Regional Investment Plan 2017

Continental South West

Final version after public consultation and ACER opinion – October 2019

Contents

Contents 2
1 EXECUTIVE SUMMARY 4
1.1 Regional Investment Plans as foundation for the TYNDP 2018 4
1.2 Key messages about the region 5
1.3 Future capacity needs 6
2 INTRODUCTION 10
2.1 Legal requirements 10
2.2 The scope of the report 10
2.3 General methodology 12
2.4 Introduction to region 12
3 REGIONAL CONTEXT 15
3.1 Present situation 15
3.1.1 Transmission grid and exchange capacities in the region 15
3.1.2 Generation, consumption and exchange physical flows in the region 17
3.1.3 Interconnection ratio in the region 20
3.2 Description of the scenarios 21
3.3 Future challenges in the region 25
3.3.1 Challenges from the market studies approach 25
3.3.2 Challenges from the network studies approach 29
4 REGIONAL RESULTS 32
4.1 Future capacity needs 32
4.2 Market results 34
4.3 Network results 37
5 ADDITIONAL REGIONAL STUDIES 39
5.1 Additional studies developed on the Spanish-French border 39
6 LINKS TO NATIONAL DEVELOPMENT PLANS 40
7 PROJECTS 42
7.1 Pan-European projects 42
7.2 Regional projects 43
8 APPENDICES 47
8.1 Additional figures 47
8.1.1 Future challenges 47
8.1.2 Market study results 47
8.1.3 Network study results 49
8.1.4 Standard cost map 52
8.2 Abbreviations 53

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

8.3 Terminology 55

1 EXECUTIVE SUMMARY

1.1 Regional Investment Plans as foundation for the TYNDP 2018

The Ten-Year Network Development Plan (TYNDP) for electricity, prepared by the European Network of Transmission System Operators for Electricity (ENTSO-E), is the most comprehensive and up-to-date planning reference for the pan-European electricity transmission network. 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 is a biennial report published every even year by ENTSO-E and acts as an essential basis to derive the Projects of Common Interest (PCI) list.

ENTSO-E is structured into six regional groups for grid planning and other system development tasks. The countries belonging to each regional group are shown in Figure 1-1.

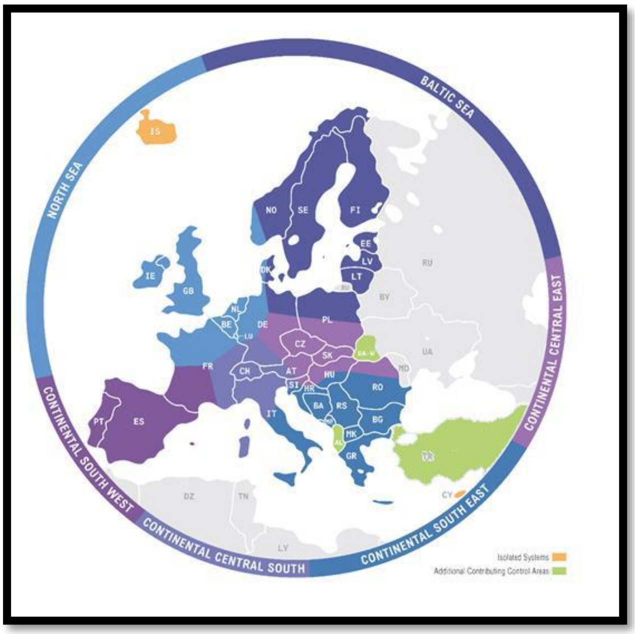


Figure 1-1: ENTSO-E system development regions

The six Regional Investment Plans form part of the TYNDP 2018 package, are supported by regional and pan-European analyses and take into account feedback received from institutions and stakeholder associations.

The Regional Investment Plans address challenges and system needs at the regional level. They 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 various scenarios in a 2040 time horizon.

In addition to revealing the 2040 challenges and proper scenario grid capacities to solve many of these challenges, the Regional Investment Plans provide all the relevant projects from the TYNDP project collection. Later in 2018, the benefits of each of these projects will be assessed and presented in the final TYNDP publication package.

To illustrate circumstances that are especially relevant to the region, available regional sensitivities and other available studies are included in the Regional Investment Plan. The operational functioning of the regional system and associated future challenges can also be assessed and described in the reports.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

Because the Regional Investment Plans (RgIPs) are published every odd year, the Regional Investment Plan 2017 builds on previous investment plans and describes changes and updates compared to earlier publications. Since the RgIPs give regional insight into future challenges, the main messages will also be highlighted in a Pan-European System Need Report. The studies of the regional plans and the Pan-European System Need Report are based on the scenarios described in the Scenario Report[1].

The RgIP will strongly support one of the predominant challenges for ENTSO-E: to establish the most efficient and collaborative way to reach all the defined targets of an effective internal energy market and a sustainable and secure electricity system for all European consumers.

1.2 Key messages about the region

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 the Portugal-Spain interconnection, and
  - the integration of the Iberian Peninsula into the European continental market through the development of the France-Spain interconnection.
- On the other hand, the RES integration. The Iberian Peninsula has been a forerunner in the installation of renewable energy (hydro and 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 three new 2040 scenarios in the Scenario Report published in October 2017, and includes an assessment of what would happen with the system in the case of encountering these 2040 scenarios while retaining the 2020 grid (that is, a no-network-development alternative).

The principal findings of this analysis are as follows:

- **Change in the generation portfolio towards a more carbon-free system**
  The 2030 scenarios already show a shift from coal to gas generation (cf. Scenario Report) and a transition from thermal to renewable generation, including the partial phase-out of nuclear in France. The optimisation 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 further market integration in the region, with a special focus on the isolation of the Iberian Peninsula**
  In 2020, in spite of the strong efforts of transmission system operators (TSOs) and the support from Member States and the European Commission (EC) through the Madrid Declaration 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[2]), Spain will not yet fulfil the 10% objective for 2020. Moreover, needs for cross-border development will also be attached to the 2030 objectives.

[1] https://www.entsoe.eu/Documents/TYNDP%20documents/14475_ENTSO_ScenarioReport_Main.pdf

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

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

The current analysis also reveals some additional needs in the 2040 horizon related to cross-border development, especially in reinforcing the Iberian Peninsula with the remainder of Continental Europe, that should be carefully analysed in the future.

- **The RES integration will pose a challenge, and it will not have a unique solution**
  The market analysis of 2040 scenarios reveals a high amount of spillage in the region with both 2020 and 2040 grids.
  In the face of the 2040 scenarios, the network as it will exist by 2020 will not be able to accommodate RES integration. This is because the renewable curtailed energy could, on average, amount to around 48 TWh in Spain, 2 TWh in France, and 8 TWh in Portugal without new network reinforcements.
  In fact, enabling future RES integration will represent a key challenge. The solution to 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 the Iberian Peninsula (mainly in the South) and in the South of France and high exports from CSW to the rest of Europe create higher flows and new flow patterns for which the grid was not designed. Therefore, these new flows incorporating higher volumes and variable directions that may be opposite to those currently known or to those identified in the previous TYNDPs result in cross-border and internal congestions in the long term. In addition, in light of the 2040 scenarios, we can foresee higher and longer transit flows and more influence than today between the France-Iberian Peninsula border and the France-Central Europe border.
  If these long-term scenarios materialise, cross-border and important internal reinforcements of today's grid will be needed to make the grid safe. These reinforcements solving congestions that are common to the three analysed scenarios are more likely to form part of the national development plans of the next several decades.
  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 projects to fulfil these needs.

- **The security of supply will have a new dimension**
  Ensuring security of supply in the future will not only be a matter of checking conventional system adequacy (to ensure sufficient generation capacity to meet demand) and system adequacy (to ensure the fulfilment of the N-1 conditions stated in the network codes in order to avoid energy not 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.

1.3 Future capacity needs

The first phases of the TYNDP-2018 process concerned building new scenarios for 2025, 2030 and 2040 and assessing system needs for the long-term horizon of 2040. As part of this work, cross-border capacity increases, which have a positive impact on the system, were identified[3] for the 2040 scenarios. A European overview of these increases is presented in the European System Need Report developed by ENTSO-E in

[3] For a description of the methodology used, see chapter 2.3.

parallel with the Regional Investment Plans for 2017. Identified needs for capacity increases at the borders of the CSW region are presented in the map below.

Depending on the scenario, the overall cross-border exchange capacities obtained in the analysis are in the range of 9000-10000 megawatts (MW) from Spain to France and up to values of 4700-5700 MW from Spain to Portugal and 4000-5000 MW from Portugal to Spain. The Spain-Italy and Spain-Great Britain borders were considered as potential reinforcements at the beginning of the identification of system needs analysis but were discarded as not being economically viable because the benefits obtained did not compensate for 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 the underground or submarine high-voltage direct current (HVDC) potential project to cross the border.

The increases in cross-border exchange capacities in Europe in such scenarios from 2020 onwards would have a significant impact on the electrical system and on society as a whole:

- They would reduce the annual average marginal cost in France, Spain and Portugal to a range between 2 and 5€/Mwh
- They would allow for integrating between 1000 and 39.000 GWh of renewable energy as maximums in the CSW region; this would otherwise be curtailed
- They would allow for up to a 5 GWh reduction in energy not served in the region
- They would enable an overall reduction of CO_2 emissions in Europe, which would vary from an increase of up to 3.000 ktons of CO_2 emissions to a reduction of up to 4.000 ktons of CO_2 emissions. Increases in CO_2 emissions are produced in the sustainable transition scenario, where a moderate increase in renewable sources is considered and, consequently, the CSW region exports a high amount of energy from gas sources

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

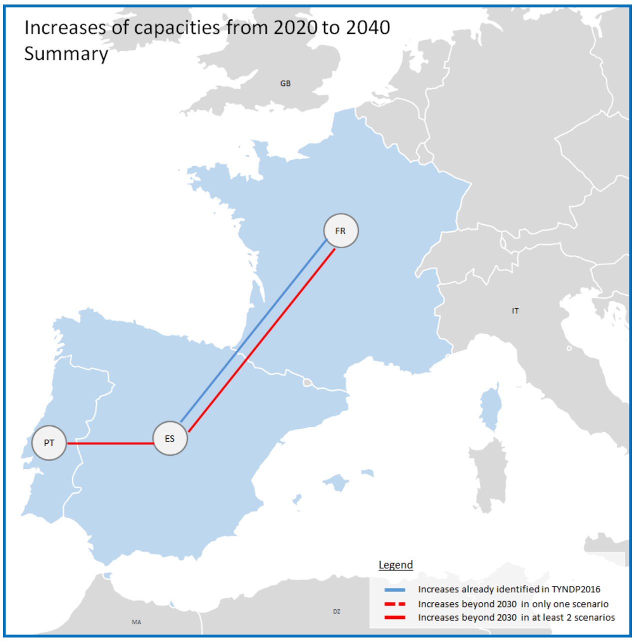


Figure 1-2: Identified capacity increase needs between the years of 2020 and 2040[4]

This map confirms that projects already at stake in the TYNDP 2016 respond to a real system need for more cross-border capacity and reflects that ambitious RES scenarios, such as the ones used for TYNDP 2018, could require more exchange capacity.

Here are the cross-border projects that are already addressing this need in the 2020-2030 horizon and that will be analysed in the TYNDP 2018. All of them have a PCI label in the third PCI list, published in 2017:

- New northern interconnection between Portugal and Spain in the Minho/Galicia regions, due to be commissioned by 2020/21 as part of the TYNDP 2018 Reference Grid;

- Biscay Gulf project between Spain and France, due to be commissioned by 2025 as part of the TYNDP 2018 Reference Grid, which should generate 2.2 gigawatts (GW) extra capacity;

- Navarra Landes and Pyrénées Atlantiques-Aragon between Spain and France, which together could generate up to 3 GW of extra cross-border capacity beyond the 2025 horizon.

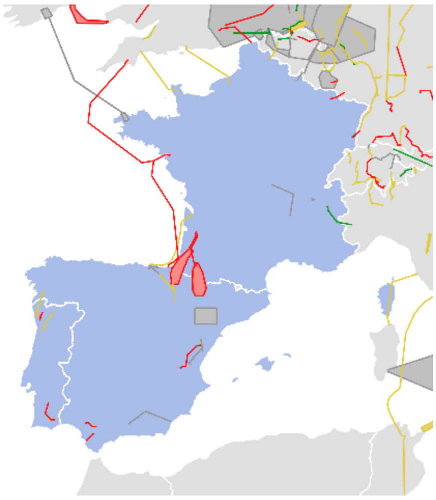


Figure 1-3: Projects to be assessed in the TYNDP CBA assessment

Beyond these projects, there are still some gaps in the 2040 scenario capacities obtained in the identification of system needs, especially on the Spain-France border. Its analysis still needs to be investigated in future releases of the TYNDP. As of now, it is not robust enough, therefore it seems too soon to propose any additional projects on this border. 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 too, all of which involve pumped storage units:

- Purifying Pumped Hydroelectric Energy Storage (P-PHES), Navaleo, in León
- Purifying Pumped Hydroelectric Energy Storage (P-PHES), Cúa, in León
- Reversible Pumped-Storage Hydroelectric Exploitation, Mont Negre, in Zaragoza
- Two reversible hydroelectric plants, Gironés and Raimats, in Tarragona

[4] "Increases already identified in TYNDP 2016" refers to the reference capacities of TYNDP 2016 for 2030, which for some borders had been adjusted for the TYNDP 2018. Projects commissioned in 2020 are not included as increases.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

2 INTRODUCTION

2.1 Legal requirements

The present publication forms part of the TYNDP package and complies with Regulation (EC) 714/2009 Article 8 and Article 12, where it is requested that TSOs shall establish regional cooperation within ENTSO-E and shall publish a Regional Investment Plan every two years. TSOs may take investment decisions based on this Regional Investment Plan. ENTSO-E shall provide a non-binding community-wide Ten-Year Network Development Plan, which shall be built on national investment plans and the reasonable needs of all system users and shall identify investment gaps.

The TYNDP package complies with Regulation (EU) 347/2013, 'The Energy Infrastructure Regulation'. This regulation defines new European governance and organisational structures that shall promote transmission grid development.

Regional Investment Plans are to provide a detailed and comprehensive overview of future European transmission needs and projects in a regional context to a wide range of audiences:

- Agency for the Cooperation of Energy Regulators (ACER), which has a crucial role in coordinating regulatory views on national plans, providing an opinion on the TYNDP itself and its coherence with national plans, and giving an opinion on the EC's draft list of PCI projects;
- European institutions (EC, Parliament, Council), which have acknowledged infrastructure targets as a crucial part of pan-European energy goals, to give insight on how various targets influence and complement each other;
- Energy industry, encompassing network asset owners (within the ENTSO-E perimeter and the periphery) and system users (generators, demand facilities and energy service companies);
- National regulatory authorities and ministries, to place national energy matters in an overall European common context;
- Organisations with a key role in disseminating energy-related information (sector organisations, NGOs, the press), for which this plan serves as a 'communication tool-kit';
- The general public, to improve their understanding of what drives infrastructure investments in the context of new energy goals (RES, market integration) while maintaining system adequacy and facilitating secure system operation.

2.2 The scope of the report

The present Regional Investment Plan (RgIP) forms part of a set of documents (see Figure 2-1 below) comprising, in a first step, the following reports: a Mid-Term Adequacy Forecast report (MAF), a Scenario Report, a Monitoring Report, a Pan-European System Needs Report, and six Regional Investment Plans.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

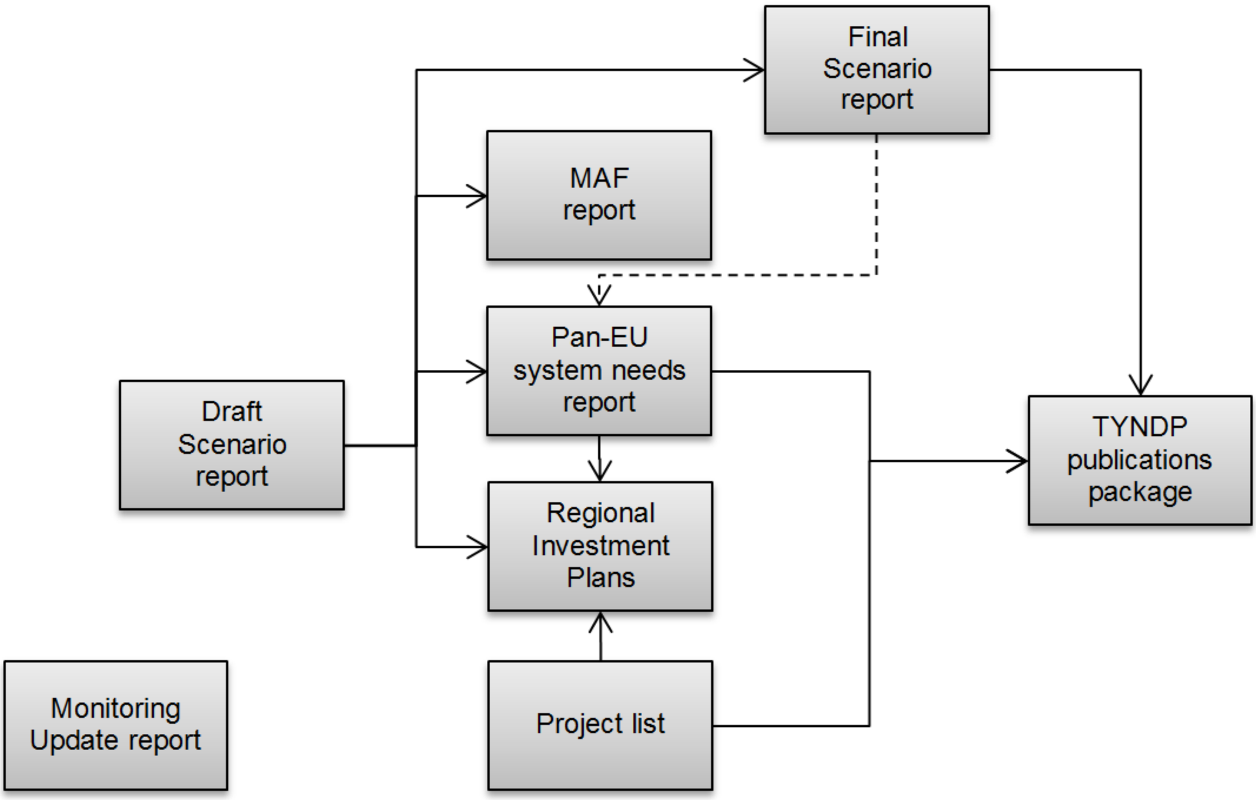


Figure 2-1: Document structure overview TYNDP 2018

The general scope of Regional Investment Plans is to describe the present situation and actual as well as future regional challenges. The TYNDP process proposes solutions that can help to mitigate future challenges. This particular approach is based on five essential steps, presented in Figure 2-2 below:

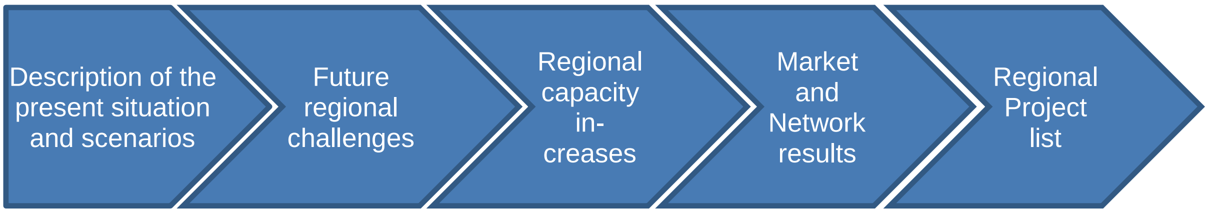


Figure 2-2: Mitigating future challenges – TYNDP methodology

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 scenarios 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.

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 work 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 in this chapter when describing the evolution of generation and demand profiles in the 2040 horizon but considering a grid as expected by the 2020 horizon.

- 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 links to the different national development plans (NDPs) of the countries of the region.
- Chapter 7 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.
- Chapter 8 (appendix) includes the abbreviations and terminology used in the whole report as well as additional content and detailed results.

The current edition of this Region Investment Plan takes into account the experiences from the latest processes, including improvements, which were in most cases received from stakeholders during the latest public consultations, such as the following:

- Improved general methodology (current methodology includes other specific factors relevant to investigation of RES integration and security of supply needs)
- A more detailed approach to determine demand profiles for each zone
- A more refined approach to demand-side response and electric vehicles
- For the first time, several climate conditions have also been considered.

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 2018 package.

2.3 General methodology

The present 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. The aim of the joint study was to identify investment needs in the long-term time horizon—triggered by market integration, RES integration, security of supply and interconnection targets—in a coordinated pan-European manner that also built on the expertise of the grid planners of all TSOs.

A more detailed description of this methodology is available in the TYNDP 2018 Pan-European System Needs Report.

2.4 Introduction to region

The CSW Group, under the scope of the ENTSO-E System Development Committee, is among the six regional groups for grid planning and system development tasks. The countries belonging to each regional group are shown in Figure 2-3 below.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

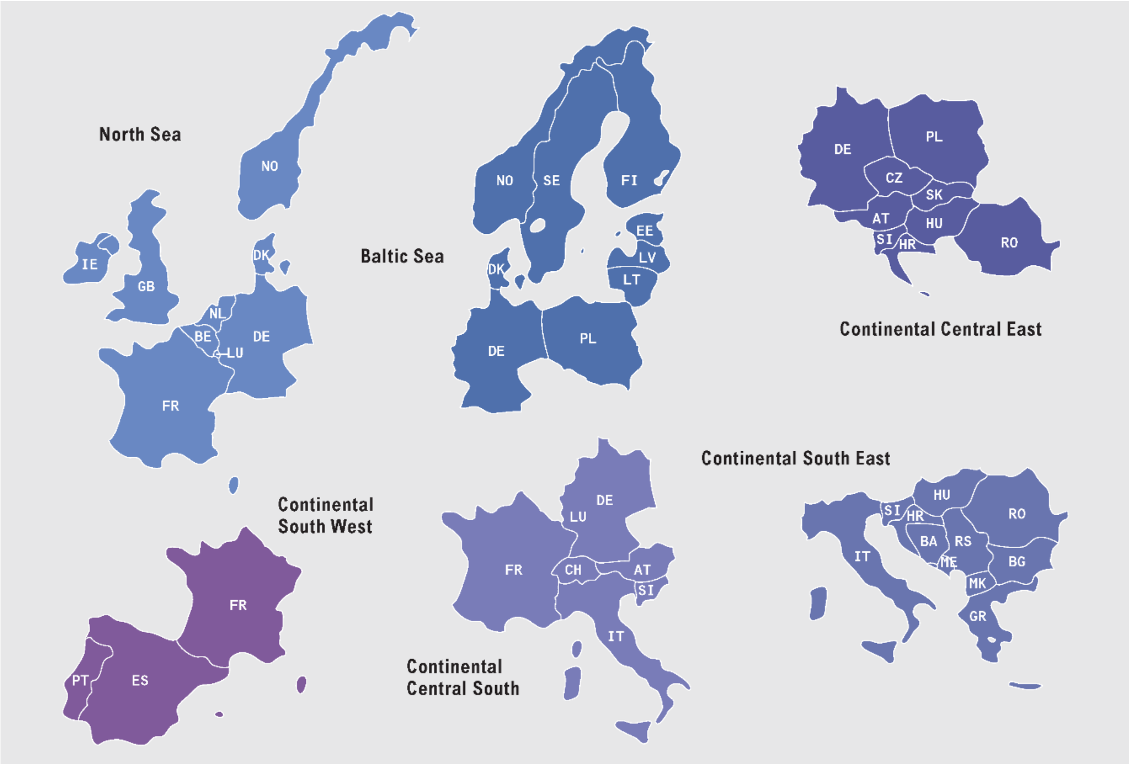


Figure 2-3: ENTSO-E regions (System Development Committee)

The CSW Group comprises three countries, which are listed, along with their representative TSO, in Table 2-1.

Country	Company/TSO
France	RTE
Portugal	REN
Spain	REE

Table 2-1: ENTSO-E regional group Continental South West membership

The CSW 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 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:

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

- 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[5]. In the case of Spain, this ratio is expected to amount to around 6% by 2020.
- The European Council of October 2014[6] endorsed the proposal by the European Commission of May 2014[7] 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 conclusions of this group were published in November 2017 in the report entitled 'Towards a Sustainable and Integrated Europe'[8].

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 with representatives from the European Commission, the national regulatory authorities and the TSOs to monitor closely the progress of the works.

All this support recently paved the way, for instance, for French and Spanish regulators to agree, on 21 September 2017, on the financial scheme of a new interconnector via Biscay Gulf; this agreement constitutes an important boost for cross-border development.

[5] 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 for EU Regulation 347/2013 (annex IV 2.a). The interconnection ratio is obtained as the sum of importing GTCs/total installed generation capacity.

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

[7] COM(2014) 330 final

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

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

3 REGIONAL CONTEXT

3.1 Present situation

3.1.1 Transmission grid and exchange capacities in the region

The interconnected network in the continental south-west region is a network that is synchronous with the remainder of 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), which 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 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 considered distribution. This is the case everywhere except Portugal, where 150kV is also considered transmission. 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.

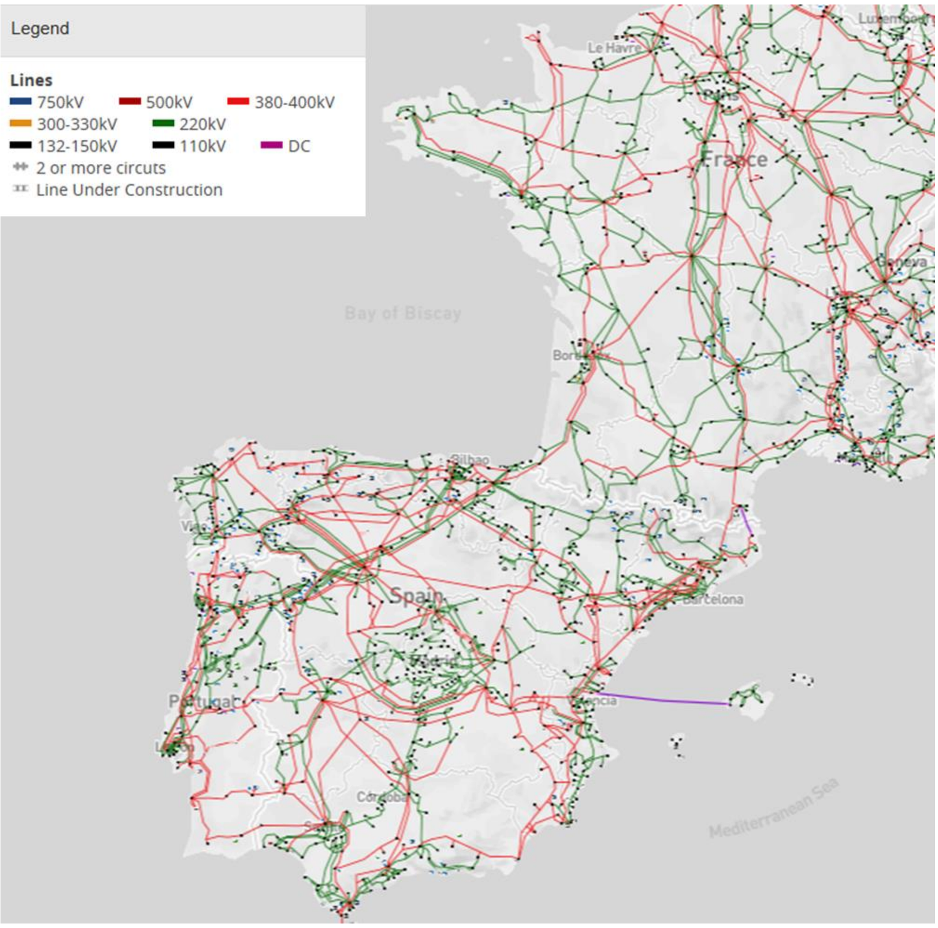


Figure 3-1: Interconnected network of the Continental South West

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

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

The figure shows the ranges of average and maximum values of NTC (in MW) based on the historical values of 2016 and 2017.

Figure 3-2: Commercial Exchange Capacities in the continental south-west region and in Morocco (non-ENTSO-E)[9]

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.

After two years 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 75% of the time and the average price differences are still in the order of 10-15 €/MWh[10], the congestion on the border—that is, the percentage of the hours in which the market agent's

[9] Source: TSO websites http://www.mercado.ren.pt/EN/Electr/MarketInfo/Interconnections/CapProg/Pages/MktSession.aspx and http://www.esios.ree.es/

[10] The maximum values were 37 €/MWh from Spain down to France and 810 €/MWh from France down to Spain and other neighbours of France from 18:00 to 19:00 on 7 November 2016, as a result of a spot market spike in France with a background of low nuclear availability. This was the second occurrence of such a situation since 2010; the previous occurrence was on 9 February 2012.

interest reaches the maximum NTC—has decreased by around 11 percentage points. Furthermore, the congestion income is now almost twice as high as it was before the HVDC (207 M€ in 2016 and 220 M€ in 2017), 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.

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 2016, the congestion rate was 8%, and average price differences were 0.23€/MWh, with some maximum values above 21€/MWh.

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. This border experiences high and increasing flows from Spain to Morocco for almost all the hours of the year.

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 2016 and its comparison to 2010.

Maximum consumption, that is, peak load, in the region decreased in this 2010-2016 period. This decrease was mainly driven by the financial crisis, although responsibility can also be attributed to energy efficiency measures. Conversely, the installed capacity increased in every country, primarily due to wind (11 GW) and solar (9 GW) energy but also due to hydro power and other RES technologies, in spite of decreasing installed capacity based on fossil fuels in Spain (-6 GW) and in Portugal (-2 GW).

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

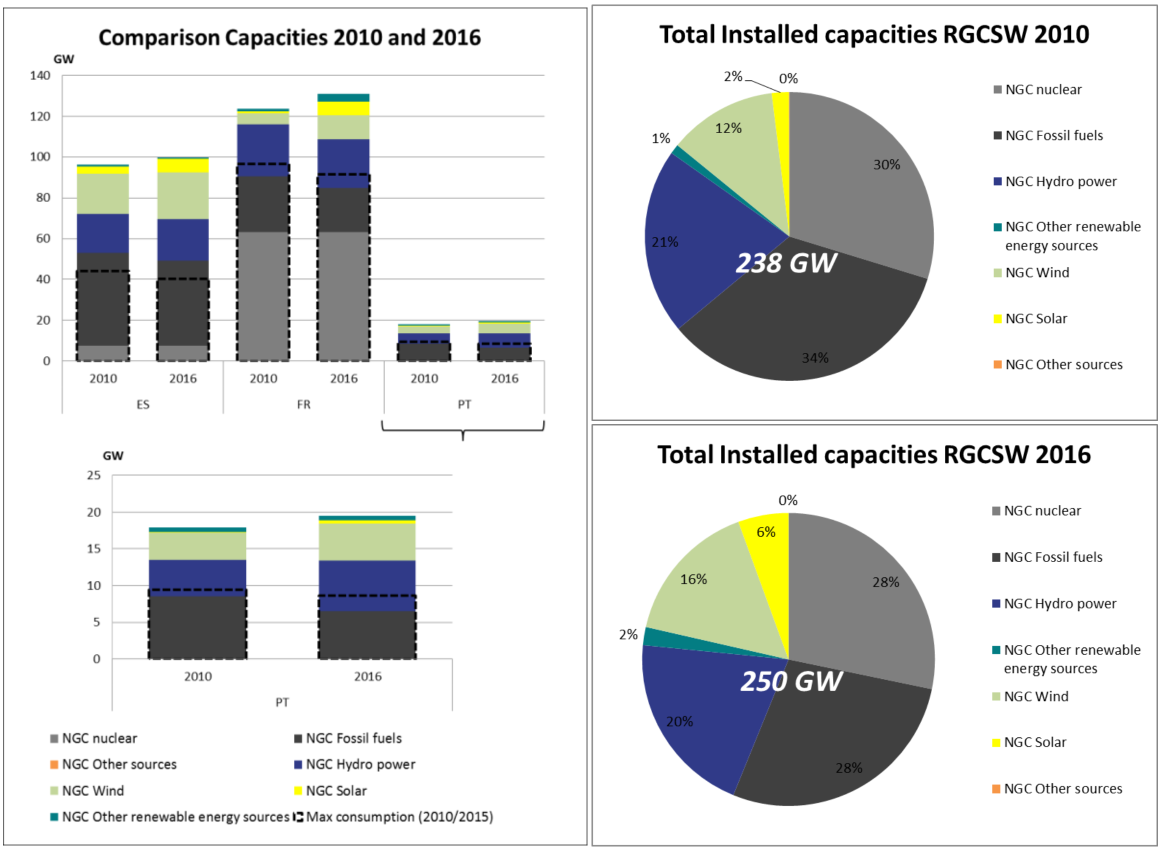


Figure 3-3: Installed generation capacities by fuel type and maximum consumption in the continental south-west region in 2010 and 2016

Consumption in this five-year period decreased in Portugal and France and slightly increased in Spain. As for peak load, this was mainly driven by the financial crisis but can also be attributed to energy efficiency measures. Related to the decrease in demand, and in spite of higher exports in the region, regional production decreased slightly. Production of thermal generation decreased by over 60TWh/y, while RES increased by 34TWh/y.

Regarding country balances, that is, the equilibrium between generation and native demand, France remained a net exporter in 2016, while Portugal and Spain changed their net balances after a stable decade. In 2016, for the first time in ten years, Portugal was a net exporter (to Spain), while Spain was a net importer. This new trend remained in 2017.

As can be seen in the figures, the main contribution to cover demand in the CSW region comes from nuclear energy, which covers 54% 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 21% of the total installed capacity. Overall, RES technologies (hydro included) supplied 29% of the demand in 2016, four percentage points more than in 2010.

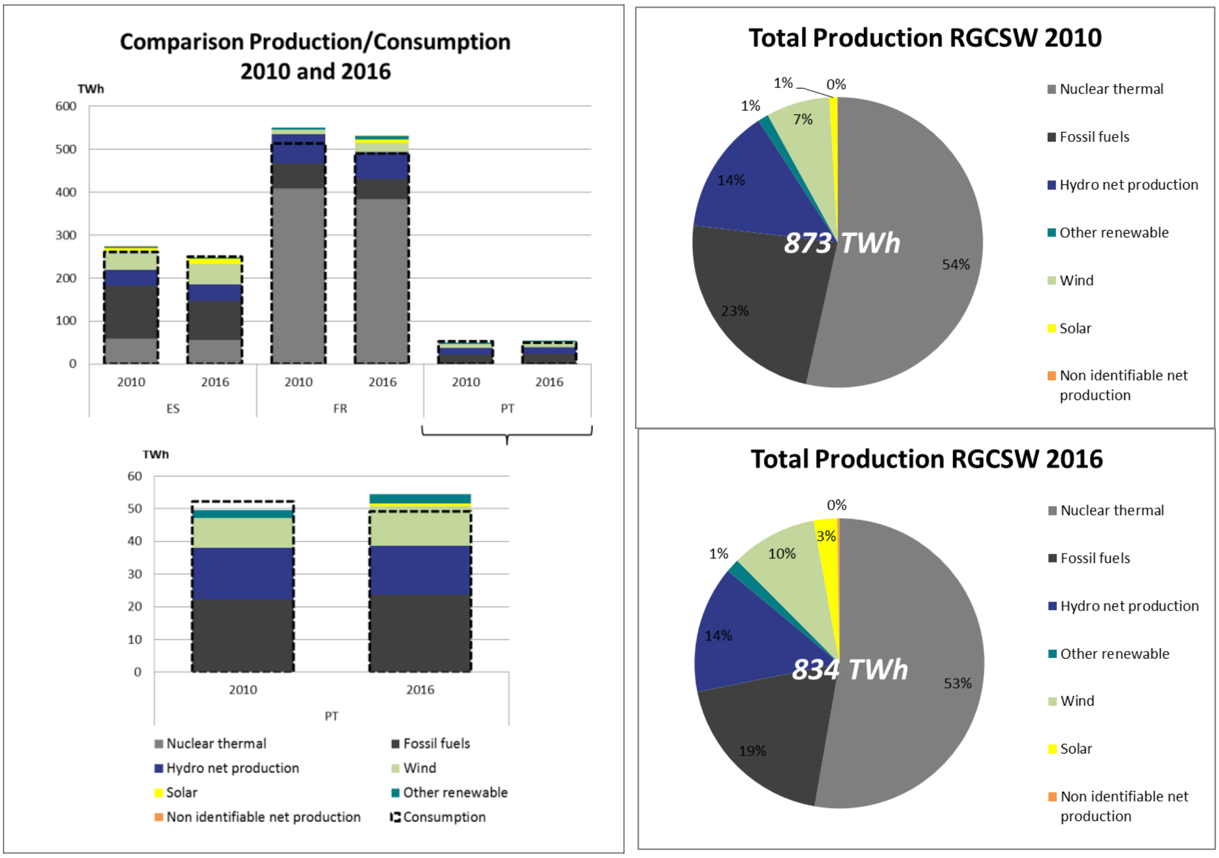


Figure 3-4: Annual generation by fuel type and annual consumption in the continental south-west region in 2010 and 2016

Figure 3-5 demonstrates that physical flows from 2010 to 2016 increased on almost all borders and in almost all directions of the CSW region. On the Portuguese-Spanish border, physical flows has increased in both directions due to the market interest and the commissioning of the southern interconnection between Algarve and Andalucía (in 2014). On the Moroccan-Spanish border, the flows from Spain to Morocco increased as a result of higher consumption in Morocco and interesting prices in the MIBEL. Conversely, the Morocco to Spain direction remains with no interest to be used.

The next figure also shows that French exports increased from 2010 to 2015 in all directions except Germany, whose RES exports have balanced cross-border exchanges. Concerning the 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 and a reduction (by half) in exports from Spain to France. This indicates that the new interconnector fulfilled its function of increasing energy exchange depending on generation availability: sufficient availability of nuclear units in France in the second half of 2015 to support the Iberian balance through an increase in French exports, and too little wind on the Iberian Peninsula in the second half of 2015 to achieve extra wind generation and take advantage of the increase in cross-border exchange capacity. Absolute values of export and imports, however, increased from 5.5 TWh in 2010 to 10.9 TWh in 2015, which in short means that cross-border exchanges doubled.

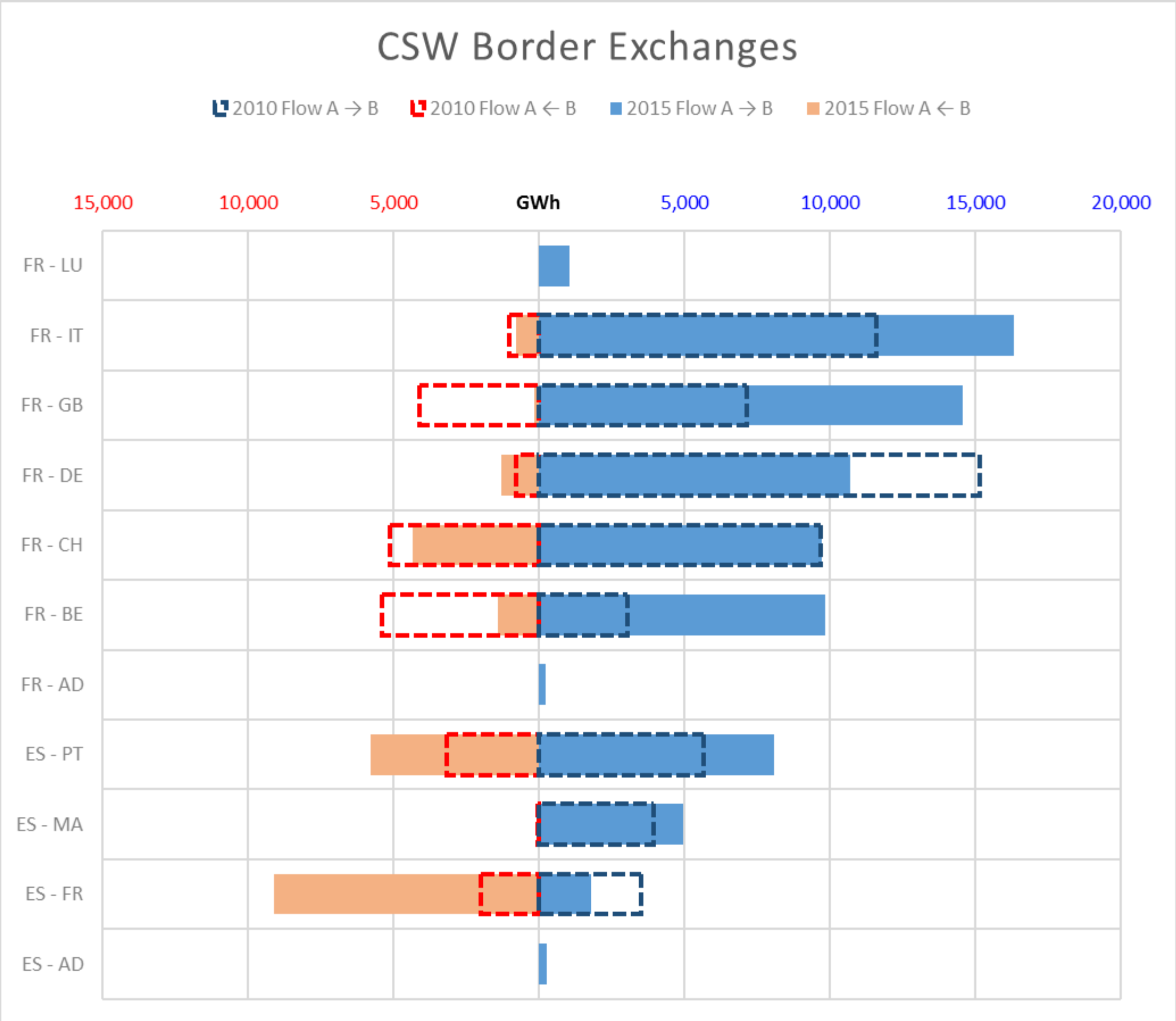


Figure 3-5: Cross-border physical flows (GWh) in the continental south-west Region in 2010 and 2015

Finally, regarding adequacy and the possibility of suffering from energy not supplied situations, the ENTSO-E Winter Outlook 2007-2018[11] reports that this winter (January) could be intense, especially in continental Western Europe (including France), in the case of a severe cold wave. During this period, the 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, that adequacy issues could be fully mitigated through the activation of strategic reserves across Europe. To summarise, additional Iberian Peninsula-France interconnection could help France and central Europe to withstand extreme climate situations and avoid energy not supplied (ENS).

3.1.3 Interconnection ratio in the region

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

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

The European Council established on 15 and 16 March 2002 the objective of reaching a minimum interconnection ratio of 10% of the installed generation capacity in every Member State[12]. In the European Commission's view, the EU energy policy goals and the 2020 and 2030 energy and climate targets will 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 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.

At present, based on the EC's 'Communication on Strengthening Europe's Energy Networks',[13] published in November 2017, three countries in the CSW region are falling short of the objective: Spain with 6% and France and Portugal with 9%. In 2020, Portugal and France are expected to fulfil the 10% objective, while Spain will still be in the range of 6-7%, still far away from the 10%.

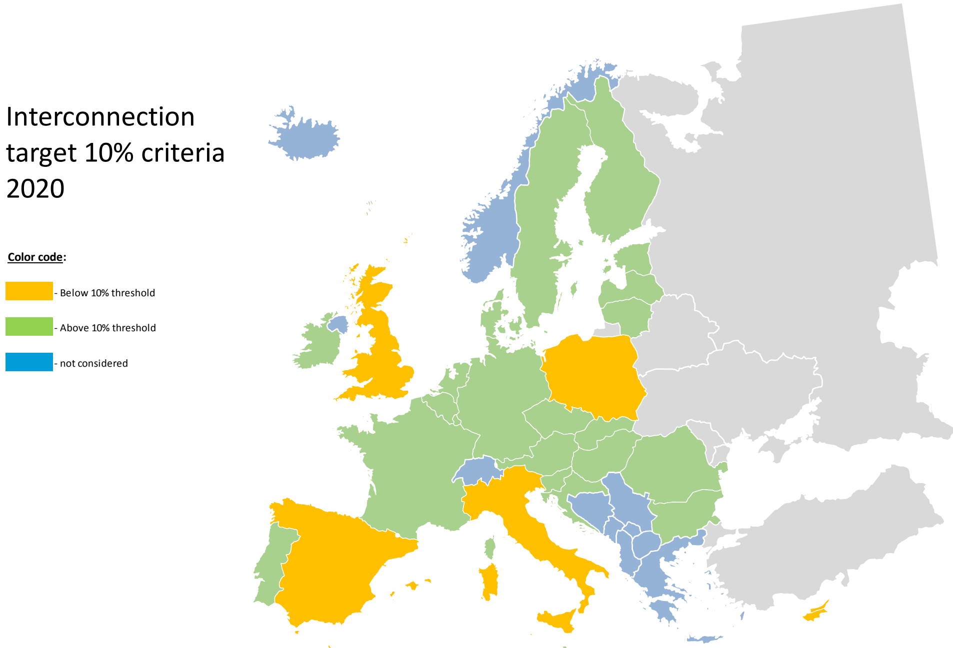


Figure3-6: Fulfilment of the 10% interconnection target in 2020 (source EC)

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 2-3%; this is a very low value, which will not improve for the 2020 horizon. The Iberian Peninsula will still be considered an electric island.

3.2 Description of the scenarios

[12] 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 for EU Regulation 347/2013 (annex IV 2.a). The interconnection ratio is obtained as the sum of importing GTCs/total installed generation capacity.

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

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

Figure 3-7 below provides an overview of the time-related classification and interdependencies of the scenarios in the TYNDP 2018 and shows the transition from the situation in 2020, including the time points 2025 and 2030, to the situation in 2040.

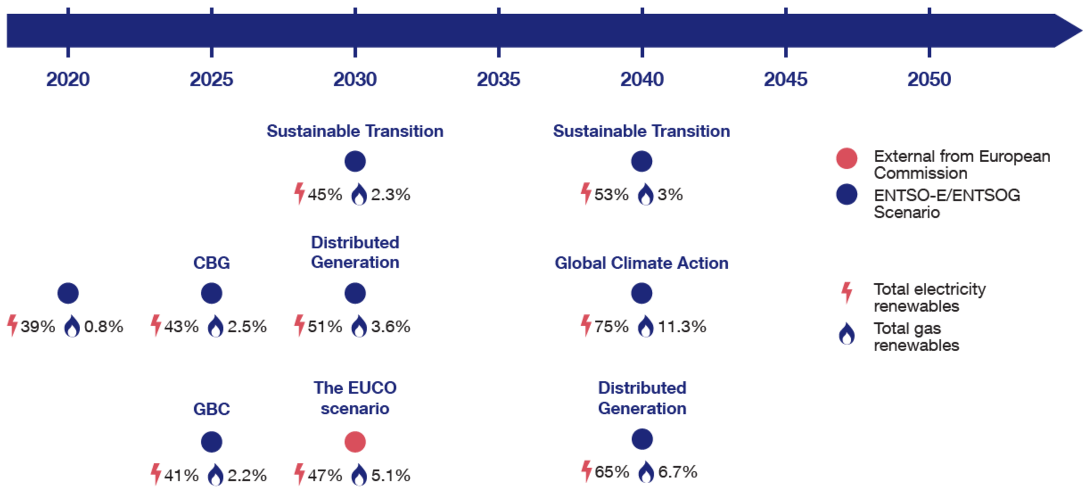


Figure 3-7: Scenario-building framework indicating bottom-up and top-down scenarios

In the scenario-building process, two types of optimisation have been applied: thermal optimisation and RES optimisation.

1. Thermal optimisation optimises the portfolios of thermal power plants. Based on a cost-benefit analysis, power plants that are not earning enough to pay for their operating costs are removed, and new power plants are added. This methodology ensures a minimum adequacy of production capacity in the system, giving a maximum of three hours of energy not served per country.
2. RES optimisation optimises the location of RES (PV, onshore and offshore Wind) in the electricity system to maximise the value of the RES production. This methodology was also used in TYNDP 2016 but has been improved in that it now utilises higher geographical granularity (more market nodes) and assesses more climate years.

The abovementioned scenarios for the 2040 timeframe consist of a top-down approach, and the data were derived from the 2030 database, as shown in Figure 3-7.

'Global Climate Action' scenario

The 'Global Climate Action' storyline considers global climate efforts. Global methods regarding CO2 reductions are in place, and the EU is on track to meet its 2030 and 2050 decarbonisation targets. An efficient Emission Trading Scheme (ETS) is a key enabler in the electricity sector's success in contributing to global/EU decarbonisation policy objectives. In general, renewables are located across Europe where the best hydro, wind and solar resources are found. In terms of non-intermittent renewables, bio methane is also developed. Due to the focus on environmental issues, no significant investment in shale gas is expected.

From a regional perspective, the 'Global Climate Action' 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, as shown in Figure 3-8. This scenario involves the highest RES growth in the CSW region between 2025 and 2040, increasing overall solar capacity by 112 GW (of which 51% would be in Spain) and wind capacity by 68 GW (of which 57% would be in France). In this scenario, some development of battery storage is expected among RES, although total installed capacity would be below 8 GW in 2040.

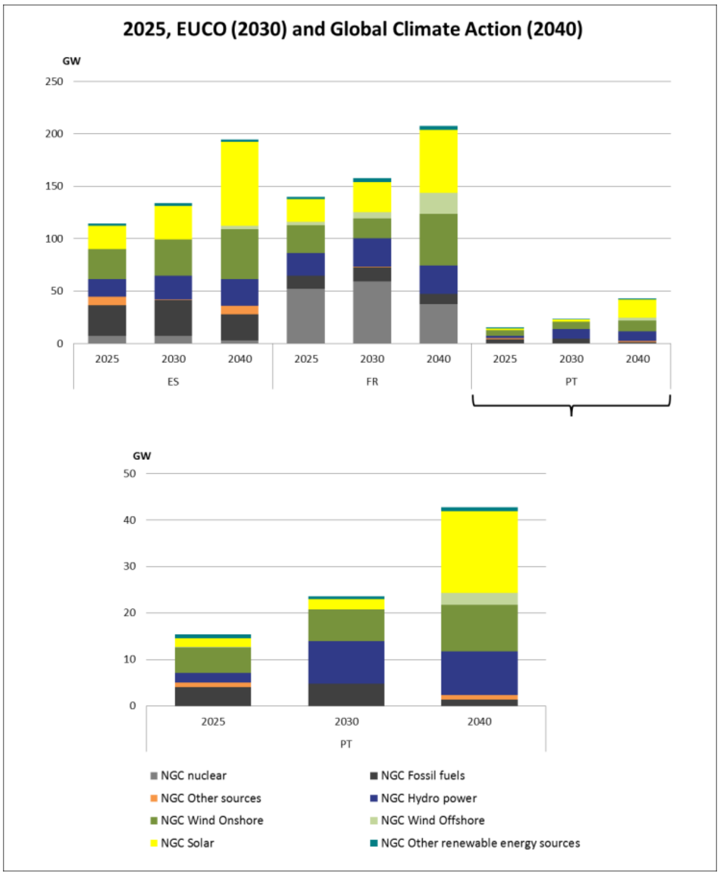


Figure 3-8: Installed net generation capacities at the regional level in the 'Global Climate Action' scenario

'EUCO' scenario

Additionally, for the year 2030, there is a third scenario, based on the European Commission's EUCO Scenario for 2030 (EUCO 30). The 'EUCO' scenario is a scenario designed to reach the 2030 targets for renewable energy (RE), CO_2 and energy savings, taking into account current national policies, such as the German nuclear phase-out.

The EC's scenario EUCO 30 was an external core policy scenario, created as part of the EC impact assessment work in 2016 by using the Price-Induced Market Equilibrium System (PRIMES) model and the EU Reference Scenario 2016 as a starting point. The EUCO 30 already models the achievement of the 2030 climate and energy targets as agreed on by the European Council in 2014, but it includes an energy efficiency target of 30%.

'Sustainable Transition' scenario

In the 'Sustainable Transition' storyline, climate action is achieved through a mixture of national regulation, emission trading schemes and subsidies. National regulation takes the shape of legislation that imposes binding emission targets. Overall, the EU is only just on track to meet the 2030 targets; as a result, it is slightly behind in terms of the 2050 decarbonisation goals. The targets are still achievable, however, if rapid progress is made in decarbonising the power sector in the 2040s.

From a regional point of view, the 'Sustainable Transition' scenario predominantly assumes moderate increases in renewable energy sources and moderate growth of new technologies in line with the EU 2030 target but slightly behind the EU 2050 target (Figure 3-9). Nevertheless, in the CSW region, total solar capacity is to be increased by 55 GW (of which 59% would be in Spain) between 2025 and 2040, and wind power is to be increased by nearly 49 GW (of which 65% would be in France).

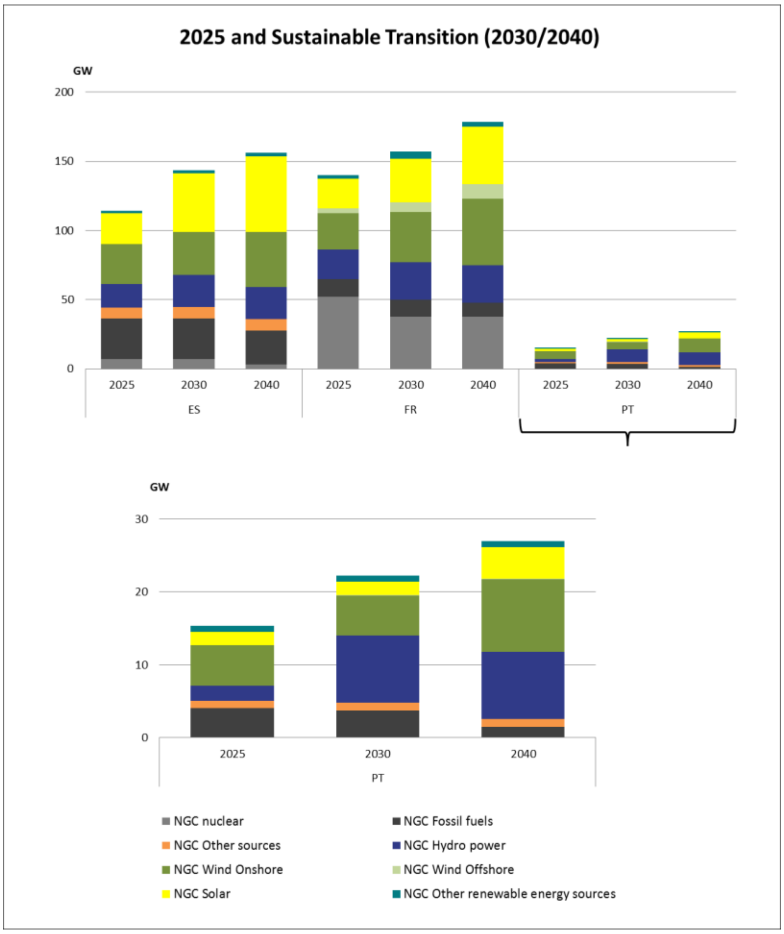


Figure 3-9: Installed net generation capacities at the regional level in the 'Sustainable Transition' scenario

'Distributed Generation' scenario

In the 'Distributed Generation' storyline, significant leaps in innovation in small-scale generation and residential/commercial storage technologies are a key driver of climate action. An increase in small-scale generation keeps the EU on track to meet the 2030 and 2050 targets. A rich 'prosumer' society has bought into the energy markets; consequently, society is engaged and empowered to help achieve a decarbonised place to live. As a result, no significant investment in shale gas is expected.

From a regional perspective, the 'Distributed Generation' scenario covers a very high growth of small-sized and decentralised, often renewable-based, energy generation and energy storage, including an increase in new technologies in the related area, which is largely in line with both the EU 2030 and EU 2050 goals (Figure 3-10). This trajectory represents the second highest RES growth of the three scenarios between 2025 and 2040 in the region. While solar installed capacity is expected to be increased approximately by the same amount as in the 'Global Climate Action' scenario, wind power growth is more moderate, with an increase of 45 GW (of which 78% would be in France), meaning slightly lower growth than in the 'Sustainable Transition' scenario. Conversely, small-scale storage is expected to grow significantly, along with RES, whereby total capacity reaches almost 39 GW in 2040 in the region.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

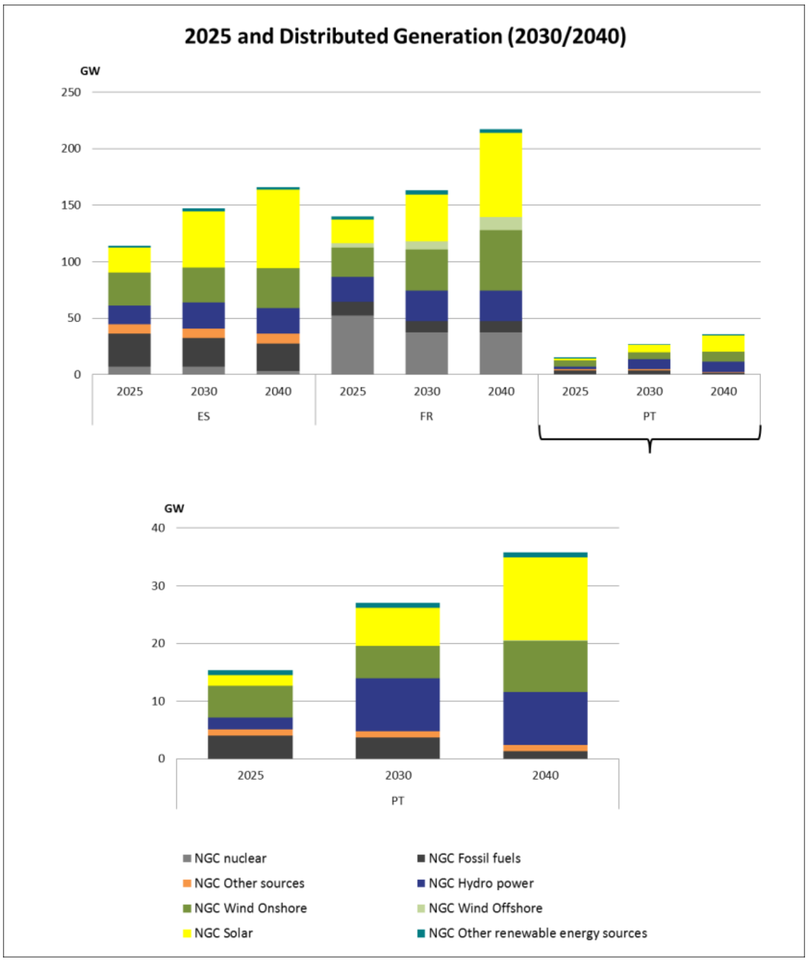


Figure 3-10: Installed net generation capacities at the regional level in the 'Distributed Generation' scenario

A more detailed description of the scenario creation is available in the TYNDP 2018 Scenario Report[14].

3.3 Future challenges in the region

The European Market and Network Study Teams have carried out simulations of all three 2040 scenarios ('Sustainable Transition', 'Global Climate Action' and 'Distributed Generation') with the expected grid of 2020. Even if these simulations were somewhat artificial (in the real world, the market and grid develop in close interaction with each other), the study revealed the following future challenges:

- poor integration of renewables (high amounts of curtailed energy)
- security of supply issues
- high price differences between market areas
- high CO2 emissions
- bottlenecks between market areas and inside these areas

3.3.1 Challenges from the market studies approach

The figures below describe the regional challenges identified by the simulations, as mentioned above. They present the average results and ranges of simulations of three different climate years for each of the three long-term 2040 scenarios. All simulations were carried out by several market models, and the results might

[14] TYNDP 2018 Scenario Report: http://tyndp.entsoe.eu/tyndp2018/

be compared with the similar figures in chapter 4, which show the 2040 market data simulations combined with an appropriate 2040 scenario grid.

Additional future regional challenges are also described.

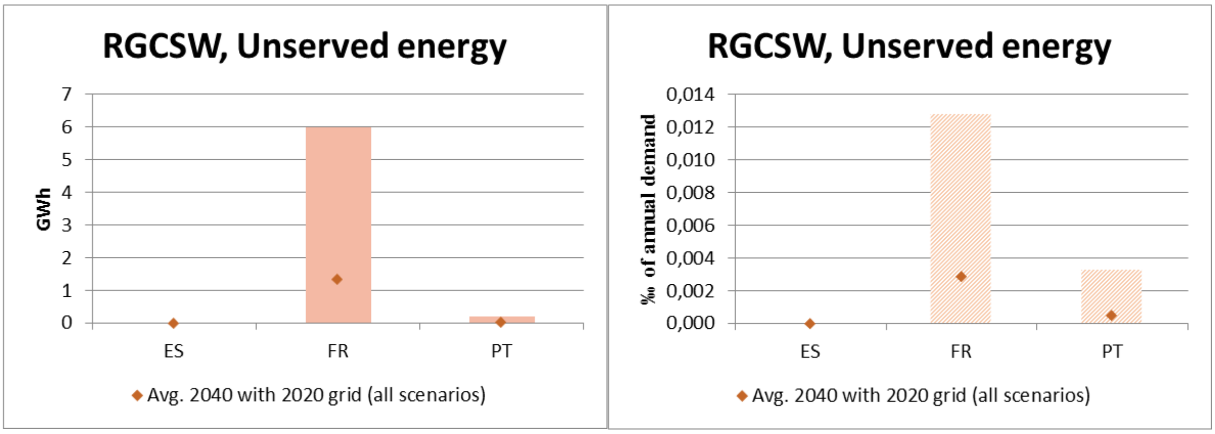


Figure 2-11: Unserved energy in the region for 2040 scenarios with 2020 grid

Figure 2-11 shows that, with the 2040 scenarios in terms of load and generation and the network expected for 2020, France could expect unserved energy due to the lack of projects expected to be commissioned between 2025 and 2030, such as the Celtic interconnector (FR-IE), Biscay Gulf, and France-Alderney-Britain (FAB) (FR-UK). No problem in the Iberian Peninsula was identified in this respect.

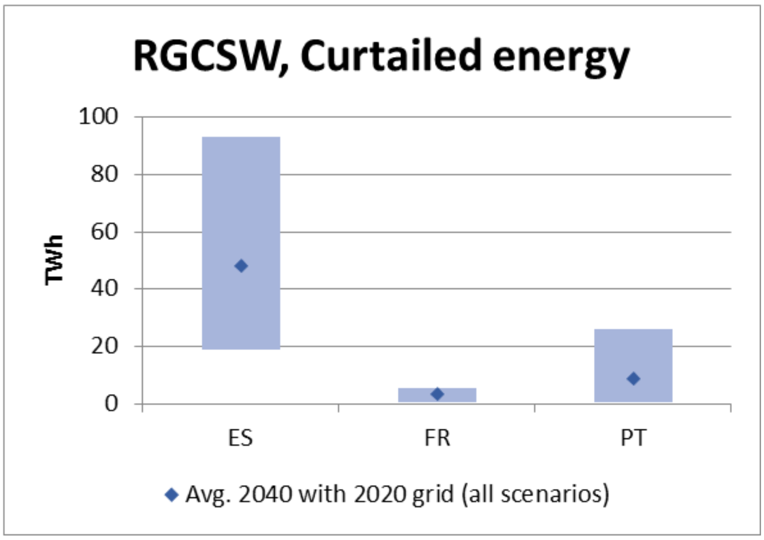


Figure 3-12: Curtailed energy in the region for the 2040 scenarios with the 2020 grid

Regarding RES integration, Figure 3-12 indicates a high level of curtailed energy in the Iberian Peninsula, especially in Spain, with the 2020 network, for which the future projects (especially those to be commissioned between 2025 and 2030) are helping to mitigate the situation but are not yet helping to resolve all the spillage.

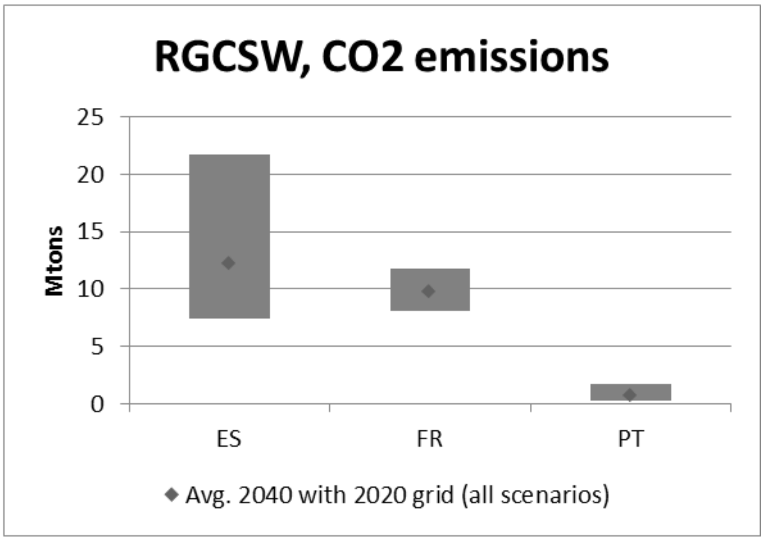


Figure 3-13: CO2 emissions in the region for the 2040 scenarios with the 2020 grid

Regarding emissions, with the 2040 scenarios in terms of load and generation and the network 2020, the level of CO2 still reflects an imperfect level of RES integration. At the same time, as a result of the scenarios themselves, a very high reduction of CO2 is expected, especially in Spain and Portugal[15].

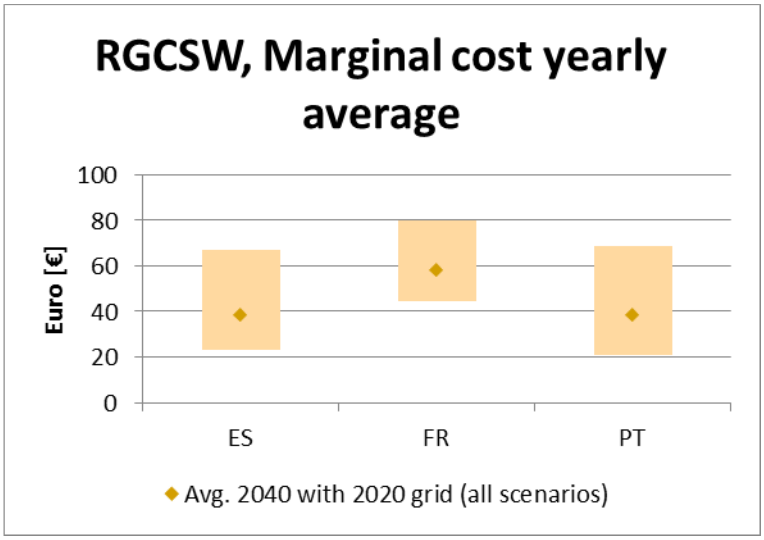


Figure 3-14: Marginal costs in the region for the 2040 scenarios with the 2020 grid

Figure 3-14 shows the marginal cost yearly average with the 2040 scenarios in terms of load and generation and the 2020 network. The values for Spain and Portugal are around 40 €/MWh, while the values for France are around 60 €/MWh. These values are coherent with the production considered in the 2040 scenarios and with expectations of higher exports in the long-term future from the Iberian Peninsula to Central Europe to integrate its high RES potential.

[15] Average CO2 emissions in 2020 are expected to be 53.2 Mtons/y for Spain, 9.6 Mtons/y for France and 11.5 Mtons/y for Portugal.

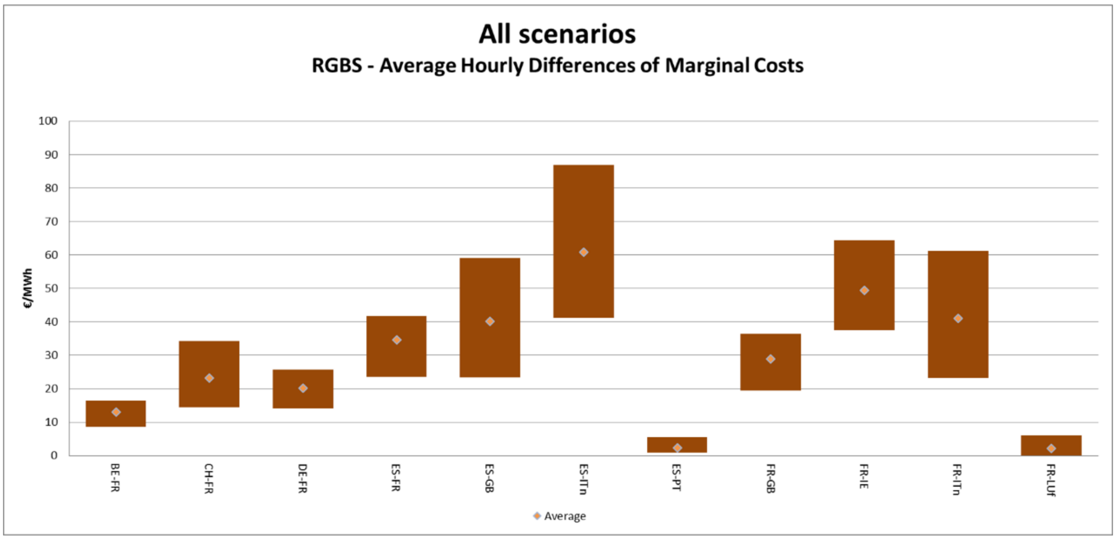


Figure 3-15: Average hourly price differences in the region for the 2040 scenarios with the 2020 grid

Figure 3-15 illustrates a low marginal cost spread on the Spanish-Portuguese border, indicating that the MIBEL market will be quite well functioning, as the new northern interconnection (to be commissioned around 2020/21) is already included in the 2020 network. The yearly average marginal cost spread[16] on the Spanish-French border, however, is around 35 €/MWh, which illustrates the relevance of projects planned to be commissioned between 2025 and 2030 and beyond to reduce the level of this spread and favour RES integration on the Iberian Peninsula. At the same time, the figure also shows that the Spain-Great Britain spread and Spain-Italy spread are higher than the Spain-France spread, at a level likely to trigger consideration of potential interconnection projects. As is demonstrated later in this report, however, the long distances between the countries concerned and certain difficulties in the submarine routes, especially in the Mediterranean Sea, make it challenging to obtain economically justified projects as an outcome.

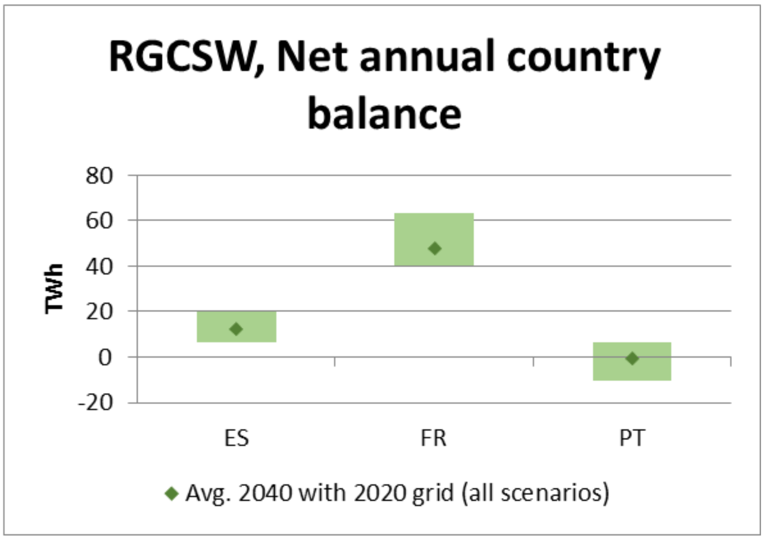


Figure 3-16: Net annual country balance in the region for the 2040 scenarios with the 2020 grid

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

Figure 3-17 presents the 99.9th-percentile highest hourly ramp (up and down) of residual load. This residual load is the remaining load after subtracting the production of variable renewable energy sources (wind and solar production). Again, results are presented for every country, as previously mentioned, that is, the average and the maximum values in the ranges of all simulations for the three different climate years and the three different long-term 2040 scenarios.

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

As the figures show, the ramps in 2040 are much higher than today's values, as their order of magnitude looks to be in the range of four to five times higher than the current values, especially in Spain and France; this reflects the significant challenge that these countries 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 the studied scenarios, and they will be further studied in TYNDP 2018. One goal will be to guarantee the necessary volume of frequency reserves in all timescales for the cases of unforeseen generation and demand imbalances.

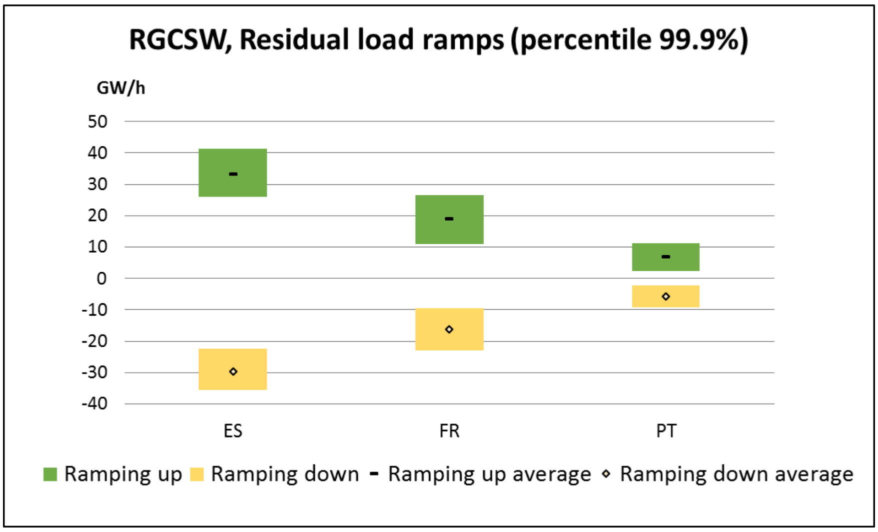


Figure 3-17: Residual ramp loads in the region for the 2040 scenarios with the 2020 grid

3.3.2 Challenges from the network studies approach

The maps in Figure 3-18 below present the network study results of the 2040 scenario market data implemented in a 2020 network model.

The upper left map shows the level of overloads on cross-border lines. In general, due to the intermittent renewable generations, the interconnections are challenged in the 2040 scenarios by larger and more volatile flows and on higher distance flows crossing Europe. This highlights that actual cross-border lines are inadequate. All cross-border lines between Spain and France would be congested in an N situation (except for the HVDC, which, because it has controllability, can limit the flows to a safe limit). In the case of the Portuguese-Spanish border, some congestions would appear in contingency situations in the Tagus area, and occasional congestions would emerge in the Douro\Duero, Alentejo\Andalusia and Algarve\Andalusia areas.

The other maps reveal needs for internal reinforcements to make the scenarios 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 flow profiles but also higher volumes, both internal and cross-border.

As previously stated, 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 Germany and Switzerland. The current network was not designed for these new power flow profiles. Therefore, a significant number of reinforcements are needed to alleviate these future congestions. In the 'Distributed Generation' scenario, these represent the most critical input for the transmission network.

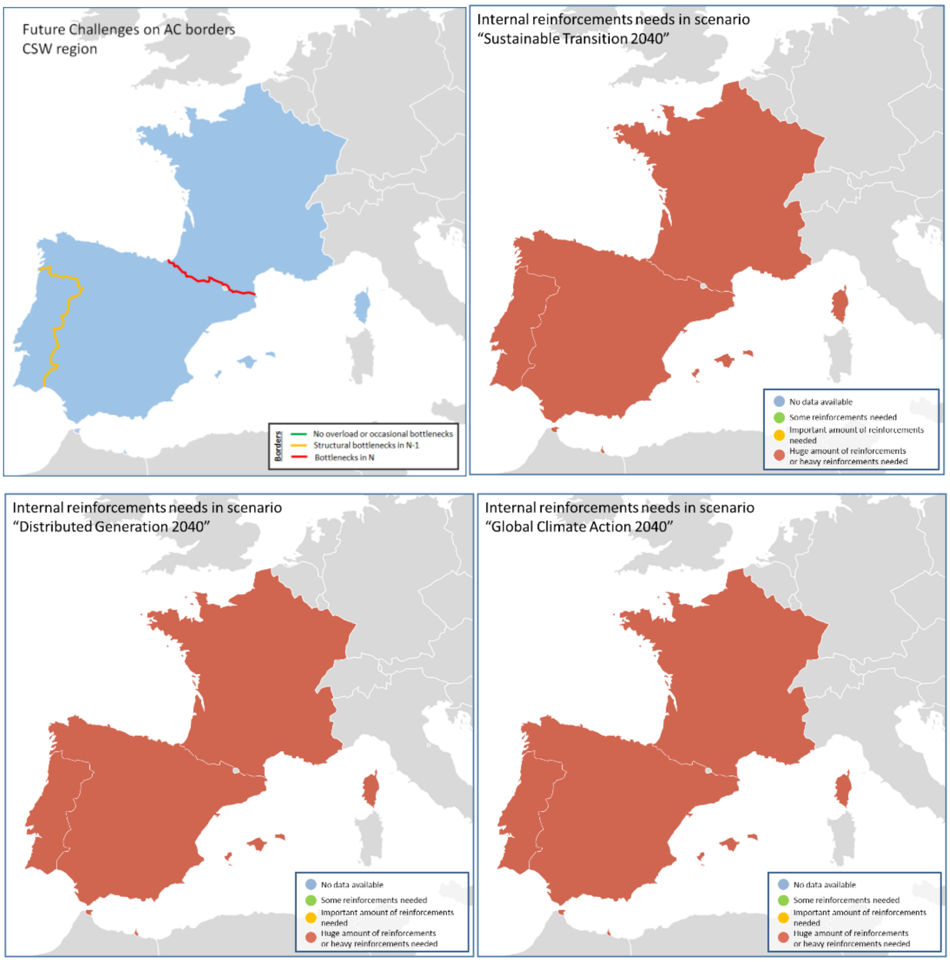


Figure 3-18: Future challenges on the borders and inside the countries

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 following issues have been observed in the Spanish system:

- The high solar generation mentioned above induces a change in the direction of the current flows, changing from north to south to south to north.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

- High flows appear from southern Spain to the Douro area, causing severe bottlenecks in the Sevilla-Douro axis.
- There are also important congestions in the Spanish Douro axis, with flows heading from Portugal to the western Spanish-French border.
- The supply of large cities, especially Madrid and Barcelona, implies harsh congestions in the feeding axis to this area, as a result of a combined effect with the new long transit power flows.

For south-western France, lines between Toulouse and Montpellier are overloaded in the case of high imports from Spain and high RES generation. Moreover, in Central France, many lines are at a crossroads of much evolution in the generation pattern.

Some projects are included in chapter 7 as regional projects that would enable solving these future problems. It is, however, too soon yet for defining in great detail the reinforcements needed for 2040, as the volumes of RES and the correct location of generation in the CSW region should be more certain.

4 REGIONAL RESULTS

This chapter presents and explains the results of the regional studies and is divided into three sections. Subchapter 4.1 provides the future capacity needs identified during the identification of system needs process or in additional (bilateral or external) studies related to capacity needs. Subchapter 4.2 explains the regional market analysis results in detail, whereas subchapter 4.3 focuses on the network analysis results.

4.1 Future capacity needs

In preparation for the TYNDP 2018, 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 aim of the joint study was to identify the needs for new cross-border capacity increases in the long-term time horizon—triggered by market integration, RES integration, security of supply and interconnection targets—in a coordinated pan-European manner that also built on the expertise of the grid planners of all TSOs.

For the CSW region, new cross-border increases were tested according to the methodology for the Spain-France, Spain-Portugal, Spain-Italy and Spain-Great Britain borders. The outcome of the analysis is synthesised in Figure 4-1 and Table 4-1.

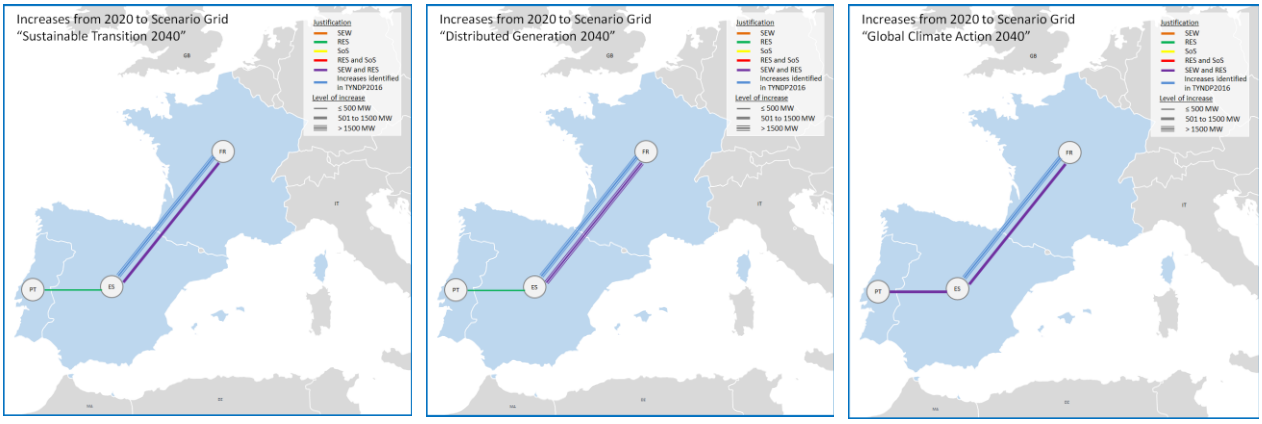


Figure 4-1: Identified capacity increase needs in the three studied 2040 scenarios in the CSW region[17]

The maps above present the needs for cross-border capacity increases beyond the expected 2020 grid for every 2040 scenario. While mature projects from earlier TYNDPs have been added directly, other increases are shown with the need(s) they fulfil, according to the 'Identification of System Needs (IoSN) methodology': needs are triggered by market integration (SEW) in the first place and afterwards and, in cases not solved previously, by security of supply (SoS) and/or renewable integration (RES) requirements.

The presented needs are based on simulations including standard cost estimates for every border investigated (the ratio between costs and benefits can be decisive for choosing between potential reinforcements). An overview of these standard costs can be found in appendix 8.1.4. The standard costs of the increases were assessed by expert review, considering as far as possible the specificity of the area (e.g. presence of mountains or sea), internal grid considerations and knowledge from previous projects on these borders (if any).

[17] 'Increases identified in TYNDP 2016' refers to the reference capacities of TYNDP 2016 for 2030, which for some borders had been adjusted for the purpose of the TYNDP 2018. Projects commissioned in 2020 are not included as increases.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

From the market point of view, and considering the potential benefits of the NTC increases (only with a SEW approach[18]) and the estimated costs of these increases, the increase of capacities on the Spain-France border showed potential benefits if increased in the three 2040 scenarios in values from 5700 MW (ST and GCA) to 6900 MW (DG) from 2020 values. The increase of capacities on the Portugal-Spain border only showed potential benefits if increased (1000 MW) in the 2040 'Global Climate Action' scenario from 2020 values, which already included the commissioning of the future northern interconnection. The estimated costs also affect the results within the region, especially on the Spain-France border, where it has been considered a cost of the 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.

In addition, due to the high amounts of spillage in the region in all scenarios, an increase of 500 MW on all borders was considered. It must be noted, however, that these increases do not resolve the spillage in the region, although they are a way to convey that interconnections would be an additional solution to this major challenge in conjunction with internal reinforcements, storage, and so forth.

Table 4-1 presents different cross-border capacities as identified during the TYNDP 2018 process within the CSW region and with the rest of Europe (i.e. French neighbours).

The first columns show the expected 2020 capacities. The next columns show the capacities relevant to the CBA, which will be carried out on the time horizons 2025 and 2030. These columns show the capacities of the reference grid and the capacities if all projects per border are added together.

The final three (double) columns show the proper capacities for each of the three 2040 scenarios. These capacities were identified during the identification of system needs phase and are dependent on the scenario.

	NTC 2020		CBA Capacities		Scenario Capacities					
			NTC 2027 (reference grid)		NTC ST2040		NTC DG2040		NTC GCA2040	
Border	=>	<=	=>	<=	=>	<=	=>	<=	=>	<=
BE-FR	1800	3300	2800	4300	4300	5800	3800	5300	4300	5800
CH-FR	1300	3150	1300	3700	2800	5200	3800	6200	3800	6200
DE-FR	2300	1800	4500	4500	4800	4800	5800	5800	4800	4800
ES-FR	2600	2800	5000	5000	9000	9000	10000	10000	9000	9000
ES-PT	4200	3500	4200	3500	4700	4000	4700	4000	5700	5000
FR-GB	2000	2000	6800	6800	6900	6900	5900	5900	5900	5900
FR-IE	0	0	0	0	700	700	1200	1200	1200	1200
FR-ITn	4350	2160	4350	2160	4350	2160	4350	2160	5350	3160
FR-LUF	380	0	380	0	380	0	380	0	380	0
FRc-ITCO	50	150	150	200	150	200	150	200	150	200

Table 4-1: Cross-border capacities expected for 2020 for the reference grid, identified during the identification of system needs phase

The reference grid is considered the starting grid for the CBA analysis in the TYNDP 2018. It considers the most mature projects that are already under construction or have entered the permitting stage and are expected to be commissioned until 2027. It includes the northern interconnection between Spain and Portugal and the Biscay Gulf project between Spain and France.

[18] 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.

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

The Spain-Portugal border, which considers the commissioning date of the future northern interconnection[19] by 2020/2021, has no additional projects under consideration. There are some gaps in the 2040 scenario capacities, which still need to be investigated in future releases of the TYNDPs, but up to now these analyses are not robust enough, therefore it seems too soon to propose any additional project on this border.

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 scenario capacities. There are some projects already under consideration, 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.

The Spain-Italy and Spain-Great Britain borders were considered as potential reinforcements in the identification of system needs analysis, but these borders were discarded because the cost considered for potential projects on these borders[20] did not compensate for the SEW savings. The long distances between the countries concerned and certain difficulties in the submarine routes, especially in the Mediterranean Sea, make it challenging to obtain economically justified projects as an outcome.

4.2 Market results

The figures below present the average results of the Pan-European market studies for all three 2040 scenarios with the 2040 scenario cross-border exchange capacities.

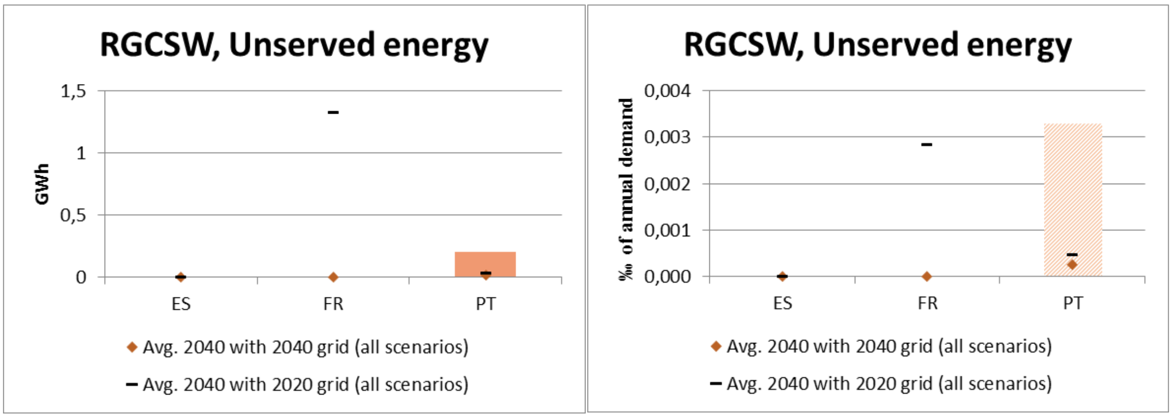


Figure 4-2: Unserved energy in the CSW region in the three studied 2040 scenarios with identified capacity increases

Figure 4-2 reveals that there is no unserved energy in the CSW region across all 2040 scenarios with an improved interconnection network that reflects the scenario capacities values presented in the previous chapter. Therefore, the 2040 cross-border capacities in Europe enable reduction of energy not served of up to 5 GWh in the CSW region.

At the same time, curtailed energy resulting from high levels of renewable installed capacity is still expected, especially in Spain and Portugal. The average results reveal curtailed energy of 30 TWh in Spain (ranging from 9 to 67 TWh), 5 TWh in Portugal (ranging from 0 to 17 TWh) and 2 TWh in France (ranging from 0 to 4 TWh). Network capacities increases in Europe from 2020 to 2040 (that is, already-planned projects and

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

[20] Additional information on cost can be found in appendix 8.1.4.

additional identified interconnection needs in this analysis) allow for reducing the spillage in the region, especially in Spain by a range of 9 to 39 TWh, with an average of 15 TWh (see figures 4-3 and 3-12).

Long-term copper plate simulation (which would represent no limit in interconnection capacity Europe-wide) would indicate a level of spillage still relevant, which would mean that the spillage issue in a 2040 horizon cannot be solved by interconnection reinforcements alone, (because spillage occurs in all countries at the same time). Therefore, further measures would be required to mitigate such energy spillage, such as storage facilities and power to gas.

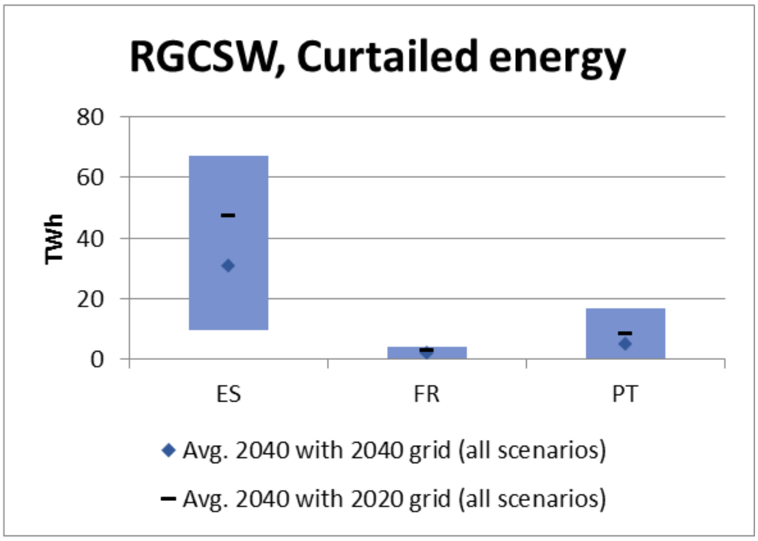


Figure 4-3: Curtailed energy in the CSW region in the three studied 2040 scenarios with identified capacity increases

Regarding CO_2 emissions, they greatly depend on the scenario, especially on the RES share of capacity, but average results are 12 Mtons/y in Spain (ranging between 7 and 19 Mtons/y), 10 Mtons/y in France (ranging between 7 and 13 Mtons/y) and 0.5 Mtons/y in Portugal (ranging between 0 and 1 Mtons/y). Cross-border exchange capacities increase Europe-wide from 2020 to 2040 allows for reducing CO_2 emissions in the region by an average of 1.3 Mtons/y, especially in Spain.

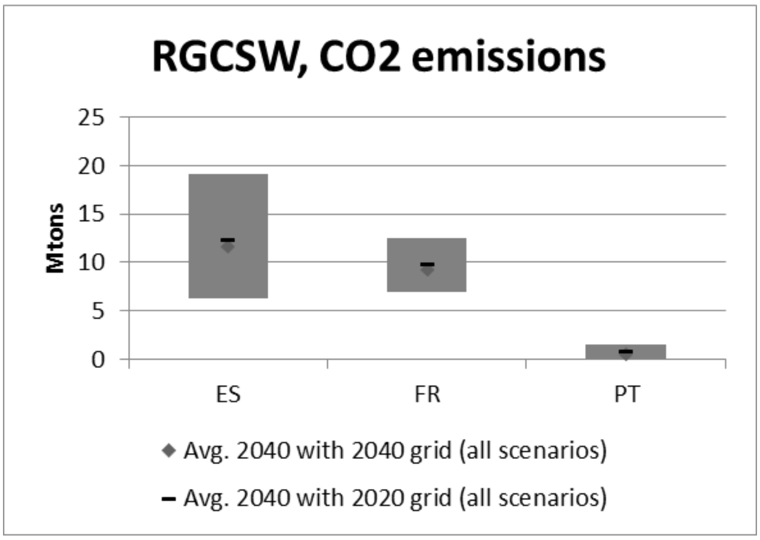


Figure 4-4: CO2 emissions in the CSW region in the three studied 2040 scenarios with identified capacity increases

In terms of marginal costs, Spain and Portugal exhibit approximate figures, with an average of 43 €/MWh (ranging between 23 and 71 €/MWh), that are generally lower than the 55 €/MWh identified in France (ranging between 40 and 73 €/MWh). Again, this reflects countries' generation portfolios, with Spain and Portugal displaying higher RES levels. Cross-border exchange capacities increase Europe-wide from 2020 to 2040 enable an average reduction of marginal cost in France of 5 €/MWh (while Spain and Portugal exhibit a slight increase).

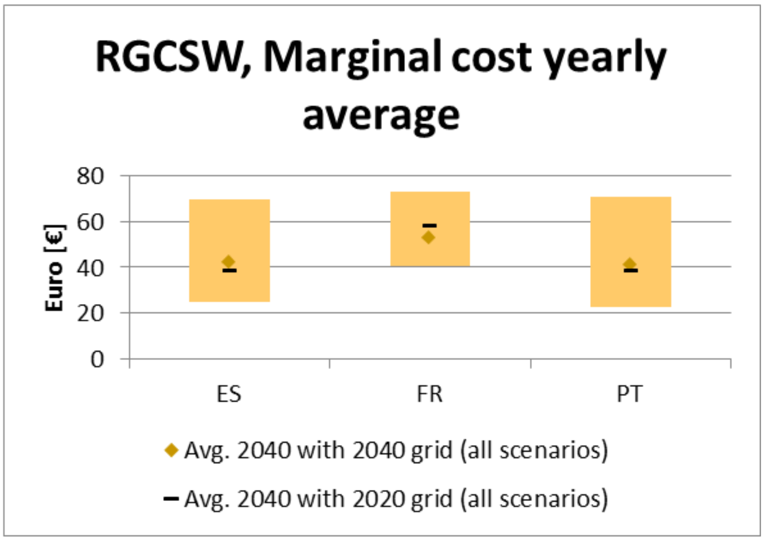


Figure 4-5: Yearly average of marginal cost in the CSW region in the three studied 2040 scenarios with identified capacity increases

With the foreseen 2040 grid, yearly average marginal cost spreads [21] are expected to be reduced significantly on almost all borders in the region, by an average of 26 €/MWh, in comparison with a 2020 grid. The exception is the border between Spain and Portugal, which generally maintains the same level of marginal

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

costs. It should be noted, however, that high differences are still expected within the CSW region and also between neighbours, as is the case with ES-FR (14 €/MWh), ES-GB (18 €/MWh), ES-ITn (29 €/MWh), FR-IE (15 €/MWh) and FR-ITn (19 €/MWh). Therefore, price convergence is still not reached.

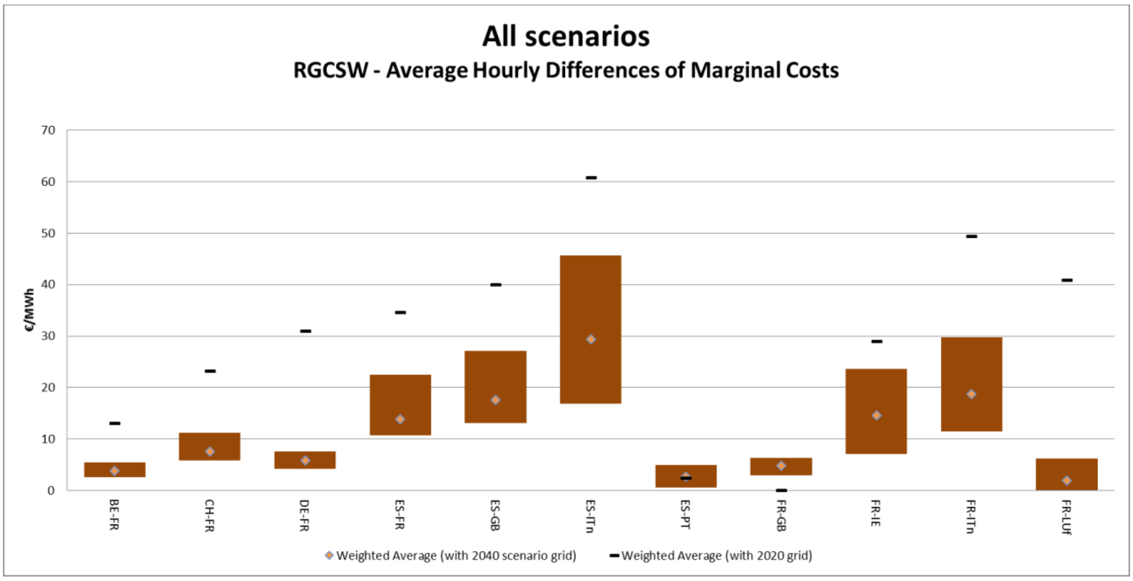


Figure 4-6: Average hourly price differences in the CSW region in the three studied 2040 scenarios with identified capacity increases

Concerning country balances, Spain and France are always net exporters, showing average exports of 25 TWh and 48 TWh, respectively. Portugal is, by a small margin, a net exporter, but its country balance can vary significantly depending on the scenario. Cross-border exchange increases from 2020 to 2040 are relevant to Spain in this matter, as they enable the country to almost double its exports.

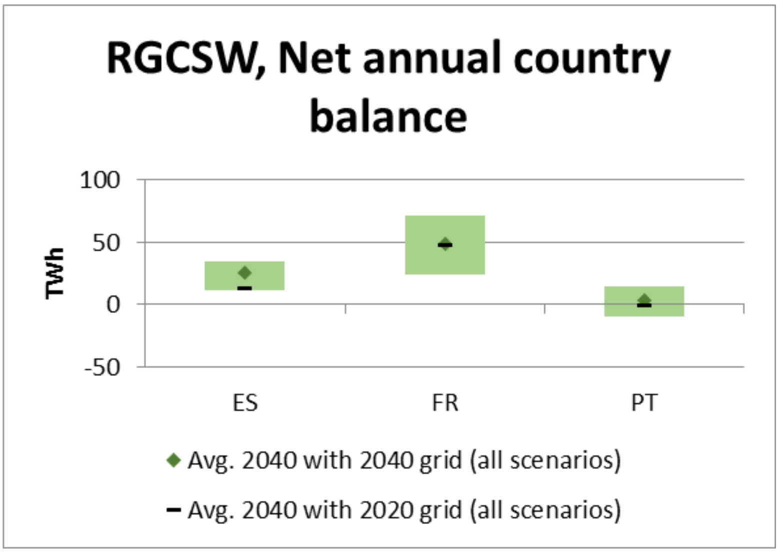


Figure 4-7: Net annual country balance in the CSW region in the three 2040 scenarios with identified capacity increases

4.3 Network results

Even with a grid including the new projects expected between 2020 and 2030 as assessed in the TYNDP 2016, the new TYNDP 2018 scenarios for 2040 cause internal congestions. The maps in Figure 4-8 below show the need for additional internal grid reinforcements, beyond those identified to resolve the restrictions in chapter 3, for all three 2040 scenarios when combined with the identified 2040 cross-border capacity needs.

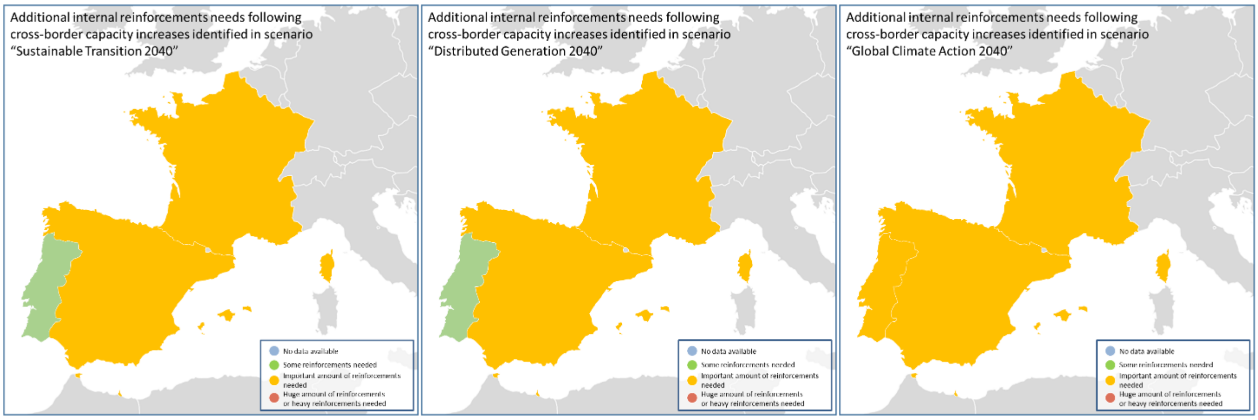


Figure 4-8: Impact of identified capacity increases on internal grid reinforcement needs in the three studied 2040 scenarios

For the Portuguese system, no important reinforcements were identified in the 'Sustainable Transition' and 'Distributed Generation' scenarios due to the identified 2040 cross-border capacity needs. In the 'Global Climate Action' scenario, a significant increase in cross-border capacity was identified, resulting in additional congestions identified in the Douro region.

For the Spanish system, it is not trivial to separate the constraints that are due to the capacity increases in this exercise from those that are associated with RES integration, as many of these constraints are highly interrelated when the increase in cross-border flows is due to higher RES production. There are, however, three principal areas of congestion in the three 2040 scenarios after the cross-border capacity increases: the Sevilla-Douro axis, the Douro–France path and Southern Catalonia.

For the French system, there are fewer congestions in the 'Sustainable Transition' and 'Global Climate Action' scenarios than in the 'Distributed Generation' scenario, but the grid in south-western France and Central France is often overloaded. In the 'Distributed Generation' scenario, a significant increase in cross-border capacity was added, which results in additional congestions or deeper congestions.

It is too soon, however, to define in a detailed manner the reinforcements needed due to the identified 2040 cross-border capacity needs, as the volumes of RES and the correct location of generation in the CSW region need to be more certain.

More detailed results from the network studies (detailed map of congestions for the three scenarios) are presented in appendix 8.1.4.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

5 ADDITIONAL REGIONAL STUDIES

This chapter introduces a regional study performed outside the ENTSO-E RGCSW cooperation. This was not the only regional study conducted, but it was the most interesting one.

Beyond the necessity of efficiently ensuring balance between production and demand at all times, the future system will also need to be operable in real time by TSOs. The changing environment radically transforms the way in which this will be accomplished, 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 with the operation of the future system when designing the transmission network.

The individual characteristics and technology of the projects are tools with which to address this operation challenge and the reasons underlying the importance of the following study.

5.1 Additional studies developed on the Spanish-French border

The Biscay Gulf project consists of an HVDC corridor that will increase the capacity of French-Spanish electricity interconnection to 5GW of imports and exports. Spanish and French TSOs are investigating the new dynamic behaviour of the power system to be expected when the Biscay Gulf project is in operation and the exchange capacity between France and Spain is increased.

In 2017, Red Eléctrica de España (REE) and Réseau de Transport d'Électricité (RTE) launched common dynamic studies work, which aims to identify the issues related to the dynamic performance of the network. Dynamic phenomena are very complex issues to detect; consequently, all these studies require many detailed data and complete collaboration between REE and RTE, which is ensured under the Inelfe[22] umbrella.

This bilateral study began with an exchange of information regarding the networks, scenarios of study, modelling assumptions and possible different hypotheses to consider in a future horizon beyond 2025, which is the expected commissioning date of the Biscay Gulf project. Considering the changing perspective of our power systems, it is important to consider a wide range of hypotheses for the possible development of the power system so that the network models to be analysed are able to represent as many possible future situations as possible. Once the set of network models were agreed upon, REE and RTE initiated their work on simulation, results analysis and investigation of sensibilities, which has not yet been concluded. Each TSO is separately conducting related studies using the common models with specific software and data and sharing the results and conclusions with the other TSOs, thus ensuring robust and coherent results.

The main aim of these dynamic studies is to identify issues related to the dynamic response of the power systems, such as voltage and frequency instabilities, transient overloads, loss of synchronism of generators or network areas and possible oscillation modes with a bad damping. Another issue concerns how to manage a peninsula with AC and DC links operating in parallel. The handling of the control conditions management of the existing HVDC connection between Baixas and Santa Llogaia and the future Biscay Gulf (together with the existing phase-shifting transformers) and their interactions must be defined and verified to ensure safe system operation.

The common dynamic studies will be completed before the final release of the technical specifications of the project as long as, if some dynamic issues are identified, some of them can be solved by means of setting requirements for the cable or HVDC converters in the specifications of the project.

[22] https://www.inelfe.eu/

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

6 LINKS TO NATIONAL DEVELOPMENT PLANS

Portugal:

Complying with legislation, in March 2015, Rede Eléctrica Nacional, S.A. (REN) submitted to the General Directorate of Energy and Geology (DGEG) a draft proposal for the Portuguese Ten-Year Development and Investment Plan for the electricity transmission network for the period between 2016 and 2025 (PDIRT 2016-2025).

Considering DGEG's determinations, REN reviewed the PDIRT 2016-2025 and in June 2015 presented to DGEG a new PDIRT 2016-2025 proposal. Between November 2015 and January 2016, this PDIRT 2016-2025 proposal was submitted to a public consultation promoted by the 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 February 2016, ERSE issued its opinion on the PDIRT 2016-2025 proposal. Subsequently, taking into consideration ERSE's opinion, REN prepared a final PDIRT 2016-2025 proposal, which was forwarded to DGEG in April 2016.

In March 2017, REN submitted to DGEG a new draft proposal for the Ten-Year Development and Investment Plan, this time for the period between 2018 and 2027 (PDIRT 2018-2027).

Considering DGEG's determinations, REN reviewed the PDIRT 2018-2027 proposal and in June 2017 sent to DGEG its new PDIRT 2018-2027 proposal.

Spain:

The current national development plan in Spain, named *'Planificación Energética. Plan de Desarrollo de la Red de Transporte de Energía Eléctrica 2015-2020*',[23] 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) provides technical support to the government.

The legal framework for this plan is the Law 24/2013, of 26 December, on the Electricity Sector and the RD1047/2013 of remuneration for the transmission activity, which established the need to publish every four years a master plan covering a period of six years and an annual and global investment limit. The three-pillar objective of the national development plan is to ensure the security of supply and sustainability at the minimum possible cost. Moreover, this plan allows Spain to fulfil the 2020 European energy objectives.

The master plan provides a list of binding transmission infrastructure for the next period, the period between 2015 and 2020 (for instance, substations, including details of new bays due to new connections of demand or generation, lines, transformers, reactive compensation and FACTS), and detailed cost-benefit analyses for certain major projects. The master plan also includes in appendix 2 a list of projects that may be needed after 2020. These projects in appendix 2 can initiate the permitting procedures, although they should be confirmed in the next master plan.

France:

The French Schéma Décennal de Développement du Réseau (SDDR)[24] 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 electricity exchanges*.' In addition, the SDDR must allude to the '*main infrastructures planned in the ten coming years*' and identify '*already-decided investments due to be commissioned in the next three years*'.

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

[24] http://www.rte-france.com/fr/article/transition-energetique-et-revolution-numerique-plus-de-10-milliards-d-euros-d

Furthermore, the Commission de Régulation de l’Energie (CRE, French Regulatory Energy Commission) must verify that this SDDR covers all the investment needs and is consistent with the electricity TYNDP.

The latest SDDR, SDDR 2016, was published in January 2017 under its final version following a public consultation. It is consistent with the TYNDP 2016.

7 PROJECTS

The following projects were collected during the project call for TYNDP 2018. 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 2018[25]. This chapter is divided into Pan-European and regional projects.

7.1 Pan-European projects

The map below shows all approved projects submitted by project promoters during the TYNDP 2018 call for projects. The projects are in different states, which are described in the CBA guidelines:

- **Under consideration**
- **Planned but not permitting**
- **Permitting**
- **Under construction**

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 2018 homepage.

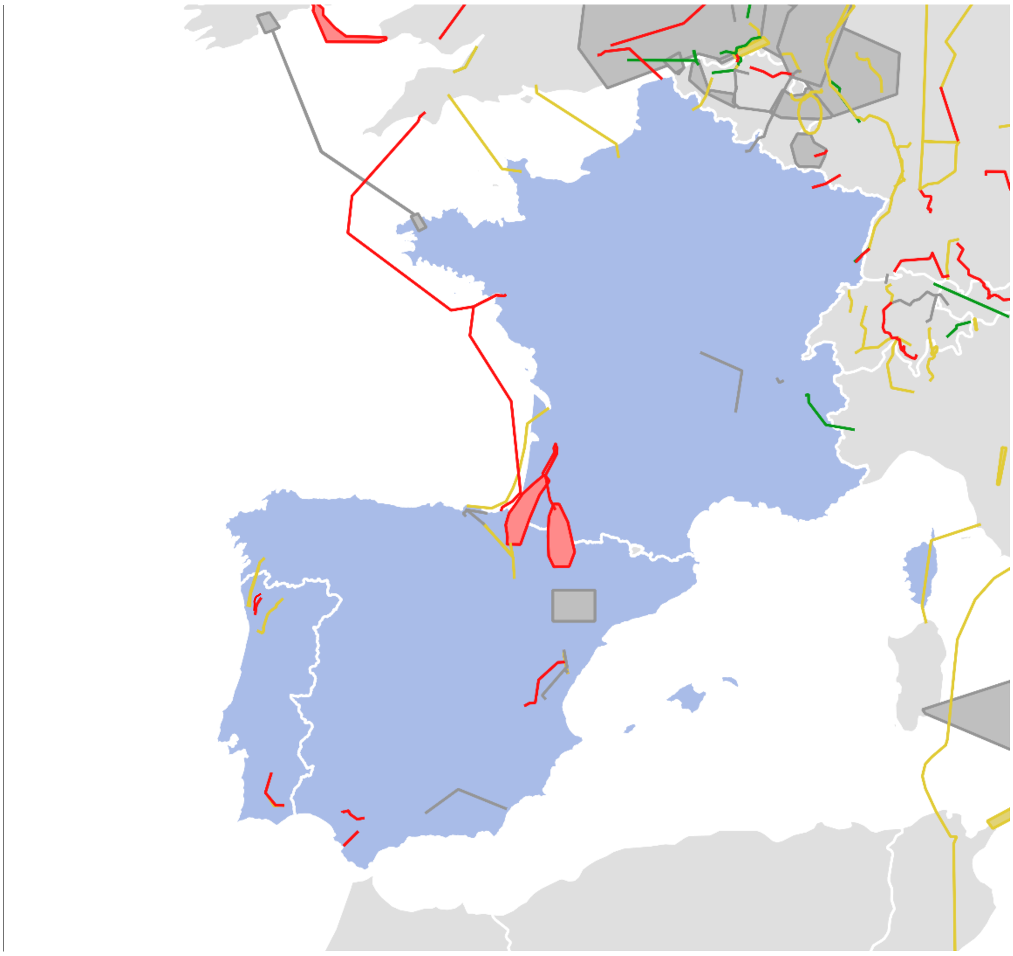


Figure 7-1 TYNDP 2018 projects: CSW regional group

25 http://tyndp.entsoe.eu/tyndp2018/

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

7.2 Regional projects

In this subchapter, 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 drivers, why they are designed to be realised in the future scenarios, and the expected commissioning dates and evolution drivers in case they were introduced in a 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 the CSW region are enumerated.

Country	Project name	Investment		Expected commissioning year	Description	Main drivers	Included in RgIP 2015?
		From	To				
FRANCE	Long-Term Perspective in Eastern France			>2027	Reconductoring or upgrading 220-kV overhead line (OHL) to 400kV	Market integration and RES integration	Yes
FRANCE	Lille-Arras	Avelin	Gavrelle	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 volatility	Yes
FRANCE	Cergy-Persan	Cergy	Persan	2018	Upgrade of an existing 35-km 225-kV line between Cergy and Persan (north-western Paris area) to 400-kV and connection to Terrier via an existing 400-kV line	Security of supply, market integration and RES integration	Yes
FRANCE	Havre-Rougemontier	Havre	Rougemontier	2019	Reconductoring of existing 54-km double-circuit 400-kV OHL to increase its capacity	Connection of new generation in the Le Havre area	Yes
FRANCE	Sud Aveyron			2020	New substation on the 400-kV Gaudière-Rueyres line for local RES integration; the commissioning year of 2020 is subject to its authorisation	RES integration	Yes
FRANCE	Massif Central South	Gaudière	Rueyres	>2027	Upgrade of the existing 400-kV overhead line, under study	Security of supply, RES integration and market integration	No*
FRANCE	Eguzon-Marmagne 400kV	Eguzon	Marmagne	2022	Reconductoring existing 400-kV OHL (maintenance), under study		No*
FRANCE	Façade Atlantique Upgrade of the North-South 400-kV Corridor Between Nouvelle Aquitaine and Vallée de la Loire			2030	Upgrade of the north-south 400-kV corridor between Nouvelle Aquitaine and Vallée de la Loire, under study	RES integration and market integration	No*
SPAIN	400-kV Madrid Ring (Moraleja-Segovia-Galapagar)	Moraleja	Galapagar	2025	Closure of the 400-kV ring of Madrid	Security of supply	Yes

SPAIN	400-kV Asturias Ring and Sama-Velilla	Gozón	Velilla	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	North Axis in Basque Country (Ichaso-Abanto/Gueñes)	Ichaso	Abanto and Gueñes	2020	New double-circuit OHL that will consist of the Ichaso-Abanto and Ichaso-Gueñes lines	Market integration	Yes
SPAIN	Uprate of Transpireneean Axis (Sabiñánigo-T-Escalona-Escalona-T-Foradada-La Pobla)	Sabiñanigo	La Pobla	2019-2021	Uprating the 220-kV OHL Sabiñanigo-T-Escalona-Escalona-T-Foradada-La Pobla axis	Market integration	Yes
SPAIN	Second Link Spanish Mainland-Mallorca	Morvedre	Santa Ponsa	<2025	HVDC subsea cable 2x500-MW link from Valencia to Mallorca	Market integration and interconnection between asynchronous systems	Yes
SPAIN	Submarine Connection Gran Canaria-Fuerteventura & Lanzarote			2025-2030	Subsea 2x100-MW connection from Gran Canaria to Fuerteventura-Lanzarote	Market integration and interconnection between isolated systems	Yes
SPAIN	Submarine AC Connection Spanish Mainland-Ceuta	Puerto de la Cruz		2022	Subsea AC connection 132-kV link from Puerto de la Cruz to Ceuta (in North Africa)	Market integration	Yes
SPAIN	Submarine Connections in Balearic Islands	x	x	2022-2025	Several subsea AC connections at 132kV between the islands	Security of supply and market integration	Yes
SPAIN	Submarine Connections in Canary Islands	x	x	2020-2022	Fuerteventura-Lanzarote link and La Gomera-Tenerife link at 120MW and 132kV	Interconnection between isolated systems, security of supply and market integration	Yes
SPAIN	RES Integration in Canary Islands	x	x	2018-2020	Transmission network reinforcements (66kV, 132kV and 220kV)	RES integration	Yes
SPAIN	Reinforcement of Southern Aragón-Cataluña Axis	TBD	TBD	2025-2030	The detail of the reinforcement is not fully defined, and it is pending a future national development plan	Market integration	
SPAIN	Reinforcement of the Axis La Serna-Magallón 400kV	La Serna	Magallón	2025-2030	The detail of the reinforcement is not fully defined, and it is pending a future national development plan	Market integration	No
SPAIN	Reinforcement of the Axis Guadaira-D.Rodrigo 400kV	Guadaira	D.Rodrigo	2025-2030	The detail of the reinforcement is not fully defined, and it is pending a future national development plan	Market integration	No
SPAIN	Reinforcement of the Axis Villaviciosa-Moraleja 400kV	Villaviciosa	Moraleja	2025-2030	The detail of the reinforcement is not fully defined, and it is pending a future national development plan	Market integration	No
SPAIN	Reinforcement of the Axis Aldeadávila-Villarino-Grijota-Herrera-Virtus (400kV)	Aldeadavila	Virtus	2025-2030	The detail of the reinforcement is not fully defined, and it is pending a future national development plan	Market integration	No
SPAIN	TSCC in Pierola 400 kV	Pierola	Pierola	2024-2028	Flexible alternating current transmission system (FACTS) TSCC device in Pierola substation	Security of supply	No
SPAIN	FACTS Statcom	x	x	2024-2028	FACTS Statcom devices in the substations of Vitoria, Carmona, Benahadux and Moraleja	Security of supply	No

SPAIN	FACTS in northwestern Spain	x	x	2024-2028	FACTS in Mesón and Tibo	Security of supply	No
SPAIN	Pumpings in Canary Islands	x	x	2025-2030	Pumping units in Soria-Chira (Gran Canaria) and Tenerife	RES integration and security of supply	No
PORTUGAL	Falagueira-Fundão	Falagueira	Fundão	2018	New 400-kV double-circuit OHL, with one 400-kV circuit installed between the existing substation of Falagueira and the future substation of Fundão	RES integration	No*
PORTUGAL	Falagueira-Estremoz-Divor-Pegões	Falagueira	Estremoz, Divor and Pegões	2019-2021	New 400-kV OHL Falagueira-Estremoz-Divor–Pegões axis including the new substations of Divor and Pegões	Security of supply and RES integration	No

(*) These projects were in the TYNDP 2016 list.

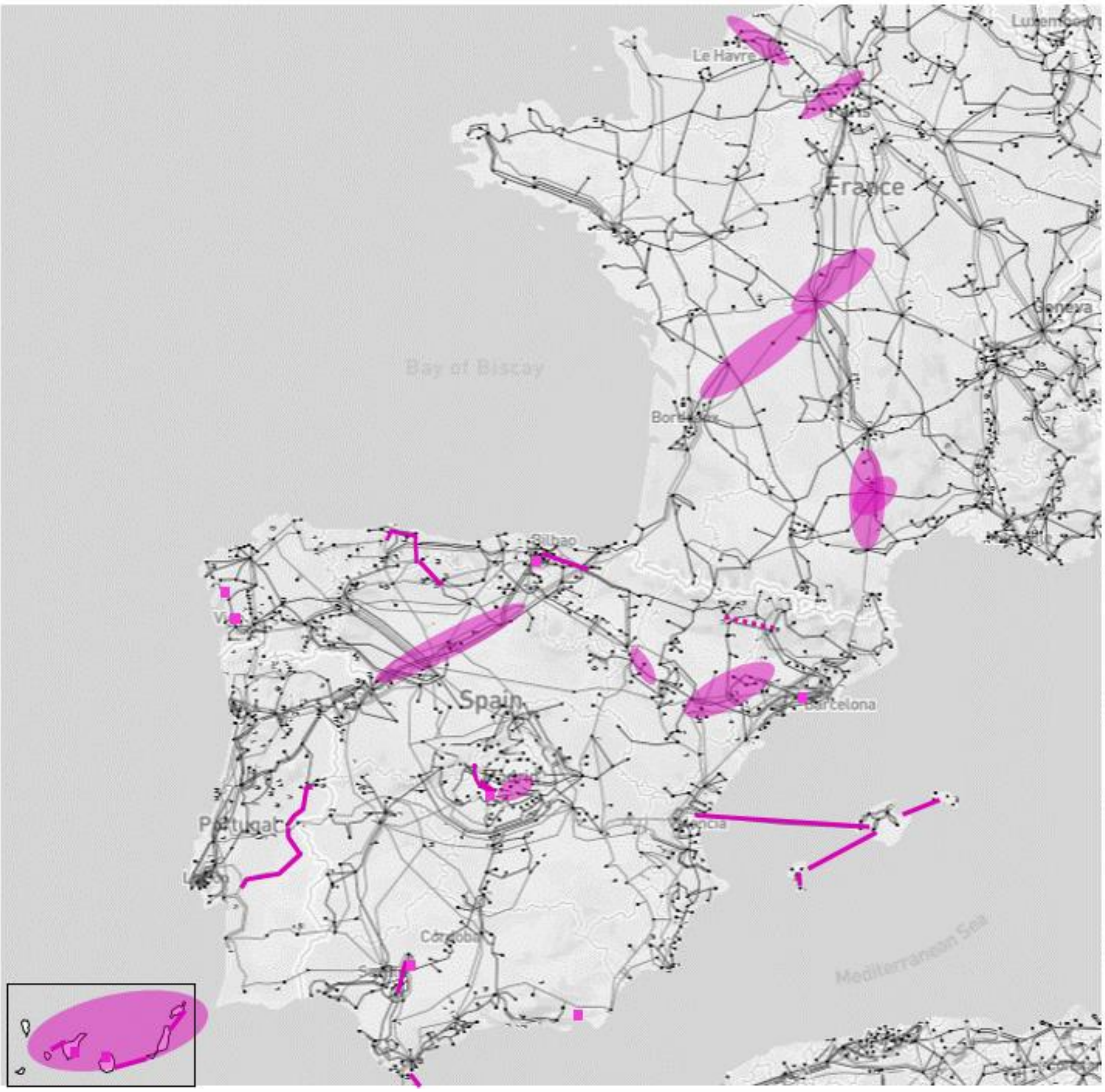
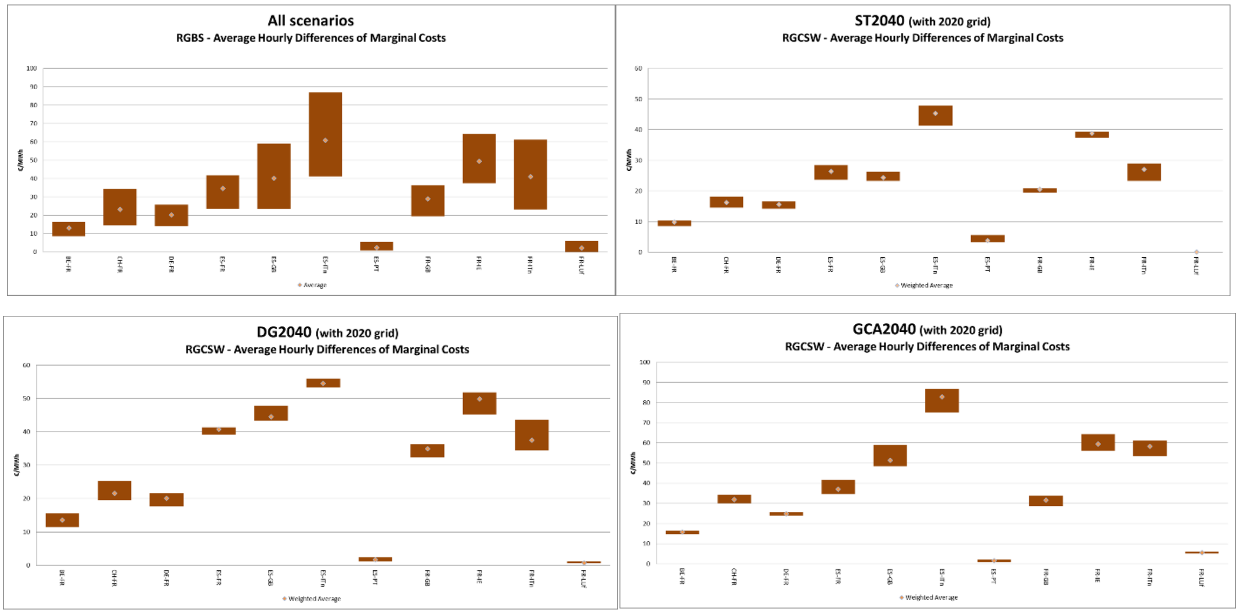


Figure 7-2: Additional regional projects

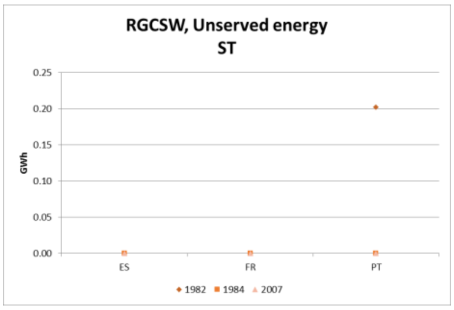
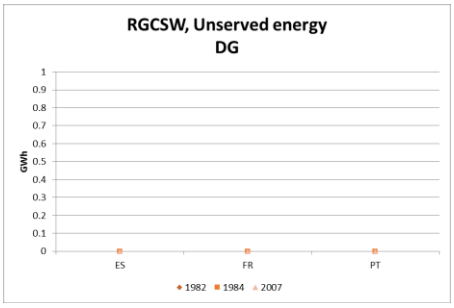
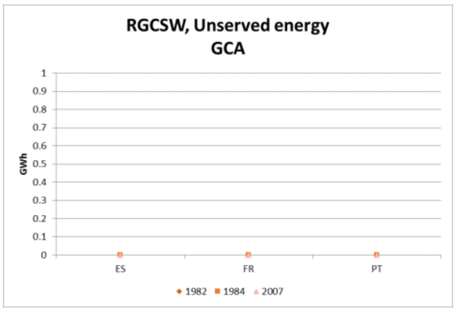
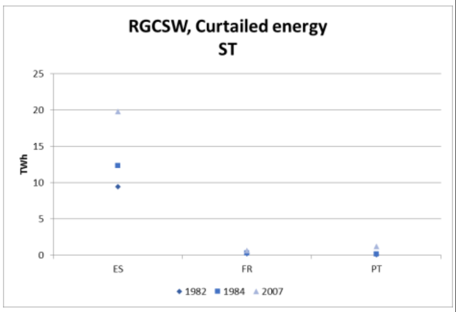
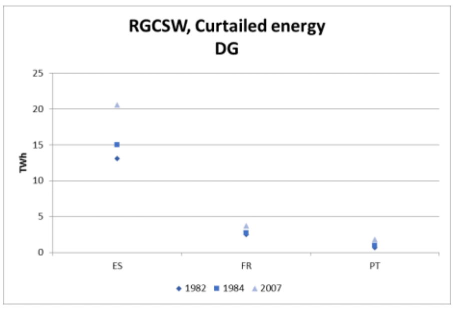
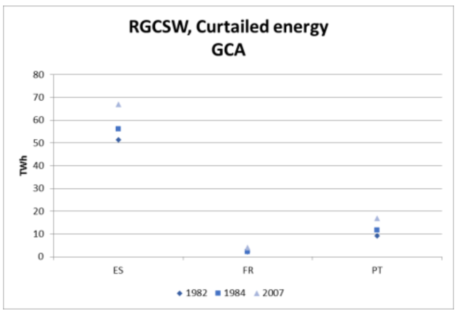
8 APPENDICES

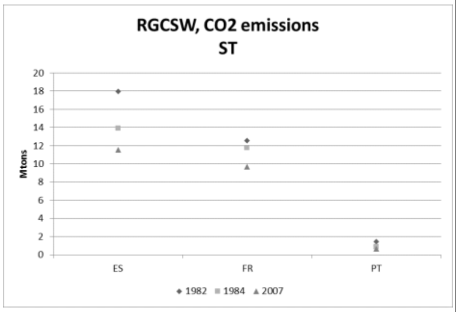
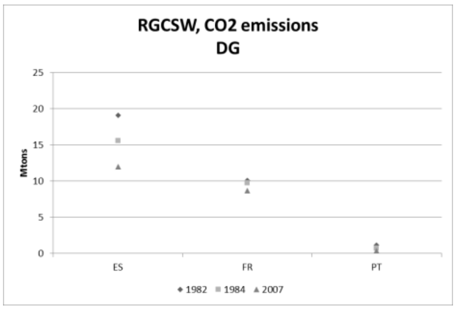
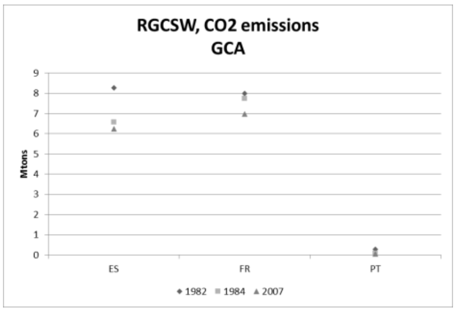
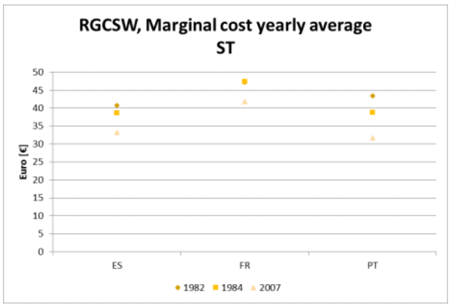
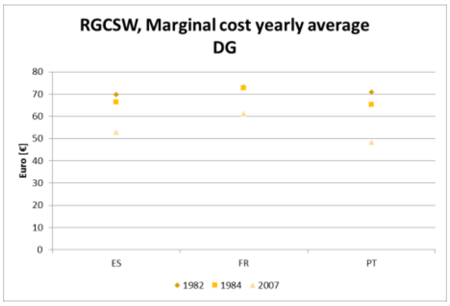
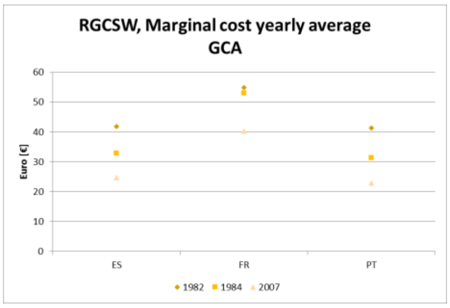
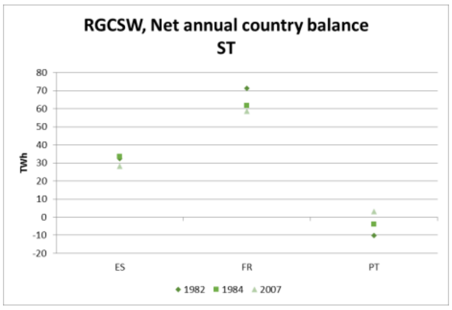
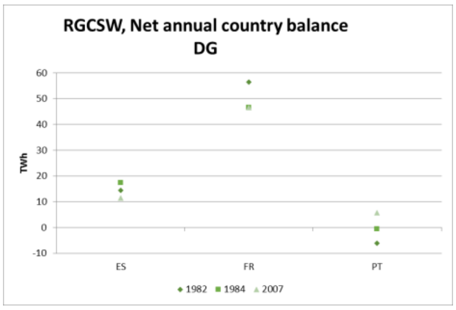
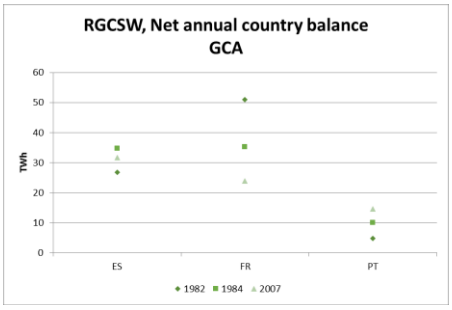
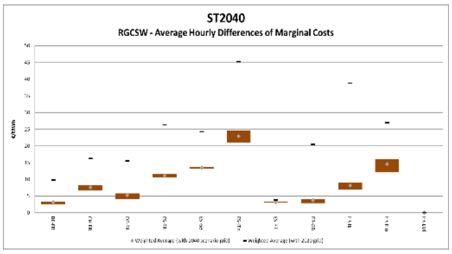
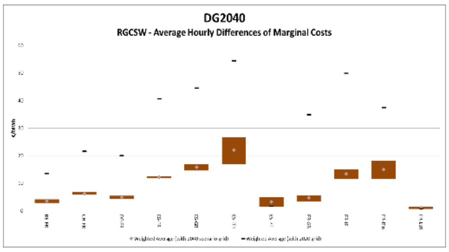
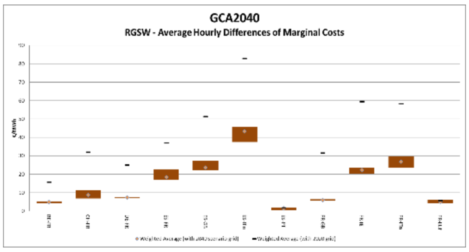
8.1 Additional figures

8.1.1 Future challenges



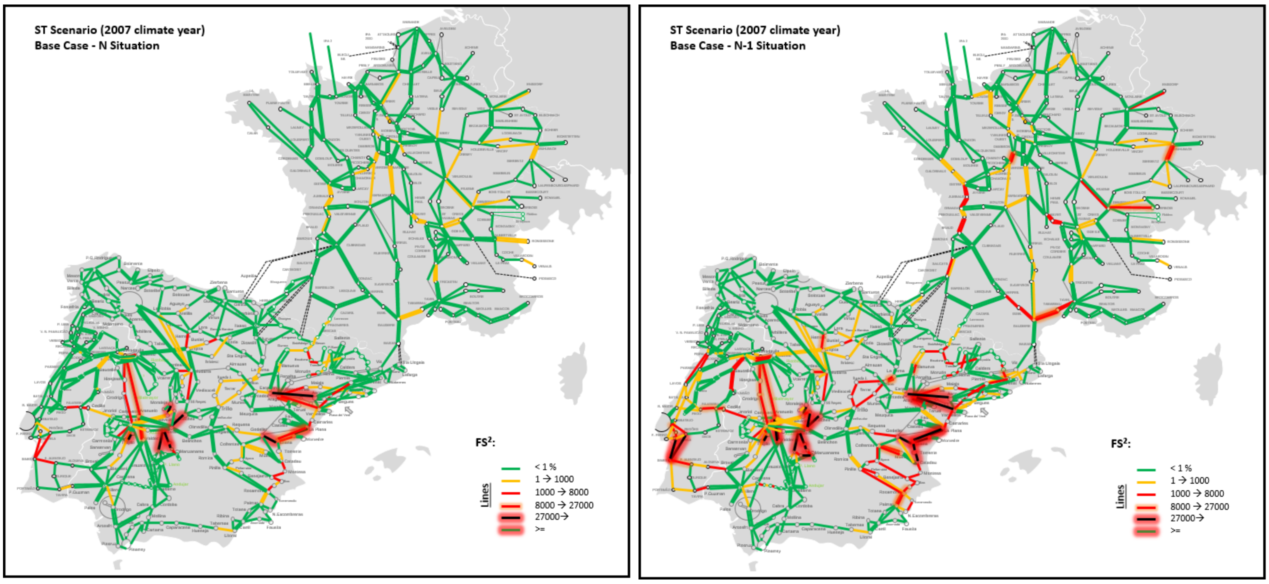
8.1.2 Market study results

Sustainable Transition 2040	Distributed Generation 2040	Global Climate Action 2040
		
		

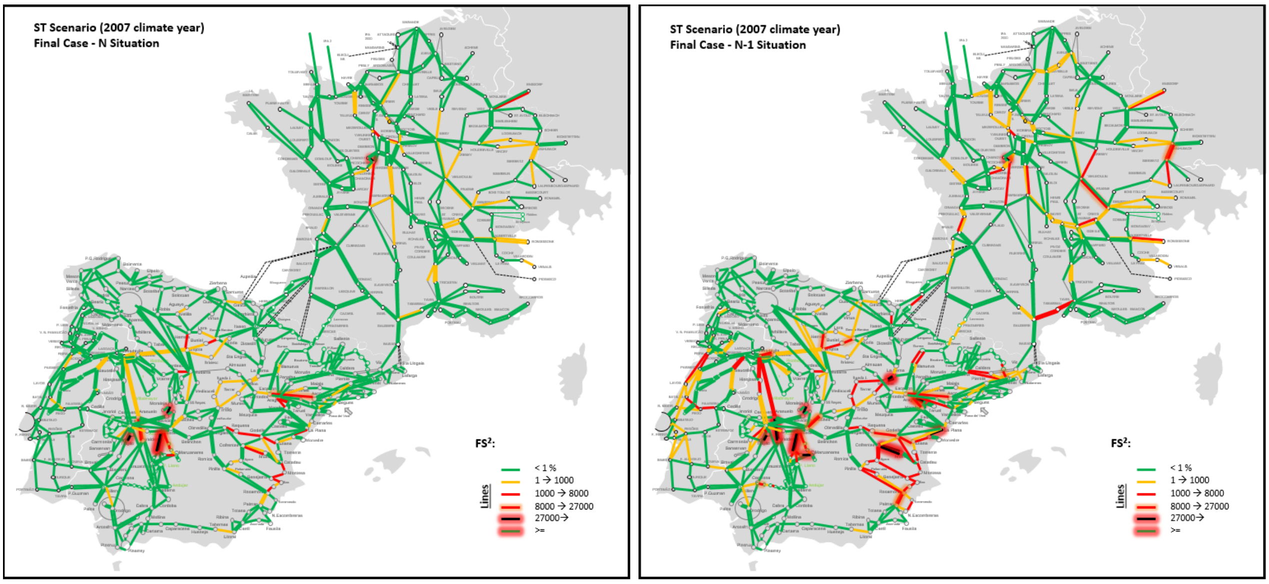
Sustainable Transition 2040	Distributed Generation 2040	Global Climate Action 2040
		
		
		
		

8.1.3 Network study results

'Sustainable Transition' scenario

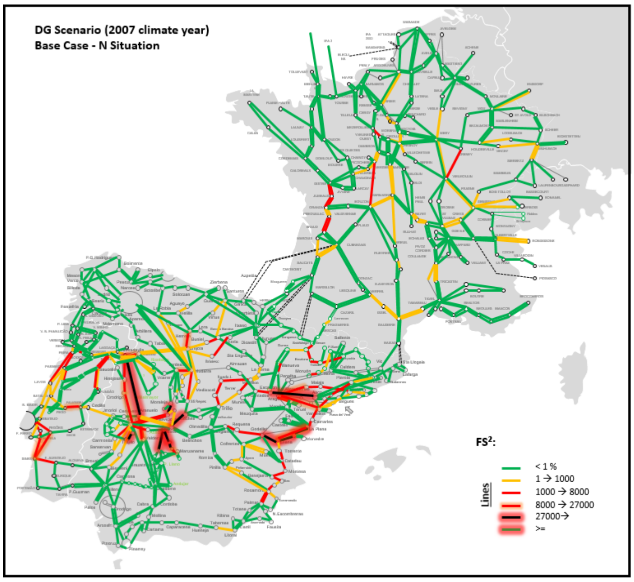


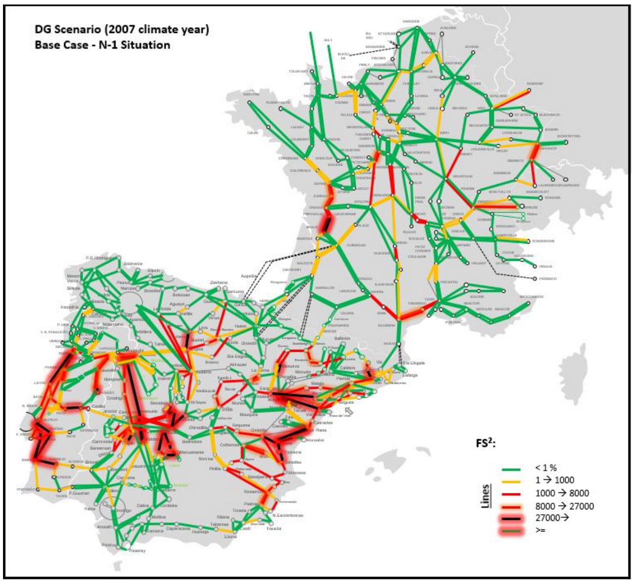
Base case: N and N-1 conditions



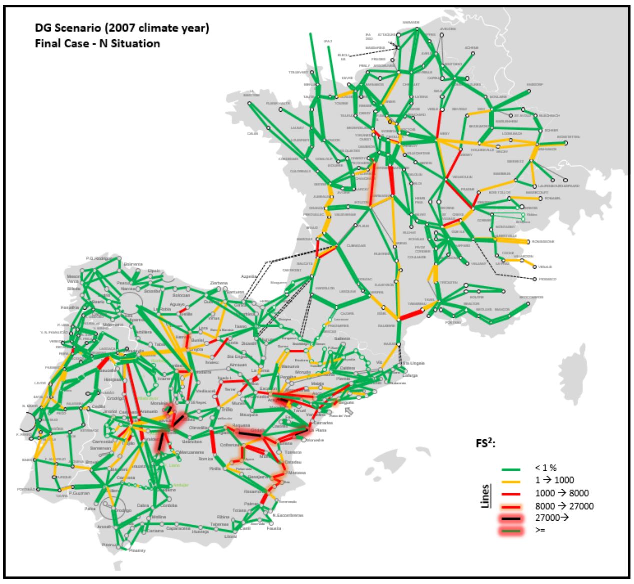
Final case: N and N-1 conditions

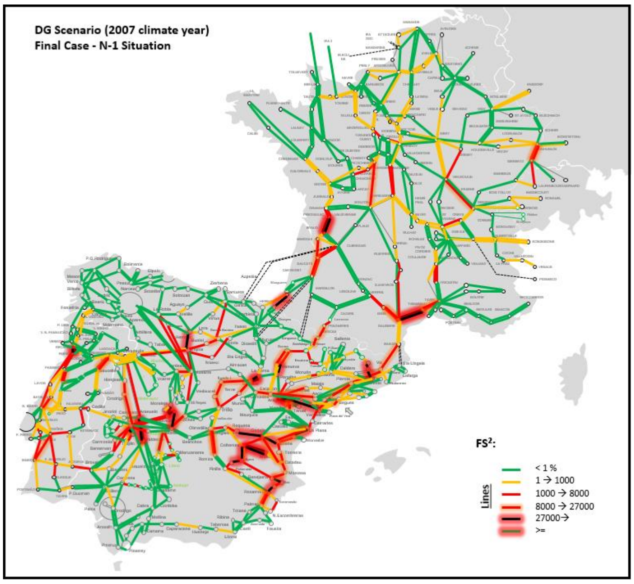
'Distributed Generation' scenario





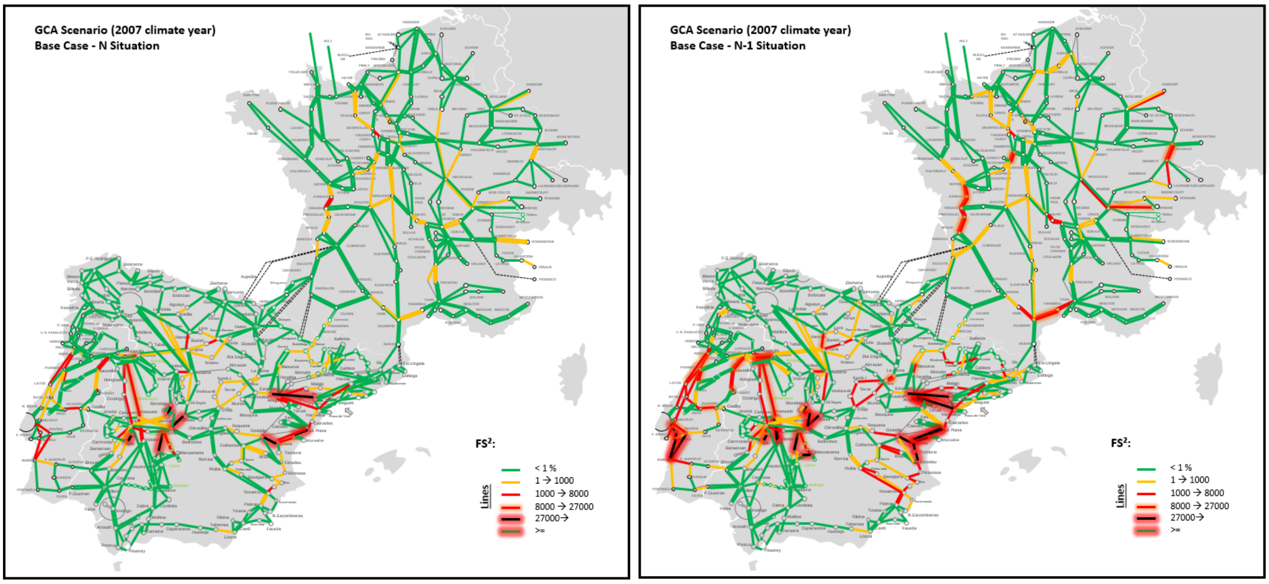
Base case: N and N-1 conditions



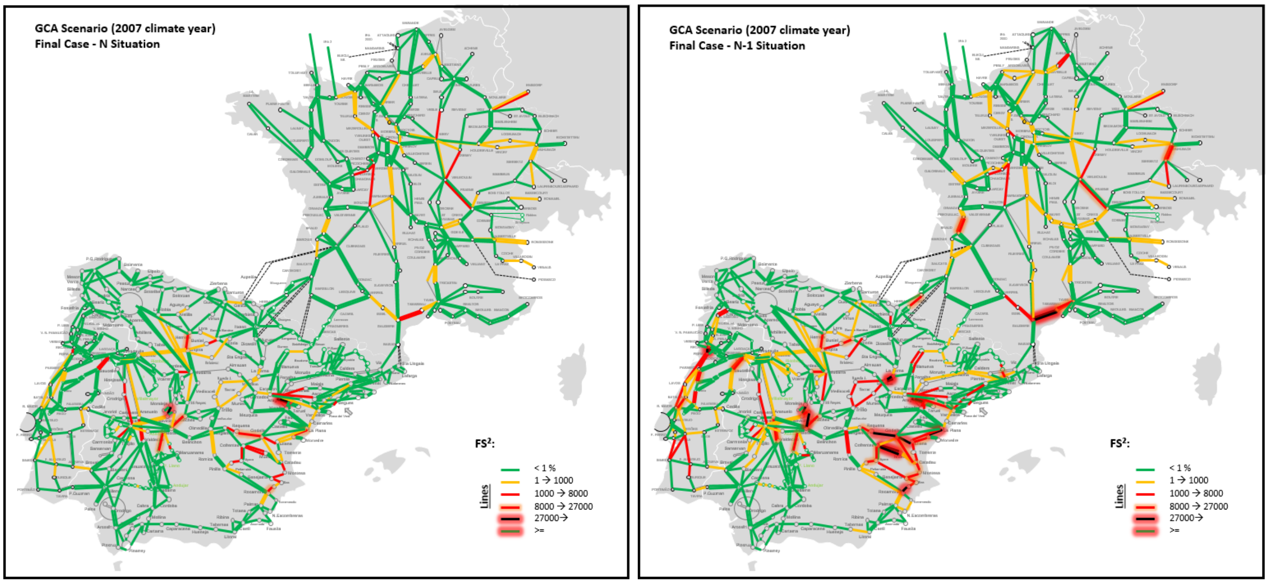


Final case: N and N-1 conditions

'Global Climate Action' scenario

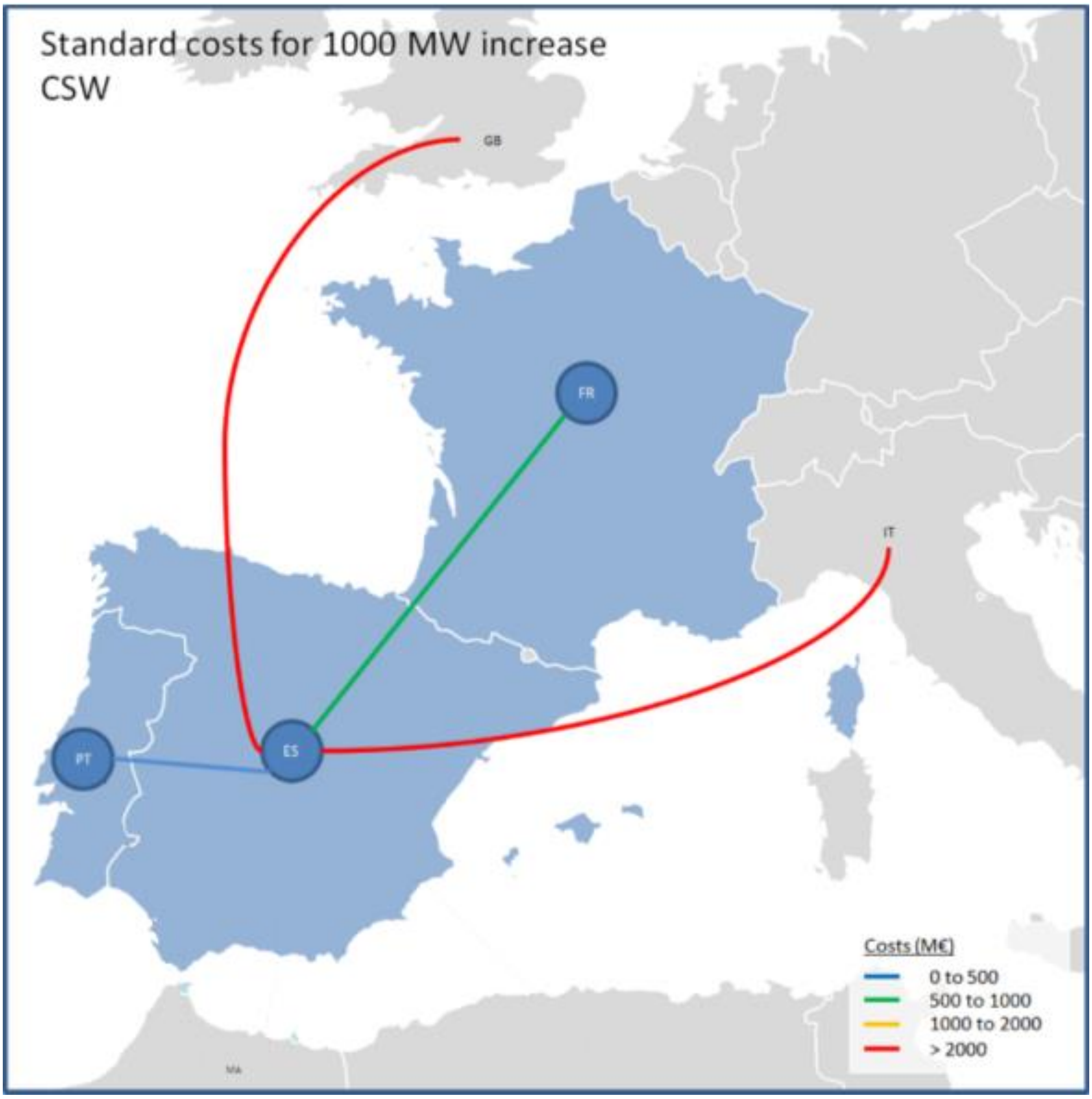


Base case: N and N-1 conditions



Final case: N and N-1 conditions

8.1.4 Standard cost map



8.2 Abbreviations

The following list presents abbreviations used in the Regional Investment Plan 2017.

- AC Alternating Current
- ACER Agency for the Cooperation of Energy Regulators
- CCS Carbon Capture and Storage
- CBA Cost-Benefit Analysis
- CHP Combined Heat and Power Generation
- DC Direct Current
- EH2050 E-Highway 2050
- EIP Energy Infrastructure Package
- ENTSO-E European Network of Transmission System Operators for Electricity
- ENTSOG European Network of Transmission System Operators for Gas
- EU European Union
- GTC Grid Transfer Capability
- HV High Voltage
- HVAC High-Voltage AC
- HVDC High-Voltage DC
- IEA International Energy Agency
- KPI Key Performance Indicator
- IEM Internal Energy Market
- LCC Line-Commutated Converter
- LOLE Loss of Load Expectation
- MS Member State
- MWh Megawatt hour
- NGC Net Generation Capacity
- NRA National Regulatory Authority
- NREAP National Renewable Energy Action Plan
- NTC Net Transfer Capacity
- OHL Overhead Line
- PCI Projects of Common Interest
- PINT Put IN one at a Time
- PST Phase-Shifting Transformer
- RgIP Regional Investment Plan
- RES Renewable Energy Sources

- RG BS Regional Group Baltic Sea
- RG CCE Regional Group Continental Central East
- RG CCS Regional Group Continental Central South
- RG CSE Regional Group Continental South East
- RG CSW Regional Group Continental South West
- RG NS Regional Group North Sea
- SEW Socio-Economic Welfare
- SOAF Scenario Outlook & Adequacy Forecast
- SoS Security of Supply
- TEN-E Trans-European Energy Networks
- TOOT Take Out One at a Time
- TSO Transmission System Operator
- TWh Terawatt hour
- TYNDP Ten-Year Network Development Plan
- VOLL Value of Lost Load
- VSC Voltage Source Converter

8.3 Terminology

The following list describes a number of terms used in this Regional Investment Plan.

Congestion revenue/congestion rent – The revenue derived by interconnector owners from 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 – 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.

Cost-benefit analysis (CBA) – Analysis carried out to define the extent to which a project is worthwhile from a social perspective.

Corridors – The CBA clustering rules, however, proved challenging for complex grid reinforcement strategies: the largest investment needs may require some 30 investment items, scheduled over more than five years but addressing the same concern. In this case, for the sake of transparency, they are formally presented in a series, a corridor, of smaller projects, each matching the clustering rules.

Cluster – Several investment items matching the CBA clustering rules. Essentially, a project clusters all investment items that have to be realised in total to achieve a desired effect.

Grid transfer capacity (GTC) – Represents the aggregated capacity of the physical infrastructure connecting nodes in reality; not only is it set by the transmission capacities of cross-border lines, but it is also set 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 represented by this branch; it is represented by a typical value across the year.

Investment – Individual equipment or facility, such as a transmission line, a cable or a substation.

Marginal costs – Current market simulations, in the framework of TYNDP studies, compute the final 'price' of electricity, taking into account only the generation costs (including fuel costs and CO2 prices) per technology. In the real electricity market, not only are the offers from generator units considered, but taxes and other services, such as ancillary services, also take part (reserves, regulation up and down, etc.), thus introducing changes in the final electricity price.

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 regarding 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.

Project – Either a single investment or a set of investments clustered together to form a project with a view to achieving a common goal.

Project candidate – Investment(s) considered for inclusion in the TYNDP.

Project of Common Interest – A project that meets the general, and at least one of the specific, criteria defined in Art. 4 of the TEN-E Regulation and that has been granted the label of PCI Project according to the provisions of the TEN-E Regulation.

Put IN one at a 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 network – The existing network plus all mature TYNDP developments, enabling the application of the TOOT approach.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

Reference capacity – The 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 gas demand and gas supply, gas infrastructures, fuel prices and global context occur.

Transmission capacity (also called Total Transfer Capacity) – The maximum transmission of active power, in accordance with the system security criteria, that is permitted in transmission cross-sections between the subsystems/areas or individual installations.

Take Out One at a 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 evaluating the load flows over the lines with and without the examined network reinforcement.

Ten-Year Network Development Plan (TYNDP) – The Union-wide report released by ENTSO-E every other year as part of its regulatory obligations as defined under Article 8 para 10 of Regulation (EC) 714/2009

Total transfer capacity (TTC) – See Transmission capacity above.

Vision – Plausible future states selected as wide-ranging possible alternatives.

ENTSO-E AISBL • Avenue de Cortenbergh 100 • 1000 Brussels • Belgium • Tel + 32 2 741 09 50 • Fax + 32 2 741 09 51 • info@entsoe.eu • www. entsoe.eu

ENTSO-E AISBL
Avenue de
Cortenbergh 100,
1000 Brussels,
Belgium

Tel (+32) 2 741 09 50

info@entsoe.eu
www.entsoe.eu

entsoe
Reliable Sustainable Connected