Ten-Year Network Development Plan 2020

Regional Investment Plan
Continental South West

August 2020 · Draft version prior to public consultation

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1. EXECUTIVE SUMMARY

1.1 Key messages

The historical main drivers for grid development in the region have been reported in every release of the RgIP and TYNDP:

- On the one hand, the insufficient cross border capacity, in order to allow the following:
  - the completion of the Iberian Electricity Market (MIBEL) through the reinforcement of 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 RES integration. The Iberian Peninsula has been a forerunner in the installation of renewable energy (hydro, solar but mainly onshore wind), and in the integration of this production into the system, with new network infrastructure in Portugal and Spain and smart management such as the Spanish renewable control centre (CECRE).

Both issues remain a challenge in the region 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 is focused on the year 2040, with the new 2040 National Trend (NT) scenario from the Scenario Report published in June 2020 and includes an assessment of what would happen with the system in case of encountering the 2040 NT scenario while retaining the 2025 grid (that is, a no investment grid after 2025). Additionally, an analysis of the identification of system needs was developed as well for the 2030 NT scenario.

The principal findings of this analysis are as follows:

- **Change in the generation portfolio towards a more carbon-free system**
  The 2030 and 2040 scenarios already show a transition from thermal to renewable generation, including the **partial phase-out of nuclear in France and a complete phase-out of coal in the Iberian Peninsula**.

  The optimization of renewable energy sources (RES) performed in the 2030 and 2040 top-down scenarios resulted in the assignment to the continental south west (CSW) region of a **massive increase 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.

- **Need for a further market integration in the region, with special focus on the isolation of the Iberian Peninsula**
  In spite of the strong efforts of 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 (see 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[1]), **Spain will not yet fulfill the 10% objective for 2020**. Moreover, **needs for cross-border development will also be attached to the 15% 2030 objectives**.

The current analysis also reveals some additional needs in the 2030 and 2040 horizon related to cross border development, especially in reinforcing the Iberian Peninsula with the remainder of Continental Europe, that should be carefully analyzed 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 curtailed energy in the region** with both 2025 reference grid and 2040 grid.

  In the face of the 2040 NT scenario, the network as it will exist by 2025 will not be able to accommodate all the RES generated. The renewable curtailed energy could amount to around 53,1 TWh in Spain, 18,5 TWh in Portugal, and 11,7 TWh in France without new network reinforcements beyond those included in the 2025 reference grid ('no investment after 2025'). Taking into account the high potential of the region in terms of RES resources, this curtailment shows the limited possibilities on supporting EU climate goals from the Iberian Peninsula without grid development.

  In fact, enabling future RES integration will represent a key challenge. The solution for this RES integration challenge will not be unique. 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**
  High use of RES technologies (mainly solar power) in 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, especially in the South-North direction** for which the grid was not designed. Therefore, these new flows incorporating higher volumes and variable directions that may be opposite to those currently known result in cross-border and internal congestions in the long term. In the light of the 2040 scenarios, it is foreseen 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 materialize, c**ross-border and important internal reinforcements of today's grid will be needed** to make the grid fit for the integration of renewable generation keeping the high security of supply standards.

  Nevertheless, to determine whether each investment need is sufficiently robust and whether the benefits to socioeconomic welfare (SEW) and other areas are enough to compensate for 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 a project 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 system adequacy (to ensure the fulfillment of the N-1 conditions stated in the network codes in order to avoid energy not

[1] https://ec.europa.eu/energy/sites/ener/files/documents/communication_on_infrastructure_17.pdf

supplied), but it will go beyond these issues. For instance, **flexibility, dynamic issues and system inertia and demand-side response** will gain importance in the security of supply.

1.2 Future capacity needs

The first phases of the TYNDP-2020 process concerned 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, capacity increases, which have a positive impact on the system, were identified[2] for the 2030 and 2040 NT scenarios. A European overview of these needs are presented in the European System Need report developed by ENTSO-E in parallel with the Regional Investment Plans 2020. Identified needs for transmission capacity increases at the borders of the CSW-region, are presented in the maps below (Figure 1.1).

The overall needs for capacity increases identified in the analysis in 2040 horizon are 5000 megawatts (MW) in the Spain-France border and 4000 MW in the Portugal-Spain border additionally to the 2025 exchange capacities from the reference grid. These capacity increases showed potential economically viability, because the benefits obtained (only SEW in this assessment) outweigh the estimated costs of the potential increases. The estimated costs also affect the results within the region, such as on the French-Spanish border where it has been considered a cost of underground high-voltage direct current (HVDC) potential project to cross the border.

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 allow for a reduction of the generation costs in the CSW region by 510 M€/year
- They would reduce the cost spread between France and Spain by around 15 €/MWh and between Portugal and Spain by around 10€/MWh.
- They would allow integrating 36,6 TWh/year of renewable energy in the CSW region; would otherwise be curtailed. This value represents 4.2% of the total demand in the CSW region or 5.6% of the total production from wind and solar energy in the CSW region.
- They would enable an overall reduction of CO2 emissions in Europe, with a reduction up to 2,5 Mtons/year of CO2 emissions in CSW emissions.

Although the quantified benefits for the CSW region presented in this report result from the Europe-wide increase of cross-border capacities, the role of capacity increases inside the CSW region on Portugal-Spain border and France-Spain border is of course essential to form the major part of these benefits.

[2] *For a description of the methodology used, see chapter 0.*

Figure 2.1: Identified capacity increase needs between years 2025 and 2040

This map confirms that projects already at stake in the TYNDP 2018 respond to a real system need for more cross-border capacity and reflects that ambitious RES scenarios, such as the ones used for TYNDP 2020, could require more exchange capacity.

Here are the cross-border projects that are already addressing this need in the 2020-2040 horizon and that will be analysed in the TYNDP2020:

- New northern interconnection between Portugal and Spain in Minho/Galicia regions due to be commissioned by 2022 as part of the TYNDP 2020 Reference Grid (PCI 2.17 in the 2019 PCI list);
- Biscay Gulf project between Spain and France, due to be commissioned by 2027 as part of the TYNDP 2020 Reference Grid, which should generate 2.2 GW extra capacity (PCI 2.7 in the 2019 PCI list);
- 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 2019 PCI list);
- BRITIB project between Spain, France and Great Britain, due to be commissioned by 2026

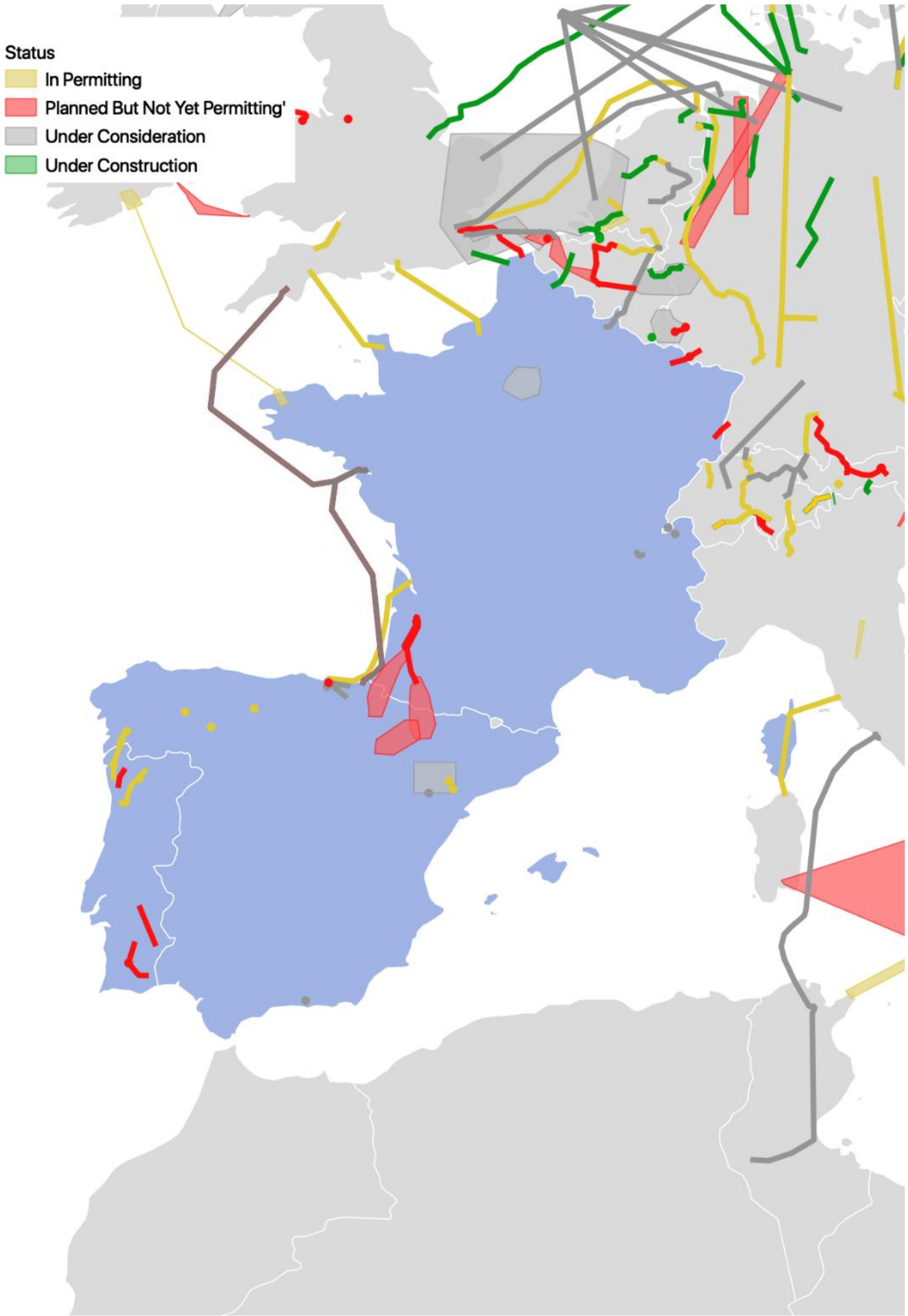

Figure 1.1: Projects to be assessed in TYNDP CBA analysis

Beyond these projects, there are still some gaps in the 2040 capacities needs obtained in the identification of system needs. Its analysis still needs to be investigated in future TYNDP releases. As of now, it is not robust enough, 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.

The cost-benefit analysis (CBA) assessment will be performed for those cross-border projects previously mentioned, some internal projects and also some storage projects:

- Reversible Pumped-Storage Hydroelectric Exploitation, Mont Negre, in Zaragoza
- Purifying Pumped Hydroelectric Energy Storage (P-PHES), Navaleo, in León (PCI 2.28 in the 2019 PCI list)
- Two reversible hydroelectric plants, Gironés and Raimats, in Tarragona(PCI 2.28 in the 2019 PCI list)
- Purifying Pumped Hydroelectric Energy Storage (P-PHES), Cúa, in León (PCI 2.28 in the 2019 PCI list)
- SR Mar de Aragon
- Reversible Hydraulic Power Plant Los Guajares, Andalucía
- Purifying – Pumped Hydroelectric Energy Storage "Velilla del Río Carrión" (P-PHES VELILLA), Castilla y león
- Distributed network of Hydrogen storage and production by electrolysis with re-electrification through a fleet of FCEVs

2. INTRODUCTION

2.1 Regional Investment Plans as foundation for the TYNDP 2020

ENTSO-E's Ten-Year Network Development Plan (TYNDP) is the most comprehensive planning reference for the pan-European electricity transmission network. Released every even year, it presents and assesses all relevant pan-European projects at a specific time horizon, as defined by a set of various scenarios to describe the future development and transition of the electricity market. The TYNDP serves as basis to derive the EU list of European Projects of Common Interest (PCI).

An essential part of the TYNDP2020 package, the six Regional Investment Plans, address challenges and system needs at the regional level, for each of ENTSO-E's six system development regions Figure 2.1).

Figure 2.1: ENTSO-E's six system development regions

The regional investment plans are part of the TYNDP2020 package, which also includes, among others, the report '[Completing the map – Power system needs in 2030 and 2040'](#) and the [Scenarios report](#), describing the scenarios serving as basis for the System Needs study and the regional investment plans.

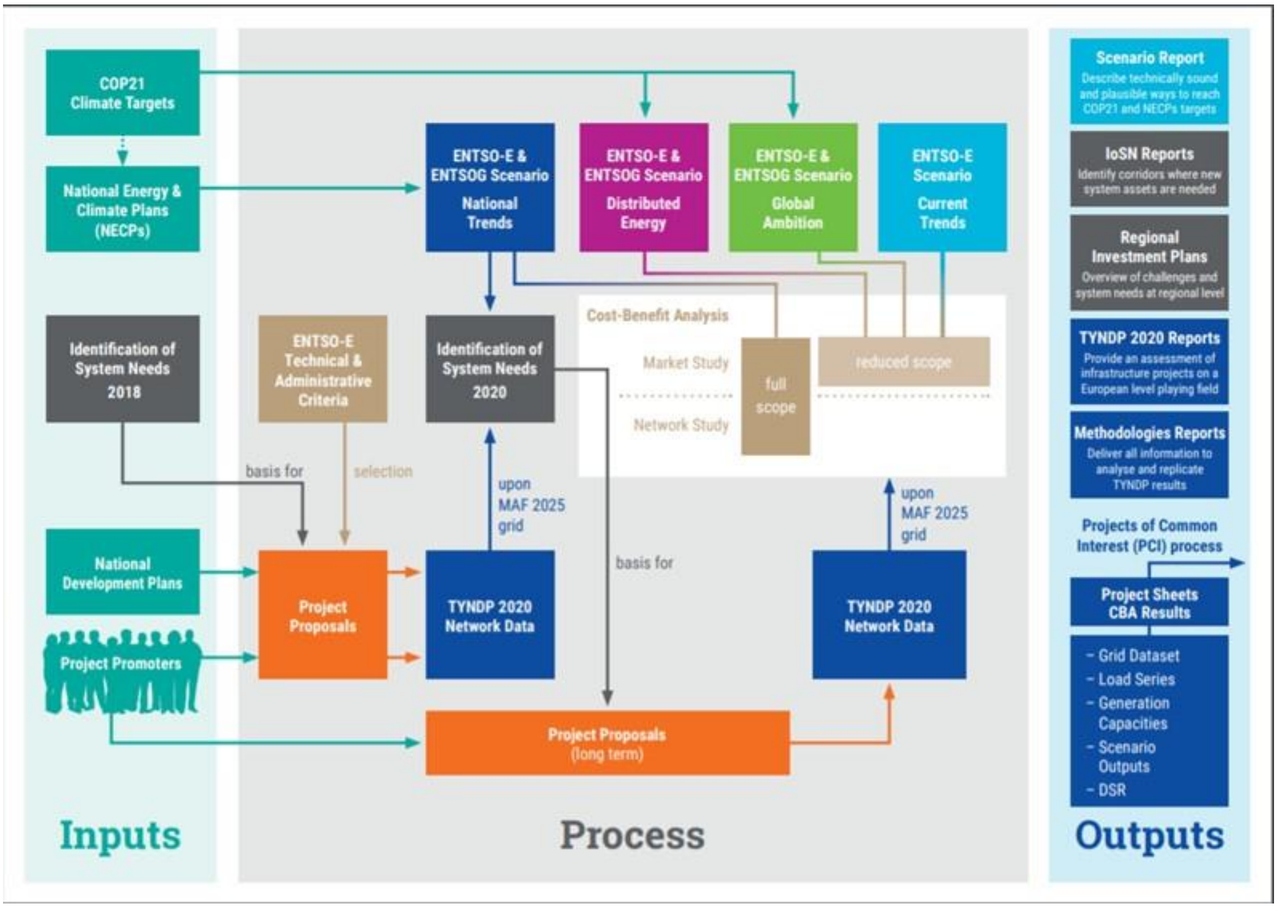

Figure 2.2: Overview of TYNDP 2020 process and outputs

2.2 Legal requirements

Regulation (EU) 2019/943 Article 34 (recast of Regulation (EC) 714/2009) states that TSOs shall establish regional cooperation within ENTSO- E and shall publish regional investment plans every two years. TSOs may take investment decisions based on regional investment plans. Article 48 further states that ENTSO-E shall publish a non-binding community-wide Ten-Year Network Development Plan, which shall be built on national investment plans and take into account regional investment plans and the reasonable needs of all system users and shall identify investment gaps.

In addition, the TYNDP package complies with Regulation (EU) N° 347/2013, which defines new European governance and organisational structures that shall promote transmission grid development.

2.3 Scope and structure of the Regional Investment Plans

The Regional Investment Plans are based on pan-European market study results combined with European and/or regional network studies. They present the current situation of the region as well as the expected future regional challenges, considering a 2040 time-horizon. To illustrate circumstances that are especially relevant to each region, available regional sensitivities and other available studies are included in the plans. The operational functioning of the regional system and associated future challenges may also be addressed.

As one of the solutions to the future challenges, the TYNDP project has performed market and network studies for the long-term 2040 time horizon National Trend scenario to identify investment needs, that is, cross-border capacity increases and related necessary reinforcements of the internal grid that can help to mitigate these challenges.

In addition, the Regional Investment Plans list the regional projects from the TYNDP 2020 project collection. In the summer of 2020, each of these projects will be assessed and presented in the final TYNDP 2020 package.

The approach followed by the regional investment plans is summarised in 2.3.

Figure 2.3: Mitigating future challenges – TYNDP Methodology.

The current document comprises seven chapters with detailed information at the regional level:

- Chapter 1 presents the key messages about the region.
- Chapter 2 sets out in detail the general and legal basis of the TYNDP and regional investment plans and provides a short summary of the general methodology used by all ENTSO-E regions.
- Chapter 3 covers a general description of the present situation of the region. The future challenges of the region are also presented when describing the evolution of generation and demand profiles

in the 2040 horizon but considering a grid as expected by the 2025 horizon. This chapter also includes links to the respective national development plans (NDPs) of the countries of the region.

- Chapter 4 includes an overview of the regional needs in terms of capacity increases and the main results from the market and network perspectives.
- Chapter 5 is dedicated to additional analyses conducted inside the regional group or by external parties outside the core TYNDP process.
- Chapter 6 contains the list of projects proposed by promoters in the region at the Pan-European level as well as important regional projects that are not part of the European TYNDP process.
- The Appendix includes the abbreviations and terminology used in the whole report as well as additional content and detailed results.

The actual Regional Investment Plan does not include the CBA-based assessment of projects. These analyses will be developed in a second step and presented in the final TYNDP 2020 package.

2.4 General methodology

The Regional Investment Plans build on the results of studies, called 'Identification of System Needs', which are conducted by a European team of market and network experts originating from the six regional groups of ENTSO-E's System Development Committee. The results of these studies have been discussed and, in some cases, extended with additional regional studies by the regional groups to cover all relevant aspects in the regions.

A more detailed description of this methodology is available in the report 'Completing the map – Power system needs in 2030 and 2040'.

2.5 Introduction to the Continental South West region

The CSW regional group, under the scope of the ENTSO-E System Development Committee, includes the following countries and TSOs (Figure and 2.1).Figure **2.4**: ENTSO-E (System Development Committee Continental South West region)

Figure 2.4: 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	REE - Red Eléctrica de España S.A.U

Table 2.1: ENTSO-E Regional Group Continental South West membership

The CSW regional group is facing two main challenges related to the transmission infrastructure development currently being addressed by the three countries involved: 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. This is a challenge faced today that will remain in the future, independently of the generation scenarios considered.

There is a political support for these cross-border reinforcements, both at the European and at the 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[3]. In the case of Spain, this ratio is expected to amount to around 6% by 2020.

[3] 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 obtained as the sum of importing GTCs/total installed generation capacity.

- The European Council of October 2014[4] endorsed the proposal by the European Commission of May 2014[5] 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 make the 15% target operational, the European Commission decided to establish a Commission Expert group on electricity interconnection targets to provide technical advice. The conclusion of this group were published in November 2017 in the report entitled 'Towards a sustainable and integrated Europe'[6].
- 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 the outcomes from the Expert group on electricity interconnection targets) and requiring 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 among the governments of Spain, France, and Portugal, the EC and the European Investment Bank gave support to ongoing regulations and studies of TSOs. 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 to reach 8 GW capacity on the France-Spain border.
- A High Level Group on Interconnections for South-West Europe, established after the Madrid Summit, with representatives from the European Commission, representatives from the governments, national regulatory authorities and the TSOs to monitor closely the progress of the works.
- In July 2018, the Lisbon Declaration of the second Energy Interconnections Summit among the governments of Portugal, France and Spain, the European Commission 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 instance, for French and Spanish regulators to agree, on 21 September 2017, on a proposal for the financial scheme of a new interconnector via Biscay Gulf; this agreement has constitute an important boost for the cross-border development.

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

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

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

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

2.6 Evolution since the RgIP 2017

Since the publication of the previous RgIP 2017, that was published for public consultation in January 2018, in terms of grid development, the progress of the projects included in TYNDP 2018 is presented in the next table[7].

Project nº	Project Name	TYNDP 2018 Commissioning Date	TYNDP 2018 Status *	Current Commissioning Date	Current Status	Progress
1	RES in north of Portugal	2022-2030	Planned But Not Yet Permitting	2020-2024	Planned But Not Yet Permitting	Ahead of Time
4	Interconnection Portugal-Spain	2021	In Permitting	2022	In Permitting	Delayed
13	Baza project**	2025	Under Consideration	-	-	-
16	Biscay Gulf	2025	In Permitting	2027	In Permitting	Delayed
85	Integration of RES in Alentejo	2024-2026	Planned But Not Yet Permitting	2023	Planned But Not Yet Permitting	Ahead of Time
193	Godelleta-Morella/La Plana**	2025	Under Consideration	-	-	-
194	Cartuja**	2029	Under Consideration	-	-	-
203	Morella-La Plana (previously Aragón-Castellon)**	2020	In Permitting	-	-	-
233	Connection of Aragon Pumping hydro	2027	Under Consideration	2027	Under Consideration	On time
255	Connection Navarra-Basque Country**	2023	In Permitting	-	-	-
269	Uprate the western 220kV Sevilla Ring	2019	In Permitting	Commissioned	In Service	Commissioned
270	FR-ES project -Aragón-Atlantic Pyrenees	2025-2026	Planned But Not Yet Permitting	2030	Planned But Not Yet Permitting	Delayed
276	FR-ES project -Navarra-Landes	2026	Planned But Not Yet Permitting	2029	Planned But Not Yet Permitting	Delayed
296	Britib	2024	Planned But Not Yet Permitting	2026	Under Consideration	Delayed
378	Transformer Gatica	2025	Planned But Not Yet Permitting	2025	Planned But Not Yet Permitting	On time
379	Uprate Gatica lines	2025	Under Consideration	2025	Under Consideration	On time

* Status of the least advance investment

**Projects not included in the TYNDP 2020 as of European significance

Table **2.2**: Progress of the TYNDP projects from CSW region

In terms of European and national policies, the entry into force of the Clean energy for all Europeans package (CEP) will impact the future development of the electricity grids.

The EU has agreed a comprehensive update of its energy policy framework to facilitate the transition away from fossil fuels towards cleaner energy and to deliver on the EU's Paris Agreement commitments for reducing

[7] *For regional investments, more detailed information is given in Appendix 1.*

greenhouse gas emissions. The completion of this new energy rulebook (CEP) marked a significant step towards the implementation of the energy union strategy, adopted in 2015.

The Regulation on the governance of the energy union and climate action (EU/2018/1999) entered into force on 24 December 2018 as part of the CEP. To meet the EU's energy and climate targets for 2030, EU Member States needed to establish a 10-year integrated national energy and climate plan (NECP) for the period from 2021 to 2030. The national plans should outline how the EU Member States intend to address energy efficiency, renewables, greenhouse gas, emissions reductions, interconnections and research and innovation.

The decommissioning of thermal power plants based on fossil fuels and the ambitious goals for integration of RES and interconnections targets are some of the measures proposed by EU Members States to increase the share of renewables in the energy sector, especially in the electricity sector, in order to reduce greenhouse gas emissions. The establishment of these ambitious goals will have impact in the future development of the electricity grids.

3. REGIONAL CONTEXT

3.1 Present situation

3.1.2 Transmission grid

The interconnected network in the continental south-west region is a network that is synchronous with the remainder of the Central Europe, for which 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), wich are themselves interconnected through the European 400 kilovolts (kV).

Due to this low interconnection capacity, the Iberian Peninsula has been historically considered an electric island. Consequently, while its isolation is being reduced through a reinforced interconnection with France, the Iberian Peninsula has also developed a highly meshed internal system in an effort to strengthen its ability 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 voltage below 220 kV is in general considered distribution. In Portugal 150 kV is also considered transmission, in the Canary islands and Balearic islands from Spain where 132 kV and 66 kV are also considered transmission, and in France 150 kV, 90 kV and 63 kV are considered transmission as well. 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 Balearic Islands 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.

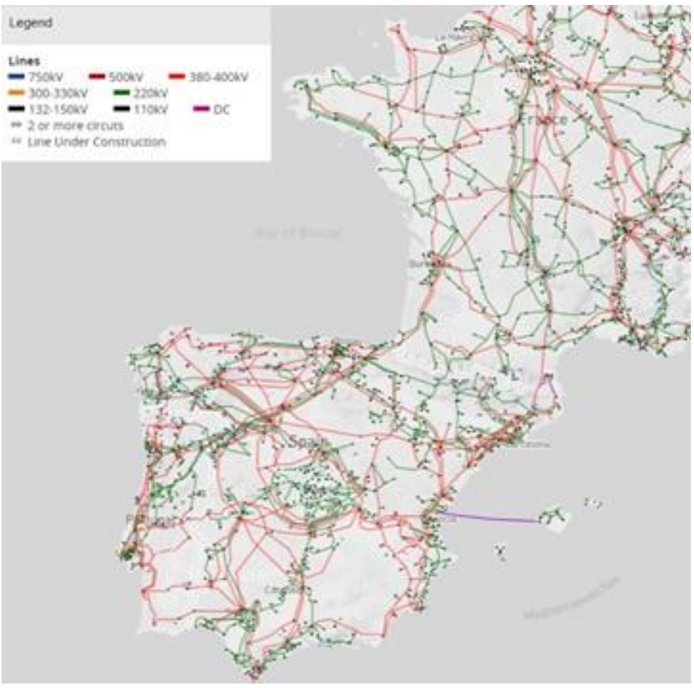

Figure 3.1: Interconnected network of the Continental South West region

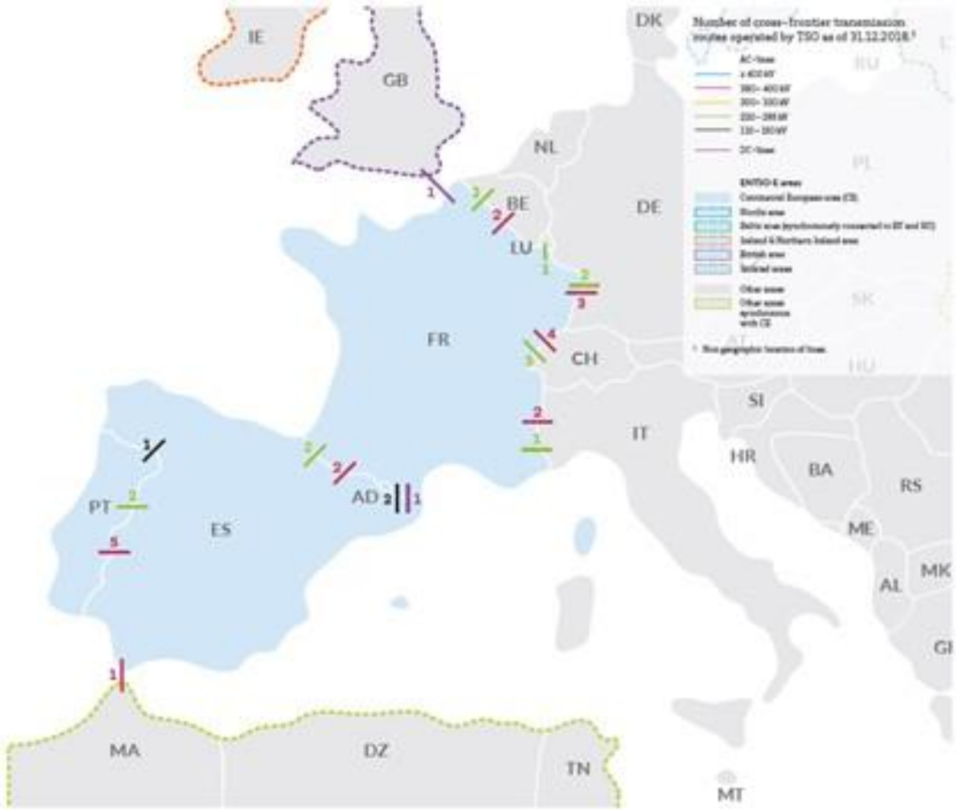

Figure 3.2: Number of cross frontier transmission routes in the Continental South West region

The following map shows the Net Transfer Capacities (NTC) in the CSW region. The NTC is the maximum exchange program between two adjacent control areas that is compatible with security standards and applicable in all control areas of the synchronous area whilst taking into account the technical uncertainties regarding future network conditions. In real time operation, these values can vary from one hour to another based on the availability of grid elements, changes in generation portfolio and new expected flows previously unplanned.

The next figures shows the NTC (in MW) based on the historical values of 2018.

Figure 3.3: Maximum commercial exchange capacities in the Continental South West Region and with Morocco (non ENTSO-E) - 2018[8]

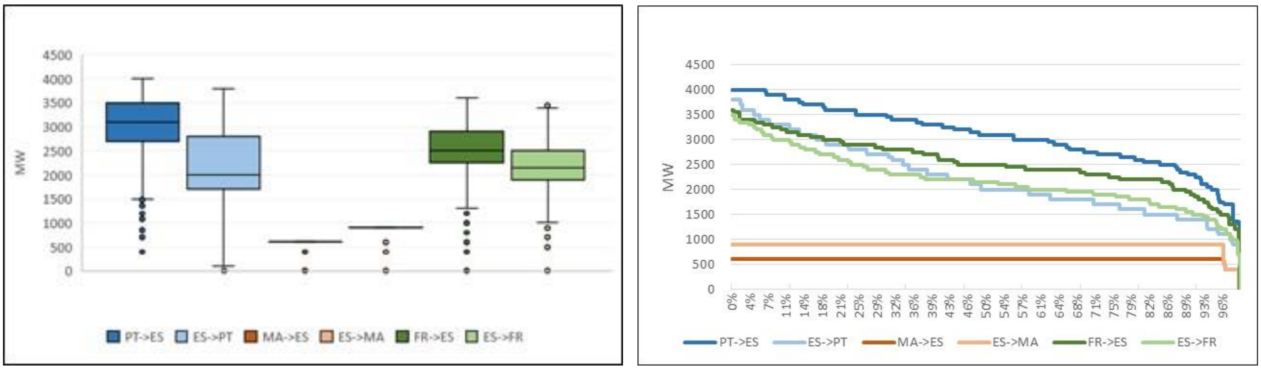

Figure 3.4: Commercial exchange capacities in the Continental South West Region and with Morocco (non ENTSO-E - 2018[9] - distribution of values

[8] The values presented in the map show the maximum values from the NTC duration curve registered in 2018. Source: https://www.iesoe.eu

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

After the failure of completion of two successive 400 kV AC projects, resulting in over 30 years without new infrastructure on the France-Spain border, and the ensuing recommendation of a European mediation to resort to direct current (DC) underground technologies in 2007, a new DC interconnection was commissioned, in June 2015. This former TYNDP project is an HVDC connection between Santa Llogaia in the Gerona area in Spain and Baixas in the Perpignan area in France.

3.1.2 Generation, consumption and exchange physical flows in the region

The following figures report the details of the generation mix in terms of installed capacity, annual generation and balances in 2018 and its comparison to 2010.

Maximum consumption, that is, peak load, in the region decreased in this 2010-2018 period. This decrease (also noticed during 2010-2016) was driven by the financial crisis and energy efficiency measures. Nevertheless, the installed capacity increased in every country, primarily due to wind (14.9 GW) and solar (11.6 GW) energy but also due to hydro power and other RES technologies, in spite of general decreasing installed capacity based on fossil fuels (-11.9 GW).

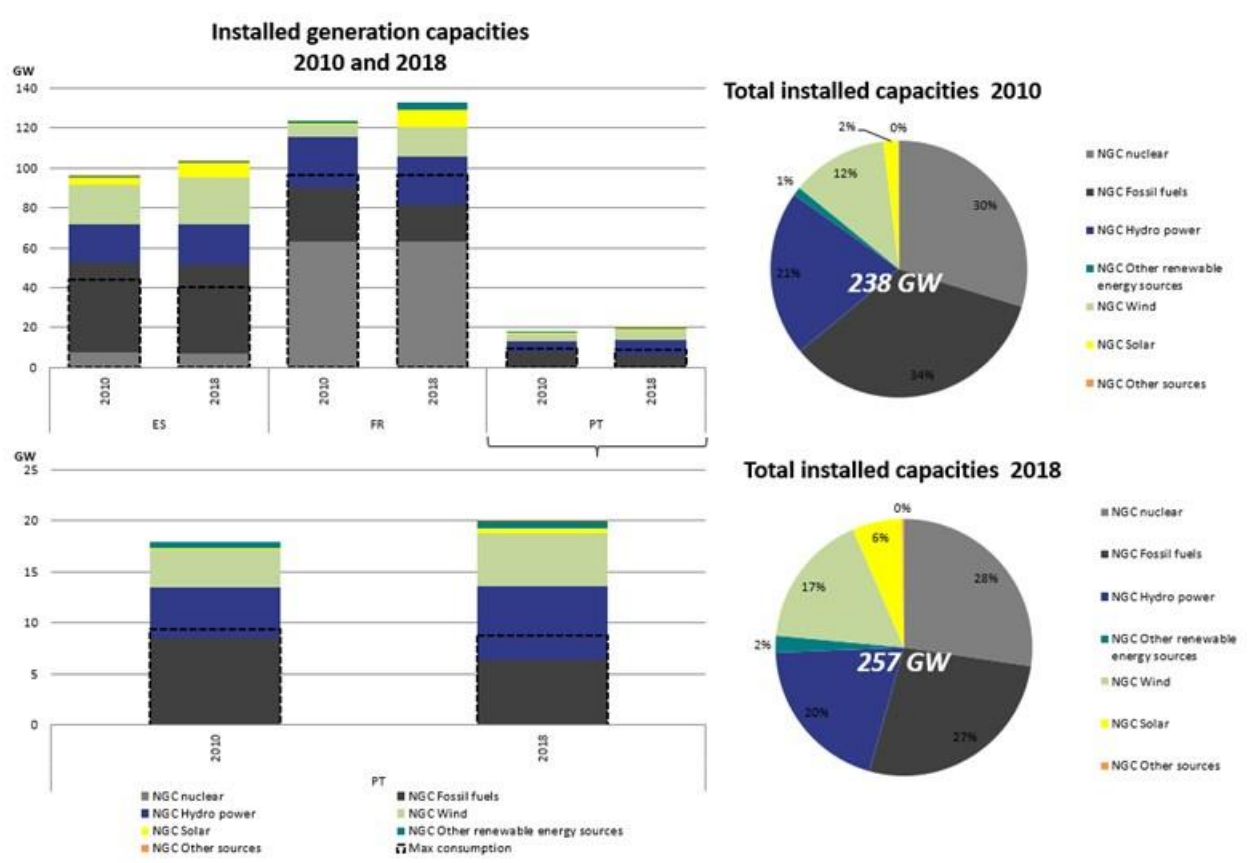

Figure 3.5: Installed generation capacities by fuel type and maximum consumption in the Continental South West Region in 2010 and 2018

Consumption in this seven-year period increased in Spain (+4.4%), slightly increased in Portugal (+0.5%) and decreased in France (-5.4%). Related to the decrease in demand, and in spite of higher exports in the region, regional production decreased slightly (-1.9%). Production of thermal generation decreased by over 36 TWh/y, while RES increased by 48 TWh/y.

Regarding country balances, that is, the equilibrium between generation and native demand, France remained net exporter in 2018, while Portugal and Spain changed their net balances compared to period 2010-2016. From 2016 until 2018, Portugal was net exporter (to Spain), while Spain was net importer

As can be seen in the figures, the main contribution to cover demand in the CSW region in 2018 comes from nuclear energy, which covers 52% of the total demand of the region (although it only covers 28% in terms of installed capacity). Wind energy and solar energy together provide 13% of the demand while representing 23% of the total installed capacity. Overall, RES technologies (hydro included) supplied 28% of demand in 2018, six percentage points more than in 2010.

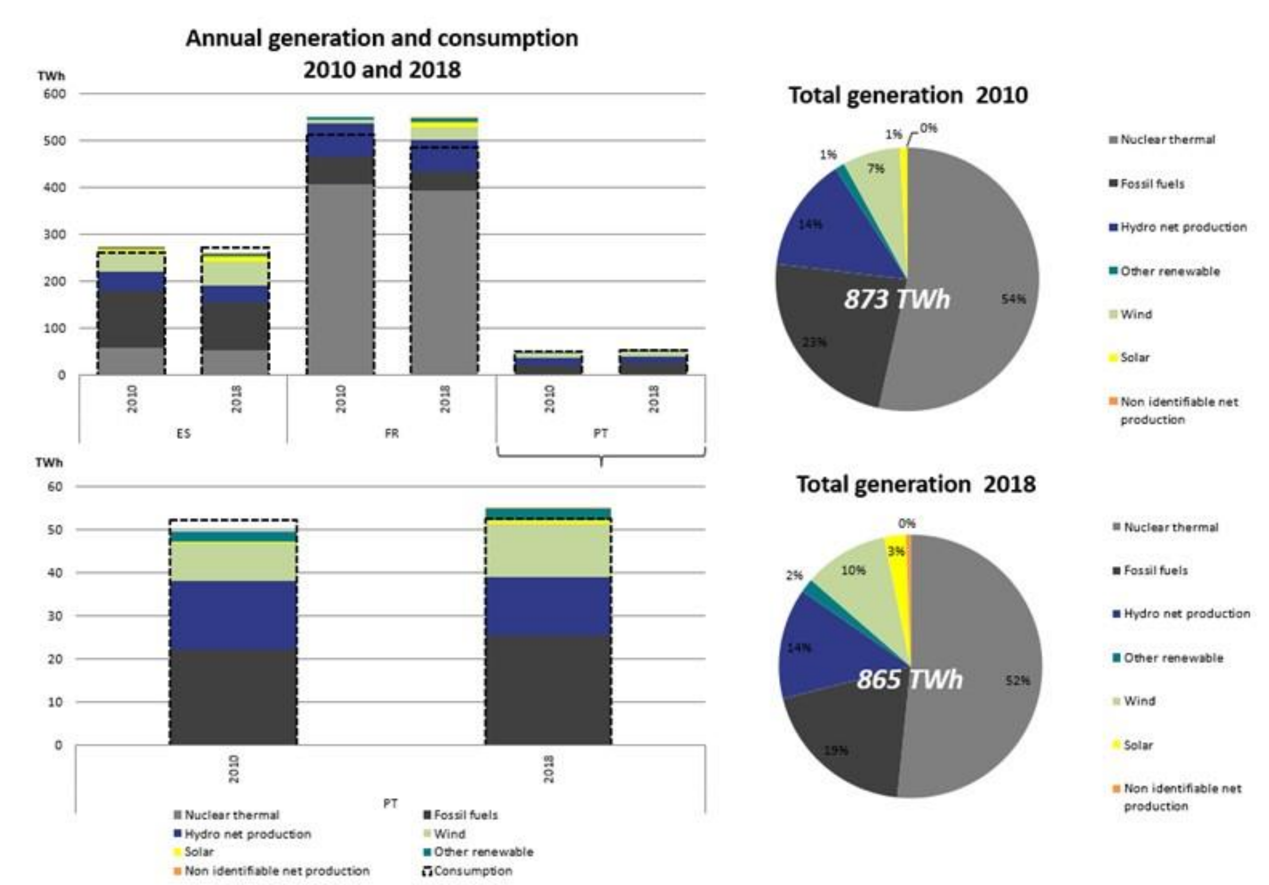

Figure 3.6: Annual generation by fuel type and annual consumption in the Continental South West Region in 2010 and 2018

Figure 3.7 demonstrates that physical flows from 2010 to 2018 increased on almost all borders and in almost all directions of the CSW region. On the Portuguese-Spanish border, physical flows has increased in Portugal to Spain direction due to market conditions and the commissioning of the southern interconnection between Algarve and Andalucía (in 2014). On the Moroccan-Spanish border, the flows from Spain to Morocco slightly decrease in spite of higher consumption in Morocco, due to commissioning of a new (coal) power plant in Morocco. Morocco to Spain remains with no interest to be used.

Figure also shows that French exports increased from 2010 to 2018 in all directions except Germany, whose RES exports have balanced the cross-border exchanges, and Switzerland. Concerning French-Spanish interconnection, whose exchange capacity doubled with the commissioning of the Baixas-Santa Llogaia DC line in June 2015, the diagram reveals a high increase in exports from France to Spain while keeping very similar exports from Spain to France. This indicates that the new interconnector fulfilled its function of increasing energy exchange depending on generation availability in France and Spain. Absolute values of export and imports, however, increased from 5.5 TWh in 2010 to 19.0 TWh in 2018, which in short means that cross-border exchanges more than tripled.

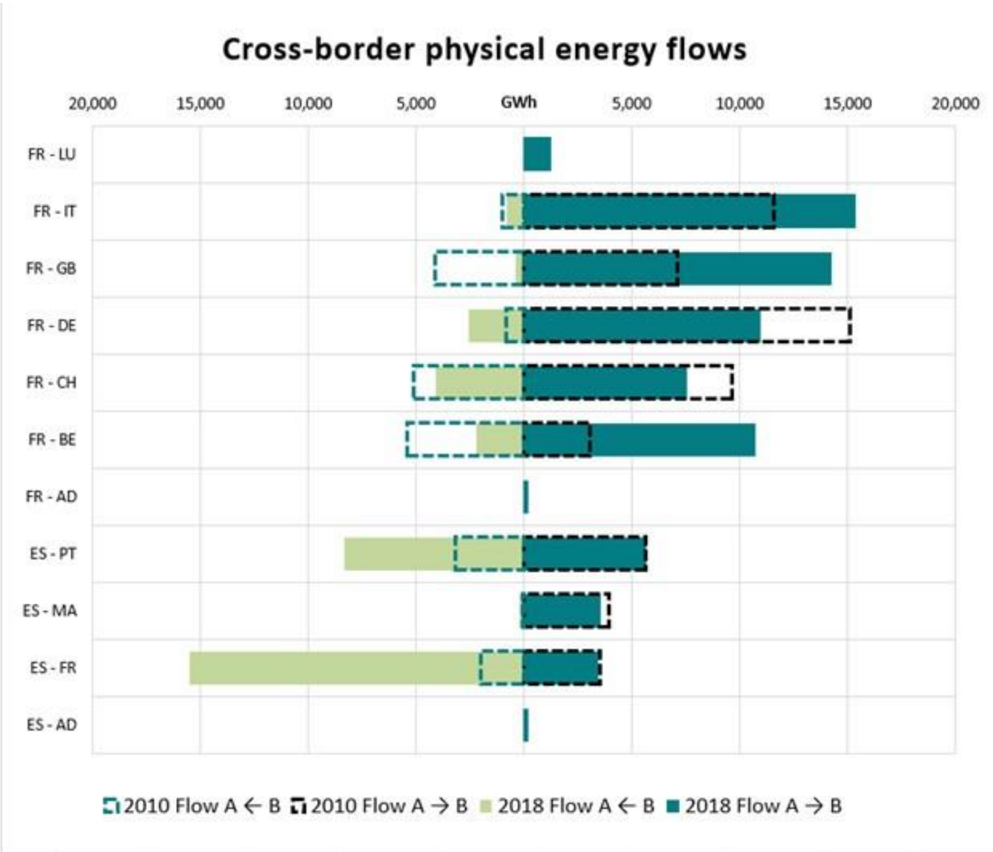

Figure 3.7: Cross-border physical flows (GWh) in the Continental South West Region in 2010 and 2018 years

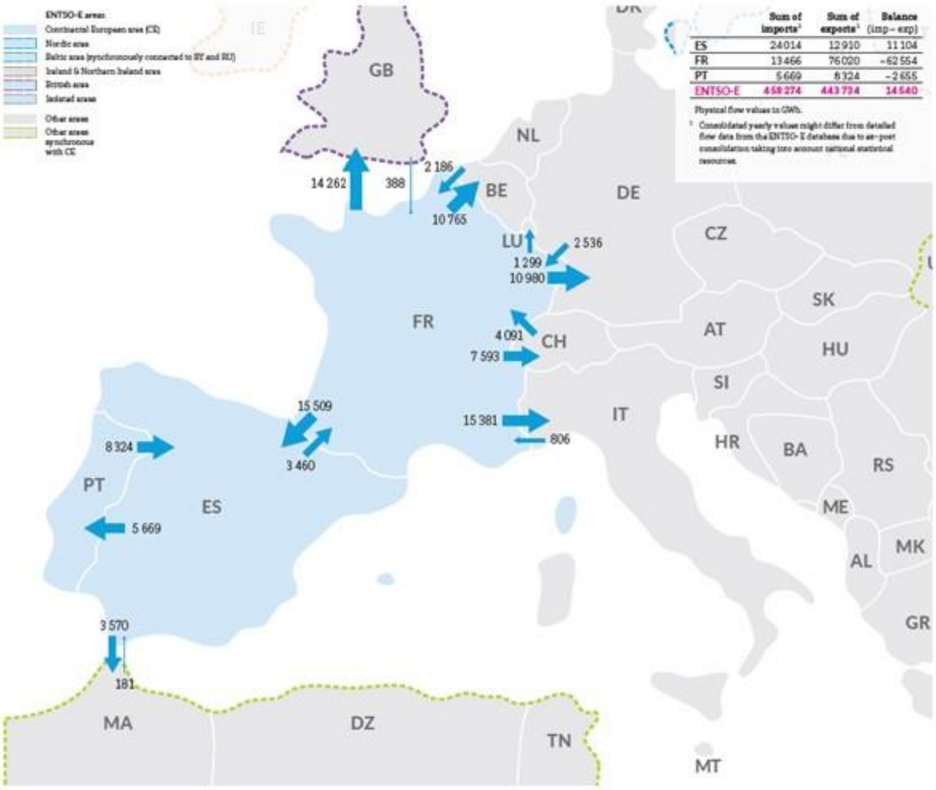

Figure 3.8: Cross-border physical flows (GWh) in the continental south-west Region in 2018

Finally, regarding adequacy and the possibility of suffering from energy not supplied situations, the ENTSO-E Winter Outlook 2019-2020[10] reports that winter periods (January) could be intense, especially in continental Western Europe (including France), in the case of a severe cold wave. During some particular weeks, remaining generation resources available in southern regions (the Iberian Peninsula, Southern Italy, parts of the Balkans) may not be accessible to Central Europe or Northern Europe due to cross-border congestions. Simulations show, however:

- Simulations show that adequacy issues could be fully mitigated through the activation of strategic reserves across Europe;
- These situations are linked to extreme weather conditions unlikely to happen in the future.

3.1.3 Grid Constraints

The average NTC values between Portugal and Spain in 2018 were 3083 MW from Portugal to Spain and 2222 MW from Spain to Portugal. The exchange capacity value has increased significantly (mainly in the direction between Portugal to Spain) with 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.

[10] *https://www.entsoe.eu/publications/system-development-reports/outlook-reports/Pages/default.aspx*

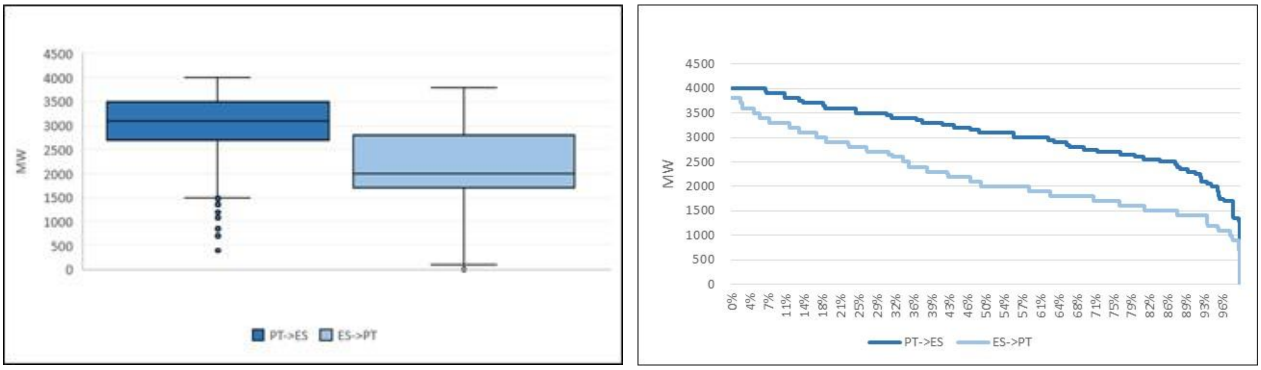

Figure 3.9: Commercial Exchange Capacities in the Portugal –Spain border - 2018[11]- distribution of values

On the Spanish-Portuguese border, NTC values enable a high level of integration. Some constraints, however, still impede achievement of the main political goal of 3000 MW NTC, established for reaching a complete operational Iberian Electricity Market (MIBEL), especially in the direction from Spain to Portugal. Moreover, in 2018, the congestion rate was 5%, and the average day ahead market prices differences was 0.31€/MWh, with some maximum values above 35€/MWh.

The average NTC values between France and Spain in 2018 were 2546 MW from France to Spain, and 2190 MW from Spain to France. The exchange capacity value has increased with the commissioning in 2015 of a new HVDC interconnection between Santa Llogaia in the Gerona area in Spain and Baixas in the Perpignan area in France.

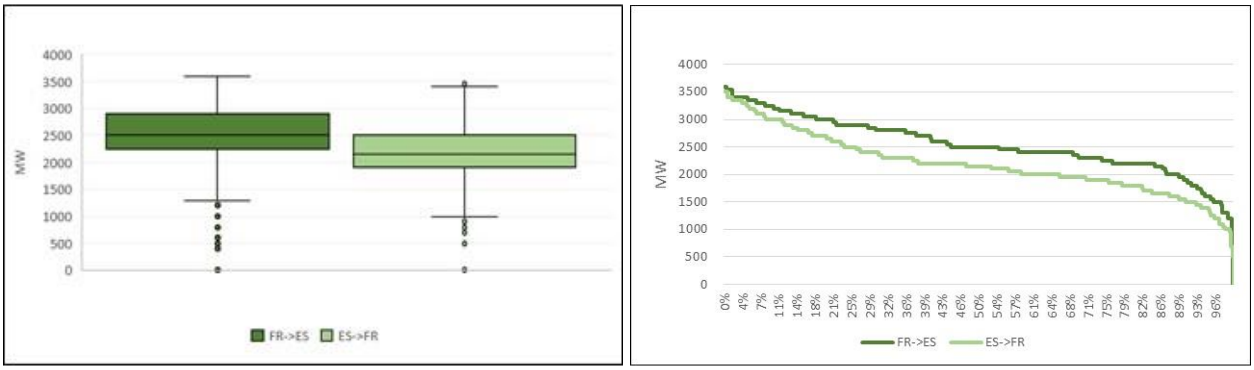

Figure 3.10: Commercial Exchange Capacities in the Spain-France border - 2018[12]- distribution of values

Since the new interconnection entry in operation, the historical data indicate that the NTC has more than doubled in both directions compared to values before this project; power flows have also increased in similar proportions. In fact, the market agents’ use of this capacity also illustrates how it contributes to higher market integration. Although congestion still occurs around 66% of the time and the average price differences are still in the order of 10 €/MWh, the congestion on the border—that is, the percentage of the hours in which the market agent’s interest reaches the maximum NTC—has decreased by around 21 percentage points. Furthermore, the congestion income is now almost twice as high as it was before the

[11] *Source: https://www.iesoe.eu*
[12] *Source: https://www.iesoe.eu*

HVDC (220 M€ in 2017 and 224 M€ in 2018), primarily due to a doubled cross-border capacity, and the cross-border balancing energy is now almost three times as high as it was before the interconnection.

It should be noted that the Iberian Peninsula (Portugal and Spain) is almost an electrical island, with only five interconnectors between France and Spain, where the latest's were constructed in 2015 and in 1982.

The continental south-west 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 from Morocco to Spain and 900 MW from Spain to Morocco (the average NTC values in 2018 were 592 MW from Morocco to Spain, and 882 MW from Spain to Morocco). This border experiences high and increasing flows from Spain to Morocco for almost all the hours of the year. Nevertheless, after the commissioning of a new coal-fired power plant at the end of 2018 in Morocco this situation has changed and Spain has started to import less costly energy from Morocco.

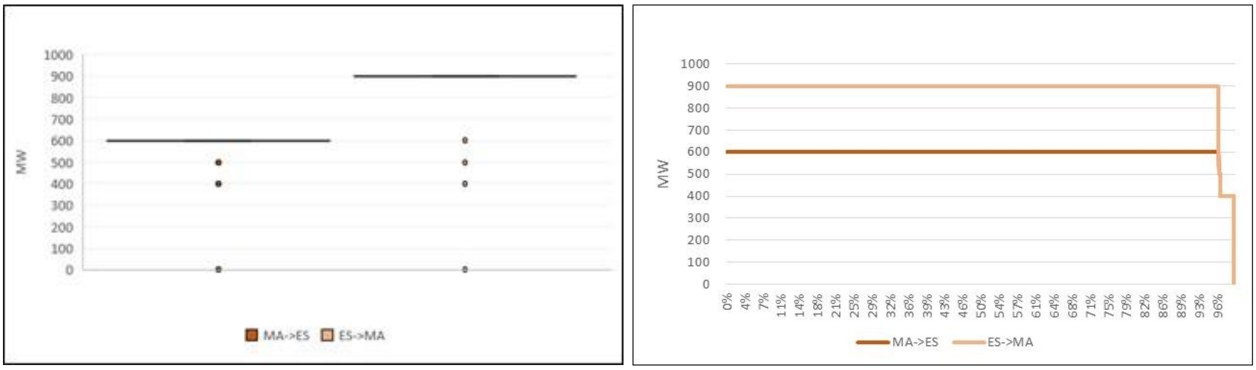

Figure 3.11: Commercial Exchange Capacities in the Spain- Morocco border - 2018[13]

Interconnection ratio in the region

The current interconnection capacity between Iberia Peninsula and mainland Europe is too low to enable the Iberian Peninsula to fully participate in the internal electricity market.

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[14]. In the European Commission's view, the EU energy policy goals and the 2020 and 2030 energy and climate targets would not be achievable without a fully interconnected European electricity grid with more cross-border interconnections, storage potential and smart grids to manage demand and ensure a secure energy supply

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

[14] *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 obtained as the sum of importing GTCs/total installed generation capacity*

in a system with higher shares of variable renewable energy. In this respect, the gradual construction of the pan-European electricity highways will also be crucial.

In October 2014, the European Council called for speedy implementation of all the measures necessary to meet the target of achieving by 2020 an interconnection level of at least 10 % of the installed electricity production capacity in all Member States.

In November 2019 the EC published the communication "Communication on strengthening Europe's energy networks"[15] the three countries in the CSW region were falling short of the objective: Spain with a 6%, and France and Portugal with a 9%, and the expectation was that in 2020 (based on TYNDP 2016 data), Portugal and France would fulfil the 10% objective while Spain would still be in a range of 6-7%, still far away from the 10%.

Figure 3.12: Fulfilment of the 10% interconnection target in 2020 (source EC)

At the same time, due to the peripheral situation of the region it is also relevant to report the interconnection ratio of the Iberian Peninsula as a whole, which is currently in the range of 2%, this is a very low value, which will not improve for the next years. The Iberian Peninsula will still be considered as an electric island.

15 COM(2017) 718 final https://ec.europa.eu/energy/sites/ener/files/documents/communication_on_infrastructure_17.pdf

3.2 Description of the scenarios

The TYNDP2020 Scenario edition published in June 2020 represents the first step to quantify the long-term challenges of the energy transition on the European electricity and gas infrastructure.

The joint work of ENTSO-E and ENTSOG, stakeholders and over 80 TSOs covering more than 35 countries provided a basis to allow assessment for the European Commission's Projects of Common Interest (PCI) list for energy, as ENTSO-E and ENTSOG progress to develop their respective TYNDPs.

We strongly recommend the reader familiarises themselves with the content included in the Scenario Report and visualisation platform, as these will provide full transparency on the development and outcomes of the scenarios mentioned in this report.

Scenario Storylines

The joint scenario building process presents three storylines for TYNDP2020

National Trends (NT), the central policy scenario, based on the Member States National Energy and Climate Plans (NECPs) as well as on EU climate targets. NT is further compliant with the EU's 2030 Climate and Energy Framework (32 % renewables, 32.5 % energy efficiency) and EC 2050 Long-Term Strategy with an agreed climate target of 80 – 95 % CO2-reduction compared to 1990 levels.

Global Ambition (GA), a full energy scenario in line with the 1,5°C target of the Paris Agreement, envisions a future characterised by economic development in centralised generation. Hence, significant cost reductions in emerging technologies such as offshore wind and Power-to-X are led by economies of scale.

Distributed Energy (DE), a full energy scenario as well compliant with the 1,5°C target of the Paris Agreement, presents a decentralised approach to the energy transition. On this ground, prosumers actively participate in a society driven by small scale decentralised solutions and circular approaches. Both Distributed Energy and Global Ambition reach carbon neutrality by 2050.

Figure 3.13: Key parameters for the scenario storylines.

Bottom-Up: This approach of the scenario building process collects supply and demand data from gas and electricity TSOs.

Top-Down: The "Top-Down Carbon Budget" scenario building process is an approach that uses the "bottom-up" model information gathered from the Gas and Electricity TSOs. The methodologies are developed in line with a Carbon Budget approach.

Full energy scenario: a full energy scenario employs a holistic view of the European energy system, thus capturing all fuel and sectors as well as a full picture of primary energy demand

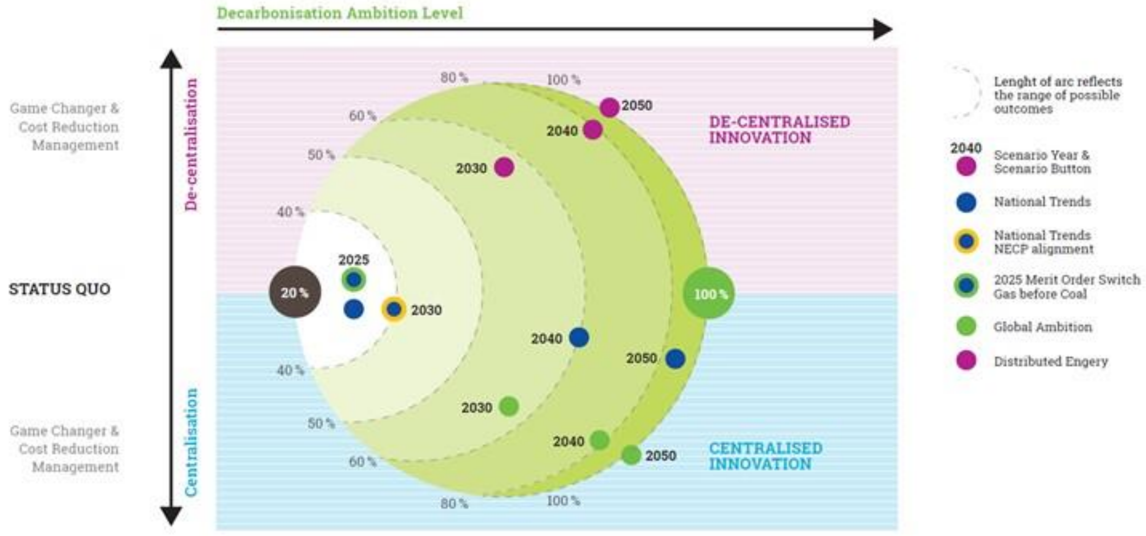

Figure 3.14- Key drivers of scenario storylines

3.2.1 Selective description of electricity results

To comply with the 1.5° C targets of the Paris Agreement, carbon neutrality must be achieved by 2040 in the electricity sector and by 2050 in all sectors.

Distributed Energy and Global Ambition (also referred to as "COP21 Scenarios") scenarios are meant to assess sensible pathways to reach the target set by the Paris Agreement for the COP 21: 1.5° C or at least well below 2° C by the end of the century. For the purpose of the TYNDP scenarios, this target has been translated by ENTSO-E and ENTSOG into a carbon budget to stay below +1.5° C at the end of the century with a 66.7 % probability.

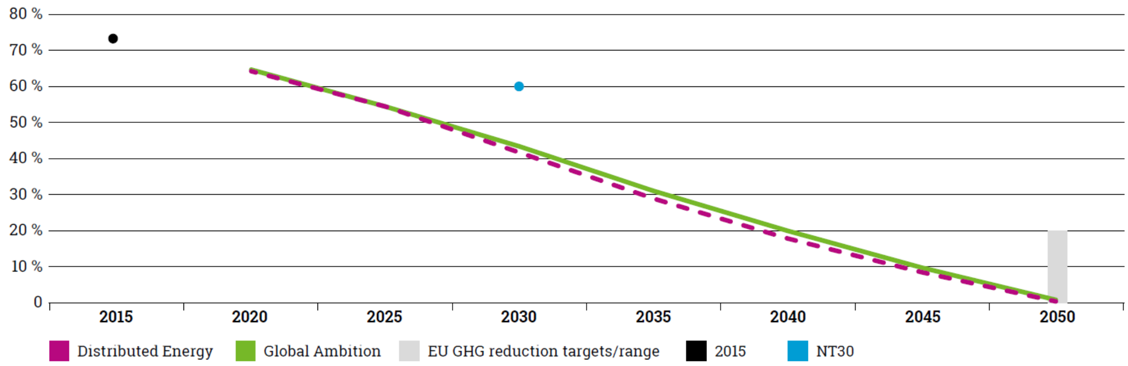

Figure 3.15 GHG Emissions in TYNDP2020 Scenarios

To optimise conversions, the direct use of electricity is an important option resulting in progressive electrification throughout all scenarios

The scenarios show that higher direct electrification of final use demand across all sectors results in increase in the need for electricity generation.

Distributed Energy is the scenario storyline with the highest annual electricity demand hitting around 4300 TWh by 2050. The results for scenarios show that there is the potential for year on year growth for EU28 direct electricity demand. Figure 3-16 provides annual EU-28 electricity demand volumes for the specified periods.

The growth rates for the storylines show that by 2040 National Trends is centrally positioned in terms of growth between the two more-ambitious top-down scenarios Distributed Energy and Global Ambition. The main reason for the switch in growth rates is due to the fact that Global Ambition has the strongest levels of energy efficiency, whereas for Distributed Energy strong electricity demand growth is linked to high electrification from high uptake of electric vehicles and heat pumps, dominating electrical energy efficiency gains.

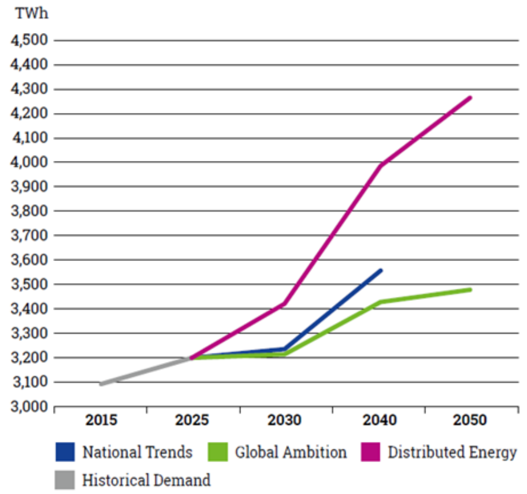

Figure 3.16 Direct Electricity Demand per Scenario (EU28)

In the COP21 Scenarios, the electricity mix becomes carbon neutral by 2040.

In EU-28, electricity from renewable sources meets up to 64 % of power demand in 2030 and 83 % in 2040. Variable renewables (wind and solar) play a key role in this transition, as their share in the electricity mix grows to over 40 % by 2030 and over 60 % by 2040.

The remaining renewable capacity consists of biofuels and hydro. All figures stated above exclude power dedicated for P2X use, which is assumed to be entirely from curtailed RES, and newly build renewables that are not grid-connected, and therefore not considered in this representation.

To move towards a low carbon energy system, significant investment in gas and electricity renewable technologies is required.

Distributed Energy is the scenario with the highest investment in generation capacity, driven mainly by the highest level of electrical demand. Distributed Energy mainly focuses on the development of Solar PV, this technology has the lowest load factor, as result Solar PV installed capacity will be higher compared to offshore or onshore wind, to meet the same energy requirement. The scenario shows a larger growth in Onshore Wind after 2030. In 2030, 14 % of electricity is produced from Solar and 30 % from wind, 44 % in total. In 2040 18 % of the electricity is generated from solar and 42 % from wind 60 % in total. The scenario also sees the least amount of electricity produced from nuclear out of the three scenarios, providing 16 % of electricity in 2030 and 10 % in 2040.

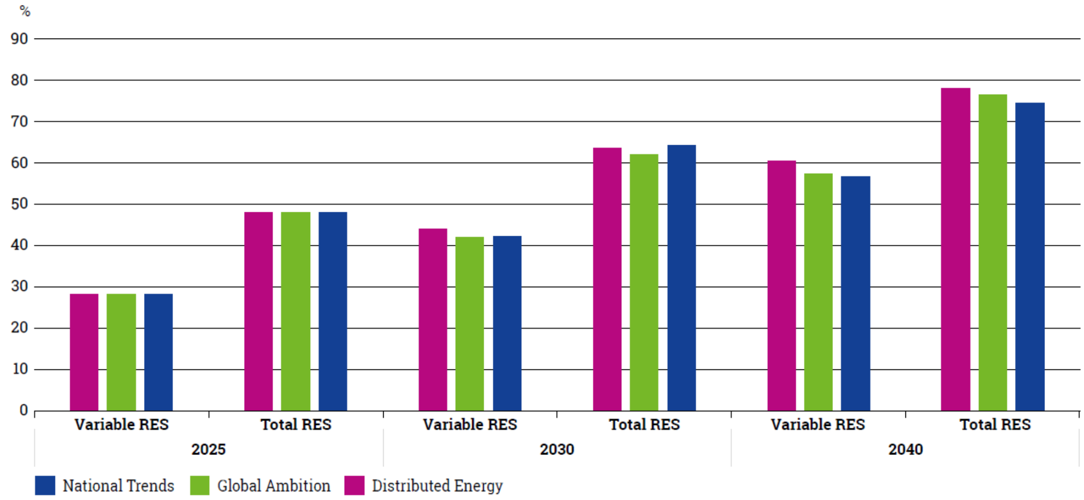

Figure 3.17 Percentage share of electricity demand covered by RES

Global Ambition has a lower electricity demand, with a general trend of higher nuclear and reduced prices for offshore wind. Consequently, the capacity required for this scenario is the lowest as more energy is produced per MW of installed capacity in offshore wind, and nuclear is used as base load technology providing 19 % of energy in 2030 and reducing to 12 % in 2040. In 2030, 10 % of electricity is produced from Solar and 32 % from wind, 42 % in total. In 2040 13 % of the electricity is generated from solar and 45 % from wind 58 % in total.

National Trends is the policy-based scenario. The variable renewable generation is somewhere between the two top-down scenarios. In 2030, 12 % of electricity is produced from Solar and 30 % from wind, 42 % in total. In 2040 14 % of the electricity is generated from solar and 42 % from wind 56 % in total. A lot of electricity is still produced from nuclear in 2030 17 % reducing to 12 % in 2040.

Shares of coal for electricity generation decrease across all scenarios. This is due to national policies on coal phase-out, such as stated by UK, Italy, Spain and Portugal or planned by Germany. Coal generation moves from 10 % in 2025, to 4 % - 6 % in 2030 and negligible amounts in 2040 which represents an almost complete phase out of coal.

Considerations on Other Non-Renewables (mainly smaller scale CHPs) source are important for decarbonisation. As it stands, carbon-based fuels are still widely used in CHP plants throughout Europe. This includes oil, lignite, coal and gas. In order to follow the thermal phase-out storylines, oil, coal and lignite should be phased out by 2040 and replaced with cleaner energy sources. Gas will contribute to decarbonisation by increasing shares of renewable and decarbonised gas.

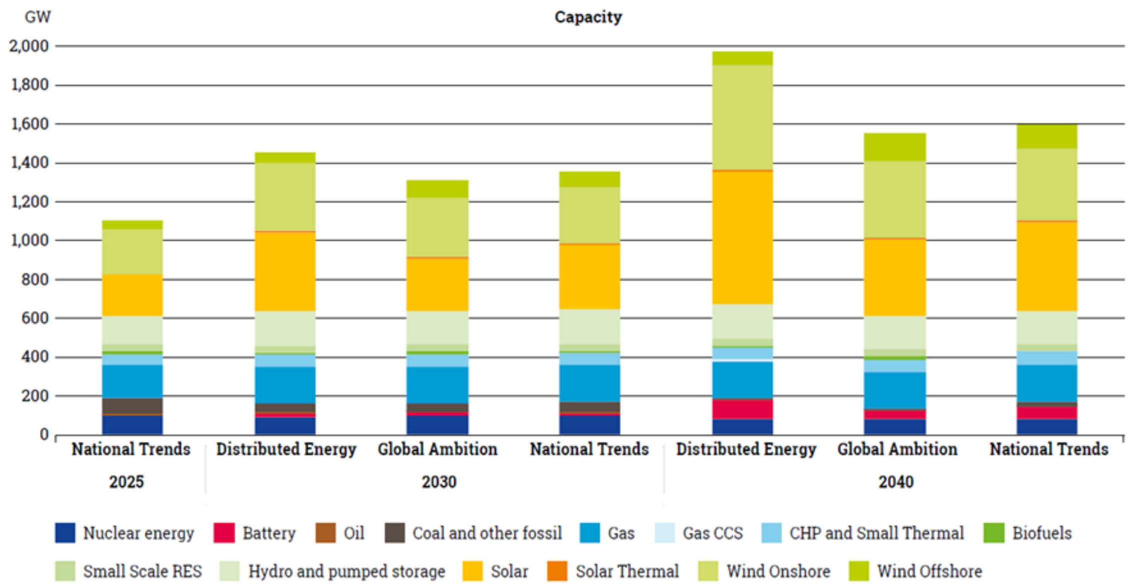

Figure 3.18 Electricity Capacity mix

Sector Coupling – an enabler for (full) decarbonisation.

For ENTSO-E and ENTSOG, sector coupling describes interlinkages between gas and electricity production and infrastructure. Major processes in this regard are gas-fired power generation, Power-to-Gas (P2G) and hybrid demand technologies. TYNDP2020 scenarios are dependent on further development of sector coupling, without these interlinkages a high or even full decarbonisation in the energy sector will not be reached.

Assuming a switch from carbon-intensive coal to natural gas in 2025, 150 Mt CO_2 could be avoided in the power generation. With increasing shares of renewable and decarbonised gases, gas-fired power plants become the main "back-up" for variable RES in the long-term. Distributed Energy even shows a further need for CCS for gas power plants to reach its ambitious target of full decarbonisation in power generation by 2040.

On the other hand, P2G becomes an enabler for the integration of variable RES and an option to decarbonise the gas supply. Hydrogen and synthetic methane allow for carbon-neutral energy use in the final sectors. Distributed Energy is the scenario with the highest need for P2G, requiring about 1500 TWh of power generation per year with 493 GW of capacities for wind and solar in 2040 to produce renewable gas. Sector coupling in National Trends, with the assumption that P2G generation is limited to "curtailed electricity", considers 12 TWh of power generation with 22 GW of P2G to produce renewable gas.

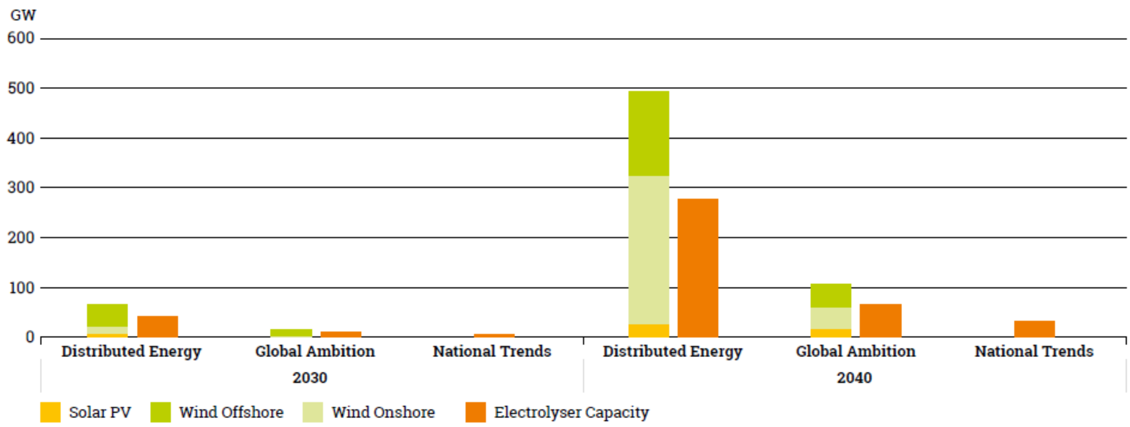

Figure 3.19 Capacities for hydrogen production

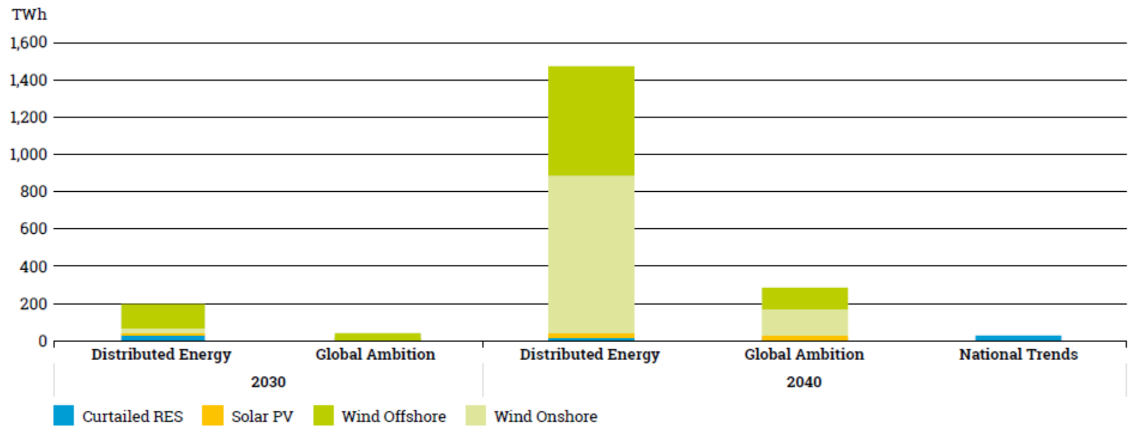

Figure 3.20 Power to Gas generation mix

3.2.2 Key findings of the scenarios for the CSW Region

National Trends (NT)

The characteristic of this scenario for the CSW RG is described following.

This scenario reflects the commitments of each Member State (draft NECPs) to meet the targets set by the European Union in terms of efficiency and GHG emissions reduction for the energy sector.

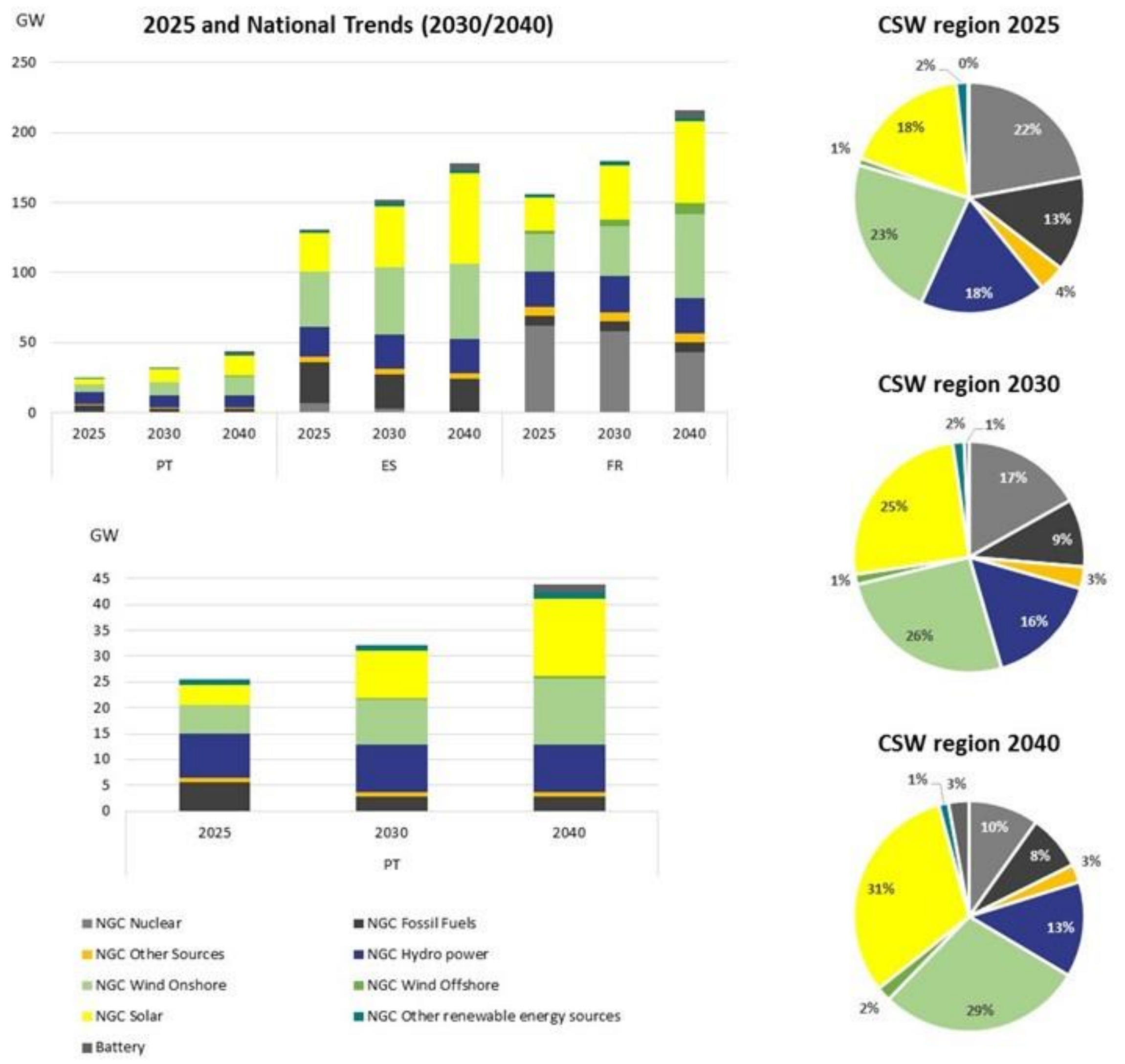

Figure 3.21 : Installed net generation capacities at the regional level in the 'National Trends' scenario

From a regional perspective, this scenario is based on a high growth of renewable energy sources (RES) and new technologies and has the goal of keeping the global climate efforts on track to meet the EU 2050 target. This scenario involves a high RES growth in the CSW region between 2025 and 2040. The overall solar capacity will increase by 83 GW (of which 45% in Spain, 41% in France and 14% in Portugal) and wind capacity by 61 GW (of which 63% in France, 24% in Spain and 13% in Portugal). In the CSW region, the RES penetration respect to the installed capacity scenario represents 61%, 70% and 77% of in 2025, 2030 and 2040, respectively. The increment of renewable generation in the CSW region is focused mainly on solar and wind energy (in Portugal the solar capacity will triple is value from 2025 to 2040, while in Spain and France the growth will be around 136% and 145% respectively).

Regarding thermal capacity, to remark a progressive reduction on nuclear and fossil fuels capacity in the region. The thermal capacity in region will be reduced 30% in 2040 respect to 2025. In Spain the thermal capacity will be reduced 32% in 2040 with respect to 2025 levels and it is expected that the total coal and nuclear capacity will be decommissioned in 2040. The Portuguese thermal capacity will be reduced 49% in

2040 with respect to 2025 levels and it is expected that the coal capacity will be decommissioned until 2030. In France the nuclear capacity will be decreased 30% in 2040 with respect to 2025 levels.

In this scenario, some development of battery storage is expected being the total installed capacity 12,7 GW in 2040.

Global Ambition (GA). This scenario has the following characteristics in the CSW RG:

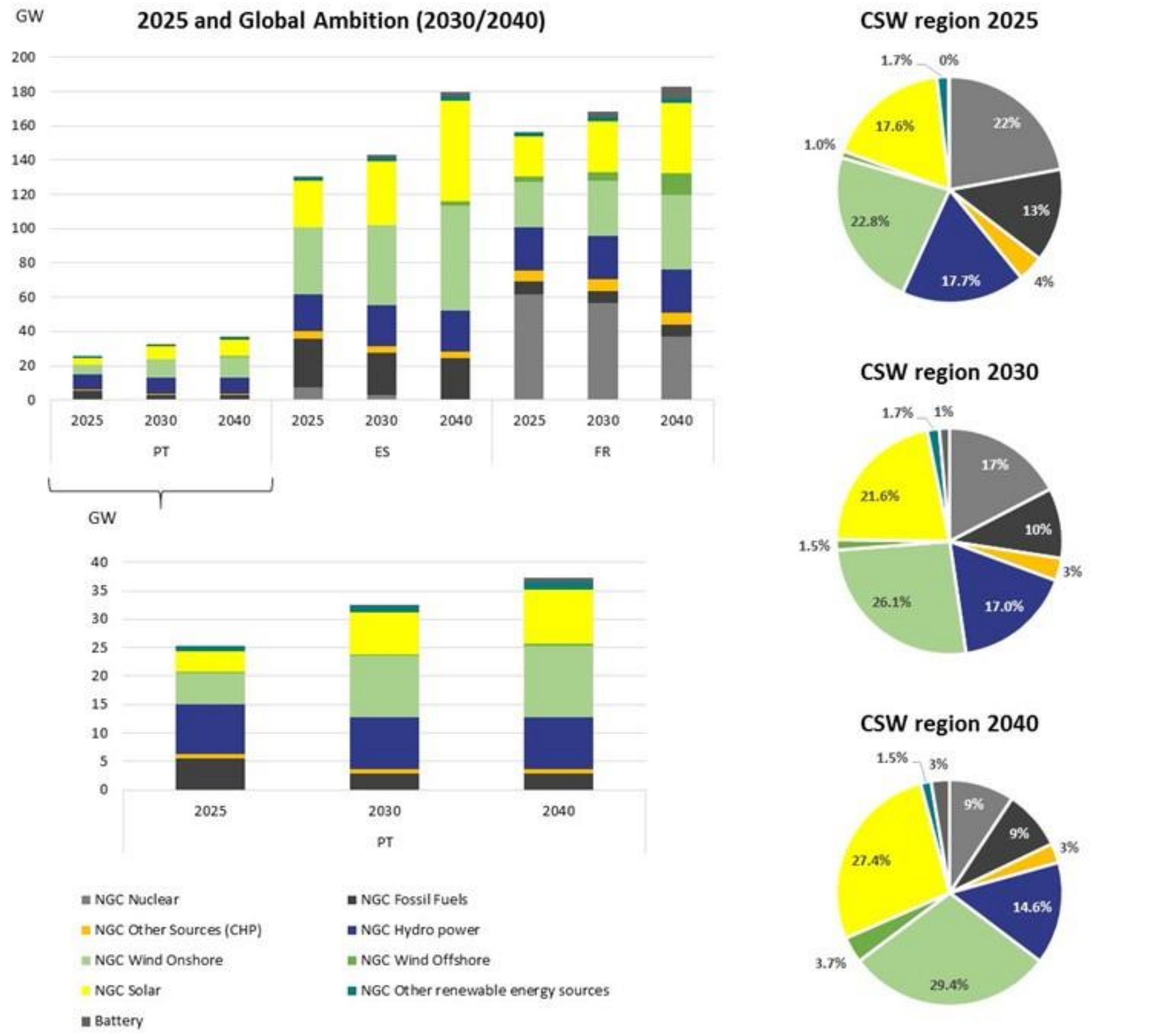

Figure 3.22: Installed net generation capacities at the regional level in the 'Global Ambition' scenario

At regional level, it is characterized by a significant amount of renewables, although to a lesser degree compared with NT scenario. The overall solar capacity will increase by 55 GW (of which 57% in Spain, 32% in France and 11% in Portugal) and wind capacity by 59 GW (of which 46% in France, 42% in Spain and 12% in Portugal). The RES penetration respect to the installed capacity scenario in the CSW region represents 61%, 68% and 77% of in 2025, 2030 and 2040, respectively. Solar and wind generation have the higher weight in the RES penetration (in Portugal the solar capacity will increase around 156% from 2025 to 2040, while in Spain and France the growth will be around 114% and 75%, respectively).

Regarding thermal capacity namely nuclear and fossil fuels capacity, the trend is slightly higher compared to the NT scenario, being the scenario with the highest reduction of thermal capacity in the region. The thermal capacity will be reduced 35% in 2040 respect to 2025. In Spain the thermal capacity will be reduced 32% in 2040 with respect to 2025 levels and it is expected that the total coal and nuclear capacity will be decommissioned in 2040. The Portuguese thermal capacity will be reduced 49% with 2040 respect to 2025 levels and it is expected that the coal capacity will be decommissioned until 2030. In France the nuclear capacity will be decreased 40% with 2040 respect to 2025 levels.

In this scenario, some development of battery storage is expected being the total installed capacity 10,5 GW in 2040.

Distributed Energy (DE) The aspects more relevant of this scenario for CSW RG are presented in the next figure**.**

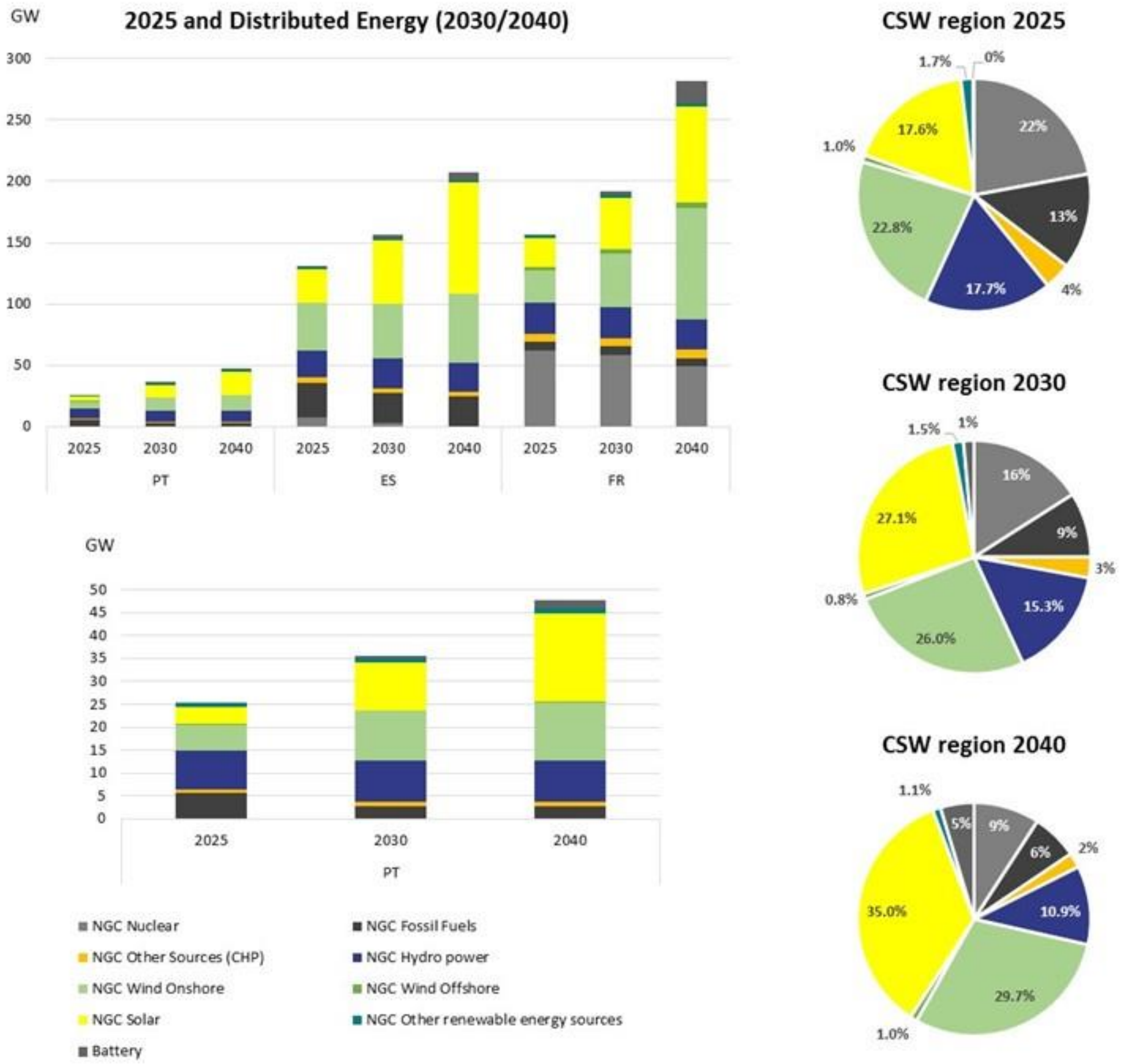

Figure 3.23: Installed net generation capacities at the regional level in the 'Distributed Energy' scenario

In the CSW region framework the 'Distributed Energy' scenario considers the highest RES growth between 2025 and 2040. The overall solar capacity will increase by 133 GW (of which 47% in Spain, 41% in France and 12% in Portugal) and wind capacity by 90 GW (of which 73% in France, 19% in Spain and 8% in Portugal).

In the CSW region, the RES penetration respect to the installed capacity scenario represents 61%, 71% and 78% of in 2025, 2030 and 2040, respectively. The increment of renewable generation in the CSW region is focused mainly on solar and wind energy (in Portugal the solar capacity will quadruple is value from 2025 to 2040, while in Spain and France the growth will be around 230%).

Regarding thermal capacity, to remark a progressive reduction on nuclear and fossil fuels capacity in the region although the trend is slightly lower compared to the NT scenario, being the scenario with the lowest reduction of thermal capacity in the region. The thermal capacity will be reduced 25% in 2040 respect to 2025. In Spain the thermal capacity will be reduced 32% in 2040 with respect to 2025 levels and it is expected that the total coal and nuclear capacity will be decommissioned in 2040. The Portuguese thermal capacity will be reduced 49% in 2040 with respect to 2025 levels and it is expected that the coal capacity will be decommissioned until 2030. In France the nuclear capacity will be decreased 21% in 2040 with respect to 2025 levels.

In this scenario, there is a high development of battery storage respect to NT and GA scenarios. It is expected being the total installed capacity 24,9 GW in 2040.

A more detailed description of the scenario building is available in the TYNDP 2020 Scenario Report[16].

[16] *TYNDP2020 Scenario Report: https://tyndp.entsoe.eu/scenarios*

3.3 Future challenges in the region

The TYNDP Study Teams have carried out simulations for the 2040 NT scenario with the expected grid of 2025 (reference grid, for more details on the reference grid, readers should refer to the IoSN main report), the study revealed the following future challenges

- insufficient integration of renewables (high amounts of curtailed energy)
- high price differences between market areas
- non-used potential to further reduce high CO2 emissions
- bottlenecks between market areas and inside these areas

Challenges from market studies approach

For the horizon 2040, the IoSN study used a zonal model methodology that considers a model with around 100 nodes and a reduced grid model that considers equivalent capacities between these nodes. Some constraints are applied on the links between nodes in order to simulate Kirchhoff's Laws. As a result, the optimal dispatch can be assessed at the European level, taking into account the network physical limits. This methodology merged both market and network simulations in one single step avoiding loops between market and network models. An expansion algorithm has been used in order to optimize the total system costs based on the optimal interconnection capacity increases. For more details on the zonal model methodology, readers should refer to the IoSN main report

The figures below describe the regional challenges identified by the simulations as mentioned above. They present results of simulations for the long-term 2040 NT scenario with a hypothetical situation where Europe would stop investing in the grid after 2025 ('no investment after 2025'). The results might be compared with the similar figures in chapter 4, which show the 2040 market data simulations combined with an appropriate 2040 scenario grid ('IoSN SEW-based needs').

Figure presents the annual generation by fuel type in the region for 2040 NT scenario with 'no investment after 2025' grid. It is possible to see that wind and solar energy (excluding the curtailed energy) will contribute with 66% of the generation to satisfy the demand in the region.

Figure 3.24: Annual generation by fuel type in the region for 2040 NT scenario with 'no investment after 2025' grid

Regarding RES integration, Figure indicates a high level of curtailed energy in the Iberian Peninsula, especially in Spain, with the 2025 network, for which the future projects (especially those to be commissioned 2025-2040) help to mitigate the situation although they don't allow to avoid all generation curtailment. The curtailed energy would represent around 16%, 2% and 27% of the expected consumption in Spain, France and Portugal, respectively, in the 2040 NT scenario.

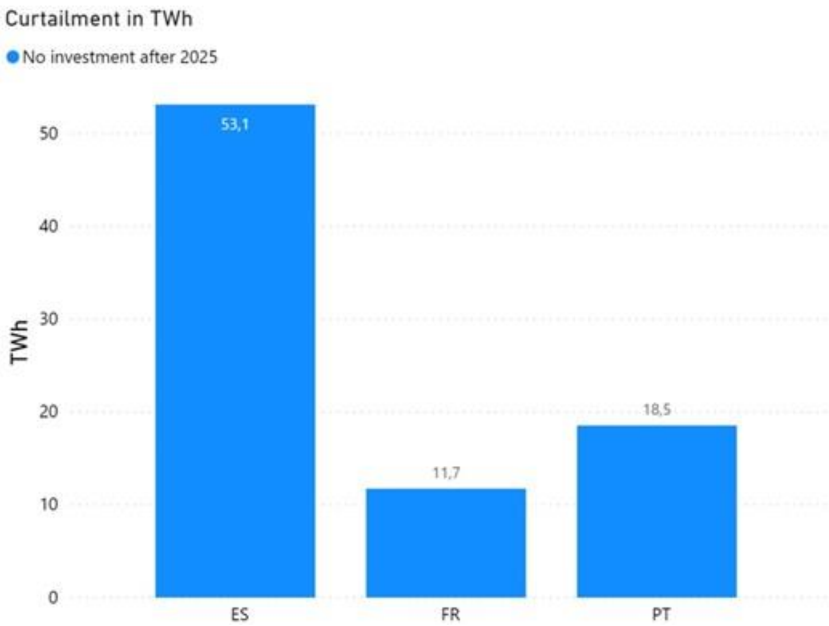

Figure 3.25: Yearly curtailed energy in the region for 2040 NT scenario with 'no investment after 2025' grid

Regarding CO_2 emissions, 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 very high reduction of CO_2 is expected, especially in Spain and Portugal[17].

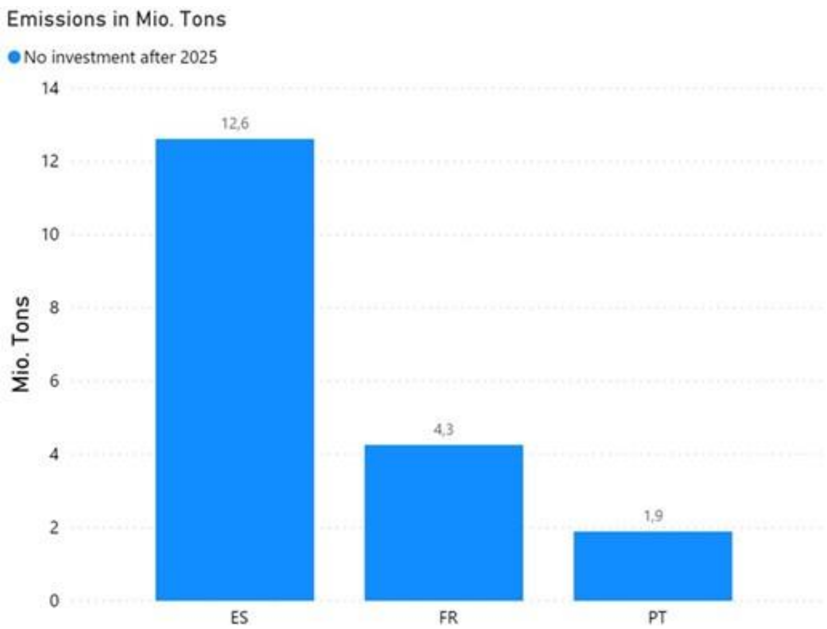

Figure 3.26: Yearly CO_2 emissions in the region for 2040 NT scenario with 'no investment after 2025' grid

[17] *Average CO2 emissions in the 2025 NT scenario are expected to be around 16,8 Mtons/y for ES, 13,0 Mtons/y for FR, and 6,1 Mtons/y for PT*

Figure 3.27 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 14,2 €/MWh, while values for Spain and France are 30,4 €/MWh and 30,8 €/MWh respectively. These values are coherent with the production considered in 2040 NT scenario and with expectations of higher exports in long-term future from the Iberian Peninsula to central Europe to integrate its high RES potential.

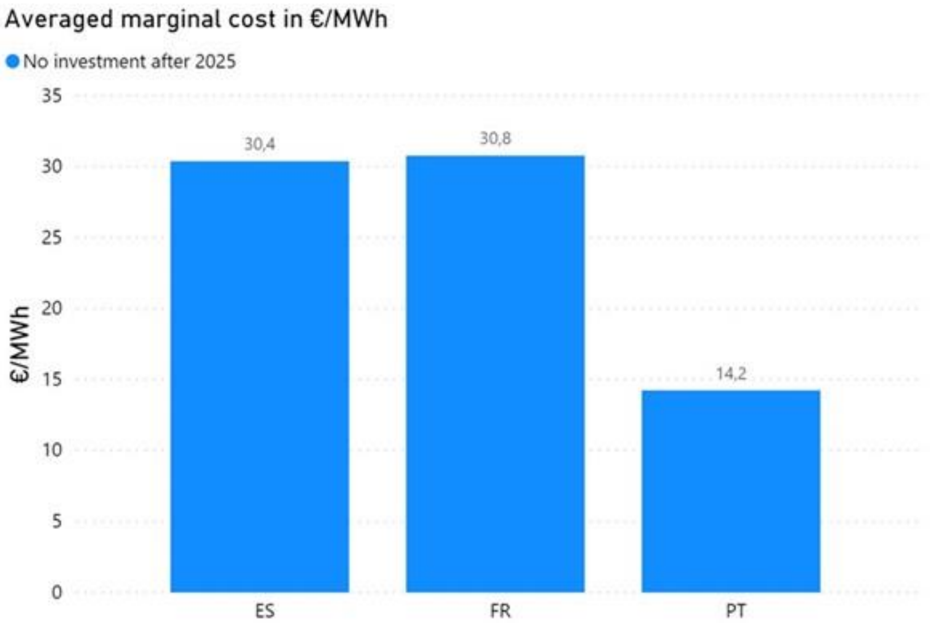

Figure 3.27: Yearly average of marginal cost in the region for 2040 NT scenario with 'no investment after 2025' grid

Concerning country balances, France and Portugal are net exporters (63,5 TWh and 10,4 TWh, respectively) and Spain is net importer (18.9 TWh).

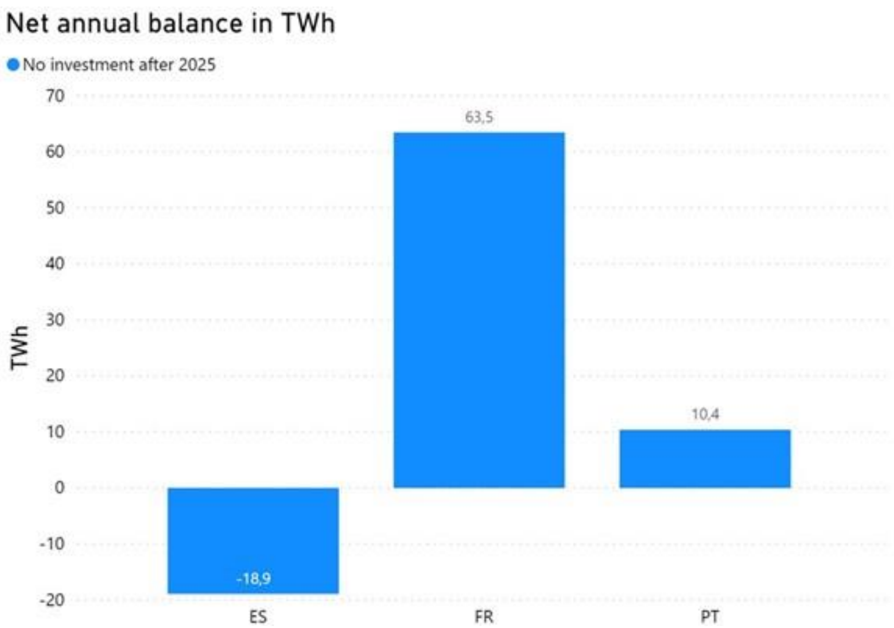

Figure 3.28: Net annual country balance in the region for 2040 NT scenario with 'no investment after 2025' grid

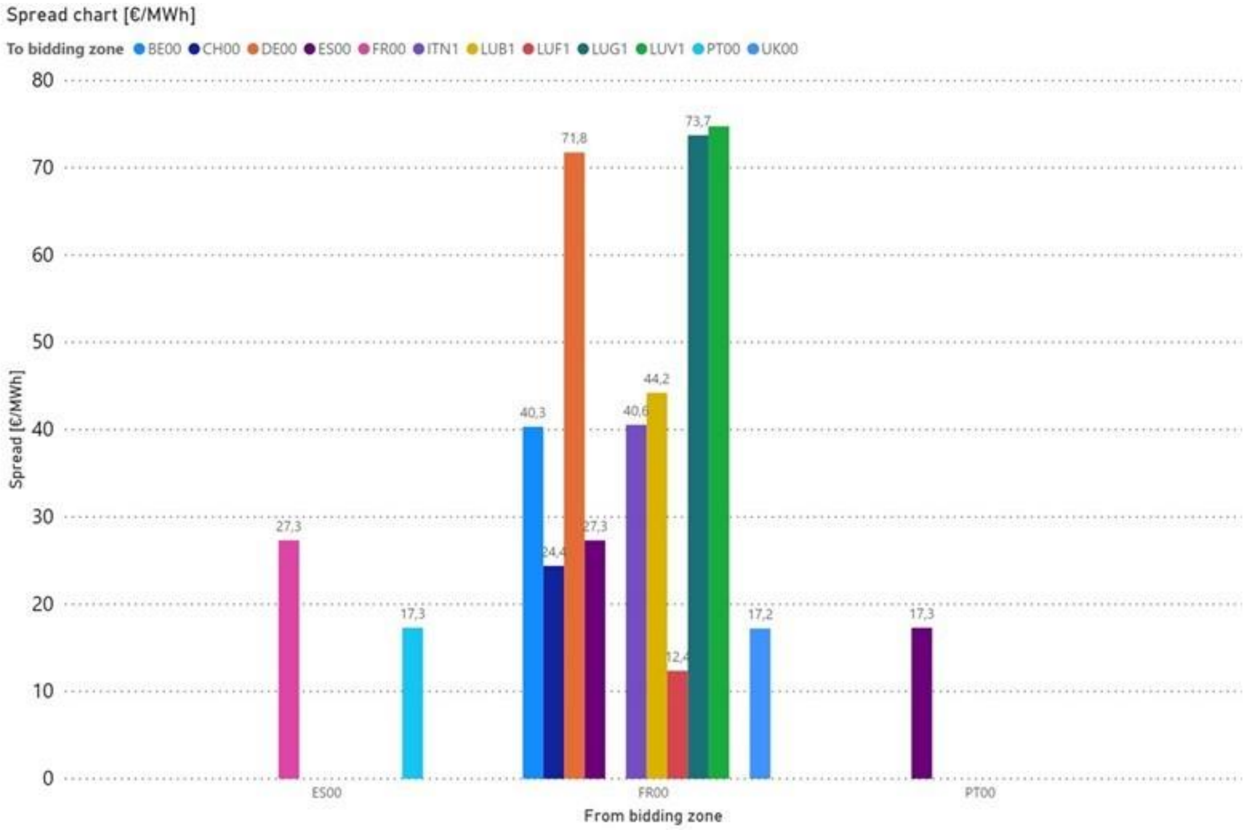

Figure 3.29: Average hourly cost differences in the region for 2040 NT scenario with 'no investment after 2025' grid

This figure illustrates the average marginal cost spread[18] within CSW region and between CSW region and its neighbouring countries (considering the 2025 network), which gives an indication of where it might be worth improving market integration. It can be noted that the marginal cost spread between the Iberian Peninsula and the remainder of the continental Europe is higher than within the Iberian Peninsula itself but is also much lower than between France and Belgium, Italy and Germany.

The residual load is the remaining load after subtracting the production of variable renewable energy sources (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 in order to maintain the frequency equilibrium.

[18] *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*

The ramps in 2040 are much higher than today values; this reflects the significant challenge that the countries in the region have to face related to system flexibility, which looms larger in the case of non-interconnection development.

Residual load ramps are an important issue in all scenarios and they will be further studied in TYNDP 2020. One goal will be to guarantee the necessary volume of frequency reserves in all timescales for the cases of unforeseen generation and demand imbalances.

The energy transition is also creating needs for system operations. Trends show a reduction of system inertia due to increasing RES integration and distributed generation, leading to higher vulnerability of the system to frequency mismatches. Flexibility options will gain in importance, both at generation and demand level, and in this context the role of TSOs in securing network stability will be key.

For more details on the residual load ramps and inertia, readers should refer to the IoSN main report

4. REGIONAL RESULTS

This chapter presents and explains the results of the regional studies and is divided into three sections. Subchapter 0 provides the future capacity needs identified during the identification of system needs process. Subchapter 0 explains the regional market analysis results in detail, whereas subchapter 0 focusses on the network analysis results.

4.1 Future capacity needs

In preparation of the TYNDP2020, to ensure that the project portfolio would be sufficient to accommodate any of the TYNDP scenarios for 2040, ENTSO-E conducted a pan-European study to identify the system needs.

The 'IoSN SEW-based needs' is a depiction of the needed effective cross-border transfer capacity increases necessary for a cost-optimized operation of the 2030/2040 system. It is important to note that considerations in terms of system resilience, system security, or other societal benefits are not included in this analysis. The cost-optimized 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 needs for transmission capacities were identified according to the methodology for the Spain-France and Spain-Portugal borders for 2030 and 2040 NT scenarios. The outcome of the analysis is synthesized in Figure , Figure and Table 4.1.

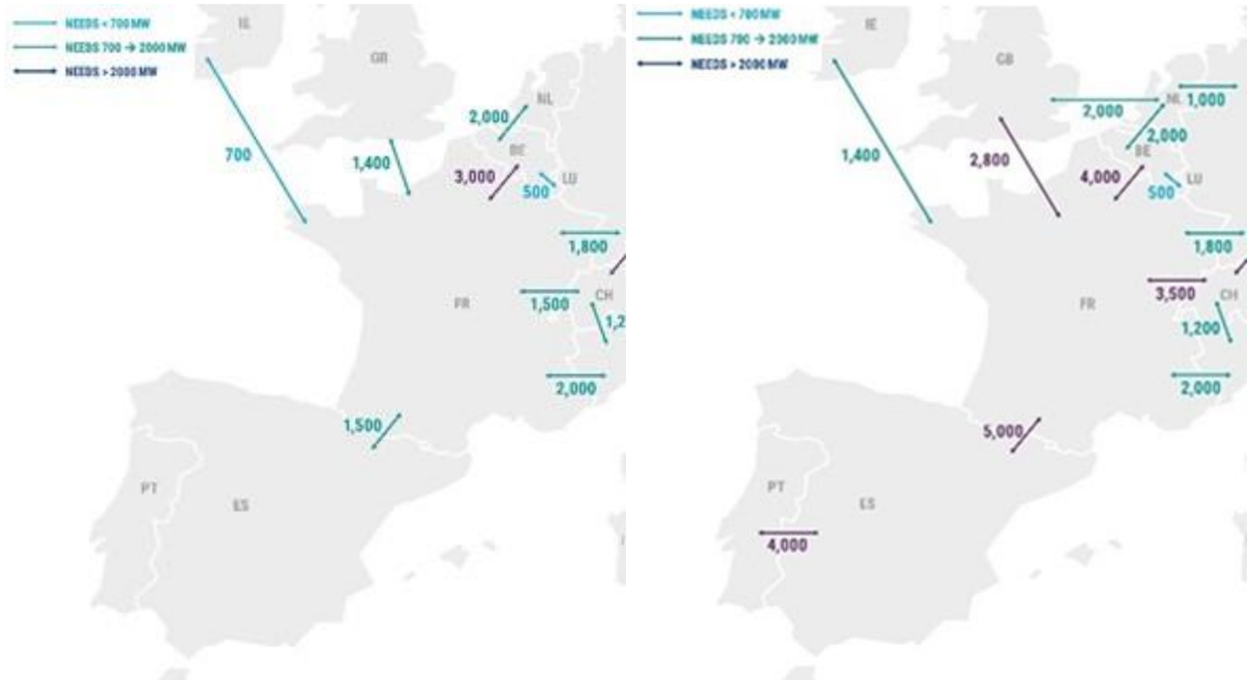

Figure 4.1: Identified capacity needs in the studied 2030 (left) and 2040 (right) NT scenarios (IoSN SEW-based needs) in CSW region

While the optimization process behind this analysis has aimed at a robust identification of the cost-optimized system, the inherent complexity of the power system implies that different depictions of the needed cross-border capacity increases lead to results of practically similar benefits. Figure 4.2 captures this effect for those borders where a different 'IoSN SEW-based needs' solution would lead to similar benefits and would therefore suggest that it is a well-identified need without being part of the 'IoSN SEW-based needs' solution (these network increases do not constitute an alternative grid solution, as they do not all belong to the same grid solution). Adding one of these increases to the IoSN SEW-based needs would deliver very close benefits to those delivered by addressing the SEW-based needs alone.

In particular, considering the sensitivity of the analysis on the cost-estimates used for the optimization process, these possibilities must be considered in order to not misdirect the sound development of the necessary solutions to the needs. This is especially important in the subsequent steps where further analyses in terms of environmental impact, viability, benefits beyond SEW and refined costs are carried out in order to complement the identified needs.

Figure 4.2: Additional network increases included in grid solutions that were only slightly more expensive than the IoSN SEW-based Needs in the studied 2030 (left) and 2040 (right) NT scenarios in CSW region

The presented needs are based on an optimization process that includes cost estimates for every border investigated (ratio between costs and benefit can be decisive for choosing among potential reinforcements). An overview of these costs assumptions can be found in Appendix 3. Costs of the 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 point of view, and considering the potential benefits of the capacity needs (only with a SEW approach[19]) and the estimated costs of those increases, the capacity needs increases in the Spain-France

[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 are economically viable*

border showed potential benefits if increased 5000 MW from the reference grid values in 2040 horizon. The capacity needs increase on the Portugal-Spain border showed potential benefits in 2040 horizon if increased 4000 MW from reference grid values, which already included the commissioning of the future northern interconnection. The estimated costs for the increases also affect the results within the region, especially on the Spain-France border, where it has been considered a cost of underground or submarine HVDC potential project to cross the border. The possibility of AC potential projects would yield higher values but could be unfeasible from the social point of view.

Table presents different cross-border capacities as identified during the TYNDP2020 process within the CSW region

The first columns show the expected 2020 capacities. The next columns show the capacities relevant to the CBA (reference grid), which will be carried out on the time horizons 2025 and 2030.

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

	NTC 2020		CBA Capacities		Capacity needs			
			NTC 2025 (reference grid)		NT 2030		NT 2040	
Border	=>	<=	=>	<=	'IoSN SEW-based needs'	Additional capacity'*	'IoSN SEW-based needs'	Additional capacity *
ES-FR	2600	2800	5000	5000	+ 1500	+ 1500	+5000	-
ES-PT	2300	2500	4200	3500	-	-	+4000	-

**Additional capacity increase on top of the "IoSN SEW-based needs (2030/2040)" capacity needs*

Table 4.1: Cross-border capacities expected for 2020, for the reference grid and capacity needs identified during the identification of system needs phase ('IoSN SEW-based needs')

The reference grid is considered the starting grid for the CBA analysis in the TYNDP2020. It considers the existing grid and the projects that are likely to be implemented by the date of the scenario that is considered in the study (for more details on the reference grid, readers should refer to the IoSN 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 reference grid and the capacity needs resulting from the IoSN analysis.

The Spain-Portugal border, which considers the commissioning date of the future northern interconnection[20] by 2022, has no additional project considered. There are some gaps with the 2040 capacity needs that still need to be investigated in future releases of the TYNDPs, but up to now those analysis are not robust enough and so it seems too soon to propose any additional project in this border.

[20] *The expected value of NTC after the new northern interconnection is in the range 3600-4200 MW in the direction Spain to Portugal and in the range 3200-3500 MW in the direction Portugal to Spain. For the IoSN studies the upper limit was used.*

The Spain-France border considers the Biscay Gulf project in the reference grid on top of the 2020 situation. There is, however, still a significant gap to fulfil the values identified for the 2040 capacity needs. There are two projects already planned (Navarra-Landes and Aragón-Atlantic Pyrenees interconnections), which are intended to reach a value of 8000 MW. The remaining gap still needs to be investigated in future releases of the TYNDPs, which will also be looking for consistency with the evolution of already-planned projects; consequently, it seems too soon to propose any additional project on this border.

4.2 Market Results

4.2.1 2030 horizon

Through the present regional investment plan focuses on the 2040 horizon, ENTSO-E's IoSN study also studied the 2030 horizon. The present section includes an overview of the findings for three key indicators. For more details on results for 2030, readers should refer to the IoSN main report and to the reports 'PCI Corridor Needs 2030'.

Methodology

For the horizon 2030, the IoSN study did not use a zonal model but a standard net transfer capacity model (NTC), with a model that only considers one zone per country and the cross-border capacity is the NTC. The use of an NTC model for the 2030 horizon ensures consistency with the next phase of the TYNDP, I.e. the cost-benefit analysis of projects which also relies on an NTC model. Related to this alignment with the CBA, the NTC model included Tunisia, which is not included in the 2040 horizon.

The figures below present the results of the Pan-European market studies for the 2030 NT scenario with the 2030 capacity needs increases ('IoSN SEW-based needs 2030') and with the capacities expected for 2020 ('2020 grid'). Also, a comparison with a long-term copper plate simulation (which would represent no limit in interconnection capacity Europe-wide) is presented.

In terms of marginal cost, Spain and Portugal show approximate figures (26,0 €/MWh and 25,5 €/MWh, respectively), and generally lower than 31,7 €/MWh identified in France. This reflects countries' generation portfolio, with Spain and Portugal showing higher RES levels. Cross-border exchange capacities Europe-wide increases from 2020 to 2030 enable an average increase of marginal cost in France by 7,3 €/MWh, in Spain by 8,2 €/MWh and in Portugal 8,7 €/MWh.

Long-term copper plate simulation would indicate a common cost across the region of 34.8 €/MWh.

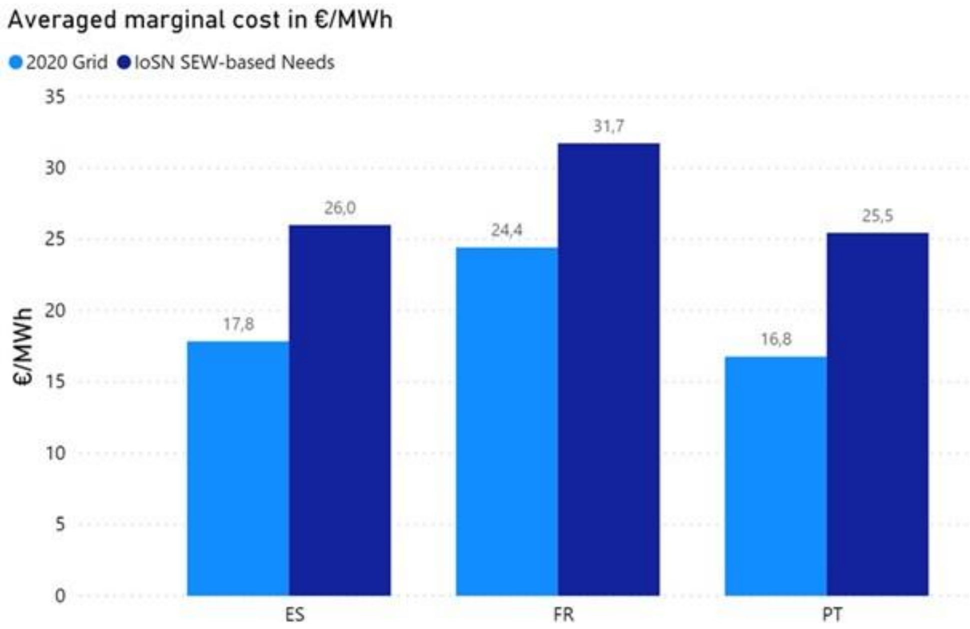

Figure 4.3: Yearly average of marginal cost in CSW region in the studied 2030 NT scenario with the 'IoSN SEW-based needs 2030' and '2020 grid'

Curtailed energy resulting from high levels of renewable installed capacity is still expected, especially in Spain and Portugal. Results show 8,8 TWh/year in Spain and 3,2 TWh/year in Portugal. The capacity needs increases in Europe from 2020 to 2030 (that is, already planned projects and additional identified interconnection needs in this analysis) allow to reduce the curtailed energy in the region in 9,9 TWh.

Long-term copper plate simulation would indicate a non-significant level of curtailed energy in the countries in the region.

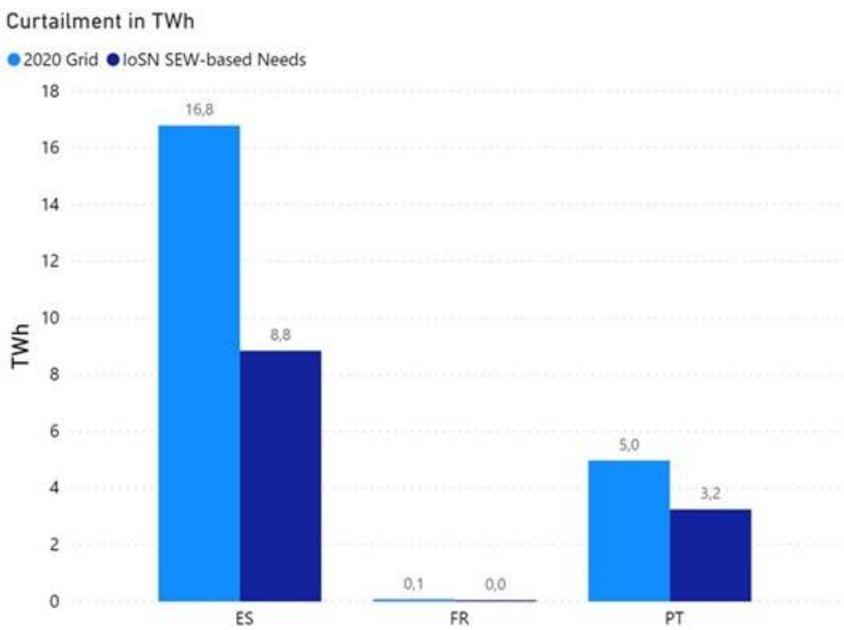

Figure 4.4: Yearly curtailed energy in CSW region in the studied 2030 NT scenario with the 'IoSN SEW-based needs 2030' and '2020 grid'

Regarding CO_2 emissions they greatly depend on scenarios, especially on RES share of capacity. In NT scenario the results are 19,1 Mtons/y in Spain, 5,5 Mtons/y in France and 2,9 Mtons/y in Portugal. Cross-border exchange capacities increase Europe-wide from 2020 to 2030 allow to reduce the CO_2 emissions in the region in 0,5 Mtons/y.

Long-term copper plate simulation would indicate an additional CO_2 emissions reduction in the region by 1,1 Mtons/y.

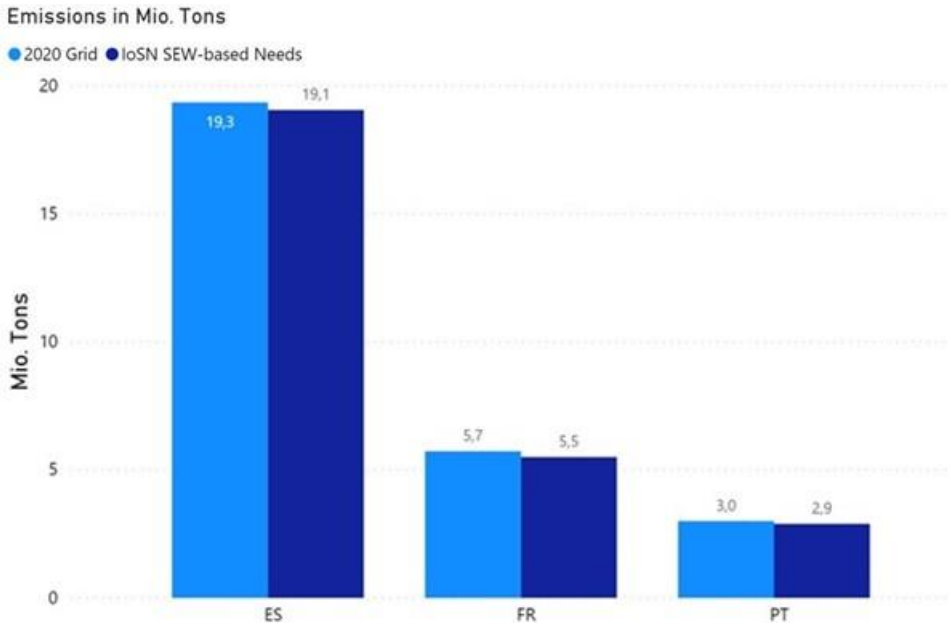

Figure 4.5: Yearly CO_2 emissions in CSW region in the studied 2030 NT scenario with the 'IoSN SEW-based needs 2030' and '2020 grid'

4.2.2 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 ('IoSN SEW-based needs 2040') and with the capacities expected for 2025 reference grid ('no investment after 2025'). Also, a comparison with a long-term copper plate simulation (which would represent no limit in interconnection capacity Europe-wide) is presented.

Figure presents the annual generation by fuel type in the region for 2040 NT scenario with the 'IoSN SEW-based needs 2040'. It is possible to see that wind and solar energy (excluding the curtailed energy) will contribute with 70% of the generation to satisfy the demand in the region.

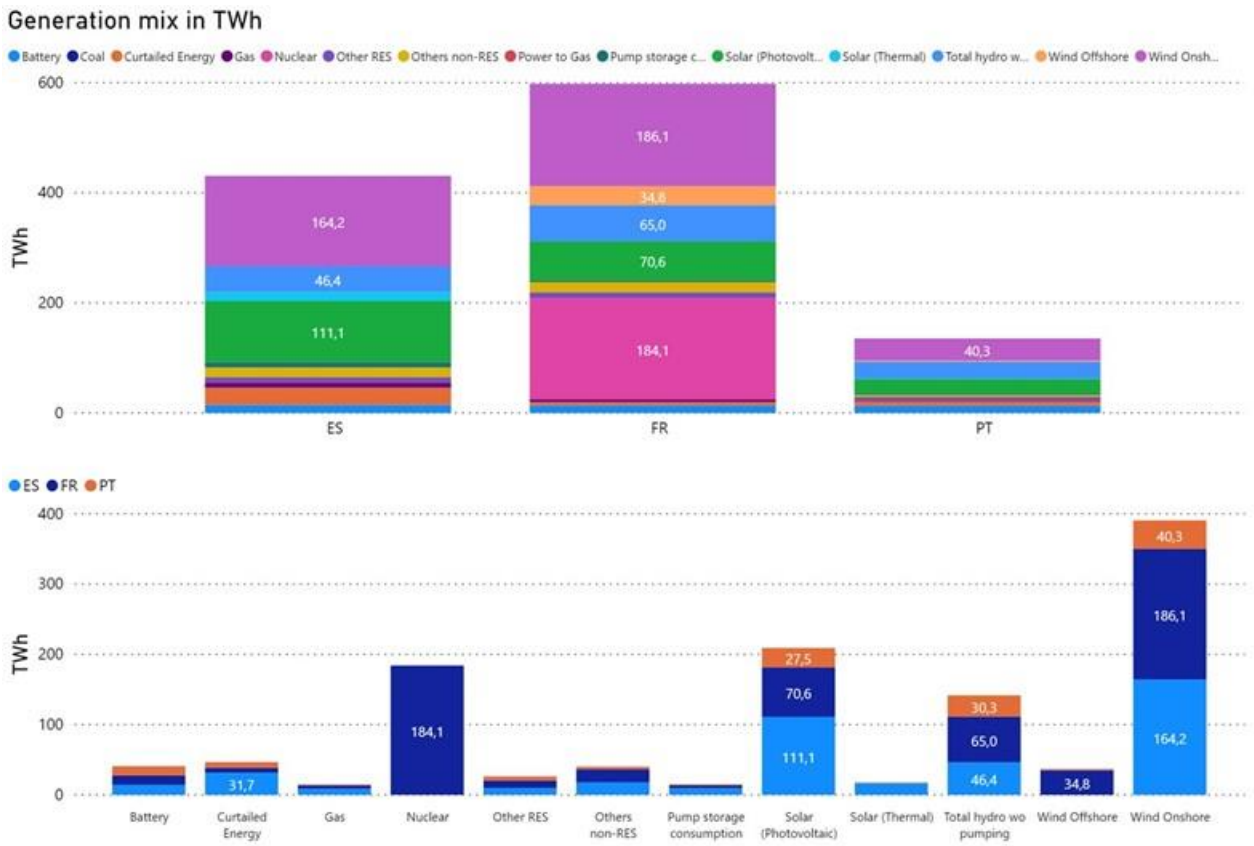

Figure 4.6: Annual generation by fuel type in the region in the studied 2040 NT scenario with the 'IoSN SEW-based needs 2040'

The figure below presents the difference in the generation mix considering the 2040 grid with the identified capacity increases ('IoSN SEW-based needs 2040') and the 2025 reference grid ('no investment after 2025'). The capacities increases will allow a better access to the RES generation from the region that will replace thermal generation in the countries inside the region and across Europe.

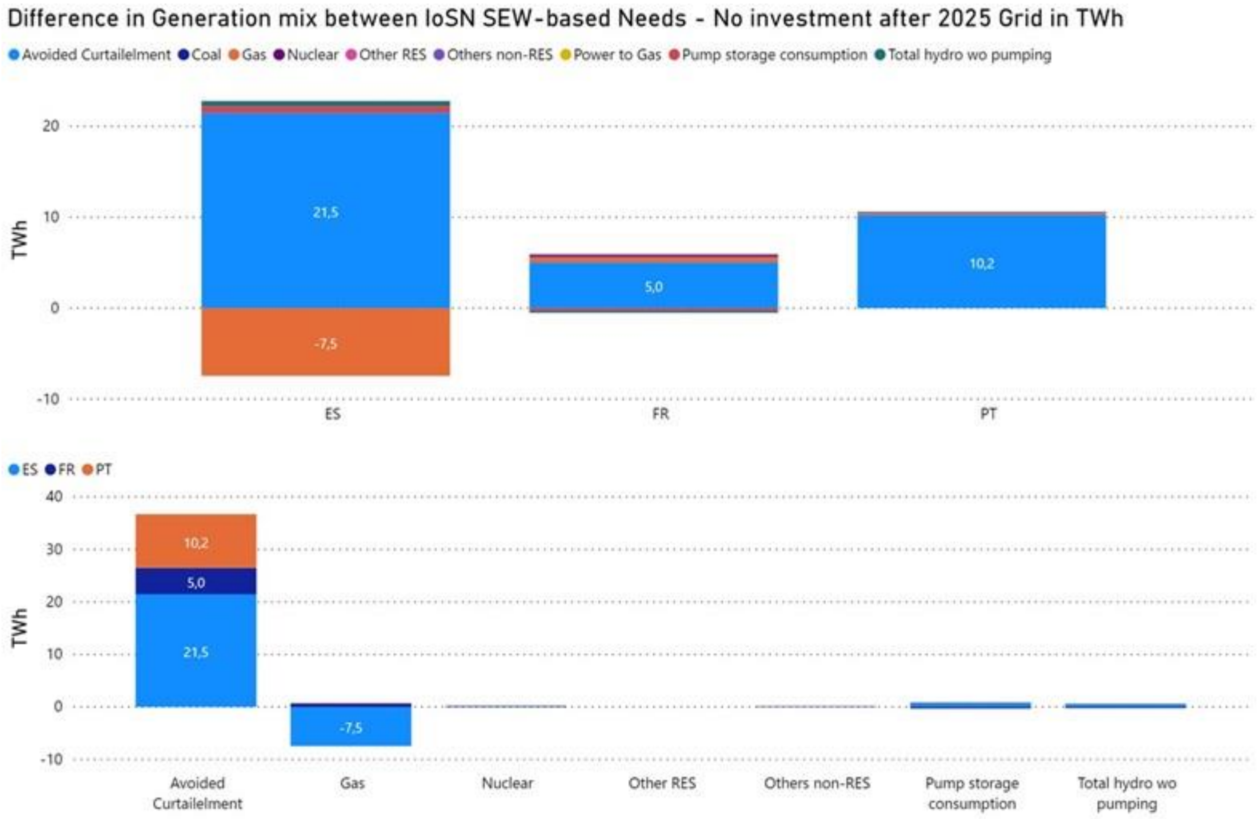

Figure 4.7: Difference in the annual generation by fuel type in the region in the studied 2040 NT scenario with the 'No investment after 2025' grid and the 'IoSN SEW-based needs 2040'

Curtailed energy resulting from high levels of renewable installed capacity is still expected, especially in Spain and Portugal. The results reveal curtailed energy of 31,7 TWh/year in Spain, 8,3 TWh/year in Portugal and 6,7 TWh/year in France. Network capacities increases in Europe from 2025 to 2040 (that is, already planned projects and additional identified capacity needs in this analysis) allow for reducing the curtailed energy in the region, especially in Spain by 36,6 TWh.

Long-term copper plate simulation would indicate a level of curtailed energy still relevant (12,8 TWh/year) in the region, which would mean that the curtailed energy issue in the 2040 horizon cannot be solved by interconnection reinforcements alone (because curtailed energy occurs in all countries at the same time). Therefore, further measures would be required to mitigate such curtailed energy, such as storage facilities and power to gas.

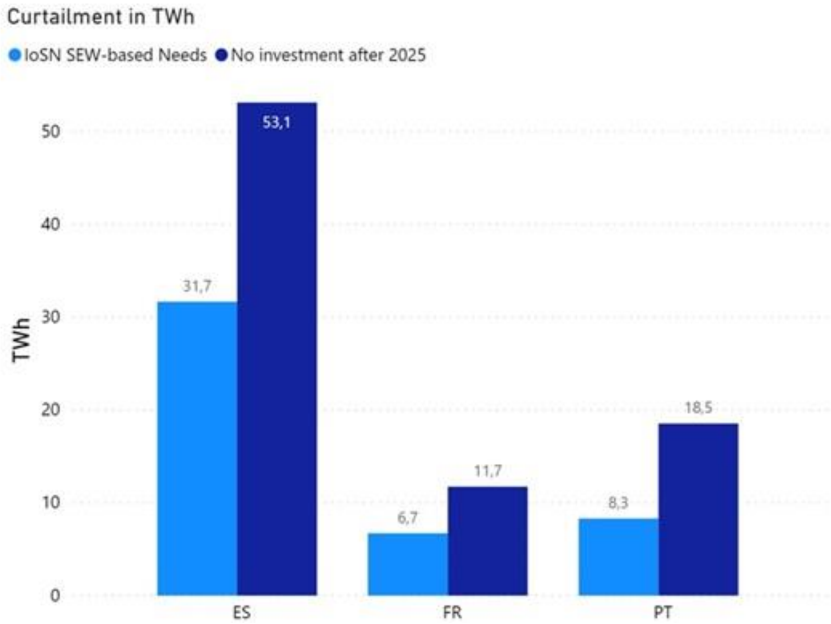

Figure 4.8: Yearly curtailed energy in CSW region in the studied 2040 NT scenario with the 'IoSN SEW-based needs 2040' and 'no investment after 2025' grid

Regarding CO_2 emissions they greatly depend on RES share of capacity, whereas the results are 9,9 Mtons/y in Spain, 4,5 Mtons/y in France and 1,9 Mtons/y in Portugal. Cross-border exchange capacities increase Europe-wide from 2025 to 2040 allow to reduce the CO_2 emissions in the region in 2,5 Mtons/y, especially in Spain.

Long-term copper plate simulation would indicate an additional CO_2 emissions reduction in the region by 1,8 Mtons/y.

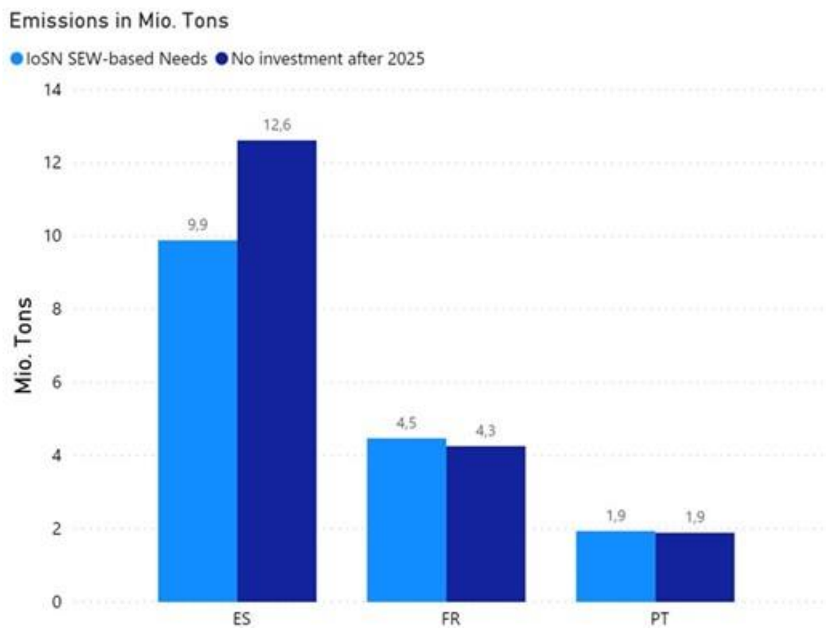

Figure 4.9: Yearly CO_2 emissions in CSW region in the studied 2040 NT scenario with the 'IoSN SEW-based needs 2040'and 'no investment after 2025' grid

In terms of marginal cost, Portugal with 19,9 €/MWh and Spain with average 26,5 €/MWh are generally lower than 29,7 €/MWh identified in France. Again, this reflects countries' generation portfolio, with Portugal and Spain showing higher RES levels. Cross-border exchange capacities Europe-wide increases from 2025 to 2040 enable an average reduction of marginal cost in France by 1,1 €/MWh and in Spain by 3,8 €/MWh, while in Portugal shows an increase (5,7 €/MWh).

Long-term copper plate simulation would indicate a convergence of costs across the region (27,3 €/MWh in Portugal, 27,9 €/MWh in Spain and 28,1 €/MWh in France).

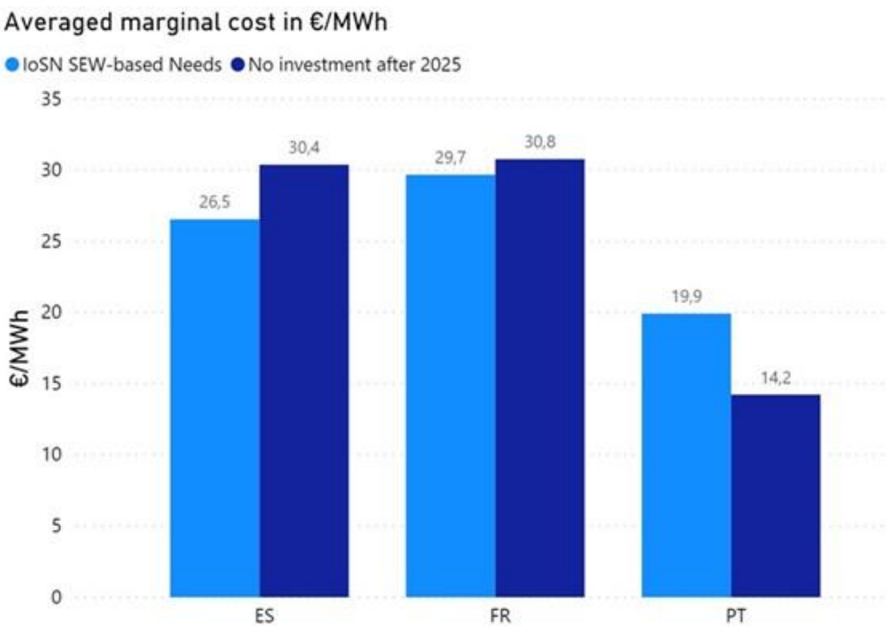

Figure 4.10: Yearly average of marginal cost in CSW region in the studied 2040 NT scenarios with the 'IoSN SEW-based needs 2040' and 'no investment after 2025' grid

With foreseen 2040 grid, yearly averages marginal cost spreads[21] are expected to be reduced significantly in almost all borders in the region, by an average around 32 €/MWh 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 neighbour countries, as is the case of ES-FR (12,4 €/MWh) and FR-ITn (19,1 €/MWh) were the marginal cost spread still remains above 10 €/MWh. Therefore, cost convergence is still not reached.

Long-term copper plate simulation would indicate a convergence of costs within the region and also between the neighboring countries.

[21] *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*

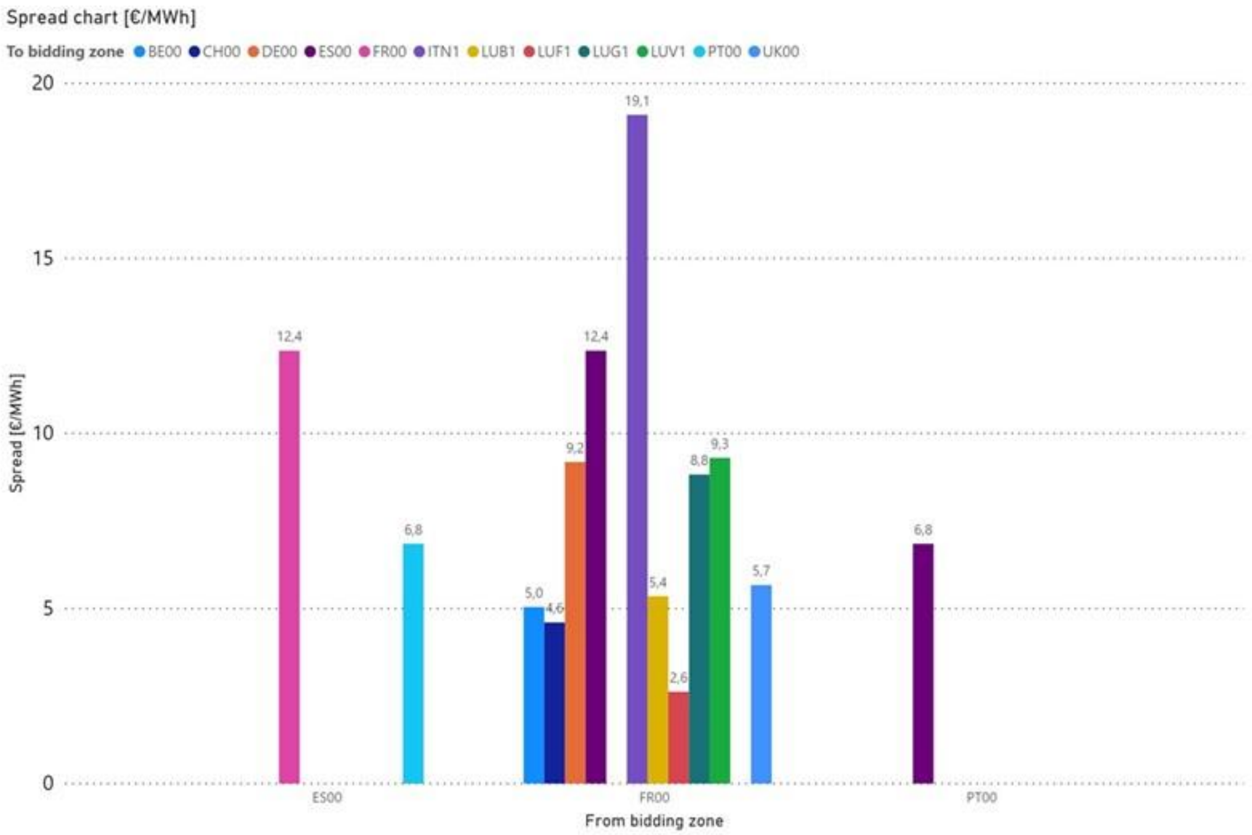

Figure 4.11: Average hourly cost differences in CSW region in the studied 2040 NT scenarios with 'IoSN SEW-based needs 2040'

Concerning country balances, France and Portugal are always net exporters (69,7 TWh and 20,1 TWh, respectively) and Spain is slightly net importer (5.2 TWh). Cross-border exchange increases from 2025 to 2040 are relevant to Portugal in this matter as they enable the country to almost double its exports and also to Spain allowing a significant reduction of imports.

Long-term copper plate simulation would indicate that Spain could change from net importer to net exporter.

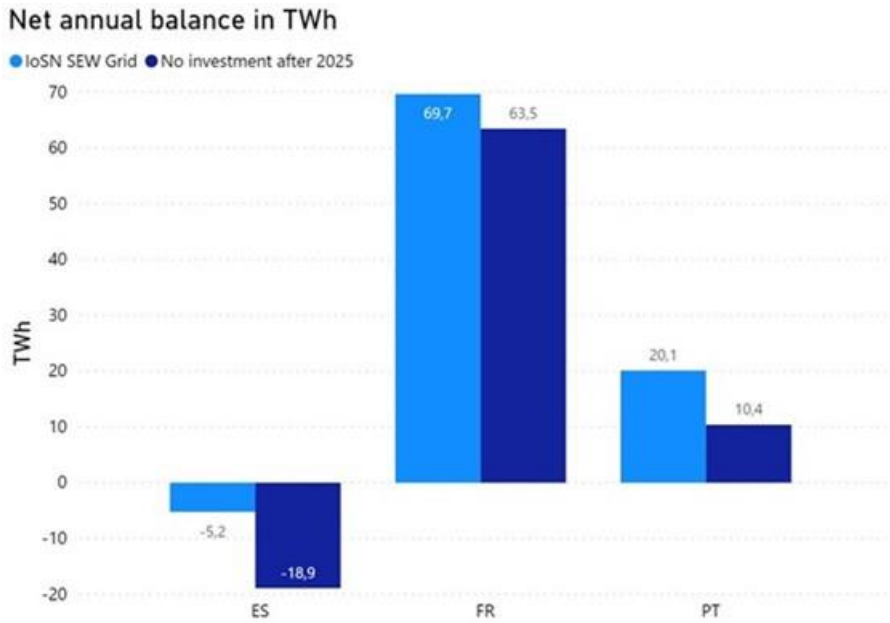

Figure 4.12: Net annual country balance in CSW region in the 2040 NT scenario with the 'IoSN SEW-based needs 2040' and 'no investment after 2025' grid

4.3 Network Results

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

Additional internal reinforcements are needed to make the NT scenario feasible from the network point of view, which implies integrating the considerable amounts of additional renewable power generation, and to accommodate not only new power flows 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 many congestions on internal and cross-border lines in Spain, Portugal and France. Spanish and Portuguese solar generation will probably be located primarily in the South. Consequently, when solar generation production is high, the region will experience very high flows internally on the Iberian Peninsula from south to north and also going 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 these future congestions.

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. The TYNDP 2020 IoSN analysis confirms the main conclusions from TYNDP 2018 and they have already been considered in the latest version 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, capacity increases and RES integration, hence constrains will appear that need to be solved with internal reinforcements to be studied in the future. Many of these constraints are highly interrelated when the increase in cross-border flows is due to higher RES production. Main areas of congestion in the 2040 scenario are located in the northern part of Spain in the West area and in the East area as well near the Spain-France border.

For the French system, the analysis carried out in the framework of the TYNDP 2020 IoSN confirms some areas of fragility on the French network, that 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 uncertain factors whose level of granularity is finer than that of the IoSN analysis: precise location of RES generation and nuclear decommissioning for example. Furthermore, while 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, without a more in-depth study. Such a detailed study would require prior confirmation of certain assumptions concerning energy transition in France and its neighbouring countries.

There are some projects included in chapter 6 as Regional projects that would allow to solve some of these future problems. However, it is too soon yet for defining with many details the reinforcements needed for 2040, as the volumes of RES and correct location of generation in the CSW region should be more certain.

More detailed results from network studies (detailed map of congestions for the three scenarios) are presented in Appendix 3.

5. ADDITIONAL REGIONAL STUDIES

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

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. It also 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 to the operation of the future system when designing the transmission network.

Individual characteristics and technology of the projects is a tool to face this operation challenge, and the reason of the importance of the following study.

Additional studies developed in the Spanish-French border

Biscay Gulf project consists on an HVDC new 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 that will increase the exchange capacity between the Iberian Peninsula and the rest of Europe up to 5.000 MW both in importing and exporting.

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

In that sense REE and RTE launched in 2017 common studies work whose main conclusions are shared in the following paragraphs:

- **Transient stability studies**: After agreeing common scenarios of study, each TSO developed their transient stability studies focusing in their own network, and with their individual modelling, methodology and acceptance criteria. The conclusions are shared, and are the following:
    - REE simulations show no relevant issues from the point of view of transient stability so, a priori and regardless possible additional requi-rement to the control system in the Technical Specification, the net-work behaves properly in the scenarios and with the control system analyzed.
    - RTE simulations show no relevant issues, although in the particular case of maximum exchange from Spain to France, high renewable production in France and high nuclear production in the French south-west area, simulations show a non-acceptable behavior so that the ex-change program shall have to be reduced.
- **Small signal stability studies**: RTE and REE have performed small signal stability studies, based on time and/or frequency domain simulations. The conclusions are the following:

- For a given exchange program, the new HVDC enhance the damping of the system, compared to present values, as the active power through the AC tie lines is reduced.
- Similar situation as today:
  - Inter-area modes are well damped for scenarios with power exchange from France to Spain
  - Similar small signal stability situation when the power exchange flows from Spain to France, i.e. the damping is similar for 5 GW (Sp to Fr) with new HVDC Biscay Gulf than for today´s maximum SP to FR exchange scenarios.

Mitigation measures to guarantee small signal stability have already been identified and are in phase of deployment nowadays. These measures will also mitigate present and future (with new HVDC inservice) low level of damping for inter-area oscillations

In consequence, these studies indicate that small signal stability will be a relevant issue for the Technical Specifications when designing the active and reactive power controls, as well as specific power oscillation damping control functions.

- **Additional investigations:** Other calculations have been performed, which show:
  - There is not an evident risk of sub-synchronous resonance between the HVDC Biscay Gulf and Spanish combined cycles located nearby Gatica, and with the French nuclear plant near Bordeaux.
  - Active power flow re-distribution pattern when changing the HVDC Biscay Gulf setpoint: 60% of active power would flow through the AC western corridor, while 40% would flow through the eastern. 400 kV Hernani-Argia would overtake around 50% of the HVDC variation.
- **Static overload and voltage control studies:** this study focuses on highlighting the internal Spanish and French needs from a steady-state point of view to reach 5GW 30% of the time when Biscay Gulf HVDC will be commissioned in 2027.

For that purpose NTC was computed considering Spanish and French network security criteria from an operational and planning point of view and monitored the internal constraints on the French and Spanish grids. All these computations in year round computations or in Point In Time selection cases have shown as a prerequisite to globally reach 5GW 30% of the time in the Spanish internal grid:

- A new transformer 400/220kV in Gatica substation
- Reinforcements of Gatica – Güenes, Azpetia-Güenes and Amorebiata – Güenes 400 kV lines

Both requirements were already identified in the past and has been included as TYDNP projects.

In addition, congestions detected on the French internal grid (Dambron-Verger 400kV) don't affect reaching 5GW 30% of the time in the scenarios considered, nevertheless RTE will monitor all the elements that still have high degree of uncertainty and that could have a trong impact on flows on this line (e.g. precise location of nuclear descomissioning or new RES).

Next steps:

- voltage control studies with a focus on Basque country where the new HVDC will lead to an increase of flows in some parts of the AC grid, which could require the installation of new reactive compensation elements additional to the new converter stations.

- investigate for a common methodology of long term evaluation of the Transmission Reliability Margin (TRM) that is the difference between the physical flows across the border and the commercial flows.
- Investigate for an optimised management of the HVDC which allows the best NTC while ensuring safe system operation, especially during high hourly ramps of commercial exchanges.

Additionally, to the Biscay Gulf studies, and in order to meet the 8 GW interconnection target between the Iberian Peninsula and the rest of Europe stablished in Madrid and Lisbon Declarations two Pyrenean projects are planned to be commissioned in 2029 and 2030 respectively. In that sense a thorough joint REE-RTE study will be needed in order to investigate about the internal reinforcement requirements in the Spanish and French networks and the optimization of the flows on the border when considering four HVDC links in parallel with AC lines.

APPENDICES

Appendix 1. Projects

The following projects were collected during the project call for TYNDP 2020. They represent the most important projects for the region. To be included in the analysis, a project has to fit several criteria. These criteria are described in the ENTSO-E practical implementation of the guidelines for inclusion in TYNDP 2020[22]. This chapter is divided into Pan-European and regional projects.

Pan-European projects

The table and figure below shows all approved projects submitted by project promoters during the TYNDP 2020 call for projects. The projects are in different states, which are described in the CBA guidelines:

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

Depending on the state of a project, it will be assessed according to the cost-benefit analysis. A full table enumerating all European projects submitted can be found on the TYNDP 2020 homepage.

Project nº	Project Name	Current Commissioning Date	Current Status*
1	RES in north of Portugal	2020-2024	Planned But Not Yet Permitting
4	Interconnection Portugal-Spain	2022	In Permitting
16	Biscay Gulf	2027	In Permitting
85	Integration of RES in Alentejo	2023	Planned But Not Yet Permitting
233	Connection of Aragon Pumping hydro	2027	Under Consideration
270	FR-ES project -Aragón-Atlantic Pyrenees	2027-2030	Planned But Not Yet Permitting
276	FR-ES project -Navarra-Landes	2027-2029	Planned But Not Yet Permitting
296	Britib	2026	Under Consideration
378	Transformer Gatica	2025	Planned But Not Yet Permitting
379	Uprate Gatica lines	2025	Under Consideration

* – Status of the least advanced investment

Table A1-1: TYNDP 2020 projects: CSW regional group

[22] https://tyndp.entsoe.eu/

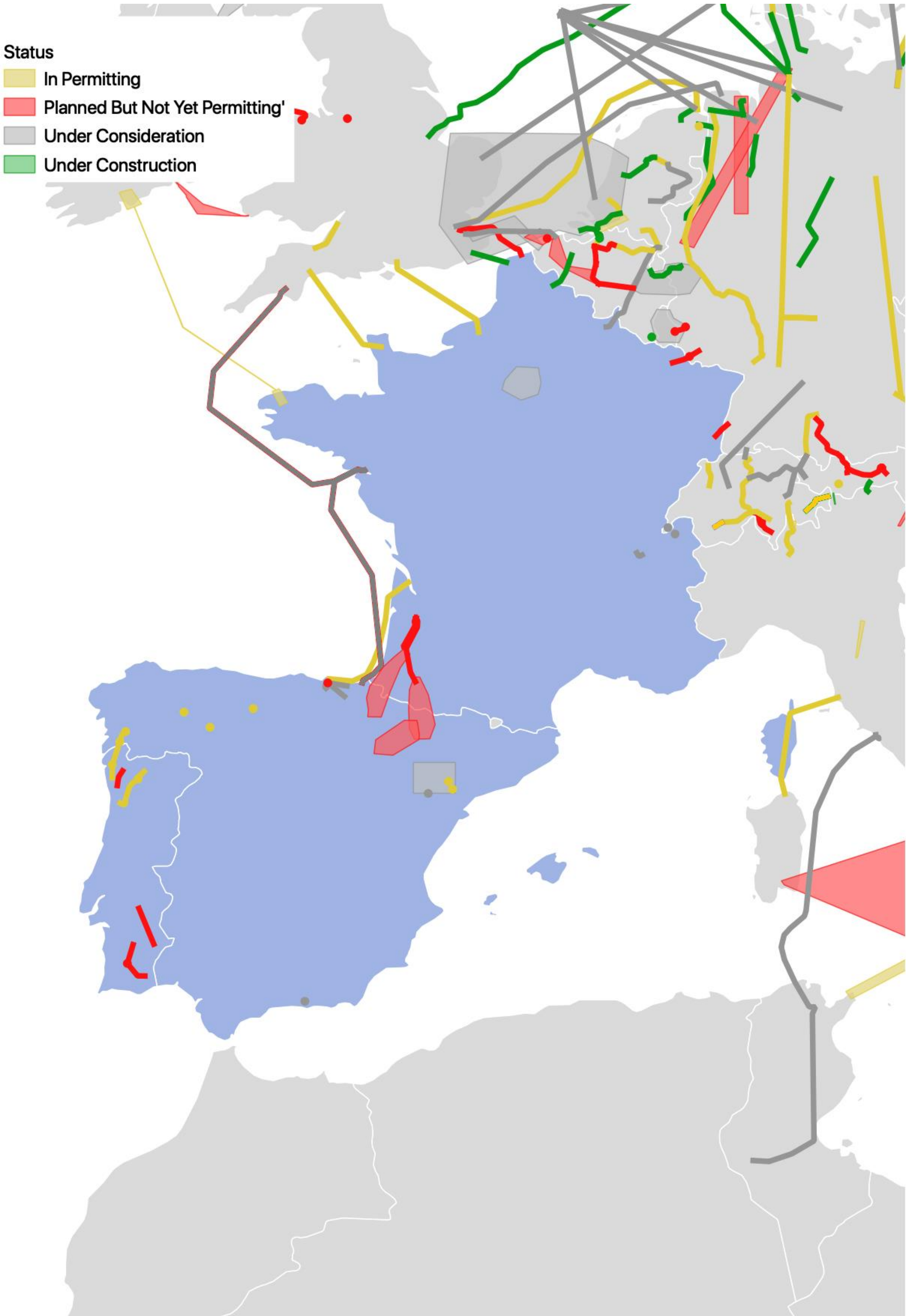

Figure A1-2: Projects to be assessed in TYNDP CBA analysis

Additional regional projects

In this chapter, the CSW projects of 'regional' significance are listed, as they are needed as substantial and inherent support for the Pan-European projects inclusion into the future transmission systems. Appropriately, all these projects include a description, the main driver, why they are designed to be realized in the future scenarios, the current expected commissioning dates and the expected commissioning date in the RgIP 2017 in case they were introduced in the previous Regional Investment Plan.

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 regarding whether the project is relevant to be included.

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

Country	Project Name	Investment		Expected Commissioning year RgIP 2017	Current Expected commissioning year	Description	Main drivers	Included in RgIP 2017?
		From	To					
FRANCE	Lille-Arras	Avelin	Gavrelle	2021	2021	An existing 30-km 400-kV single-circuit OHL in the Lille area will be substituted by a new double-circuit 400-kV OHL.	Security of supply and RES integration; the project aims to ensure the security of supply, taking into account RES generation variability	Yes
FRANCE	Sud Aveyron			2020	2022	New substation on the 400-kV Gaudière-Rueyres line for local RES integration.	RES integration	Yes
FRANCE	Eguzon-Marmagne 400kV	Eguzon	Marmagne	2022	2022	Reconductoring existing 400kV OHL (maintenance)	Maintenance, RES integration and market integration	Yes
FRANCE	Long term perspective "Façade Atlantique"			2030	>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"			N/A	>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	No

FRANCE	Long term perspective "Normandie – bassin parisien"			N/A	>2030	Upgrade of the north-south 400kV corridor between Normandy and Paris basin, under study.	RES integration	No
FRANCE	Long term perspective "Massif central – Centre"			>2027	>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	2023	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	Godelleta-Morella/La Plana**	Godelleta	Morella/La Plana	2025	2025	New 400 kV axis between Morella and La Plana substations	Integration of RES and accommodation of flows	Yes*
SPAIN	North Axis in Basque Country (Ichaso-Abanto/Gueñes)	Ichaso	Abanto and Gueñes	2020	2020	New double circuit OHL that will consist on the Ichaso-Abanto and Ichaso-Gueñes lines	Market integration	Yes
SPAIN	400-kV Asturias Ring and Sama-Velilla**	Gozón	Velilla	2022-2027	2022-2027	This project consists of closing the 400-kV Asturias Ring in the northern part of Spain and comprises a new 400-kV OHL line between Gozón and Sama, with two new 400-kV substations in Reboria and Sama (Spain), whose main purpose is to support the distribution network; the connection between Sama and Velilla intends to reinforce the Asturian connection with the centre of the country	Security of supply and market integration	Yes
SPAIN	Uprate of Transpireneean Axis (Sabiñánigo-TEscalona-Escalona-TForadada – La Pobla)	Sabiñanigo	La Pobla	2019-2021	2019-2021	Uprating the 220 kV OHL Sabiñanigo-T- Escalona-Escalona-T-Foradada-La Pobla	Market integration	Yes
SPAIN	Second Link Spanish Mainland-Mallorca**	Morvedre	Santa Ponsa	<2025	<2025	HVDC Subsea cable 2x500MW link from Valencia to Mallorca	Market integration and interconnection between asynchronous systems	Yes
SPAIN	Reinforcement of Southern Aragón-Cataluña axis	TBD	TBD	2025-2030	<2025	The detail of the reinforcement is not fully defined, and it is pending a future national development plan	Market integration	Yes
SPAIN	Reinforcement of the Axis La Serna – Magallón 400 kV	La Serna	Magallón	2025-2030	2025-2030	The detail of the reinforcement is not fully defined, and it is pending a future national development plan	Market integration	Yes
SPAIN	Reinforcement of the Axis Aldeadávila – Villarino--Grijota-Herrera-Virtus (400kV)**	Aldeadavila	Virtus	2025-2030	2020	The detail of the reinforcement is not fully defined, and it is pending a future national development plan	Market integration	Yes
SPAIN	TSCC in Pierola 400 kV**	Pierola	Pierola	2024-2028	2024-2028	Flexible alternating current transmission system (FACTS) TTCC device in Pierola substation	Security of supply,	Yes
SPAIN	FACTs Statcom**	x	x	2024-2028	2024-2028	FACTS Statcom devices in the substations of Vitoria, Carmona and Benahadux	Security of supply,	Yes
SPAIN	FACTs in northwestern Spain**	x	x	2024-2028	2024-2028	FACTs in Tibo	Security of supply,	Yes

PORTUGAL	Falagueira-Fundão	Falagueira	Fundão	2018	2020	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	2019-2021	2021	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	New 400-kV OHL Rio Maior-Fanhões	Security of supply and RES integration	No

(*) These projects were in the TYNDP2018 list
(**) The final technical definition of these projects will depend on the final Spanish Development Plan 2021-2026 currently ongoing

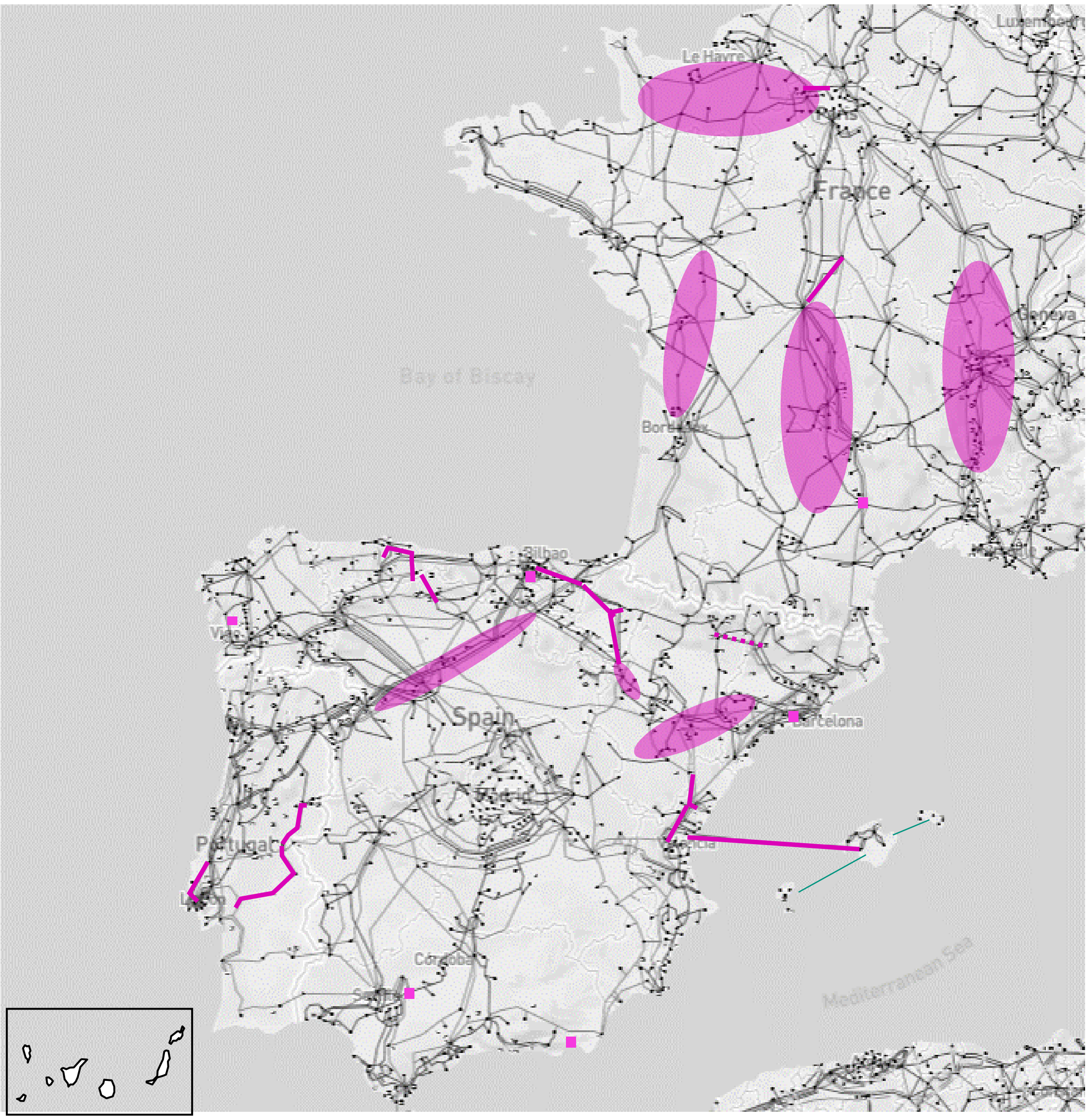

Figure A1-3: Additional regional projects in the CSW regional group

Appendix 2. Links to national development plans

Portugal

The final proposal of the Portuguese Ten-Year Development and Investment Plan for the electricity transmission network for the period between 2018 and 2027 (PDIRT 2018 2027) was submitted to the General Directorate of Energy and Geology (DGEG) in August 2018 and it was approved by the member of the Portuguese government responsible for the energy sector (dispatch of the Portuguese Secretary of State of Energy of 14 February 2019).

Complying with legislation, in March 2019, REN - Rede Eléctrica Nacional, S.A. (REN) submitted to DGEG a draft proposal for the Portuguese Ten-Year Development and Investment Plan for the electricity transmission network for the period between 2020 and 2029 (PDIRT 2020-2029).

Considering DGEG's determinations, REN reviewed the PDIRT 2020-2029 and in July 2019 presented to DGEG a new PDIRT 20120-2029 proposal. Between January 2020 and February 2020 this PDIRT 2020-2029[23] proposal was submitted to a public consultation promoted by the Portuguese Energy Services Regulatory Authority (ERSE), for the purpose of gathering information and comments from various economic agents, consumers and other stakeholders. After this public consultation period, in May 2020, ERSE issued its opinion on the PDIRT 2020-2029 proposal. Subsequently, taking into account ERSE's opinion, REN prepared a new PDIRT 2020-2009 proposal, which was forwarded to DGEG in June 2020.

Spain

The current National Development Plan in Spain, named *"Planificación Energética. Plan de Desarrollo de la Red de Transporte de Energía Eléctrica 2015-2020"*[24] was published in October 2015 by the Spanish Government (Ministry of Industry, Energy and Tourism). In this process, the Spanish TSO (Red Eléctrica de España) acts as technical support for the Government.

The legal framework for this plan is the Law 24/2013 of the Electric Sector and the RD1047/2013 of remuneration of the transmission activity, where is it established the need to publish every 4 years a Master Plan which covers a period of 6 years, and an annual and a global investment limit. The 3-pillar objective for the National Development Plan is to ensure the Security of Supply, being sustainable, and do it at the minimum possible cost. Moreover, it allows Spain to fulfil the 2020 European energy objectives.

The Master Plan provides a list of binding transmission infrastructure for the next period 2015-2020 (f.i. substations including detail of new bays due to new connections of demand or generation, lines, transformers, reactive compensation, FACTs, etc.) and detailed cost benefit analysis for certain major projects. The Master Plan also includes in the Appendix 2 a list of projects that would be needed after

[23] https://www.erse.pt/media/harhy1bu/proposta-de-pdirt-e-2019_relat%F3rio.pdf; https://www.erse.pt/media/1mrlurih/proposta-de-pdirt-e-2019_anexos.pdf

[24] http://www.minetad.gob.es/energia/planificacion/Planificacionelectricidadygas/desarrollo2015-2020/Paginas/desarrollo.aspx

2020. These projects in Appendix 2 can start the permitting procedures although they should be confirmed in the next Master Plan.

The Ministerial Order TEC/212/2019 on 25 February 2019 kicked off the process of preparing the new master plan 2021-2026 which has the primary goal of turning the electricity transmission grid into a key vector in Spain's energy transition.

The planning process is a participatory process conducted by Spain's General State Administration and, its autonomous communities, and which involves too its National Commission on Markets and Competition, the TSO and all of the sector actors. Society as a whole is also given a say in information and consultation processes. The process is structured into the following six phases: proposals, preliminary studies, debate, studies, consolidation and approval, which is expected in 2021.

France

The French Schéma Décennal de Développement du Réseau (SDDR)[25] is published every year by RTE, in compliance with article L321-6 of the French Energy code, transposing the CE 2009-72 Directive. Along the lines of the energy code, "*SDDR is based on existing offer and demand as well as on reasonable mid-term assumptions concerning the evolutions of generation, demand, and cross-border electicity exchanges*". In addition, the SDDR has to mention "*main infrastructures planned in the 10 coming years*" and identify "*already decided investments due to be commissioned in the next three years*",

Furthermore, the Commission de Régulation de l'Energie (CRE, French Regulatory Energy Commission) has to check whether this SDDR covers all the investment needs and its consistency with the electricity TYNDP.

The latest SDDR, SDDR 2019, was published in September 2019 under its final version following a public consultation. It is consistent with the TYNDP 2018.

[25] https://www.rte-france.com/fr/article/evolution-du-reseau-electrique-francais-l-horizon-2035

Appendix 3. Additional figures

Network study results

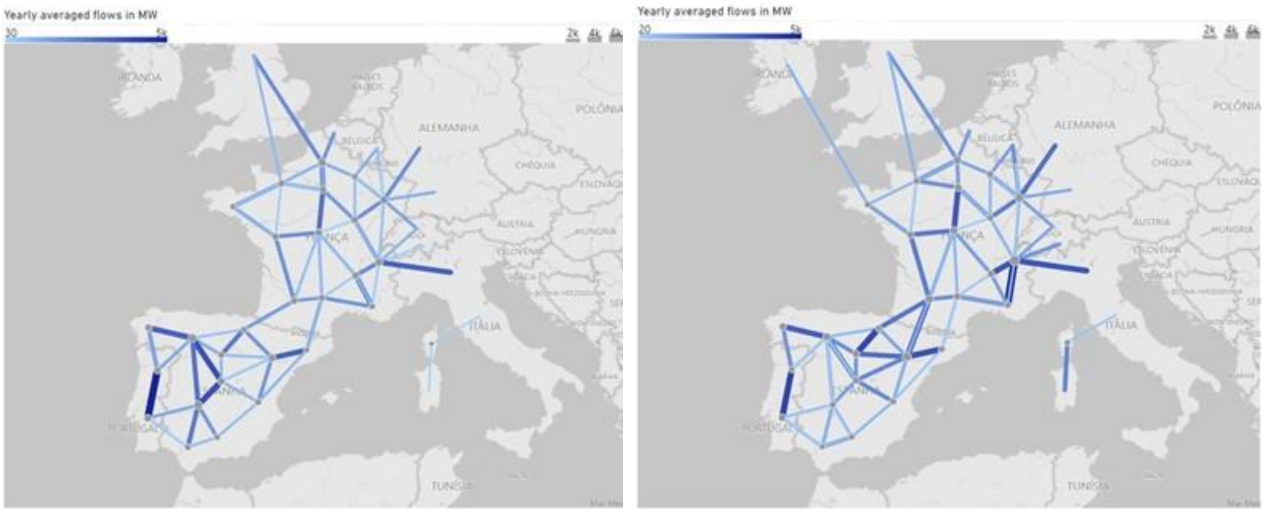

Figure A3-1: Yearly average flows in the studied 2040 NT scenario with the 'no investment after 2025' grid (left) and 'IoSN SEW-based needs 2040' (right)

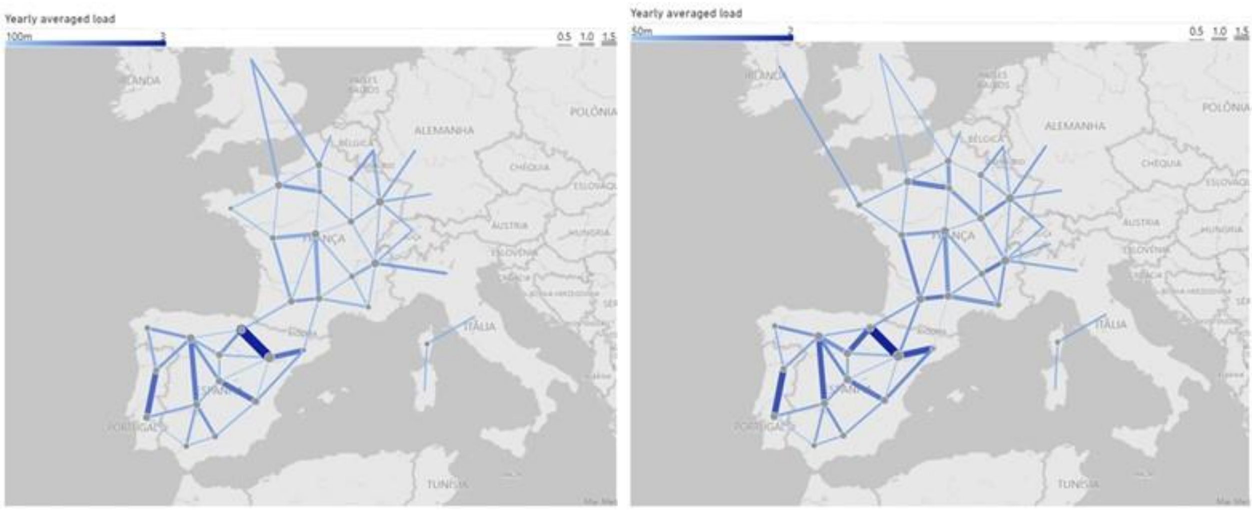

Figure A3-2: Yearly average load in the studied 2040 NT scenario with the 'no investment after 2025' grid (left) and 'IoSN SEW-based needs 2040' (right)

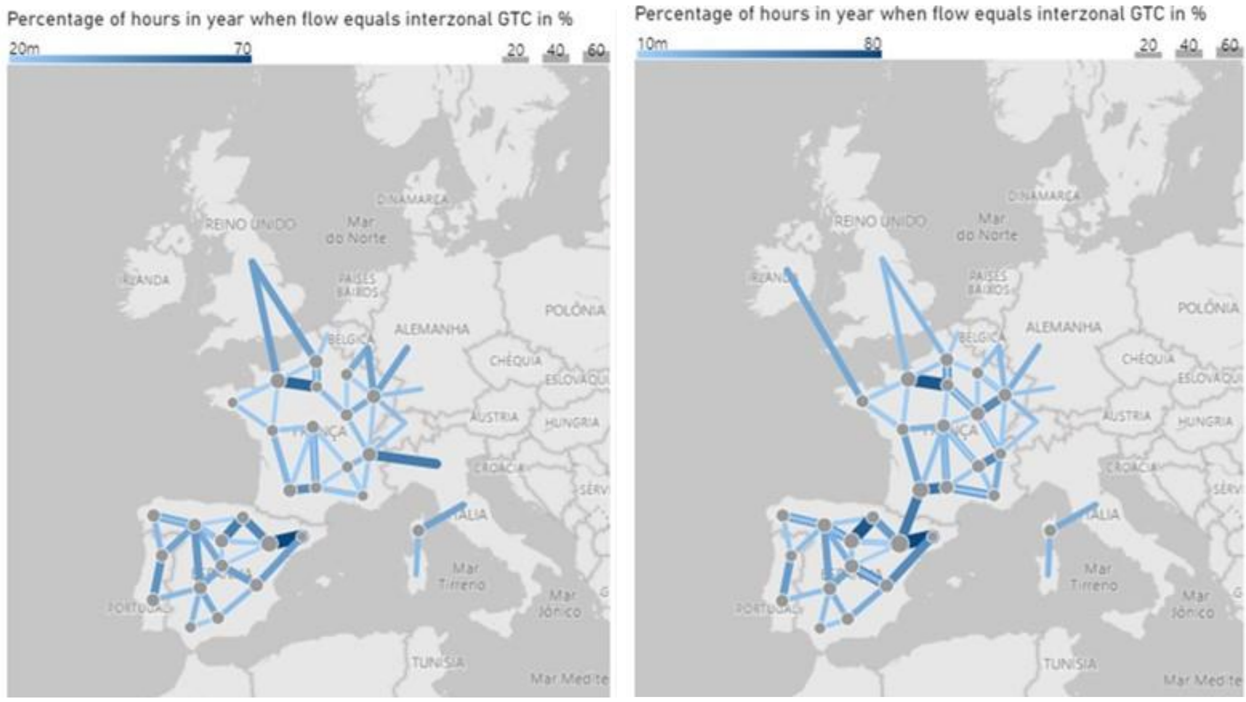

Figure A3-3: Internal constraints duration in the studied 2040 NT scenario with the 'no investment after 2025' grid (left) and 'IoSN SEW-based needs 2040' (right)

Candidate capacity increases and cost assumptions

The following capacity increases were proposed to the optimiser. The capacity increases listed in this appendix include projects submitted to the TYNDP 2020 and conceptual increases that do not correspond to existing projects. Cost assumptions are theoretical assumptions that include the assumed costs of reinforcement of internal networks that would be necessary for the cross-border capacity increases.

When there are several values on the same border, a sequential consideration of the capacity increases has been proposed to the optimiser.

Border	Capacity (MW)	CAPEX (M€)
ES00-FR00	1500	1170
ES00-FR00	1500	1470
ES00-FR00	2000	2500
ES00-FR00	4000	5700
ES00-PT00	500	61
ES00-PT00	1000	87
ES00-PT00	1500	120
ES00-PT00	500	87
ES00-PT00	1000	90
ES00-PT00	1500	114
ES00-PT00	500	157
ES00-PT00	1000	233
ES00-PT00	1500	268
ES00-PT00	500	176
ES00-PT00	1000	295
ES00-PT00	1500	331

Appendix 4. Glossary

Term	Acronym	Definition
Agency for the Cooperation of Energy Regulators	ACER	EU Agency established in 2011 by the Third Energy Package legislation as an independent body to foster the integration and completion of the European Internal Energy Market both for electricity and natural gas.
Baltic Energy Market Interconnection Plan in electricity	BEMIP Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections between Member States in the Baltic region and the strengthening of internal grid infrastructure, to end the energy isolation of the Baltic States and to foster market integration; this includes working towards the integration of renewable energy in the region.
Bottom-Up		This approach of the scenario building process collects supply and demand data from Gas and Electricity TSOs.
Carbon budget		This is the amount of carbon dioxide the world can emit while still having a likely chance of limiting average global temperature rise to 1,5 °C above pre-industrial levels, an internationally agreed-upon target.
Carbon Capture and Storage	CCS	Process of sequestrating CO2 and storing it in such a way that it will not enter the atmosphere.
Carbon Capture and Usage	CCU	The captured CO2, instead of being stored in geological formations, is used to create other products, such as plastic.
Combined Heat and Power	CHP	Combined heat and power generation.
Congestion revenue / rent		The revenue derived by interconnector owners from the sale of the interconnector capacity through auctions. In general, the value of the congestion rent is equal to the price differential between the two connected markets, multiplied by the capacity of the interconnector.
Congestion		Means a situation in which an interconnection linking national transmission networks cannot accommodate all physical flows resulting from international trade requested by market participants, because of a lack of capacity of the interconnectors and/or the national transmission systems concerned.
	COP21	21st Conference of the Parties to the United Nations Framework Convention on Climate Change, organised in 2015, where participating states reached the Paris Agreement.

Cost-benefit analysis	CBA	Analysis carried out to define to what extent a project is worthwhile from a social perspective.
Curtailed electricity		Curtailment is a reduction in the output of a generator from otherwise available resources (e. g. wind or sunlight), typically on an unintentional basis. Curtailments can result when operators or utilities control wind and solar generators to reduce output to minimize congestion of transmission or otherwise manage the system or achieve the optimum mix of resources.
Demand side response	DSR	Consumers have an active role in softening peaks in energy demand by changing their energy consumption according to the energy price and availability.
e-Highway2050	EH2050	Study funded by the European Commission aimed at building a modular development plan for the European transmission network from 2020 to 2050, led by a consortium including ENTSO-E and 15 TSOs from 2012 to 2015 (to e-Highway2050 website).
Electricity corridors		Four priority corridors for electricity identify by the TEN-E Regulation: North Seas offshore grid (NSOG); North-south electricity interconnections in western Europe (NSI West Electricity); North-south electricity interconnections in central eastern and south eastern Europe (NSI East Electricity); Baltic Energy Market Interconnection Plan in electricity (BEMIP Electricity).
Energy not served	ENS	Expected amount of energy not being served to consumers by the system during the period considered due to system capacity shortages or unexpected severe power outages.
Grid transfer capacity	GTC	Represents the aggregated capacity of the physical infrastructure connecting nodes in reality; it is not only set by the transmission capacities of cross-border lines but also by the ratings of so-called "critical" domestic components. The GTC value is thus generally not equal to the sum of the capacities of the physical lines that are represented by this branch; it is represented by a typical value across the year.
Internal Energy Market	IEM	To harmonise and liberalise the EU's internal energy market, measures have been adopted since 1996 to address market access, transparency and regulation, consumer protection, supporting interconnection, and adequate levels of supply. These measures aim to build a more competitive, customer-centred, flexible and non-discriminatory EU electricity market with market-based supply prices.
Investment (in the TYNDP)		Individual equipment or facility, such as a transmission line, a cable or a substation.
Mid-term adequacy forecast	MAF	ENTSO-E's yearly pan-European monitoring assessment of power system resource adequacy spanning a timeframe from one to ten years ahead.

Net transfer capacity	NTC	The maximum total exchange programme between two adjacent control areas compatible with security standards applicable in all control areas of the synchronous area and taking into account the technical uncertainties on future network conditions.
N-1 criterion		The rule according to which elements remaining in operation within a TSO's responsibility area after a contingency from the contingency list must be capable of accommodating the new operational situation without violating operational security limits.
National Energy and Climate Plan	NECP	National Energy and Climate Plans are the new framework within which EU Member States have to plan, in an integrated manner, their climate and energy objectives, targets, policies and measures for the European Commission. Countries will have to develop NECPs on a ten-year rolling basis, with an update halfway through the implementation period. The NECPs covering the first period from 2021 to 2030 will have to ensure that the Union's 2030 targets for greenhouse gas emission reductions, renewable energy, energy efficiency and electricity interconnection are met.
North Seas offshore grid	NSOG	One of the four priority corridors for electricity identified by the TEN-E Regulation. Integrated offshore electricity grid development and related interconnectors in the North Sea, Irish Sea, English Channel, Baltic Sea and neighbouring waters to transport electricity from renewable offshore energy sources to centres of consumption and storage and to increase cross-border electricity exchange.
North-south electricity interconnections in central eastern and south eastern Europe	NSI East Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections and internal lines in north-south and east-west directions to complete the EU internal energy market and integrate renewable energy sources.
North-south electricity interconnections in western Europe	NSI West Electricity	One of the four priority corridors for electricity identified by the TEN-E Regulation. Interconnections between EU countries in this region and with the Mediterranean area including the Iberian peninsula, in particular to integrate electricity from renewable energy sources and reinforce internal grid infrastructures to promote market integration in the region.
Power to gas	P2G	Technology that uses electricity to produce hydrogen (Power to Hydrogen – P2H2) by splitting water into oxygen and hydrogen (electrolysis). The hydrogen produced can then be combined with CO2 to obtain synthetic methane (Power to Methane – P2CH4).
Project (in the TYNDP)		Either a single investment or a set of investments, clustered together to form a project, in order to achieve a common goal.

Project of common interest	PCI	A project which meets the general and at least one of the specific criteria defined in Art. 4 of the TEN-E Regulation and which has been granted the label of PCI project according to the provisions of the TEN-E Regulation.
Put IN one at the Time	PINT	Methodology that considers each new network investment/project (line, substation, PST or other transmission network device) on the given network structure one by one and evaluates the load flows over the lines with and without the examined network reinforcement.
Reference grid		The existing network plus all mature TYNDP developments, allowing the application of the TOOT approach.
Reference capacity		Cross-border capacity of the reference grid used for applying the TOOT/PINT methodology in the assessment according to the CBA.
Scenario		A set of assumptions for modelling purposes related to a specific future situation in which certain conditions regarding electricity and gas demand and supply, infrastructures, fuel prices and global context occur.
Take Out One at the Time	TOOT	Methodology that consists of excluding investment items (line, substation, PST or other transmission network device) or complete projects from the forecasted network structure on a one-by-one basis and to evaluate the load flows over the lines with and without the examined network reinforcement.
Ten-Year Network Development Plan	TYNDP	The Union-wide report carried out by ENTSO-E every other year as (TYNDP) part of its regulatory obligation as defined under Article 8, para 10 of Regulation (EC) 714 / 2009.
Top-Down		The "Top-Down Carbon Budget" scenario building process is an approach that uses the "bottom-up" model information gathered from the gas and electricity TSOs. The methodologies are developed in line with the Carbon Budget approach.
Trans-European Networks for Energy	TEN-E	Policy focused on linking the energy infrastructure of EU countries. It identifies nine priority corridors (including 4 for electricity) and three priority thematic areas.

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