 49 €/MWh respectively.

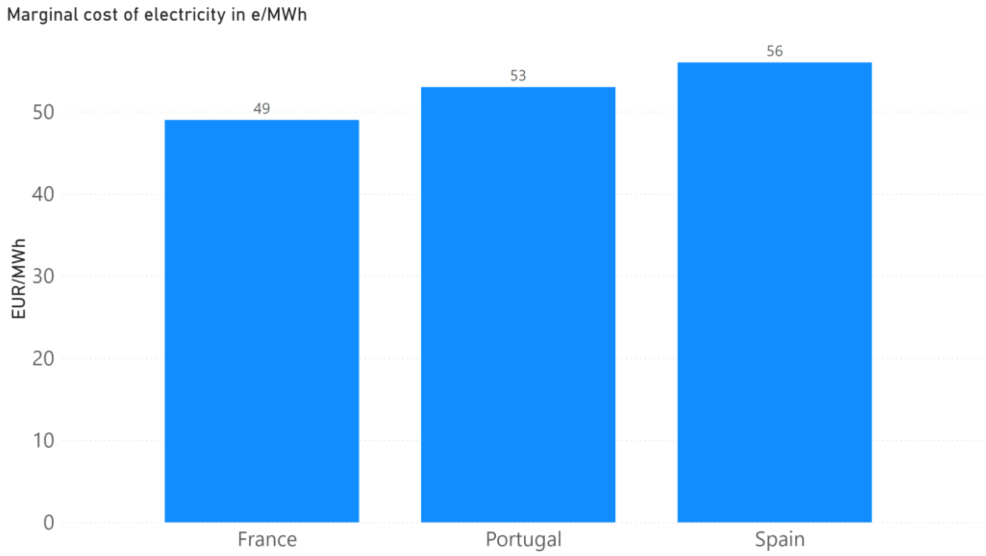

Figure 17: Yearly average of marginal cost in the region for the 2040 NT scenario with 'no grid' investment after 2025

Concerning country balances, In 2040 France and Portugal are net exporters (75 TWh and 7 TWh respectively), while Spain is a net importer (16 TWh).

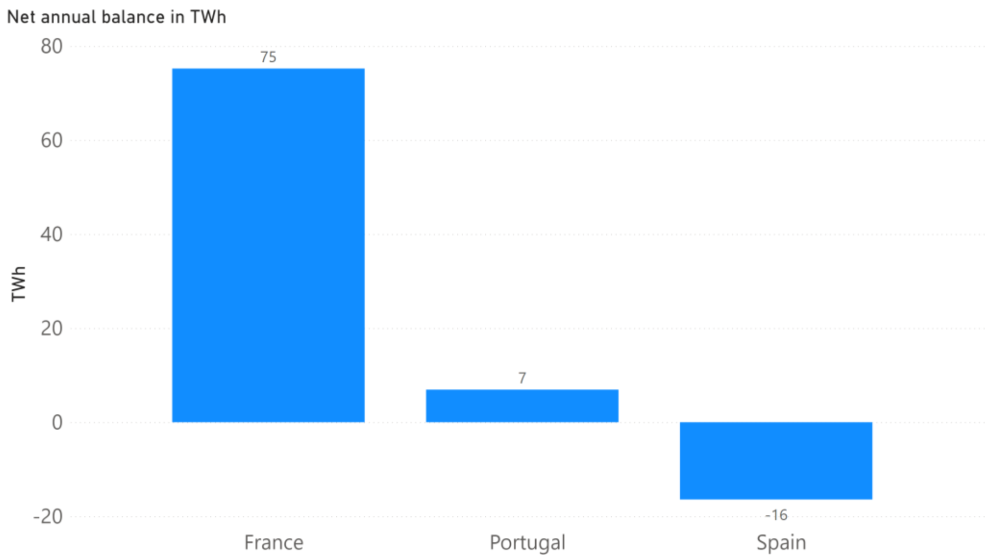

Figure 18: Net annual country balance in the region for the 2040 NT scenario with 'no grid' investment after 2025

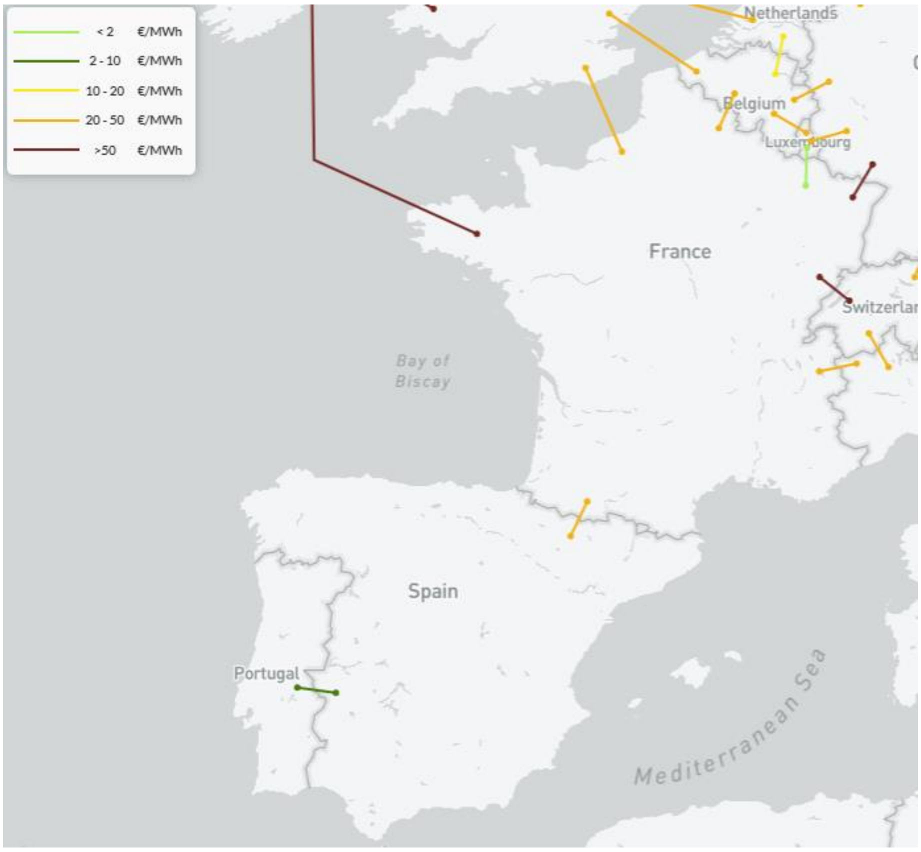

Figure 19: Average hourly cost differences in the region for the 2040 NT scenario with 'no grid' investment after 2025

Figure 19 illustrates the average marginal cost spread[17] within the CSW region (PT-ES: 4€/MWh and ES-FR: 35€/MWh) and between the CSW region and neighbouring countries (based on the 2025 network), which indicates where it might be worth improving market integration.

As the energy transition progresses, new challenges appear for system operations. Trends show a reduction of system inertia due to increasing RES integration and distributed generation, thus leading to the higher vulnerability of the system to frequency mismatches. Flexibility options will gain in importance, both at generation, demand and infrastructure level, and in this context the role of TSOs in securing network stability will be key.

The residual load is the remaining load after subtracting the production of variable RES (wind and solar production). The NT scenarios consider a high RES installed capacity that produces at zero marginal costs and therefore tends to displace conventional generator units from the market. Unlike conventional generators with more expensive but controllable sources of primary energy, primary energy from RES has a variable and non-dispatchable nature. The higher the RES, the higher the variations that can be considered as needs for flexibility to maintain the frequency equilibrium.

The ramps in 2040 are much higher than today; this reflects the significant challenge that the countries in the region must face related to system flexibility, which is more significant in the event of non-interconnection development beyond 2025.

Residual load ramps are an important issue in all scenarios, and they will be studied further to guarantee the necessary volume of frequency reserves in all timescales for the cases of unforeseen generation and demand imbalances.

For more details on the residual load ramps and inertia, readers should refer to the System Needs Study main report and System Dynamic and Operational Challenges report.

3.2 Future capacity needs

The 'economic grid' is a depiction of the required effective cross-border transfer capacity increases and flexibility solution necessary for a cost-optimised operation of the 2030/2040 system. It is important to note that considerations of system resilience, system security, or other societal benefits addressed in the CBA of projects are not included in this analysis. The cost-optimised operation of the 2030/2040 system is a function of the cost estimates for the cross-border capacity increases and the generation costs.

For the CSW region, new grid reinforcements (interconnections) and other flexibility solutions[18] (storage and CO_2 free peaking units) needs were identified according to the methodology for the 2030 and 2040 NT scenarios. The outcome of the analysis is synthesised in Figure 20 and Table 3.

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[17] The yearly average marginal cost spreads is the yearly average of absolute values of costs spreads, then higher than the difference between yearly average marginal cost of two considered countries.
[18] Storage and CO2 free peaking units needs were accessed only for 2040 horizon

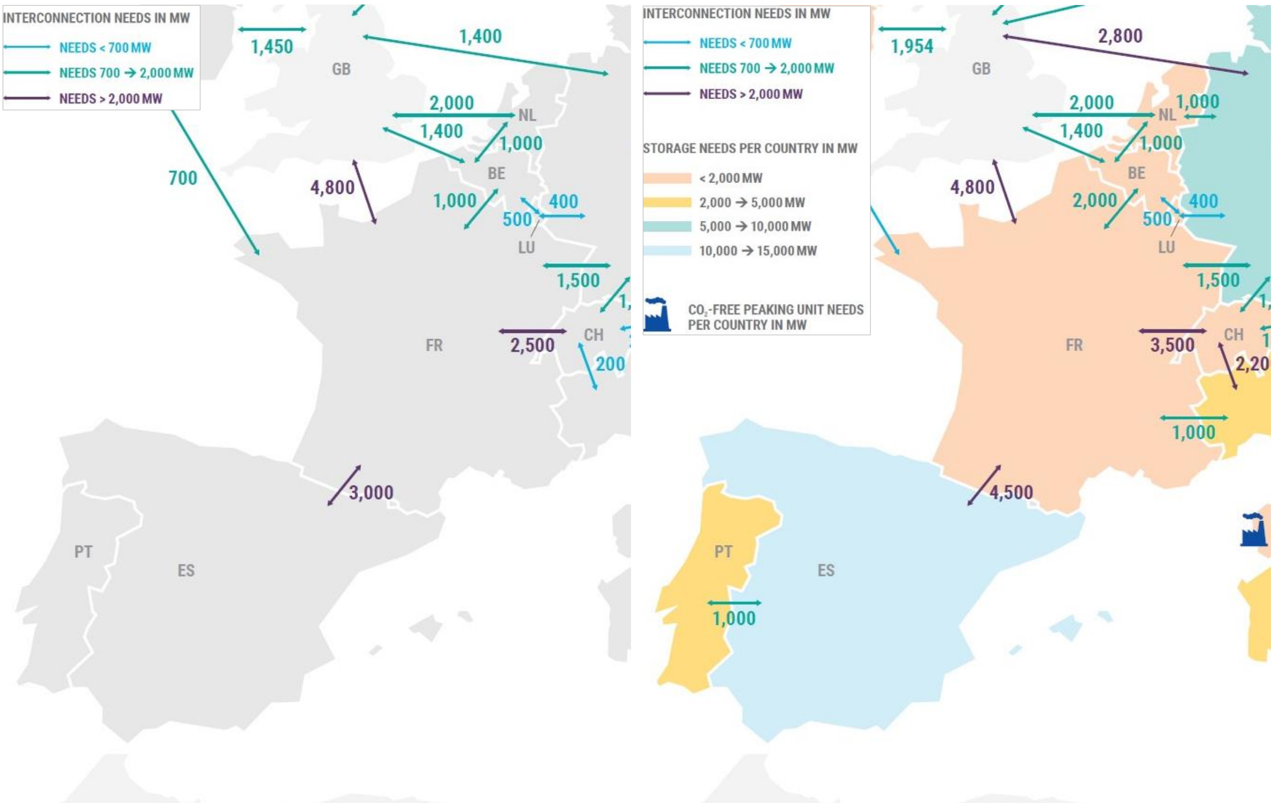

Figure 20: Identified needs in the studied 2030 (left) and 2040 (right) NT scenarios ('economic grid') in the CSW region

The needs presented are based on an optimisation process that includes cost estimates for every border investigated and economic assumptions for storage and peaking units aligned with scenario building (the ratio between costs and benefit can be decisive in choosing between potential reinforcements). An overview of these costs assumptions can be found in the System Needs Study main report.

Costs of the interconnection increases were assessed by expert view, considering as far as possible the specificity of the area (e.g., presence of mountain or sea), internal grid considerations and knowledge from previous projects at these borders (if any).

From the market perspective, and considering the potential benefits of the grid reinforcements and other flexibility solutions (only with a SEW approach)[19] and also the estimated costs of those increases, the capacity needs increases on the France–Spain border showed potential benefits if increased by 4500 MW from the starting grid values in the 2040 horizon, resulting in total values of 9500 MW by 2040. The capacity needs increase on the Portugal–Spain border showed potential benefits in the 2040 horizon if increased by 1000 MW from starting grid values, resulting in total values of 4500/5200 MW. The estimated costs for the increases also affect the results within the region, particularly on the France–Spain border, where the cost of underground or submarine HVDC potential cross border reinforcements has been considered to cross the border, based on the

[19] *Other potential benefits included in the CBA methodology or beyond it are not considered; however, it is assumed that if the SEW benefit alone compensates for the cost the capacity increases, they are economically viable.*

experience and previous projects. The possibility of AC potential projects would yield higher values but could be unfeasible from a social perspective.

Error! Reference source not found.synthetises the needs identified during the TYNDP 2022 process w ithin the CSW region.

The first columns show the expected 2022 capacities. The next columns show the capacities relevant to the CBA (reference grid), which will be carried out on the time horizons 2030 and 2040.

The next two (double) columns show the grid reinforcements (interconnections) needs identified for the 2030 NT and 2040 NT scenarios. These capacities needs were identified during the identification of the system needs phase and are dependent on the time horizon.

The last two columns show the other flexibility solutions (storage and CO_2 free peaking units) needs identified for the 2040 NT scenario.

	CBA Capacities				Interconnection				Storage	Peaking unit
	NTC 2022		NTC 2025 (starting grid)		NT 2030		NT 2040		NT 2040	NT 2040
Border / Country	=>	<=	=>	<=	'IoSN Economic needs'	Total NTC	'IoSN Economic needs'	Total NTC		
ES-FR	2800	2800	5000	5000	3000	8000/8000	4500	9500/9500	-	-
ES-PT	2700	2700	4200	3500	-	4200/3500	1000	5200/4500	-	-
PT	-	-	-	-					2500	0
ES	-	-	-	-					13900	0
FR	-	-	-	-					1500	0

Table 3: Cross-border capacities expected for 2022, for the reference grid, capacity and flexibility needs identified during the identification of system needs phase ('Economic grid')

The IoSN starting grid considers the existing grid and the projects likely to be implemented by the date of the scenario considered in the study (for more details on the reference grid, readers should refer to the System Needs Study main report). It includes the northern interconnection between Spain and Portugal, and the Biscay Gulf project between Spain and France.

From the table above, it is possible to identify the gaps between the capacities resulting from the current situation and starting grid and the capacity needs resulting from the IoSN analysis.

On the 2040 time horizon, optimisations were performed to also identify needs on based storage in order to optimise interconnectors / curtailment and peaking units, thus solving an ENS issue.

In the CSW region around 18 GW (14 GW, 1.5 GW and 2.5 GW respectively in Spain, France and Portugal) of additional installed capacity in storage were found valuable on top of starting point (capacities in 2030 in the NT scenario). In the IoSN analysis, the highest needs of storage were found in a country with a high RES curtailment. The results show that in the 2040 time horizon, storage helps to cope with the large amounts of the variable RES in the system in the region.

No need for peaking units in the CSW region was found, assuming the countries remain adequate in this scenario with the Economic Grid results.

3.3 'Economic Grid' analysis

3.3.1 2030 horizon

Though the present regional investment plan focuses on the 2040 horizon, ENTSO-E's IoSN study also studied the 2030 horizon. The current section includes an overview of the findings for three key indicators. For more details on 2030 results, readers should refer to the System Needs Study main report and to the Needs online visualisation platform[20].

Methodology

For the horizon 2030, the IoSN study used a zonal model methodology that considers a model with around 100 nodes, and a reduced grid model that considers equivalent impedances and capacities between these nodes. Some constraints are applied on the links between nodes to simulate Kirchhoff's mesh rules. As a result, the optimal dispatch can be assessed at the European level, considering the physical limits of the network. This methodology merged both market and network simulations in a single step, avoiding loops between market and network models. An expansion algorithm has been used to optimise the total system costs based on the optimal interconnection capacity increases. For more details on the zonal model methodology, readers should refer to the System Needs Study main report

The figures below present the results of the pan-European market studies for the 2030 NT scenario with the 2030 capacity needs increases ('Economic grid') and with the capacities for 2025 ('No grid').

In terms of marginal cost Spain, Portugal and France have the same value of 49€/MWh. Cross-border exchange capacities Europe-wide increase from 2025 to 2030 to enable a higher market integration with low average increase of marginal cost in Portugal and Spain by 1 €/MWh, and a high average increase in France by 5€/MWh.

[20] https://needs.entsoe.eu/

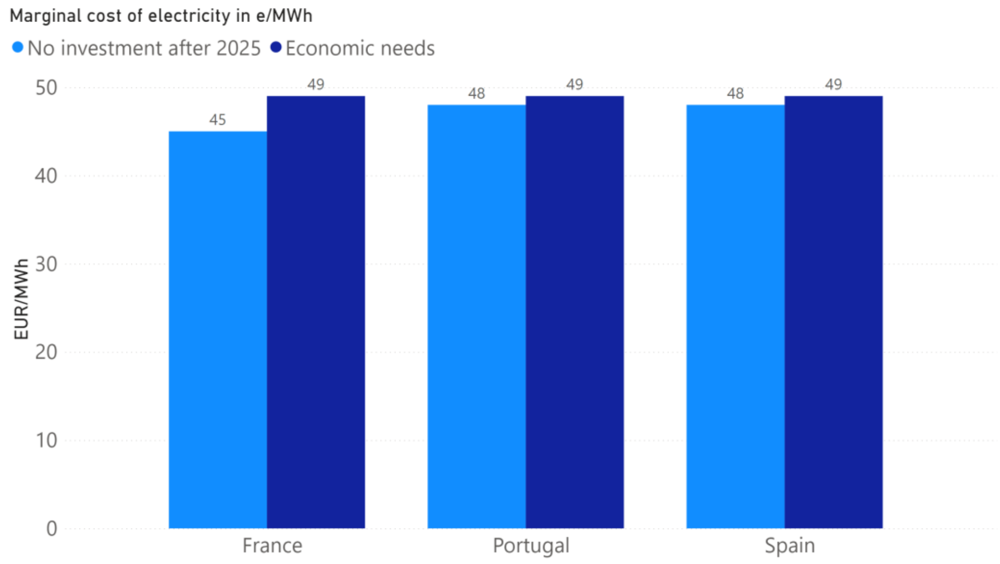

Figure 21: Yearly average of marginal cost in CSW region in the studied 2030 NT scenario with the 2030 'Economic grid' and 'no grid' investment after 2025

Curtailed energy resulting from high levels of renewable installed capacity is still expected, particularly in Spain. Results show 5.9 TWh/year in Spain and 0.7 TWh/year in Portugal and 0.4 TWh/year in France. The capacity need increases in Europe from 2020–30 (that is, already planned projects and additional identified interconnection needs in this analysis) allow the curtailed energy in the region to be reduced by 4.4 TWh.

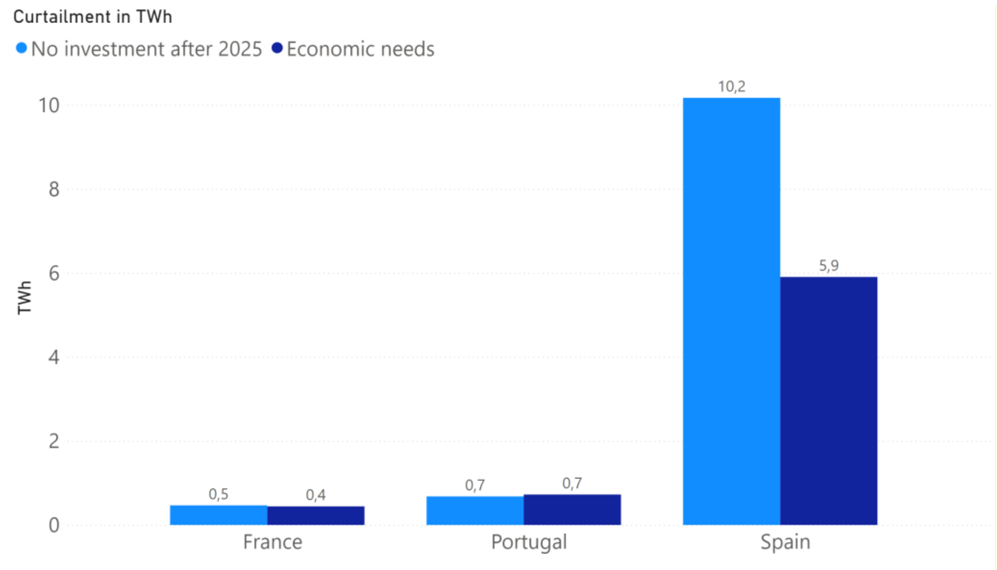

Figure 22: Yearly curtailed energy in CSW region in the studied 2030 NT scenario with the 2030 'Economic grid' and 'no grid' investment after 2025

Regarding CO_2 emissions, these depend greatly on the scenario, particularly on the RES share of capacity. In the NT scenario, the results are 17.0 Mtons/y in Spain, 7.4 Mtons/y in France and 3.4 Mtons/y in Portugal. Cross-border exchange capacities which increase Europe-wide 2025–2030 allow the CO2 emissions in the region to be reduced by 0.9 Mtons/y.

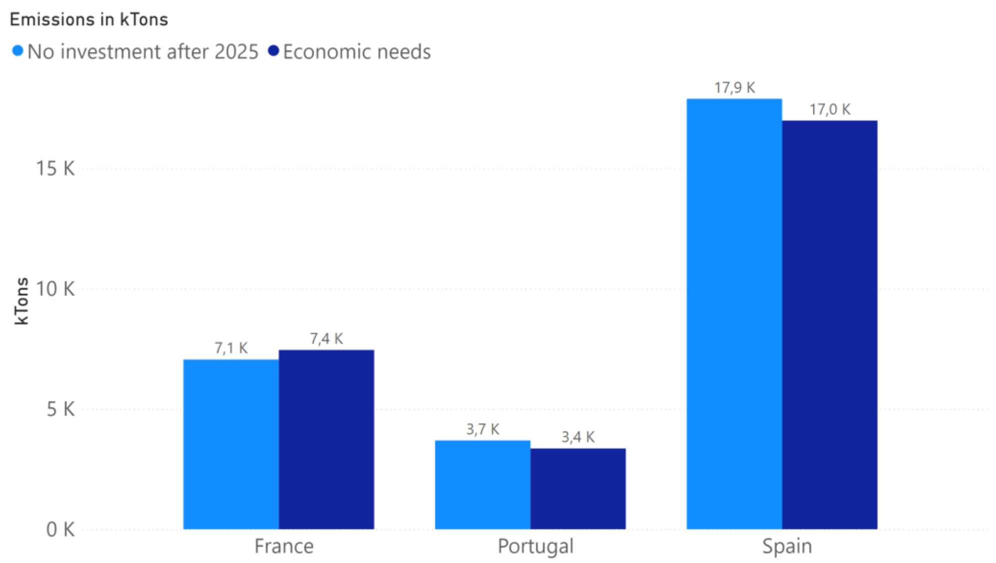

Figure 23: Yearly CO_2 emissions in CSW region in the studied 2030 NT scenario with the 2030 'Economic grid' and 'no grid' investment after 2025

3.3.2 2040 horizon

The figures below present the results of the Pan-European market studies for the 2040 NT scenario with the 2040 transmission capacity needs increases ('Economic grid') and with the capacities expected for 2025 reference grid ('no grid').

Figure 24 presents the annual generation by fuel type in the region for 2040 NT scenario with the 'Economic grid'. It is possible to see wind and solar energy (excluding the curtailed energy) contributing up to 52% of the generation to satisfy the native consumption in the region.

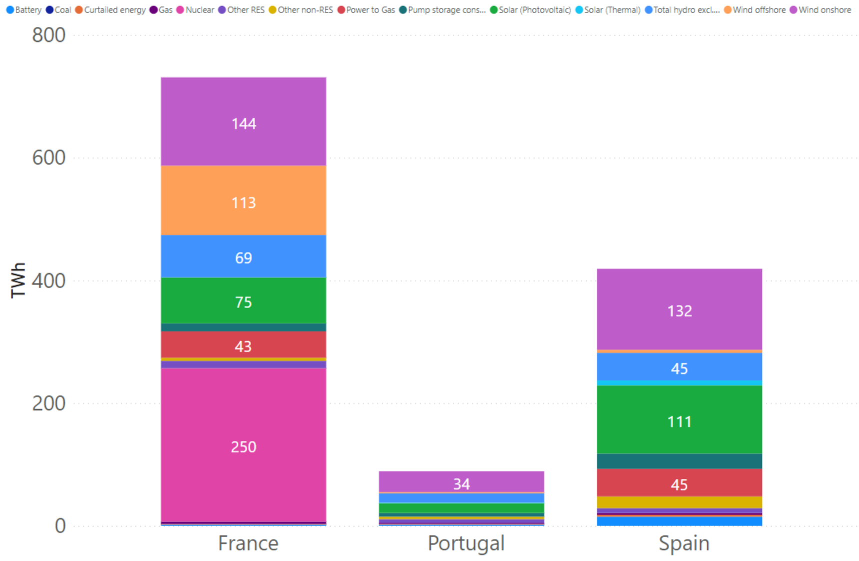

Figure 24: Annual generation by fuel type in the region in the studied 2040 NT scenario with the 2040 'Economic grid'

Considering the differences in the generation mix in the 2040 grid with the identified needs ('Economic grid') and the 2025 reference grid ('no grid'), an increase of batteries usage is foreseen, allowing a reduction of the RES curtailment and better access to the RES generation from the region, which will replace thermal generation in the countries inside the region and across Europe.

Curtailed energy resulting from high levels of renewable installed capacity is still expected in the region. The results reveal curtailed energy of 2.6 TWh/year in Spain, 1.4 TWh/year in Portugal and 1.4 TWh/year in France. Network capacities and other flexibility solutions (storage) increases in Europe from 2025–2040 (that is, projects already planned and additional identified capacity needs in this analysis) allow the curtailed energy in the region to be reduced by 9.7 TWh.

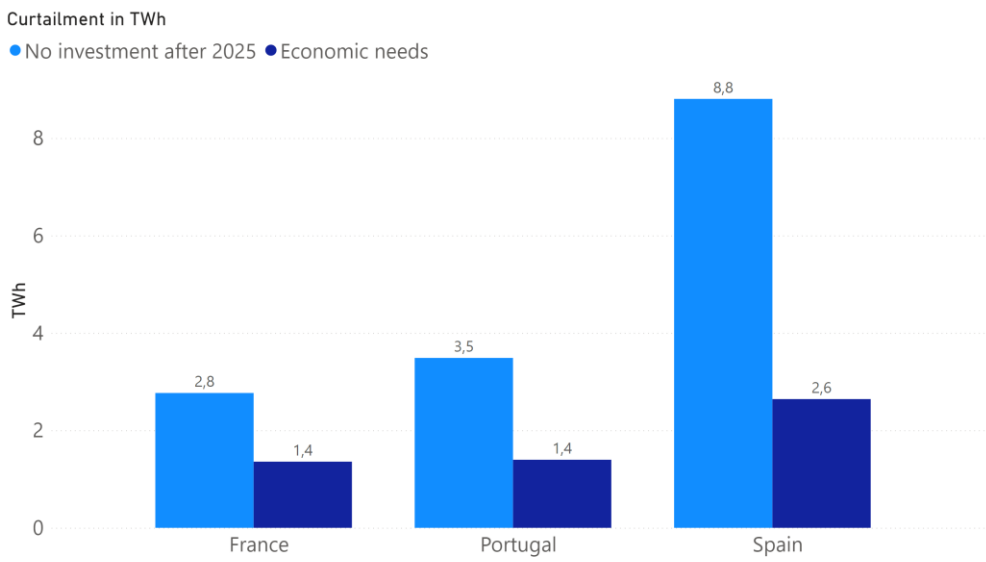

Figure 25: Yearly curtailed energy in CSW region in the studied 2040 NT scenario with the 2040 'Economic grid' and 'no grid' investment after 2025

Regarding CO_2 emissions, these depend greatly on RES share of capacity, whereas the results are 1.0 Mtons/y in Spain, 1.6 Mtons/y in France and 0.6 Mtons/y in Portugal. Cross-border exchange capacity increases and other flexibility solutions Europe-wide 2025–40 allow reductions in CO_2 emissions in the region by 3.7 Mtons/y, notably in Spain.

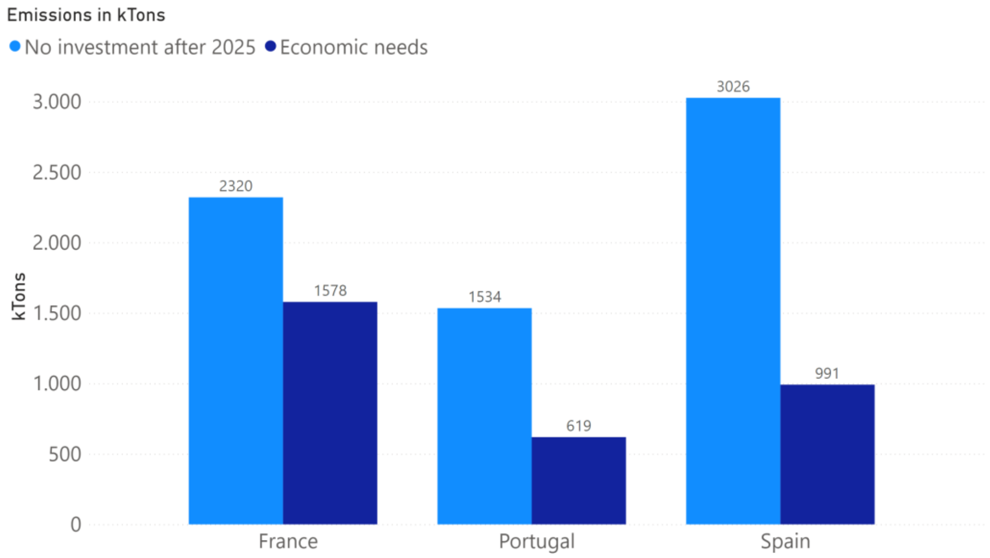

Figure 26: Yearly CO_2 emissions in CSW region in the studied 2040 NT scenario with the 2040 'Economic grid' and 'no grid' investment after 2025

Regarding marginal cost, Portugal with 53 €/MWh and Spain with average 55 €/MWh are generally higher than the 51 €/MWh identified in France. Cross-border exchange capacities and flexibility solutions Europe-wide increases 2025-40 will enable an average reduction of marginal cost in Spain of 1 €/MWh, while in France this shows an increase (2 €/MWh).

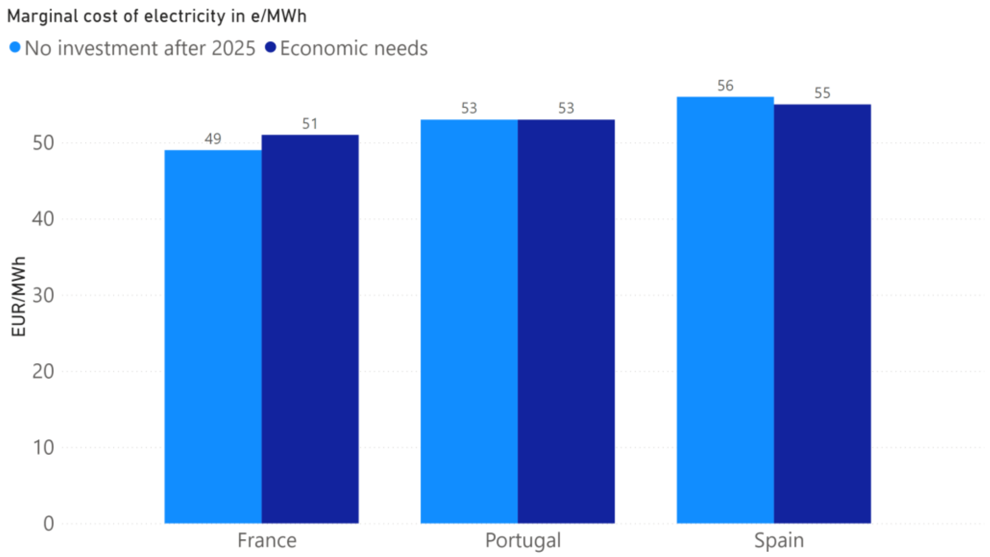

Figure 27: Yearly average of marginal cost in CSW region in the studied 2040 NT scenarios with the 2040 'Economic grid' and 'no grid' investment after 2025

With the foreseen 2040 grid, yearly average marginal cost spreads[21] are expected to be reduced significantly at almost all borders in the region in comparison to a 2025 grid. However, it should be noted that high differences are still expected within the CSW borders and also between the borders with the neighbouring countries, as is the case for France–Spain (11 €/MWh). Therefore, cost convergence is still not reached and important reinforcements in this border would still be needed .

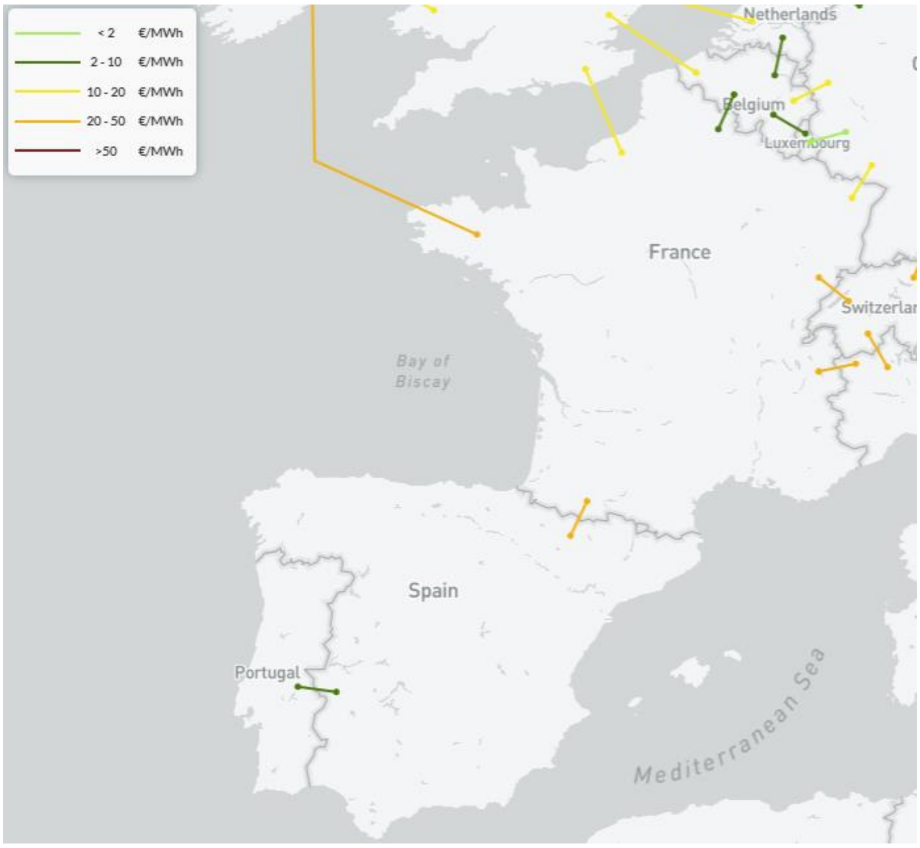

Figure 28: Average hourly cost differences in CSW region in the studied 2040 NT scenarios with 2040 'Economic grid'

Concerning country balances, France and Portugal are always net exporters (92 TWh and 6 TWh respectively) and Spain is a net importer (18 TWh).

[21] *The yearly average marginal cost spread is the yearly average of absolute values of costs spreads, then higher than the difference between yearly average marginal cost of two considered countries.*

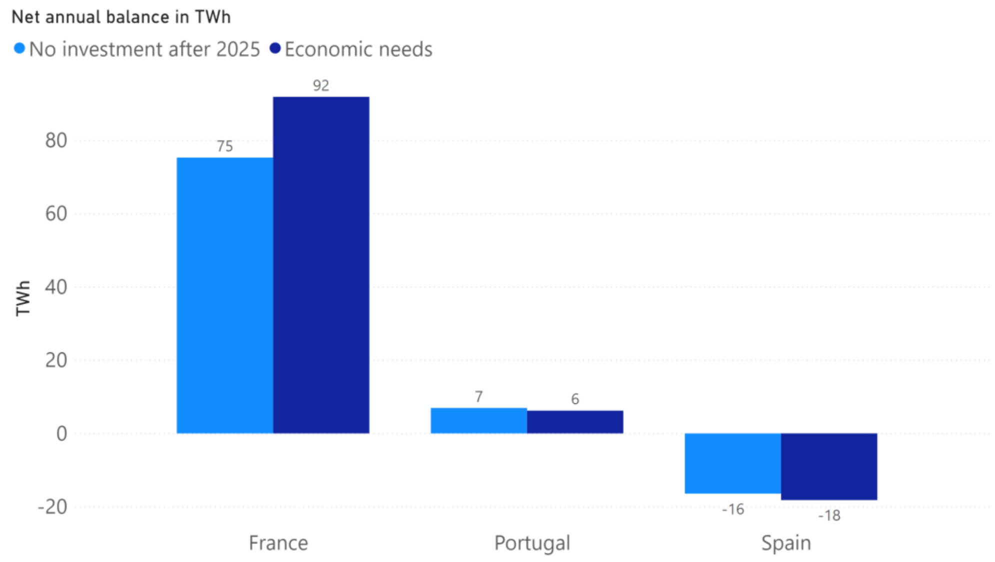

Figure 29: Net annual country balance in CSW region in the 2040 NT scenario with the 2040 'Economic grid' and 'no grid' investment after 2025

3.4 Network challenges

In general, because of the variable renewable generation, the interconnections in the 2040 NT scenario are challenged by larger and more volatile flows and higher-distance flows crossing Europe. This highlights that the current cross-border lines are inadequate.

Additional internal reinforcements are required to make the NT scenario feasible from a network perspective, which demands integrating the considerable amounts of additional renewable power generation, and to accommodate not only new power flow profiles but also higher volumes, both internal and cross-border.

The high prominence of RES technologies (mainly solar) on the Iberian Peninsula and in the south of France engenders much congestion on internal and cross-border lines in Spain, Portugal and France. Spanish and Portuguese solar generation will probably be located mainly in the South. Consequently, when solar generation production is high, the region will experience high flows internally on the Iberian Peninsula from south-to-north and also through the CSW region and towards central Europe. The current network was not designed for these new power flows profiles; therefore, a significant number of reinforcements are needed to alleviate this future congestion.

For the Portuguese system, the high solar generation mentioned previously induces a change in the direction of the current predominant flows, changing from north-to-south to south-to-north. During day hours with high solar production, severe congestions may be found, and a significant number of network reinforcements are needed to alleviate these future congestions. These conclusions were already detected in previous TYNDP editions and they have already been considered in the latest versions of the Portuguese national development plan, where several investments were considered to solve these congestions.

For the Spanish system, new large power flows across the country are experienced due to both cross-border capacity increases and RES integration, especially high volumes of solar in the south causing constraints in their path to the big demand areas in the centre of the country and on the Mediterranean coast. Several reinforcements valid for the mid- and long-term have been introduced in the recent Spanish network development plan, and others will need to be solved with internal reinforcements that still require analysis and will be affected by the cross-border needs here detected.

For the French system, the analysis carried out in the framework of the TYNDP 2022 IoSN confirms some areas of fragility on the French network. These were already identified in the French national development plan although with a higher level of congestion due to a more advanced energy transition (2040 horizon in the TYNDP vs. 2035 in the French national development plan) and an increase in exchange capacities on all borders.

An expert analysis was carried out to integrate the costs of internal reinforcements into the IoSN analysis. Nevertheless, the extent of internal reinforcements is highly dependent on many unknown factors, whose level of granularity is finer than that of the IoSN analysis: precise location of RES generation and nuclear decommissioning, for example. Furthermore, although it is possible to estimate the impact of a border reinforcement on the internal network, it is much more complex to anticipate the impact of a set of reinforcements such as the one found in the IoSN analysis, in which almost all the borders revealed a strong need for reinforcement. This would require a more in-depth study, which in turn would require prior confirmation of certain assumptions concerning the energy transition in France and its neighbouring countries.

There are some regional projects included in Chapter 6 that would help to solve some of these future problems. However, it is too soon to define the reinforcements needed for 2040 in detail, as the volumes of RES and the correct location of generation in the CSW region should be more certain.

4. Regional Studies

This chapter introduces studies performed outside the ENTSO-E RG CSW cooperation.

Beyond the necessity to efficiently balance 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 manner in which will be done, leading to new technical needs for the system. It also increases both the interdependency of TSO processes to operate the system in a secure and efficient manner, and the need to consider the challenges associated with the operation of the future system when designing the transmission network.

Individual characteristics and technology of the projects are tools to address this operational challenge, and the reason for the importance of the following studies.

4.1 Biscay Gulf

The Biscay Gulf project consists of a new HVDC submarine interconnection of 2,000 MW of capacity and 370 km along the Bay of Biscay, between the Spanish substation Gatica 400 kV and the French substation Cubnezais 400 kV, located close to Bordeaux. This project will increase the exchange capacity between the Iberian Peninsula and the rest of Europe by up to 5,000 MW for both importing and exporting.

For such an important project, it is necessary to perform studies to analyse the influence of the new connection on the behaviour of both the Spanish and French electrical systems, so as to identify if internal reinforcements are required and any issue or need that would be necessary to translate into a requirement for the HVDC connection within the Technical Specification, in order to ensure 5GW of exchange capacity.

Several studies have been addressed commonly by Red Eléctrica and RTE since 2017:

- Transient stability studies were performed by each TSO in its own country, applying national criteria after agreement on common scenarios for the study. The simulations showed no relevant issues, although in the particular case of maximum exchange from Spain to France with high renewable production in France and high nuclear production in the French southwest, the exchange programme should be reduced to ensure system security.

- Red Eléctrica and RTE have performed small signal stability studies, based on time and frequency domain simulations, concluding a similar situation to today and that the new HVDC enhances the damping of the system compared to present values as the active power through the AC tie lines is reduced. Even so, several mitigation measures (using setpoint on HVDCs, adding Statcoms…) to mitigate low-level damping for inter-area oscillations were identified and are currently in the deployment phase.

- Additional investigations were performed regarding the confirmation of no impact of subsynchronous resonance between the HVDC Biscay Gulf and some combined cycles near the new link, and regarding the power flow redistribution pattern when changing the HVDC setpoint, confirming that 50% of the flow would be assumed by the Hernani-Argia 400 kV line while 40% would flow through the eastern AC corridor.

- Red Eléctrica and RTE also performed static overload and voltage control studies focused on highlighting the internal and French needs from a steady-state perspective to reach 5 GW 30% of the time when the Biscay Gulf HVDC is commissioned, considering both the last national development plans.

On the other hand, from the implementation perspective, the project is currently in the phase of offers assessment and estimates to contract sign in 2023.

4.2 Additional studies developed on the Spain–France border

In addition to the Biscay Gulf studies, and to meet the 8 GW interconnection target between the Iberian Peninsula and the rest of Europe established in the Madrid and Lisbon Declarations, two projects in the central part of the border are planned to be commissioned in 2030. These projects, one in the Navarra–Landes area, and the other in the Aragón–Atlantique Pyrennes area, have been Projects of Common Interest of the EC since 2015.

To better define the details of these projects, its costs and benefits, determine which one should come first, investigate the internal reinforcement requirements in the Spanish and French networks and the optimisation of the flows on the border when considering four HVDC links in parallel with AC lines and two different modes of HVDC operation, angle difference control (ADC) and constant power control (CPC), a joint Planning Study between Red Eléctrica and RTE is in progress.

The first preliminary results obtained from the studies performed so far show:

- From the market perspective, results using both TSOs tools are consistent when discussing the SEW benefit. Values for this indicator are higher for the present TYNDP 2022 than those for the previous one (2020). Nevertheless, the costs distribution of SEW benefits requires further investigation.

- From the network perspective, results for additional internal reinforcements are needed, mainly in the Spain–France direction; in the French side in order to reach 8 GW 30% of the time as a minimum target. On the Spanish side, the reinforcements needed have already been planned and included in the current Spanish National Development Plan 2021–2026. The next steps have been defined and focused on the following topics:

- Assessed a higher capacity project (2x1500 MW for instance) for the 8 GW target.

- Initiate the assessment of the feasibility of the internal network reinforcements identified (on desks studies).

Assess the feasibility of the projects (for each one, Aragón–Atlantic Pyrenees and Navarra–Landes) by updating and completing the analysis performed in the past including technological update and cost revaluation.

4.3 Additional studies developed on the Portugal–Spain border

Considering the energy transition, especially decarbonisation and the integration of large amounts of renewable energy generation of different technologies in the Iberian Peninsula electrical system in the coming years, as foreseen in the NCEPs, REN and Red Eléctrica agreed to develop different joint studies regarding:

- Mid and long-term NTC assessment under new network conditions and generation mix;
- System Transient Stability/Frequency Stability in order to evaluate the stability and security of the Iberian electrical system; and
- Small Signal Stability to evaluate and dampen Inter-area Oscillation.

5. Future Challenges in the Region

This chapter provides an overview of the future challenges in the region and the possible future studies that could be performed.

5.1 Next 10 years period (2030 horizon)

The IoSN exercise indicates there is no need based on SEW to increase capacity beyond 4200 MW from Spain to Portugal and 3500 MW from Portugal to Spain, values that correspond to the already planned northern interconnection. In the short term, detailed network studies on this project need to be carried out commonly by Red Eléctrica and REN to deliver accurate values of NTC in this decade.

On the other hand, this IoSN exercise provides an economic grid need of 8000 MW on the France–Spain border. Beyond the Biscay Gulf project included in the starting grid, there are two projects already planned (the Navarra–Landes and Aragón–Atlantic Pyrenees interconnections), which are intended to reach a value of 8,000 MW, which own a PCI label. During the next few years, additional studies for these projects should be performed to be able to commission them on time.

In addition, in this decade additional studies could be needed to explore the cost and benefits of strengthening the existing interconnection between this region and North Africa.

Beyond cross-border projects, the proper integration of new storage facilities and other flexibility measures would need to also be further assessed.

5.2 Next 20 years period (2040 horizon)

The IoSN exercise provides an economic grid need of 9500 MW on the France–Spain border and interest to increase the capacity from Spain to Portugal to 5200 MW and from Portugal to Spain to 4500 MW. This long-term gap needs to be investigated in future releases of the TYNDPs to confirm it and be more precise on the timing for the need, which will also be looking for consistency with the evolution of projects already planned. Consequently, it is considered too early to propose projects for this detected need. In addition, it will be interesting to check the feasibility of potential projects and confirm the estimated costs that the candidate projects use as input for this exercise.

To summarise, some additional cross-border projects could be considered in the future if the trends identified in the 2040 scenarios are confirmed in the coming years. On the other hand, detailed analysis on internal networks will need to be performed to ensure the structural congestions derived from future scenarios are alleviated, ensuring both the flexibility and security of the system.

6. Appendix

6.1 Projects relevant for the region (TYNDP projects, PMI/PMI projects, other relevant projects)

The table and figure below show all approved projects submitted by project promoters during the TYNDP 2022 call for projects. The projects are at different stages, which are described in the CBA guidelines:

- Under Construction
- Planned but not permitting
- In Permitting
- Under Consideration

Depending on the state of a project, it will be assessed according to the CBA. A full table enumerating all European projects submitted can be found on the TYNDP 2022 homepage.

ID	Project name	TYNDP 2022 - Commissioning year	Status
1	RES in north of Portugal	2022	Under Construction
4	Interconnection Portugal-Spain	2024	In Permitting
16	Biscay Gulf	2027	In Permitting
85	Integration of RES in Alentejo	2023	Planned but not yet Permitting
270	FR-ES project -Aragón-Atlantic Pyrenees	2030	Planned but not yet Permitting
276	FR-ES project -Navarra-Landes	2030	Planned but not yet Permitting
378	Transformer Gatica	2025	Planned but not yet Permitting
379	Uprate Gatica lines	2026	Planned but not yet Permitting
1125	Offshore Wind Connection Occitanie	2030	Under Consideration
1126	Offshore Wind Connection PACA	2030	Under Consideration
1127	Offshore Wind Connection South Atlantic	2032	Under Consideration
1129	New RES at Minho region	2029	Planned but not yet Permitting
1012	P-PHES Navaleo	2026	In permitting
1027	P-PHES Cúa	2028	In permitting
1039	Pumped hydro Los Guajares	2026	Under consideration
1041	Pumped hydro Velilla	2028	In permitting
1054	Pumped hydro Aguayo	2026	In permitting
1052	P-PHES Buseiro	2028	Under consideration

* – Status of the least advanced investment

Table A1-1: TYNDP 2022 projects: CSW regional group

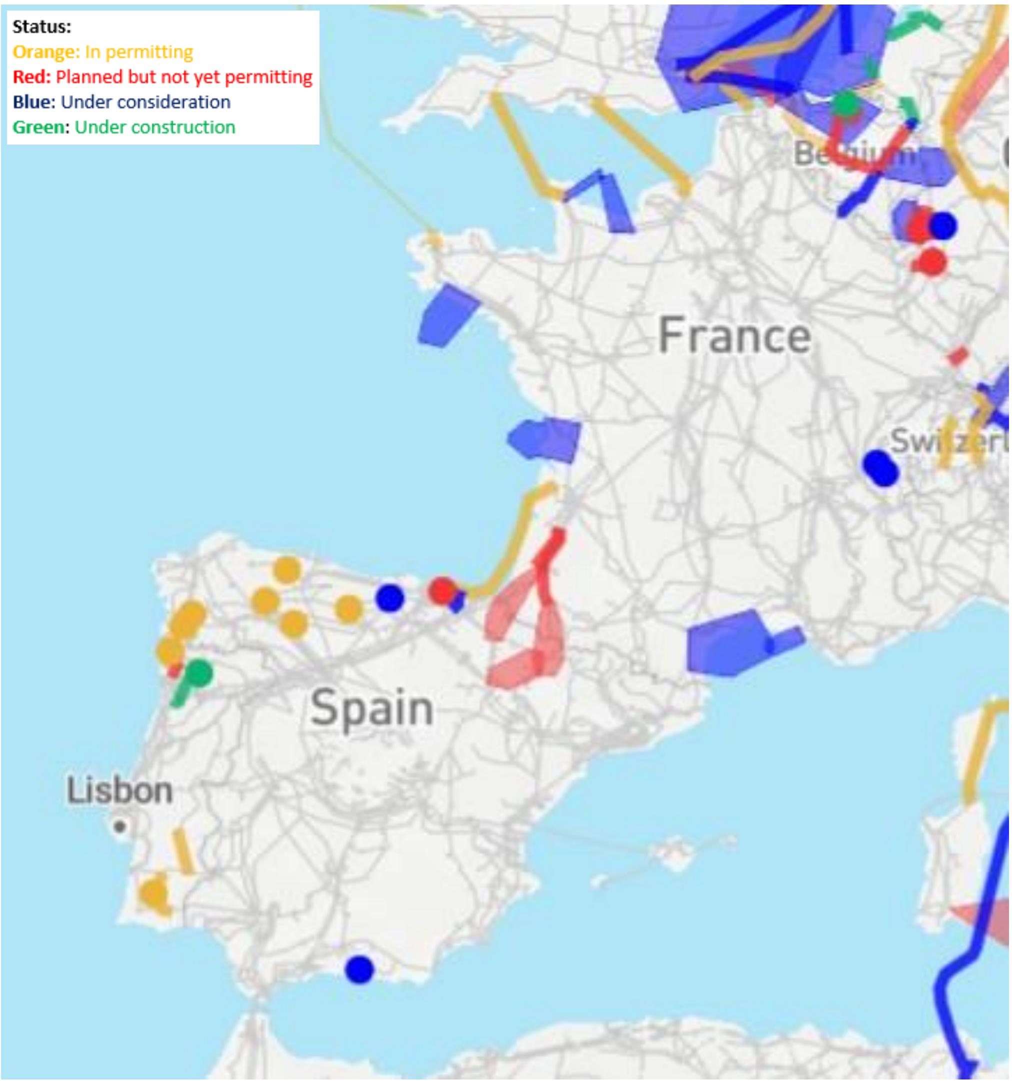

Figure A1-2: Projects to be assessed in the TYNDP CBA analysis

In this chapter, the CSW projects of regional significance are listed as they are needed to provide substantial and inherent support for the inclusion of Pan-European projects into the future transmission systems. Appropriately, all these projects include a description, the main driver, why they are designed to be realised in the future scenarios, the current expected commissioning dates and the expected commissioning date in the RgIP 2022 in the event that they were introduced in the previous RgIP.

There are no criteria for the inclusion of the projects of regional significance in this list. They are included based purely on the project promoter's discretion as to whether the project is relevant for inclusion.

In the table below, projects of regional and national significance in CSW region are listed.

Country	Project Name	Investment From	To	Expected commissioning year RgIP 2020	Current expected commissioning year	Description	Main drivers	Included in RgIP 2020?
FRANCE	Sud Aveyron			2022		New substation on the 400-kV Gaudière–Rueyres line for local RES integration.	RES integration	Yes
FRANCE	Dambron–Chaingy	Dambron	Chaingy	>2030		New line 400kV	Maintenance, RES integration and market integration	No
FRANCE	Eguzon–Marmagne 400kV	Eguzon	Marmagne	>2030		Reconstruction in double circuit	Maintenance, RES integration and market integration	Yes
FRANCE	Long-term perspective “Façade Atlantique”			>2030		Upgrade of the north–south 400kV corridor between Nouvelle Aquitaine and the Loire valley, under study	RES integration and market integration	Yes
FRANCE	Long-term perspective “Rhône – Bourgogne”			>2030		Upgrade of the north–south 400kV corridors between Lorraine and Alsace and Franche–Comté, between Champagne–Ardenne and Bourgogne and in the Rhone valley Upgrade of the 400kV east-west corridors between Languedoc and the Rhone valley and in the West of Provence Under study.	RES integration and market integration	Yes
FRANCE	Long-term perspective “Normandie – bassin parisien”			>2030		Upgrade of the north–south 400kV corridor between Normandy and Paris basin, under study	RES integration	Yes
FRANCE	Long-term perspective “Massif central–Centre”			>2030		Upgrade of the north–south 400-kV corridors in the Massif central-Centre, under study	RES integration and market integration	Yes
SPAIN	Connection Navarra–Basque Country	Ichaso	Muruarte/ Castejón	2023	2024	New AC OHL 400 kV double circuit Ichaso-Castejón/Muruarte 400 kV (one circuit Castejón–Ichaso, second Muruarte–Ichaso)	Integration of RES and accommodation of flows	Yes
SPAIN	New corridors Aragón–Levante	Morella and Mezquita	La Plana and Godelleta	2025	>2026	Two new 400 kV connections between Aragón and Levante: a new double circuit between Morella and La Plana substations and a new axis Mezquita-Platea-Godelleta	Integration of RES and accommodation of flows	Yes
SPAIN	North Axis in Basque Country (Ichaso–Abanto/Gueñes)	Ichaso	Abanto and Gueñes	2020	2023	New double circuit OHL that will consist of the Ichaso–Abanto and Ichaso–Gueñes lines	Market integration	Yes
SPAIN	Reinforcement of 400 kV grid in Asturias	Gozón	Soto	2022–2027	2024	This project comprises two new 400 kV OHL line between Soto, Grado and Gozón, whose main purpose is to support the distribution network; the connection between Grado and	Security of supply and market integration	Yes

						Soto intends to reinforce the Asturian connection with the centre of the country		
SPAIN	Uprate of Transpireneean Axis (Sabiñánigo–Tescalona–Escalona–TForadada – La Pobla)	Sabiñanigo	La Pobla	2019-2021	2024	Uprating the 220 kV OHL Sabiñanigo–T-Escalona–Escalona–T-Foradada–La Pobla	Market integration	Yes
SPAIN	Second Link Spanish Mainland–Mallorca**	Fadrell	San Martín	<2025	2026	HVDC Subsea cable 2x500MW link from Valencia to Mallorca connecting to a new 400 kV substation Fadrell in the peninsula	Market integration and interconnection between asynchronous systems	Yes
SPAIN	Reinforcement of Southern Aragón–Cataluña axis	Escatrón	Secuita	<2025	2024	The investment consist of two new lines, one in 400 kV and one in 220 kV from Escatrón to Els Aubals and the new substation La Secuida	RES integration and Market integration	Yes
SPAIN	Reinforcement of the Axis La Serna–Magallón 400 kV	La Serna	Magallón	2025-2030	2025	New 400 kV double circuit between both substations	RES integration and Market integration	Yes
SPAIN	Repowering of 400 kV axis	Mudarra and Aldeadávila	Herrera and Almaraz/Arañuelo	2020	2022	Uprating of the 400 kV axis Mudarra-Grijota-Herrera and DC Aldeadávila–Hinojosa–Almaraz/Arañuelo	RES Integration and Market integration	Yes
SPAIN	FACTS in Pierola 400 kV	Pierola	Pierola	2024-2028	>2026	Flexible alternating current transmission system (FACTS) TTCC device in Pierola substation	Security of supply	Yes
SPAIN	STATCOM in Vitoria, Tabernas, Moraleja and Lousame	Vitoria	Vitoria	2024-2028	2022–2026	STATCOM devices in the substations of Vitoria, Tabernas, Moraleja and Lousame	Security of supply	Yes
PORTUGAL	Falagueira-Fundão	Falagueira	Fundão	2020	commissioned	New 400 kV double circuit OHL, with one 400 kV circuit installed between the existing substation of Falagueira and the future substation of Fundão.o	RES integration	Yes
PORTUGAL	Falagueira–Estremoz-Divor–Pegões	Falagueira	Estremoz, Divor and Pegões	2021	commissioned	New 400kV OHL Falagueira–Estremoz–Divor–Pegões axis including the new substations of Divor and Pegões	Security of supply and RES integration	Yes
PORTUGAL	Rio Maior–Fanhões	Rio Maior	Fanhões	2026–2028	2023–2024	New 400-kV OHL Rio Maior-Fanhões	Security of supply and RES integration	Yes
PORTUGAL	Sines–Vale Pereiro–F.Alentejo	Sines	Vale Pereiro and F. Alentejo	-	2025–2026	New 400-kV OHL Sines–Vale Pereiro–F. Alentejo and Vale Pereiro switching station	RES integration	No
PORTUGAL	F.Alentejo–Pegões–Rio Maior	F.Alentejo	Pegões and Rio Maior	-	2025–2026	New 400 kV double circuit OHL F.Alentejo–Pegões–Rio Maior.	RES integration	No
PORTUGAL	Rio Maior-Batalha	Rio Maior	Batalha	-	2025–2026	New 400-kV OHL Rio Maior–Batalha.	RES integration	No
PORTUGAL	Lares			-	2025–2026	Lares switching station and modification of lines.	RES integration	No
PORTUGAL	Paraimo–Arouca–Recarei			-	2025–2026	New 400 kV OHL Paraimo–Arouca–Recarei, Arouca switching station and modification of lines.	RES integration	No
PORTUGAL	Fundão–V.N. Foz Coa	Fundão	V.N. Foz Coa	-	2025–2026	New 400 kV OHL Fundão-V.N Foz Coa, V.N Foz Coa switching station and modification of lines.	RES integration	No

6.2 Additional regional projects in the CSW Regional group

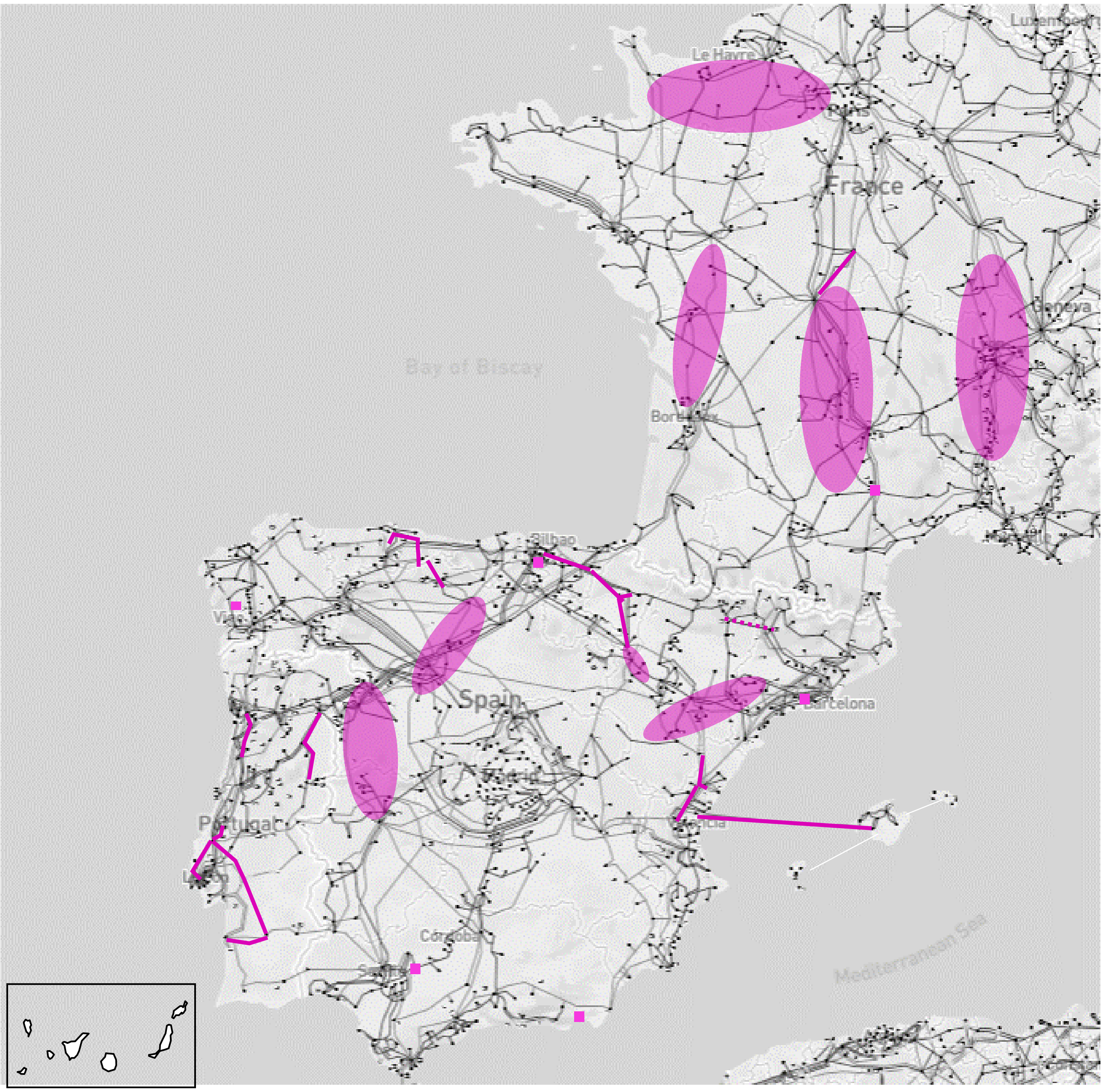

Figure A1-3: Additional regional projects in the CSW Regional group

6.3 Links to NDPs

Portugal

Complying with legislation, in March 2021, Rede Eléctrica Nacional, S.A. (REN) submitted a draft proposal for the Portuguese National Development Plan for the electricity transmission network for the period 2022–2031 (PDIRT 2022–2031) to the General Directorate of Energy and Geology (DGEG) and the Portuguese Energy Services Regulatory Authority (ERSE).

Between May–June 2021, the PDIRT 2022–2029[22] proposal was submitted for public consultation organised by ERSE[22] to gather information and comments from various economic agents, consumers and other stakeholders.

Following this public consultation period, DGEG and ERSE issued its opinions on the PDIRT 2022–2031 proposal. Considering both opinions, REN subsequently prepared a new PDIRT 2022-2031 proposal, which was submitted to DGEG in November 2021.

Spain

The network development plan for the period 2021–2026 has been approved by the Spanish Ministry Council on the 22 March 2022. It was the result of a three year process, open to the participation of all members of society through the submission of proposals for development between March and June 2019; the participation in a public consultation between February and April 2021.

The Network Development Plan 21–26 will prepare the Spanish transmission grid to be able to connect and integrate more renewable energy in the coming years: thanks to its developments, 67% of electricity generation will originate from RES by 2026.

In addition, it has been achieved with an approach based on efficiency, trying to maximise the use of the existing network (8000 km of the existing network will be repowered), not only by conventional reinforcements such as uprates, upgrades, change of conductors or increase of voltage, but also through the incorporation of elements in the transmission network that take advantage of the latest technological developments available, in response to the system's need for flexibility and greater use of the existing network (Dynamic Line Rating, synchronous compensators, FACTs, full integrated batteries to optimise the network, etc).

The network development plan can be consulted on a specific website[23] where the main key aspects are explained, and both the main report and executive summary are available. In addition, this

[22] https://www.erse.pt/comunicacao/destaques/erse-coloca-em-consulta-publica-a-proposta-de-pdirt-e-2021/
[23] https://www.planificacionelectrica.es/en

website includes an interactive map of projects that allows navigation through the main projects, and consultation of its project sheets, in which drivers, costs and benefits are displayed.

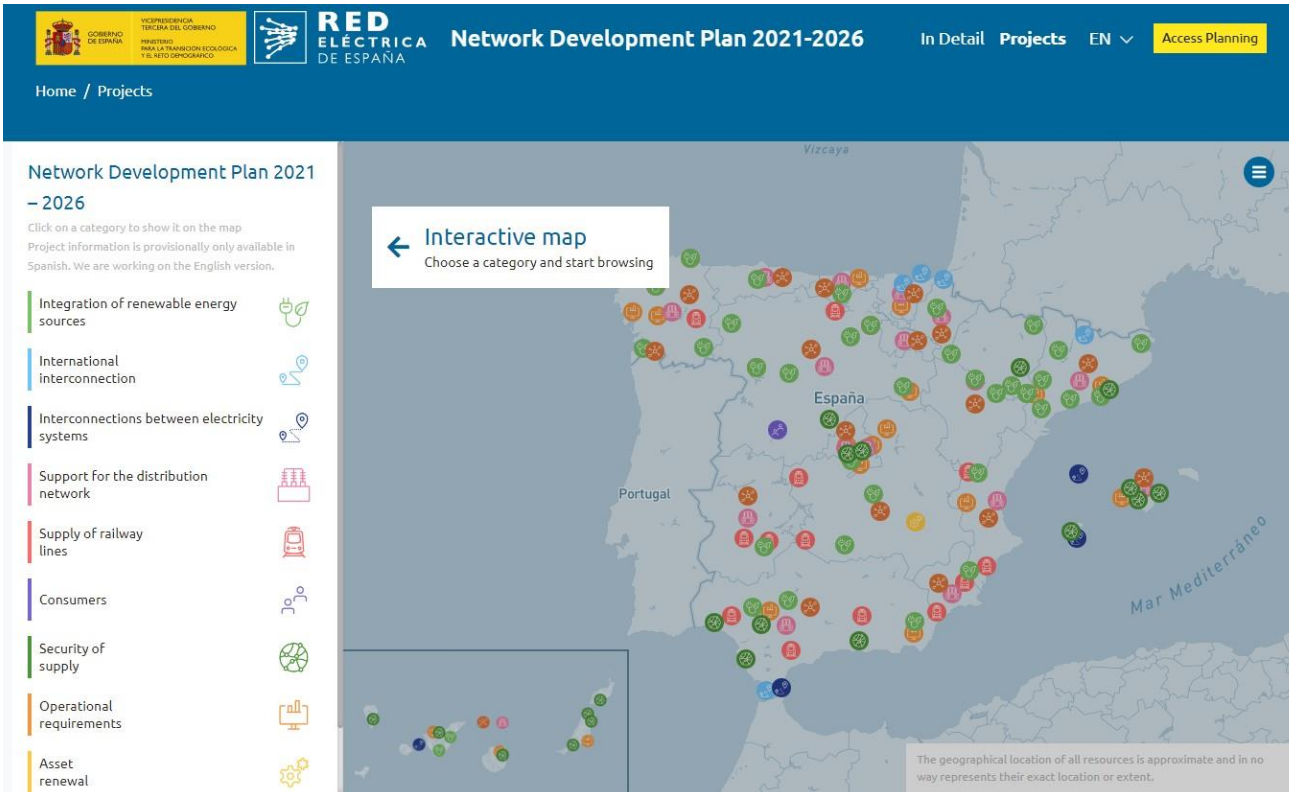

Figure A-14: Interactive map of projects of the Spanish National Development Plan 2021–2026

France

France is fully engaged in the energy transition. The draft energy-climate law currently being considered by the French Parliament has committed the country to carbon neutrality by 2050.

RTE's'schéma décennal de développement du réseau1' (or SDDR) is the French transmission network development plan. It was published in 2019. It sets forth a proposal for the way in which the transmission system should evolve over the next 15 years in order to meet public targets, highlighting the challenges and possible margins for manoeuvre, as well as the areas in which there needs to be coherence. It serves as an operational interpretation of the draft multi-annual energy programme and may change, depending on the end documents (the energy law, the national low-carbon strategy and the multiannual energy programme) and opinions formulated about the draft SDDR (by the ministry, the French energy regulator and the Environmental authority). It lists the existing levers that need to be actioned to ensure that the networks do not end up constituting an insuperable obstacle to the energy transition, but instead end up facilitating it

Schéma décennal de développement de réseau 2019 - Synthèse – English version.pdf (rte-france.com)

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